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Review

Measuring wanting and liking from animals to humans: A systematic review

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ABSTRACT

Animal research has shown it is possible to want a reward that is not liked once obtained. Although these findings have elicited interest, human experiments have produced contradictory results, raising doubts about the existence of separate wanting and liking influences in human reward processing. This discrepancy could be due to inconsistences in the operationalization of these concepts. We systematically reviewed the methodologies used to assess human wanting and/or liking and found that most studies operationalized these concepts in congruency with the animal literature. Nonetheless, numerous studies operationalized wanting in similar ways to those that operationalized liking. These contradictions might be driven by a major source of confound: expected pleasantness. Expected pleasantness underlies cognitive desires and does not correspond to animal liking, a hedonic experience, or to animal wanting, which relies on affective relevance, consisting of the perception of a cue associated with a relevant reward for the organism's current physiological state. Extending the concept of affective relevance and differentiating it from expected pleasantness might improve measures of human wanting and liking.

Contents

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1. Introduction

Psychologists and neuroscientists have long tried to understand how individuals decide to invest their limited resources to pursue a particular rewarding outcome (e.g., Delgado, 2007; Rescorla and Solomon, 1967; Spence, 1956). Common sense suggests that people decide to invest their resources to pursue the outcome they like the most. However, in many situations, individuals invest a considerable amount of effort to pursue an outcome even though after they obtain it, they do not experience it as pleasurable. A clear example occurs in the case of drug addiction, in which individuals are willing to go to extraordinary lengths to obtain a substance that will eventually elicit no pleasurable feelings during its consumption (Robinson and Berridge, 2003). In the nineties, Berridge and Robinson, 1998 proposed the incentive salience hypothesis that challenged the hedonic perspective. Proponents of this hypothesis suggested that the pursuit of an outcome is not always directly proportional to the pleasure experienced during consumption, because reward processing is a process involving multiple distinct parallel components, including the motivation to obtain a reward (i.e., wanting) and the hedonic pleasure felt during its consumption (i.e., liking; see also Berridge, 2009b). These components are typically positively correlated but can also be dissociated, thereby making organisms work for a reward that they will not appreciate once obtained.

This proposal, based on an animal model, has garnered great interest among researchers investigating motivational processes in humans (e.g., Finlayson et al., 2007b; Kringelbach et al., 2012; Mela, 2006; Nawijn et al., 2015). Several scholars have considered the independence of wanting and liking as a potential mechanism underlying a variety of human behaviors that negatively impact well-being such as overeating, pathological gambling and the consumption of addictive substances (Finlayson et al., 2007b; Pool et al., 2015c; Tibboel et al., 2011; Wölfling et al., 2011). However, human experiments have led to contradictory results, opening a debate on the existence of two dissociable components in human reward processing (Havermans, 2011, 2012). It has even been claimed that a correct operational definition of wanting and liking as conceived by Berridge and Robinson, 1998 is lacking in human research (Havermans, 2012). Clear operational definitions are particularly important for studies conducted on humans because such studies offer much larger variability in operationalizing psychological constructs–which can be an important source of confound–than animal studies. In the present article, we systematically review the literature that investigates wanting and liking among human populations, as well as systematically describe how these concepts were operationalized regarding the important tenets of the incentive salience hypothesis. We thereby aimed to (1) systematize and quantify, across all kinds of human rewards, the contradictory operationalizations of wanting and/or liking that have been previously highlighted (Havermans, 2011,2012) and (2) identify possible sources of confounds that might be responsible for the contradictory results.

1.1. The incentive salience hypothesis

The incentive salience hypothesis has been conceived as an extension of early models of incentive motivation (Bindra, 1974; Bolles, 1972; Spence, 1956; Toates, 1998). These models challenged the drive reduction theory that accounted for motivated behaviors exclusively in terms of the need to reduce a particular imbalanced physiological state, such as hunger (i.e., drives), in order to reestablish homeostasis. Spence (1956) was the first to propose that the amount of energy invested in an action (e.g., walking toward a restaurant) can be influenced by the perception of external stimuli (e.g., the restaurant logo) that have been associated with a reward through the organism's experiences. Subsequently, other incentive motivation theorists (Bindra, 1974; Bolles, 1972; Toates, 1998) suggested that the motivational increase subsequent to the perception of the reward-associated cue is proportional to the experienced hedonic pleasure, which is triggered by the consumption of the reward: the more pleasurable the reward, the bigger the increase in motivation triggered by the reward cue. Therefore, according to this suggestion, incentives should influence the organism's motivation in a logical way: the amount of effort mobilized to obtain the reward is always justified by the hedonic experience during reward consumption. For several years, this intrinsic relationship between motivation and hedonic pleasure has been so deeply integrated in affective neuroscience that the amount of hedonic pleasure for a particular reward has been measured in multiple studies as the amount of effort mobilized to obtain it. This operationalization has been used in research conducted on animals in particular because they cannot verbally report the hedonic pleasure that they experienced (see Bindra, 1974; Bolles, 1972; Toates, 1998). Most researchers assumed that if an organism works to obtain a reward, it must mean that it likes it. In the nineties, Berridge and co-workers challenged this hedonic perspective of incentive motivational theories through a corpus of experiments conducted on rodents (Berridge and Robinson, 1998; Mahler and Berridge, 2012; Pecina et al., 2003; Wyvell and Berridge, 2000, 2001). They demonstrated that it is possible to make a rodent work to obtain a reward that it does not like. The most innovative aspect of this series of experiments was the use of two different measures for incentive motivation and hedonic pleasure: the former was measured in a classic way (e.g., the increase in mobilized effort after the perception of a rewarding cue), and, critically, the latter was measured by a distinct dependent variable consisting of prototypical orofacial expressions during reward consumption. These orofacial expressions are elicited by the consumption of pleasant (e.g., sweet taste) or unpleasant (e.g., bitter taste) food and seem to be reliable indexes of hedonic experiences in several organisms (e.g., rats, apes, monkeys, human babies; see Berridge, 2000). Through these measures, Berridge and co-workers showed that two different dissociable neuronal networks underlie hedonic pleasure and incentive motivation in rodents (Berridge, 2000; Pecina and Berridge, 2000, 2005; Pecina et al., 2003; Wyvell and Berridge, 2000, 2001). An important demonstration in this work is that increasing the level of dopamine in the mesolimbic region increases the amount of effort mobilized to obtain a reward without simultaneously modifying the measure of hedonic pleasure experienced during its consumption. From these empirical findings, the investigators formulated

the *incentive salience hypothesis*, which postulates that reward processing involves multiple components, including one that is motivational (*wanting*) and another that is hedonic (*liking*), which rely on separate neural networks that can be dissociated under particular circumstances (Berridge and Kringelbach, 2015; Berridge and Robinson, 2003). The interaction between the organism's brain state (e.g., increased level of mesolimbic dopamine) or physiological state (e.g., hunger/satiety) and the elements present in the environment (e.g., reward-associated cue) is an important tenet of the incentive salience hypothesis. Indeed, computations of wanting dynamically incorporate the current physiological state, reflecting the real internal state of the organism at a particular time with respect to an ideal set point that regulates homeostasis (also called k factor; Zhang et al., 2009). Examples of such physiological states could be satiation, hunger, and thirst, as well as drug effects or stress (Berridge and O'Doherty, 2014). The ability of a reward-associated stimulus to trigger a motivational state is strongly modulated by the relevance of the reward for the physiological state of the individual (Robinson and Berridge, 2013; Zhang et al., 2009). In some cases, the organism's state can increase both cue-triggered wanting and the liking experience during reward consumption; for instance, hunger increases the relevance of a food reward that becomes both more wanted and liked (Havermans et al., 2009). In other cases, the organism's state can selectively increase wanting without modifying liking; for instance, stress prioritizes reward relevance (Leyton, 2010), increasing cue-triggered wanting for a particular reward but not liking during reward consumption (see Pool et al., 2015c for a review).

Berridge and Robinson (2003) proposed that wanting and liking can be further classified depending on whether they are processed at an implicit or explicit level (see also Anselme and Robinson, 2015). Explicit and implicit liking both refer to the hedonic impact of the reward during its consumption and simply differ in terms of explicitness/implicitness; however, explicit and implicit wanting rely on different psychological mechanisms. Implicit wanting, also called incentive salience, relies on a Pavlovian system and refers to cue triggered motivational reactions that can occur without a conscious experience. Explicit wanting, also called cognitive desires, relies on a goal-directed system and often involves the subjective feeling of being attracted toward a desired object. Moreover, cognitive desires rely on expectations individuals have about the pleasantness of the reward, which are built based on past liking experiences. Therefore, cognitive desires are not completely independent from liking, whereas implicit wanting or incentive salience is potentially independent from any hedonic aspect of the reward including expected pleasantness (Berridge and Aldridge, 2008). Please note that in the context of the incentive salience hypothesis and the aforementioned animal literature, the term *wanting* refers to implicit wanting or incentive salience. Therefore, in the present article the term *wanting* is used to refer to incentive salience or implicit wanting.

1.2. Key elements of the wanting and liking measures in animals

As an extension of incentive motivation theories, the incentive salience hypothesis considers three keys elements when measuring wanting and liking. The first is the rewarding outcome (also referred to as the unconditioned stimulus), the second is the reward-associated cue (also referred to as the conditioned stimulus), and the third is the physiological state of the individual. Wanting and liking depend on different interactions of some of these elements at specific moments in time. Wanting is triggered by the interaction between an individual in a particular state and the perception of a reward cue and can be measured by the effort mobilized in the instrumental action. Notice that the incentive (i.e., the reward-associated cue or the reward) is thus presented *before* the instrumental action. Timing is particularly important; indeed, if the incentive is presented *after* the instrumental action, the process no longer relates to incentive motivation but rather to reinforcement learning. In addition, the specific influence of wanting is stronger *before* reward consumption, since *during* reward consumption, the hedonic experience is dominant. Similarly, liking is triggered by the interaction between an individual in a particular state and the consumption of a reward that is measured through the hedonic reaction *during* or immediately *after* reward consumption. Here again, timing is critical because liking is conceived as a hedonic experience; if the measurement is not taken close to reward consumption, it will reflect the encoded memory of the hedonic experience rather than the hedonic experience itself. This might be particularly problematic because memories of past hedonic experiences are used to build *expected pleasantness* (Balleine, 2005). Expected pleasantness, which consists of prediction and expectations about how pleasant or unpleasant something is going to be, represents the mechanism underlying cognitive desires that do not correspond to either animal liking or animal wanting, but rather a distinct motivational control system (i.e., goal-directed system) of reward-seeking behaviors (Berridge and Aldridge, 2008; Berridge and O'Doherty, 2014; Dickinson and Balleine, 1994; Wassum et al., 2011b).

Given the importance of the rewards and the reward cues for measures of the incentive salience hypothesis in animals, we decided to systematically describe different aspects of the rewards or reward cues (e.g., kind of reward, format) presented in the methodological procedures that measure wanting and liking in humans.

1.3. Wanting and liking in humans: success and controversy

The incentive salience hypothesis, which has been formulated on the basis of an animal model (Berridge and Robinson, 1998,2003), has garnered great interest among researchers who are investigating motivational processes in humans. Several lines of research have subsequently been launched to investigate the effect of dopamine deregulation on motivation and hedonic pleasure for a particular reward (e.g., Brauer et al., 2001; Evans et al., 2006; Volkow et al., 1997), the role of wanting and liking in addictive behaviors (e.g., Goldstein et al., 2010; Tibboel et al., 2011; Wachtel et al., 2002), or the role of these two components in the normal processing of rewards related to different needs, such as offspring caretaking (with babies) or nourishment (with food) (e.g., Finlayson et al., 2007a; Parsons et al., 2011). This corpus of experiments provided evidence supporting the idea that the same processes found in rodents could potentially exist in humans. More particularly, in clinical disorders involving dopamine deregulation (Evans et al., 2006; Volkow et al., 1997), it has been argued that the level of mesolimbic dopamine influences the motivational processes without necessarily modifying the hedonic experience of reward consumption. Moreover, it has been suggested that different brain regions are activated by a motivational state such as the expectation of a reward (e.g., amygdala; O'Doherty et al., 2002; Small et al., 2008) and by a hedonic state such as the consumption of a reward (e.g., orbitofrontal cortex; O'Doherty et al., 2002; Small et al., 2008). Although the aforementioned findings support the existence of two distinct components in human reward processing that reflect wanting and liking, other experiments have provided contradictory evidence against a dissociation between wanting and liking in humans (Havermans, 2011, 2012; Tibboel et al., 2011). Specifically, Havermans (2011,2012) highlighted that in studies investigating wanting and liking for food reward in humans, construct operationalizations are far from the original incentive salience hypothesis and often contradict each other: in some cases, a similar operationalization is used to measure wanting

in one study and liking in another (Finlayson et al., 2007a; Lemmens et al., 2009). He argued that, in research conducted on humans, measures of wanting and liking still need to be validated by dissociating them under precise circumstances that are clearly predicted by the incentive salience hypothesis. In the absence of such a validation, the differential contributions of wanting and liking found in studies conducted on humans are likely to reflect poor construct validity rather than real effects. He also proposed abandoning the distinction between wanting and liking in the investigation of food reward in humans, claiming that wanting and liking are so intrinsically related that they cannot be considered as two distinct components having separate influences.

1.4. The present review

Several researchers agree that the incentive salience hypothesis has important explanatory power in the understanding of various human behaviors, in particular problematic behavior such as overeating, addictive consumption of substances or pathological gambling (Finlayson et al., 2007b; Goldstein et al., 2010; Pool et al., 2015c; Wölfling et al., 2011). Nonetheless, results of studies investigating the incentive salience hypothesis with food reward in humans led to skeptical conclusions being drawn concerning the existence of wanting and liking as two distinct components with separate influences (Havermans, 2011,2012). These criticisms raised two important aspects that seem to be problematic for the hypothesis: (1) operationalizations of wanting and liking are often far from the original incentive salience hypothesis and (2) measures of wanting and liking are inconsistent across studies and often contradict one another.

Here, we systematically review studies on wanting and liking for all rewards in humans to estimate the extent to which these aspects represent a problem. We systematically describe (1) how wanting and liking were measured across these studies and (2) how the methodological procedures integrated the key elements (i.e., reward cue, reward consumption and their respective timing) of the incentive salience hypothesis. From the results of this systematic description of the existing literature, we argue that the majority of studies seem to correctly integrate the main tenets of the incentive salience hypothesis; however, numerous studies operationalize the concepts of wanting and liking in contradictory ways. We claim that these contradictory operationalizations are often derived from confusion over the concept of expected pleasantness that is sometimes considered liking, but at other times considered wanting. Finally, we suggest that clarifying the distinctions between (1) expected pleasantness and affective relevance and (2) experience and memory could improve the conceptual clarity of the mechanisms involved in wanting and liking, thereby reducing sources of confusion when operationalizing these constructs.

2. Method

2.1. Inclusion criteria

To select the studies included in this systematic review, we used the following criteria:

1. The article had to be published in a peer-reviewed journal and written in English
2. The article had to report original data collected from a human population between January 1990 and April 2015.
3. The study had to have measured at least one of the constructs of interest (i.e., “incentive salience”, “wanting”, “incentive motivation”, “liking”, “hedonic pleasure”) with an explicit reference to the incentive salience theoretical framework (e.g., Berridge and Robinson, 1998,2003; Robinson and Berridge, 2003).

2.2. Literature search strategy

The first potential studies were identified by searching the electronic ProQuest and PubMed databases. We searched for all available records starting from January 1990 until April 2015, using the following combination of keywords in the title or abstract of the article: (*wanting OR “incentive motivation”*) *AND* (*liking OR pleasure*) *OR “incentive salience”*. This search yielded 545 hits. After the removal of duplicates and clearly off-topic articles (e.g., geography or city planning); we obtained an initial pool of 378 articles. To ensure that they met the inclusion criteria, the initial pool was winnowed through a five-step process (see Fig. 1). During the first four steps, only the abstracts of the articles were read. At the last step, the articles were read in full. If there was a doubt at any step, the article was kept for further inspection. Step 1 was designed to include only those articles reporting original experimental data; at this stage, all reviews and meta-analyses were excluded. In total, 268 articles survived Step 1. At Step 2, articles were included only if they were conducted on a human population; 143 articles survived. Step 3 was designed to exclude all articles that exclusively measured perceptual processing or attentional orienting toward the rewarding stimulus. This particular prediction of the incentive salience hypothesis has been fully reviewed elsewhere (Pool et al., 2015a). Here, we aimed to review studies measuring the motivational and hedonic, rather than attentional, correlates of the incentive salience predictions. In total, 126 articles survived Step 3. At Step 4, articles that did not use rewarding stimuli were excluded and 125 articles survived. At the last step, the remaining articles were read in full by one rater (graduate level and author of this article). This step was designed to include only those articles that aimed to measure at least one of the constructs of interest (i.e., “incentive salience”, “wanting”, “incentive motivation”, “liking”, “hedonic pleasure”), with an explicit reference to the incentive salience theoretical framework (e.g., Berridge and Robinson, 1998). Two raters (both graduate level and authors of this article) first read the same 20% of the abstracts of the articles. The overall agreement was very high (Cohen’s $k = .92$), disagreements were discussed and a consensual solution was used. Only one rater (graduate level and first author of this article) read the remaining articles in full. For each of the 51 articles that survived Step 5 we did an electronic search in the Google Scholar database to find out whether the first authors published other relevant articles. We obtained 33 other relevant hits, leading to a final database of 84 articles.

2.3. Data extraction

For each of the selected articles, we summarized different aspects of the study (see Appendix A and Table 1 for an overview).

First, we characterized the type of study by the measure used (e.g., behavioral, questionnaires, electroencephalography [EEG], functional magnetic resonance imaging [fMRI], positron emission tomography [PET]). Studies that used physiological measures (e.g., acoustic startle) or manipulation of physiological factors (e.g., food, alcohol or drug administration) were described as physiological.

Second, we specified the type of population that the study investigated: for instance, the study authors may have been interested in a population of healthy individuals, or of individuals with problematic food consumption or of those who reported a problematic use of alcohol.

Third, we characterized *which* particular reward was the object of the measure of wanting and liking; for instance, we described whether the measure of wanting quantified wanting for food, for alcohol, for a pleasant photograph or for a pleasant odor.

Table 1
Summary of the methodological aspects described in the present review.

Aspect	Variable	Examples
Population	Population targeted in the study	Healthy, problematic use of substances, problematic food consumption
Type	Type of study	Behavioral, fMRI, physiological
Method	Object of the measure	Food, nicotine, alcohol
	Reward format	Photo, odor, sample
	Cue format	Photo, symbol, sight of a sample
	Measure	Self-reports, implicit associations, effort mobilized
	Timing of the measure	After cue exposure, during cue exposure, after reward consumption

Note. fMRI: functional magnetic resonance imaging.

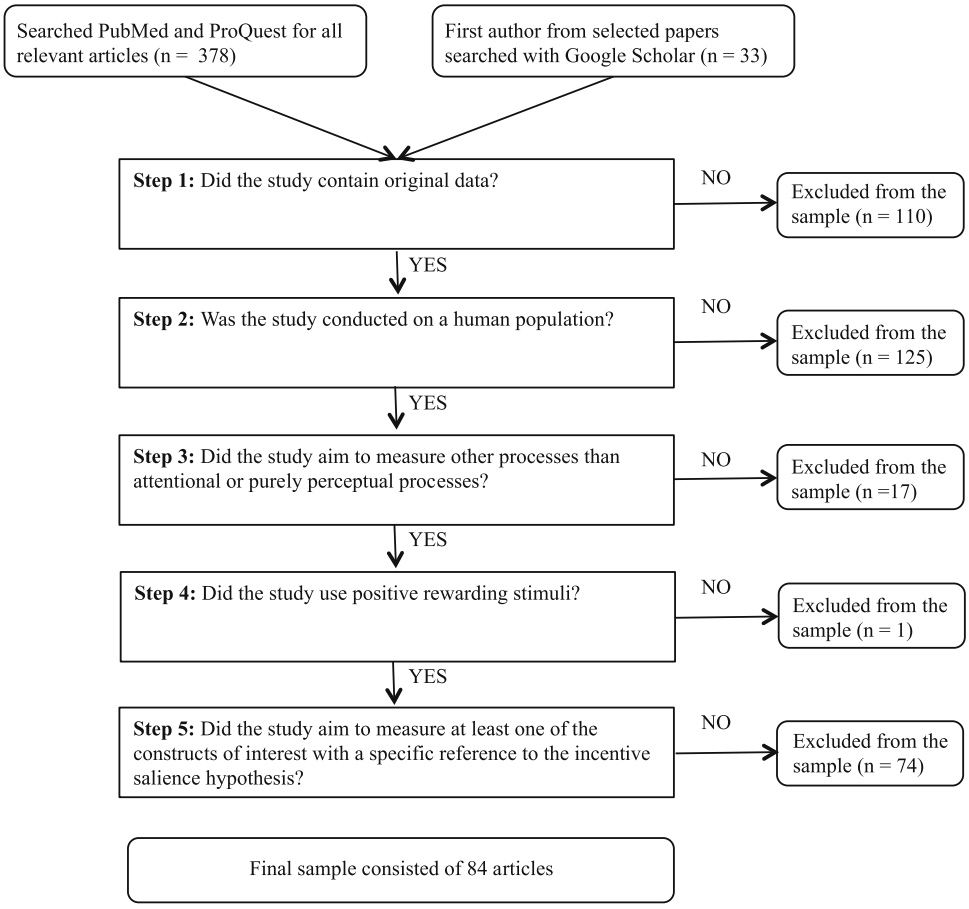

Fig. 1. Flowchart illustrating the search and winnowing processes.

Fourth, we specified the format (e.g., a sample, an odor, a photograph) in which the reward was presented to the participants. The same was done for the format of the reward-associated cue when the methodological procedure involved an exposure to any cues associated with the reward that was the object of the wanting or liking measures. The cue-reward associations could have been learned in the laboratory (e.g., through associative learning procedures) or outside the laboratory (e.g., pictures of food associated with food through everyday life experiences).

Fifth, we described *how* wanting and liking were measured in the experimental procedure. For instance, some studies asked participants to report their level of wanting or liking by using quantitative scales (e.g., visual analogue scales, Likert scales), whereas others measured the participants' brain activity during a motivational or a hedonic state.

Finally, we described *when* this measure was taken during the procedure. This description was based on the reward and cue presentation and could be coded as before, during or after the cue or reward consumption. In cases in which the reward was administered during the motivational task (e.g., Epstein et al., 2011), we considered the measure to be taken during consumption. In cases where wanting and/or liking for a particular reward was measured while perceiving the reward cue (e.g., a photograph in McNeil et al., 2015a,b), we considered the measure to be taken during the cue perception.

We assessed interrater variability by comparing the descriptions of two raters (both graduate level and authors of this article) for 20% of the journal articles included in the systematic review. Cohen's *k* varied between .76 and 1 across the different variables, with a mean of .93. The disagreements were discussed and a consensual solution was used for the final description.

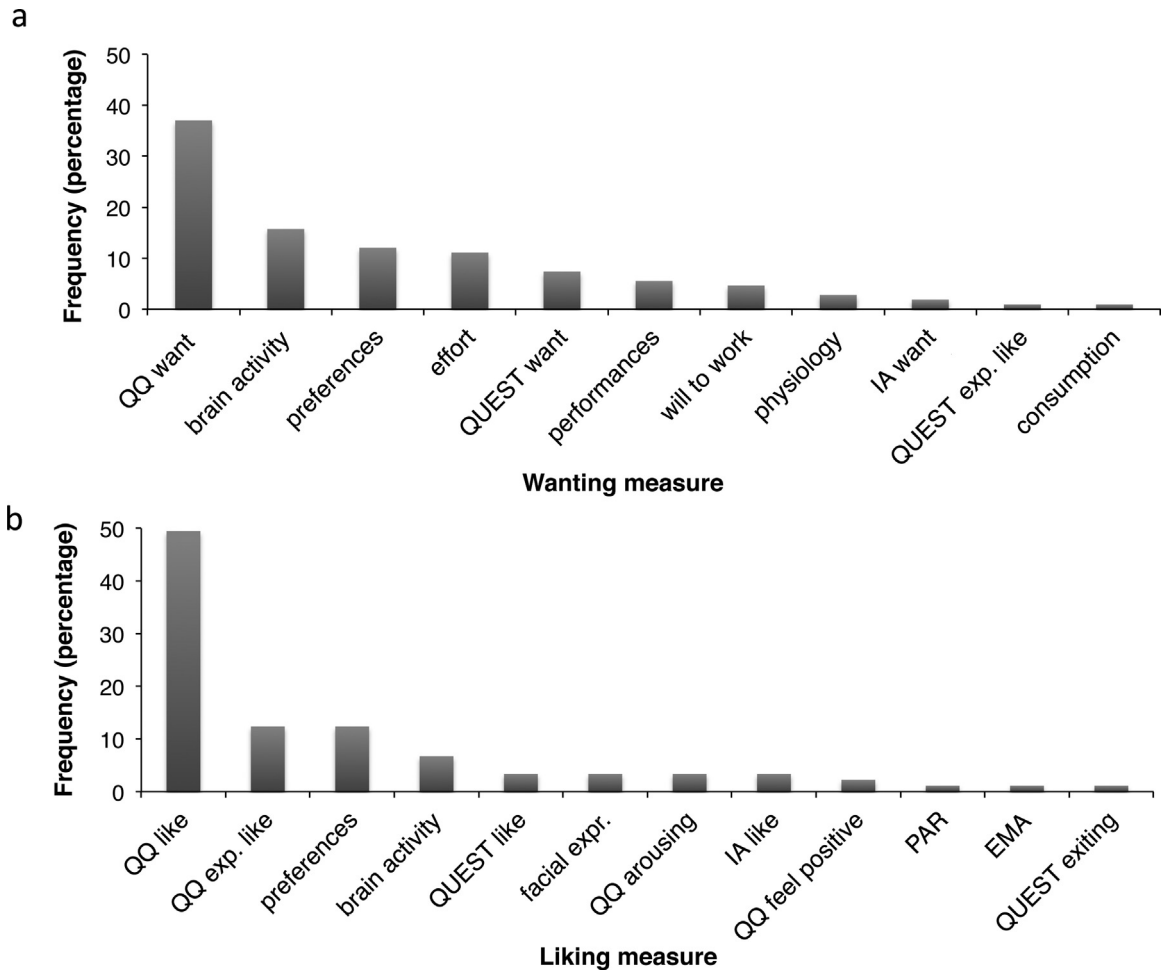

Fig. 2. Frequency (in percentage) of the different types of measures used to assess (a) wanting and (b) liking. EMA: evaluative movement task; exp.: expected; facial expr.: facial expression; IA: implicit association; PAR: postauricular reflex; QUEST: questionnaire; QQ: quantitative question; will.: willingness.

3. Results

3.1. Population

The majority of the selected studies (55.55%) investigated wanting and/or liking in healthy humans. However, the interest in these constructs as potential mechanisms underlying problematic behaviors was evident: a large proportion (25.55%) of human studies investigated wanting and/or liking in populations reporting problematic consumption of substances such as drugs, alcohol and nicotine; an important proportion (11.11%) targeted a population reporting problematic consumption of food, mostly related to excessive food consumption (e.g., overeating, bulimia, binge eating); and a smaller proportion of recent studies (3.33%) extended this investigation to behavioral addiction such as excessive video game playing or gambling. Finally, a small set of studies (4.44%) tried to measure wanting and/or liking in populations reporting other disorders such as schizophrenia and depression (see Table 2).

Table 2
Frequency (in percentage) of the population, type of study and object of studies investigating human wanting and/or liking.

Variable	Descriptor	Percentage
Population	Healthy	55.55
	Problematic use of substance	25.55
	Problematic food consumption	11.11
	Other disorders	4.44
	Behavioral addiction	3.33
Type of study	Physiological	53.57
	Neurobiological	30.95
	Behavioral	10.71
	Questionnaire	4.76
Object	Food	52.79
	Dependence substances	17.25
	Erotic/attractive	8.12
	Money	7.61
	Multiple	6.59
	Odor	4.06
	Activity/behavior	2.53
	Touch	1.01

3.2. Types of studies

Physiological studies (e.g., mobilized effort, electromyography, food or drug administration) represented the largest proportion (53.57%) of studies investigating human wanting and/or liking. The interest in physiological manipulation is congruent with the incentive salience hypothesis, according to which the physiological state of the individual represents a critical factor in determining both wanting and liking (Berridge and Robinson, 1998). Because the incentive salience hypothesis was conceived in neuroscience, it is not surprising that neurobiological studies (e.g., fMRI, PET, EEG, brain lesions) also represented a large proportion of the selected studies (30.95%). Behavioral (10.71%) and survey/questionnaire (4.76%) studies were less frequent (see Table 2).

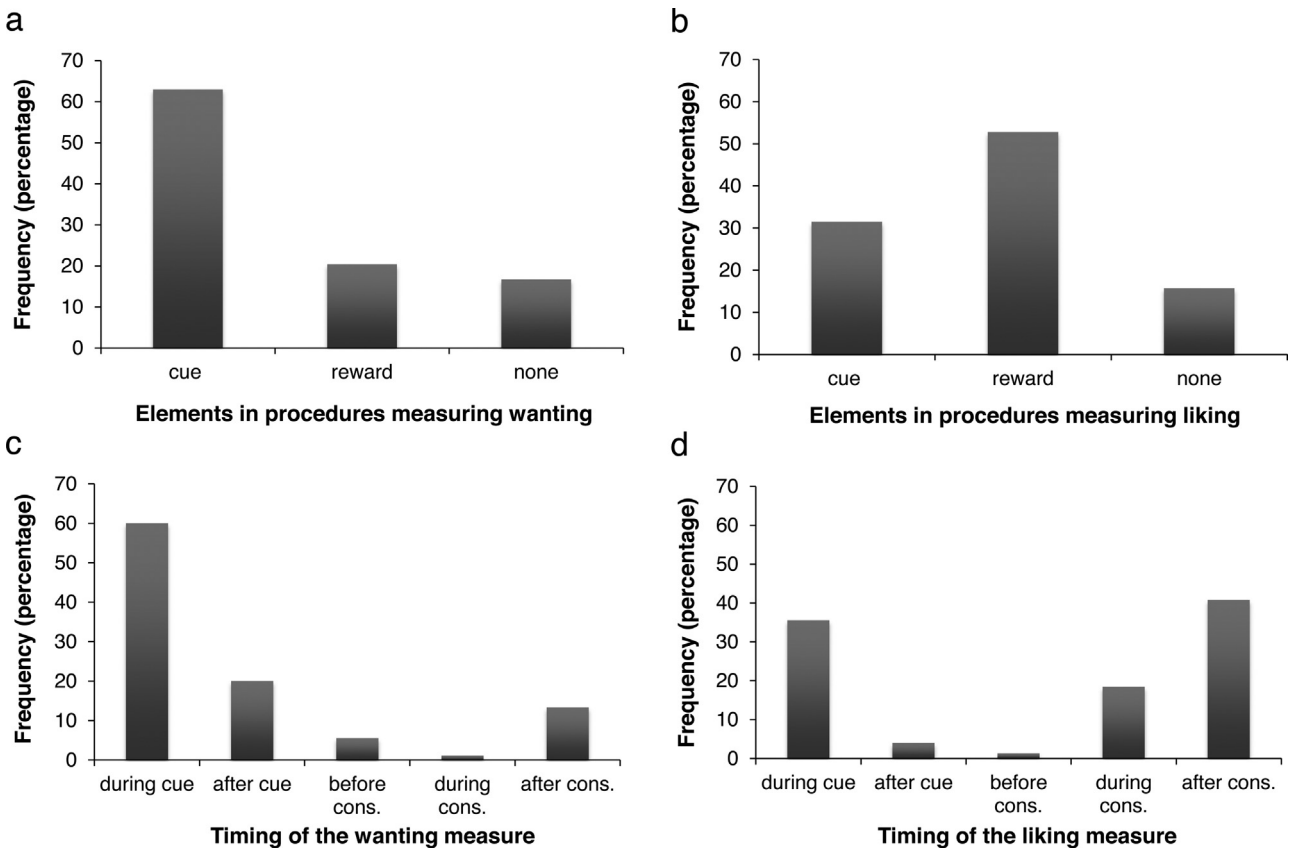

Fig. 3. Frequency (in percentage) of wanting (a) and liking (b) measures taken in methodological procedures that presented participants with a cue, a reward or neither of these two elements. Frequency (in percentage) of wanting (c) and liking (d) measures taken during or after the cue presentation, or before, during or after the reward consumption or receipt. cons.: consumption/receipt.

3.3. Object of the measure

Most of the methodological procedures in the selected studies measured wanting and/or liking for food reward (52.79%). This might be related to the history of the incentive salience hypothesis, which was initially developed for animal studies using food rewards (Berridge, 2000; Berridge and Robinson, 1998). Moreover, food has two main advantages with respect to the incentive salience hypothesis: first, being a primary reward, it can be consumed, thereby triggering a hedonic experience that can be measured and reported; second, the relevant physiological state (i.e., hunger) plays a critical role in the incentive salience hypothesis, which can easily be manipulated. Studies measuring wanting and/or liking for potentially addictive substances (e.g., cocaine, alcohol, nicotine) were relatively frequent (17.25%), again highlighting the interest in using these concepts to explain dysfunctional behaviors in humans such as substance addiction. Less frequent were studies measuring wanting and/or liking for money (7.61%), erotic/attractive stimuli (8.12%), other types of primary reward such as pleasant touches (1.01%) or pleasant activities (e.g., video gaming, physical activity; 2.53%), or multiple types of rewards (6.59%; see Table 2).

3.4. Measures

The present systematic review has highlighted how human wanting and liking have been studied through a large variety of measures, which can be described as having adopted four different strategies.

The most widespread strategy relied on the participants' knowledge of motivational and hedonic terms (e.g., wanting, craving, liking, appreciating). Most of the measures (37.03% for wanting studies and 49.43% for liking studies; see Fig. 2) consisted of a single quantitative question asking the participants about their feelings. These rating scales have been largely used to measure affective experiences such as pleasure and pain, and have shown high validity (e.g., Bartoshuk, 2014). Several authors (see Appendix A) have adapted this measure by asking participants to report, through a variety of different terms, their motivational feelings for a reward (i.e., wanting, craving, desire, urge to consume, desire to consume more) and their hedonic feeling for a reward (i.e., liking, pleasantness, appreciation, positive feelings). A particular case of these rating scale measures is a question on "expected pleasantness" that has been used to measure wanting in some methodological procedures (1%; see Fig. 2a). Other methodological procedures have used it as a measure of liking (12.35%; see Fig. 2b). Other measures (8.33% for wanting; 4.49% for liking) consisted of questionnaires or questionnaire subscales that targeted motivational (e.g., craving) or hedonic feelings (e.g., remembered or imagined liking). In some cases, rating scales and questionnaires used to measure liking targeted processes that are often considered motivational, such as excitement (1.12%) or arousal and attractiveness (3.37%). A small proportion of measures (2.27% for wanting; 3.37% for liking) aimed to develop an implicit index by adapting a task largely used in psychology: the implicit association task (Greenwald et al., 1998). In the classic version of the task, participants are asked to classify words into four categories: two representing target concepts (e.g., peace and war) and two representing attributes (e.g., positive and negative). In the association compatible blocks, participants are asked to press on a button (e.g., the right arrow key) for one concept and its congruent attribute (e.g., peace/positive) and on a different button (e.g., the left arrow key) for the other concept and its congruent attribute (e.g., war/negative). In the association

incompatible blocks, participants are asked to press on a button for a concept and its incongruent attribute (e.g., peace/negative) and on a different button for the other concept and its incongruent attribute (e.g., war/positive). Participants respond faster in the association compatible blocks than in the association incompatible blocks. The difference in reaction times between the two blocks is thought to reflect the strength of the association between a target category and its compatible attribute. This task has been adapted to measure the strength of an implicit association between the representation of a particular reward and the concepts of wanting and liking by using the attributes "I like", "I do not like" and "I want", "I do not want" (see Tibboel et al., 2015b for a detailed review). Although this task provides an implicit measure, in terms of underlying mechanisms it still requires high-level processing such as the semantic representation of the concepts of wanting and liking.

The second strategy consisted of trying to adapt measures from the animal literature. These studies measured wanting by the effort mobilized (11.11%), the willingness to work or to pay (4.62%), other indexes mixing performances and willingness to consume the reward (5.55%), or the amount of reward consumed (1%; see Fig. 2a). Researchers who adopted this strategy used methodological procedures that measured liking through electromyography of the facial muscles. Even though this measure corresponds most to the orofacial expressions used to assess animal liking, it has been relatively little used (3.37%; see Fig. 2b). This might be due to the difficulty in finding a clear indicator of hedonic pleasure in human facial expressions, which seems more suitable for measuring aversive experiences such as disliking; in particular, the activity of the *corrugator supercilii* seems to reflect disliking experiences (Booth et al., 2010; Horio, 2003; Hu et al., 1999). Other experimental work tried to develop another index of implicit liking: the evaluative movement task (1.12% see Fig. 2b). In this task, participants were asked to press on a keyboard to move a photograph of a reward toward or away from their first name, which was displayed on a computer screen. Pressing the key to move the reward toward their first name is taken as an implicit index of liking. However, this measure has a strong motivational component (i.e., approach, avoidance) that raises doubts of its validity as a pure hedonic index.

The third strategy used to test the incentive salience hypothesis on humans is to induce a motivational and/or a hedonic state and to measure the corresponding neural correlates (15.5% for wanting; 6.74% for liking; see Fig. 2). Beyond studies selected in the present systematic review, this strategy has successfully been used to investigate brain correlates of human hedonic pleasure (De Araujo et al., 2003; Kringelbach et al., 2003) and human incentive motivation (Prevost et al., 2012; Talmi et al., 2008). In these studies, behavioral performances and subjective ratings of liking were measured throughout the neuroimaging experiments and correlated with changes in brain activity.

The final strategy consisted of assessing participants' preferences for a particular reward over other rewards. Preference measures have been equally used to reflect wanting (12.03%; see Fig. 2a) in some studies and liking (12.35%; see Fig. 2b) in others. Several preference indexes were used across studies: some studies explicitly asked participants to report how much they preferred a particular reward in general (e.g., Born et al., 2011), whereas others measured relative preferences by presenting participants with possible combinations of different types of rewards and asking them to rapidly indicate which one they liked the most (e.g., Lemmens et al., 2009). Finlayson et al. (2007a) also developed implicit preference indexes: participants are presented with pairs of different rewards and they had to select the reward they wanted the most. The reaction time of each decision is thought to reflect the degree to which a reward is wanted over its alternative. This implicit index has been widely used in the literature as a measure of wanting or incentive salience (see Appendix A). Note that although preference indexes computed through participants' choices are equally taken to reflect human wanting and liking, they are more likely to reflect wanting. Different theoretical descriptions (Berridge and O'Doherty, 2014; Berridge and Robinson, 1998) have stated that wanting roughly corresponds to the concept of "decision utility" (Kahneman et al., 1997) that refers to the degree to which an outcome is chosen. Indeed, Berridge and Aldridge, 2008 proposed that irrational wanting can be observed in compulsive reward seeking behaviors (e.g., drug addiction, binge eating) and can be interpreted as a case of "decision utility", where the "decision utility" is disconnected from the "predicted utility" (i.e., the expectation of how much a future reward will be liked) and the "experienced utility" (i.e., the hedonic pleasure experience during the reward consumption). Such a process could thereby result in the decision to pursue a reward that is not expected to be liked and that is not actually liked once obtained.

Table 3
Frequency (in percentage) of the format in which the cue and reward were presented in the methodological procedures assessing human wanting and/or liking.

Variable	Descriptor	Percentage
Cue format	Photo	76.04
	Symbol	9.37
	Sample sight	5.21
	Video	5.21
	Odor	4.16
Reward format	Sample	50.72
	Photo	27.53
	Odor	13.04
	Other	4.34
	Caress	2.89
	Symbol	1.44

3.5. Reward, cue and timing

Reward and reward-associated cues are critical elements for the incentive salience hypothesis: wanting is triggered by the perception of a cue, while liking is triggered by reward consumption or receipt. The present systematic review highlights that most of the methodological procedures that have been used in investigating human wanting and/or liking included these elements (see Fig. 3a and b). More important, in congruence with the incentive salience hypothesis, the largest proportion (62.96%) of methods assessing human wanting included the presentation of a cue, whereas the largest proportion (52.80%) of methods assessing human liking included the presentation of an actual reward. However, a relatively high proportion of studies (31.46%; see Fig. 3b) presented cues while measuring liking. If incentive motivational elements such as reward cues are presented during the hedonic measure, then the measure does not purely reflect the hedonic experience, but is likely to reflect both motivational and hedonic influences. In particular, taking the hedonic measure during cue presentation rather than during reward consumption might be problematic because the measure reflects the encoded memory of the hedonic experience rather than the hedonic experience itself. Such memories of past hedonic experiences are used to build *expected pleasantness*, which does not correspond to animal liking.

The cue was visual in most methodological procedures (95.83%): participants were presented with photographs (76.04%), videos (5.21%) and symbols (9.37%) associated with the reward, or participants were simply presented with a reward sample that they could not yet consume (5.21%; see Table 3). A smaller proportion of methods involved olfactory cues (4.16%; see Table 3) such as food odors predicting a food taste. In most of the studies, the reward was a sample (e.g., food or drug) that could be consumed (50.72%; see Table 3). Rewards presented in this format are advantageous for measuring liking reactions, since they can trigger a strong hedonic experience

of sensory pleasure that can easily be reported. Other researchers have adapted a similar strategy by presenting the reward as pleasant odors (13.04%) or caresses (2.89%; see Table 3). In an important proportion of methods, the reward was presented visually when the reward object was, e.g., a pleasant photograph (27.53%), or a symbol indicating the receipt of a monetary reward (1.44%).

For the methodological procedures in which the cue and/or the reward were presented, we coded when wanting and/or liking measures were administered with respect to these elements. Timing is particularly important for tenets of the incentive salience hypothesis: wanting is a motivational component; thus, its specific influence is present *before* reward consumption. Wanting is triggered by the perception of a cue; thus, it should be measured during or after the cue perception, whereas liking is an experience triggered by reward consumption and thus it should be measured during or immediately after reward consumption.

The vast majority of methods (80.00%) investigating wanting integrated the time aspect accordingly, i.e., measured wanting during (60.00%; see Fig. 3c) or immediately after (20.00%; see Fig. 3c) a cue presentation. A smaller proportion of methods (14.44%) measured wanting during (1.11%; see Fig. 3c) or immediately after (13.33%; see Fig. 3c) reward consumption. In these cases, the wanting measure is likely to reflect hedonic influences and learning processes, as the administration of a reward after a stimulus or an instrumental action triggers Pavlovian or instrumental learning processes.

The majority of studies in which methodological procedures (59.21%) were used to investigate liking involved timings that were similar to those used in animal studies, measuring liking during (18.42%) or immediately after (40.78%; see Fig. 3d) reward consumption. However, in a substantial proportion of methods (39.47%), liking was measured during (35.52%; see Fig. 3d) or immediately after (3.94%; see Fig. 3d) the presentation of a cue. This might be problematic for several reasons. First, as previously mentioned, according to the incentive salience hypothesis, the presentation of a cue triggers wanting; thus, these measures are likely to reflect motivational influences. Second, in animal studies, liking is defined as an experience; thus, if the measurement is taken when the reward has not been consumed, it is unlikely to reflect the hedonic experience itself. Finally, studies often measured liking during or after cue perception in preference indexes and expected pleasantness questions, and, as illustrated in the previous section (Section 3.4), these two measures could potentially be problematic since they are also used to reflect wanting in other studies.

4. Discussion

The aim of the present review was to describe as systematically as possible how wanting and liking have been measured across studies investigating human reward with respect to the key elements of the incentive salience hypothesis (i.e., cue, reward and their respective timing). Through this systematic review of the human literature, we aimed to quantify the contradictory operationalizations of the wanting and liking constructs that have been previously highlighted (Havermans, 2011,2012) and to identify potential confounds that might have led to these contradictions.

We were able to include 84 publications in the present review by using stringent criteria: we included only those studies that explicitly aimed to measure wanting and/or liking with specific reference to the incentive salience hypothesis (Berridge and Robinson, 1998,2003; Robinson and Berridge, 2003). This number of studies confirms that among researchers investigating human reward, there is a great deal of interest in testing predictions of the incentive salience hypothesis. Basic research tested whether results from animal studies could be replicated in human studies by using brain imagining techniques (e.g., fMRI, PET; Born et al., 2011; Leyton et al., 2002), dopaminergic manipulations (e.g., dopaminiergic drug administration; Leyton et al., 2002, 2005) or methods that are as similar as possible to the original animal studies (e.g., Pool et al., 2015b). More applied research explored whether the potential independence of wanting and liking might represent a mechanism underlying a variety of problematic behaviors such as excessive food consumption (e.g., Lemmens et al., 2011c), substance addiction (e.g., Goldstein et al., 2010) or behavioral addictions (e.g., gambling, excessive video game playing; Thalemann et al., 2007; Wölfling et al., 2011).

Overall, this systematic review showed that the majority of studies on human wanting and liking have integrated key elements of the incentive salience hypothesis in their methodological procedures. Nonetheless, an important number of studies included measures that do not reflect wanting and liking as defined in the animal literature. These studies generated confusion about the wanting and/or liking constructs and might represent the source of the contradictory findings produced by the human experimental literature.

More precisely, most of the studies measured human wanting after or during the perception of a reward-associated cue. This measure is congruent with the idea that wanting is produced by a synergetic interaction between the current physiological state of an individual (e.g., hunger) and the encounter of a cue (real or vividly imagined; e.g., a food photograph) associated with a reward (e.g., food) that is relevant to the individual's current physiological state (Berridge and O'Doherty, 2014; Berridge and Robinson, 1998; Zhang et al., 2009). Neither the cue nor the physiological state is by itself sufficient to trigger wanting: the synergetic combination of these two elements is critical. An individual in a particular physiological state will not show any wanting behavior if he or she does not encounter a cue, and a cue will not elicit wanting behavior if the associated reward is not relevant for the physiological state of the individual (Robinson and Berridge, 2013; Tindell et al., 2009; Wyvell and Berridge, 2000; Zhang et al., 2009). Therefore, all the procedures that did not measure wanting during or after the perception of a real or vividly imagined cue are unlikely to truly reflect the specific influence of wanting. Even though these studies are not the majority, they still represent more than a third of the studies selected in the present systematic review.

Similarly, most of the studies measured liking during or immediately after the consumption of the reward, which is in line with the incentive salience hypothesis that defines liking as the hedonic experience of the consumption or the receipt of an immediate reward (Berridge, 2000; Berridge and Kringelbach, 2015; Berridge and O'Doherty, 2014; Berridge and Robinson, 1998, 2003). Therefore, measurements of liking should be taken as close as possible to reward consumption in order to reflect the hedonic experience. Nonetheless, the present review revealed that in almost half of the methodological procedures assessing human liking, the reward itself was not presented to the participants, but rather only reward cues, or questions were asked on expected, remembered or imagined likeability. All these measures are based on the encoded *episodic memory* of the past hedonic pleasure experienced. Kahneman and Riis (2005) illustrated several cases in which the memory of an experience did not correspond to the *experience* itself, because of variables biasing the encoding process of the experience. For instance, the same experience will be remembered in a remarkably different way if the most intense emotional moment is situated at the beginning or the end of the experience. Thus, remembered liking usually diverges from experienced liking. Remembered liking in humans does not refer to the same concept being measured in animal studies, in which liking is clearly conceived as a hedonic experience.

A major problematic aspect of human wanting and/or liking investigations is represented in the measures of preferences and expected pleasantness. Different implicit and explicit indexes of preferences and expected pleasantness taken at the same time in the methodological procedure (i.e., during cue perception) were used to reflect wanting in 13% of the studies, whereas these indexes were used to reflect liking in 25% of the studies. This finding descriptively quantifies the observation of Havermans (2011,2012) on the difficulty of congruently operationalizing wanting and liking among human researchers. But what are the reasons underlying this difficulty?

4.1. Expected pleasantness as a major confound

We argue that expected pleasantness represents a major conceptual confound underlying the problematic operationalization of wanting and liking in humans. More than 12% of the measures specifically asked participants to report their expectancies of pleasure, mostly to measure liking but sometimes also to measure wanting. In more than 47% of the studies that aimed to measure liking, the researchers did not present the reward in the procedures that they used, but simply asked participants to remember or imagine how much they liked or would like a particular reward. These questions reflect memories or expectations of liking rather than the experience itself.

Cognitive representations such as expected pleasantness are easier to access in humans than in animals; therefore, they are more widely present in the human literature. Expected pleasantness is an evaluation of how good or how bad a particular reward is going to be. This prediction involves active reconstruction of past episodic memories of liking experiences with the current reward and the use of these episodic memories to *anticipate* or *predict* a future experience (Dickinson and Balleine, 1994; Kahneman and Tversky, 1984). It has been widely demonstrated that while reward memories and reward anticipation are based on past liking experiences, most of the time they do not correspond perfectly (Kahneman and Riis, 2005). In the literature on human wanting and liking, some scholars consider expected pleasantness to be part of the liking component of reward processing, since its representation is mainly based on past liking experiences (e.g., Finlayson et al., 2007a; Soussignan et al., 2012). Other scholars, however, consider it to be the mechanism underlying wanting: expectations of pleasure are part of the anticipatory reward component and determine the motivation to obtain the reward (e.g., Dawkins et al., 2006; Gard et al., 2007). One way to move toward resolving this controversy is to analyze the role of expected pleasantness in the original incentive salience hypothesis. In one of its first formulations (Berridge and Robinson, 1998), the hypothesis did not clearly specify the difference between the mechanism underlying wanting and that of expected pleasantness. Later, however, the exact role of expected pleasantness with respect to wanting was further formulated (Berridge, 2007; Berridge and Aldridge, 2008; Zhang et al., 2009). More precisely, the incentive salience hypothesis distinguishes between (a) cognitive desires or explicit wanting based on a high-level goal-directed system, and (b) incentive salience or implicit wanting, based on a more primary Pavlovian system (see Fig. 4). It is important to note that even though cognitive desires are sometimes also referred to as explicit wanting, they *do not* correspond to the wanting component that can be dissociated from the hedonic properties of the reward in the framework of the incentive salience hypothesis. Cognitive desires do not simply differ from wanting in terms of explicitness/implicitness, but they rely on different underlying mechanisms. Cognitive desires are driven by the expected pleasantness of the reward. Expected pleasantness is build based on memories of past liking experiences. Since cognitive desires rely on a mechanism that depends on past liking experiences, they

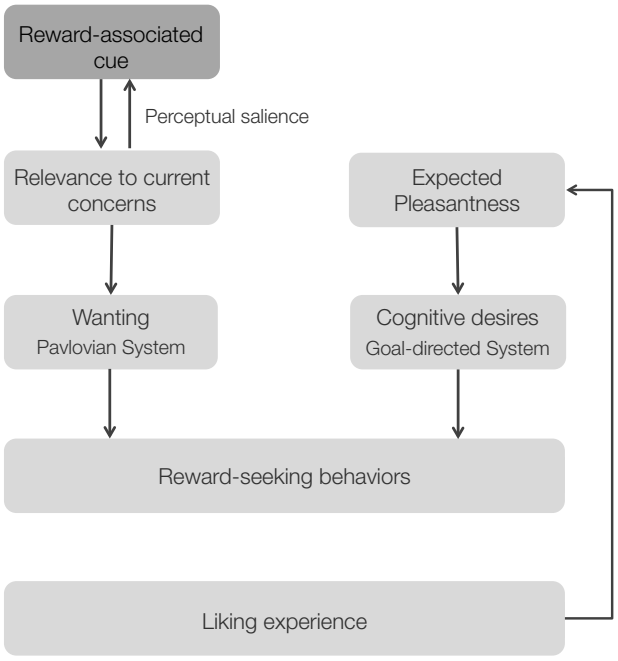

Fig. 4. Illustration of the mechanisms proposed to be involved in wanting and liking. Wanting is underlain by the interaction between the perception of a cue (conditioned stimulus; CS) associated with a reward (unconditioned stimulus; UCS) and the relevance of this reward for the current concerns of the individual. It is distinct and potentially independent from the expected pleasantness as well as the liking experience during the reward consumption or receipt. The reward relevance also increases the perceptual salience of the reward and the reward-associated cue. Liking, which consists in the hedonic experience during the reward consumption or receipt, influences expected pleasantness of a reward based on the memories of past liking experiences, in turn determining cognitive desires. While cognitive desires rely on the goal-directed system, wanting relies on the Pavlovian system, thus they represent two distinct motivational control systems of reward seeking behaviors.

are not completely independent from liking. On the other hand, wanting is potentially independent from any hedonic aspect of the reward, including expected pleasantness. This potential independence of wanting from any hedonic aspect of the reward implies that it is theoretically possible that individuals could mobilize effort to obtain a reward that they do not expect to like and that they are not going to like when they obtain it (Berridge and Aldridge, 2008; Berridge and O'Doherty, 2014). Since such a condition has mostly been observed through specific manipulations of mesolimbic dopamine in rodents, scholars working with human participants have argued that such dissociation does not have ecological validity (Havermans, 2011,2012). They argue that such brain manipulations do not provide an alternative explanation for the increased wanting for a reward that is not liked. On the basis of the absence of an alternative mechanism underlying wanting, some authors have suggested that the concept of wanting still implies a theoretical gap that needs to be filled (Frijda, 2010b).

4.2. Differentiating expected pleasantness from affective relevance as a solution

The major criticism of the construct of wanting concerns the lack of an alternative explanation to expected pleasantness in terms of underlying mechanisms. However, the incentive salience hypothesis does propose a clear computational mechanism underlying wanting (Zhang et al., 2009). This mechanism consists of a synergetic interaction between the physiological state of the individual and the perception of a cue associated with a reward: after the cue perception, wanting is not determined by the expected

pleasantness, but is directly modulated by the relevant physiological state.

One might object that physiological states such as hunger and thirst might also engender a parallel modification of expected pleasantness of rewards such as food and water. However, a large corpus of animal studies suggests that the functioning of these two mechanisms is different and that they rely on dissociable neural networks (e.g., Cardinal et al., 2002; Wassum et al., 2011b), as developed hereafter.

First, the representation of expected pleasantness, determining goal-directed actions in instrumental learning, critically depends upon episodic memory of the past pleasant experiences (Balleine, 2005; Dickinson and Balleine, 1994). Only if the reward (e.g., a particular food) is consumed in a new shifted physiological state (e.g., hunger), and the individual experiences the increased pleasantness of consuming the reward in the shifted physiological state (e.g., eating that particular food when hungry), is the expected pleasantness consequently modified (Balleine, 1992, 2005; Dickinson and Balleine, 1994). Studies showed that if the encoding of the increased valence of the reward under a shifted physiological state is pharmacologically blocked, individuals do not adapt the effort they mobilize to obtain the food reward according to the new physiological state (Wassum et al., 2011a). Motivational behaviors driven by expected pleasantness thus depend upon the episodic memories of prior experiences with the rewards. Research conducted on animals demonstrated that this mechanism relies on a network that includes the basolateral nucleus of the amygdala, which plays a critical role in encoding and updating experienced pleasantness (Johnson et al., 2009; Wassum et al., 2011a,b; Wellman et al., 2005), as well as prelimbic regions of the prefrontal cortex (Balleine and Dickinson, 1998; Killcross and Coutureau, 2003) and dorsomedial regions of the striatum (Yin et al., 2005), which retrieve and compute expected pleasantness to modulate the behavioral output.

Second, the mechanism underlying wanting does not necessarily depend on episodic memories; it dynamically varies according to the physiological state, without requiring the re-experience of reward pleasantness in the shifted physiological state (Robinson and Berridge, 2013; Tindell et al., 2009; Zhang et al., 2009). This finding implies that wanting of a particular reward can dramatically change according to a shift in the physiological state, even though the expected pleasantness for that reward has not changed. A growing corpus of experiments has demonstrated that cues that have been associated with non-attractive outcomes during learning trigger wanting if they are presented under a shifted physiological state in which the previously non-attractive outcome is now relevant (Dayan and Berridge, 2014; Dickinson and Balleine, 1990; Dickinson and Dawson, 1987; Robinson and Berridge, 2013; Tindell et al., 2009). A clear example of such a phenomenon has been provided by Robinson and Berridge (2013). In their study, rodents learned to associate a Pavlovian cue with a salt outcome, which was experienced as unpleasant during the learning phase. After the learning phase, rodents were put in a sodium-depleted state (which rodents had never experienced before) that induced a strong appetite for salt. These rodents had never before experienced or consumed salt in this new physiological state; therefore, they could not update their expectancies about the pleasantness of the salt outcome. Subsequently, the cue previously associated with the salt was presented. Even though rodents had never consumed salt in the new physiological state of sodium depletion, the presentation of the salt-associated cue induced a strong wanting: the Pavlovian cue that during the learning phase was avoided had now become strongly attractive, resulting in rodents showing several approach behaviors toward it (e.g., sniffing, grasping, nibbling). These experiments suggest that the mechanism underlying wanting is not a simple Pavlovian reflex, but that the Pavlovian cue activates the identity of the associated reward, which is relevant for the current physiological state, thus determining wanting. From a neural point of view, this mechanism seems to rely on a different network than expected pleasantness, which includes, among others, the central nuclei of the amygdala (Mahler and Berridge, 2009; Robinson et al., 2014), the ventral pallidum (Tindell et al., 2009), the ventral striatum and the ventral tegmental area (Wassum et al., 2013; Wyvell and Berridge, 2000).

In summary, theories investigating animal affective processes suggest the existence of two different mechanisms: (a) expected pleasantness, which critically relies on the episodic memory of past liking experiences and (b) synergetic interaction between a physiological state's need and a cue associated with a reward that is relevant for the current physiological state's need. Whereas expected pleasantness drives cognitive desires, the interaction between the individual's physiological state and the perception of the relevant reward-associated cue determines incentive salience or wanting (Berridge and O'Doherty, 2014). Therefore, cognitive desires being driven by memories of past liking experiences are not completely independent from liking, whereas wanting is underlain by a mechanism that is completely independent from the liking component (see Fig. 4).

Like the theories based on animal research, theories interested in the elicitation of affective processes in humans (Moors et al., 2013; Sander et al., 2005; Scherer et al., 2001; Smith and Ellsworth, 1985) stated a clear distinction between pleasantness evaluation, consisting of expectations about how pleasant or painful a stimulus event will be, and affective relevance evaluation, consisting of the interaction between the stimulus event and the current concerns of the individual perceiving it. Current concerns are affective representations of psychological and physiological motives (e.g., self-achievement), needs (e.g., hunger) and values (e.g., security) that are of major importance for the individual (Frijda, 1988). Therefore, affective relevance represents a mechanism that is similar to that proposed to underlie wanting in the animal literature: both are composed of the interaction between the outcome attributes and the organism's motivational state (e.g., Cunningham and Brosch, 2012; Robinson and Berridge, 2013; Sander et al., 2005; Zhang et al., 2009). Although animal experiments manipulated affective relevance by inducing physiological motivational states such as hunger or thirst (Balleine, 1994; Dickinson and Dawson, 1987; Robinson and Berridge, 2013), scholars investigating affective processing highlighted that in humans, a larger variety of motives (i.e., concerns based on socialization, personal sensitivity or momentary goals) is easily accessible in an experimental setting (Frijda, 2010a; Sander et al., 2005). While several concerns exist and are accessible in humans, they do not have the same importance for the individual. Concerns are organized in a dynamic hierarchy of priorities that can vary depending on the situation. The degree of affective relevance is determined by the number and the importance of concerns for which the outcome properties are relevant (Sander et al., 2005). The affective relevance of an outcome is thus not based on pleasure, even though they often correlate in the case of reward processing.

Consideration of the distinction between expected pleasantness and affective relevance as two different mechanisms underlying cognitive desires and wanting or incentive salience might significantly improve the quality of the methodological procedures that are used to assess the specific influences of wanting and liking and more generally contribute to a better understanding of human reward seeking behaviors.

First, expected pleasantness that determines cognitive desires is built on the episodic memory of this hedonic liking during reward consumption. This functioning implies that self-reported measures of wanting, likely to reflect cognitive desires, are underlain by a mechanism that relies on past liking experiences and therefore are not recommended in studies that aim to measure the selective

influences of wanting (by separating it from liking). The problem is not related to self-reports per se, but rather to the constructs that are reflected in these measures (e.g., cognitive desires) and their underlying mechanisms (e.g., expected pleasantness). Indeed, in the human literature, self-reported rating scales seem to be the most reliable index of the hedonic experience (Bartoshuk, 2014; Pichon et al., 2015). However, liking rating scales need to be administered during or immediately after the consumption of the reward; otherwise, they are likely to reflect episodic memories of past hedonic experiences or expected pleasantness that are mechanisms driving cognitive desires.

Second, consideration of the interaction between the current concern of the individual and the perception of a cue associated with a relevant outcome as a mechanism underlying wanting might be used in future studies to build behavioral manipulations inducing a wanting and liking dissociation without direct manipulation of brain activity. For instance, when an organism is working to obtain a reward under stressful conditions, the relevance of the reward is prioritized (Leyton, 2010). Research conducted on humans showed that in such circumstances, the activity of neural circuitry underlying wanting (i.e. amygdala, nucleus accumbens) increases after the perception of the cue and decreases during reward receipt (Kumar et al., 2014). This translates behaviorally into an increase in cue-triggered wanting without a parallel increase in liking (Pecina et al., 2006; Pool et al., 2015b).

Finally, considering affective relevance as a mechanism underlying wanting or incentive salience might provide some insight into the understanding of compulsive reward-seeking behaviors.

Several authors suggested that the conceptualization of separable wanting and liking might improve the understanding of problematic overeating that extends well beyond metabolic needs (Berridge, 2009a; Finlayson et al., 2007a; Johnson, 2013; Pecina and Smith, 2010; Pecina et al, 2006). Indeed, wanting or incentive salience for rewarding food does not exclusively rely on an interaction between the food's attributes and physiological states related to homeostasis such as hunger or thirst. It also relies on the interaction with others physiological states of the individual such as stress (Pecina et al., 2006; Pool et al., 2015a), dopaminergic activity, or opioid activity in the wanting neural network (Berridge, 2009; Pecina and Smith, 2010). The interaction between the perception of reward-associated cues and these latter kinds of physiological states is thought to be implicated in problematic overeating behaviors such as binge eating (Pecina and Smith, 2010; Berridge, 2009a).

Recent evidence supported this idea by showing that indexes of wanting or incentive salience for rewarding food are a powerful predictor of food intake in individuals suffering from binge eating disorders (e.g., Finlayson et al., 2011; Dalton and Finlayson, 2014). Broadening the underlying mechanisms of wanting from relevance to the current physiological state to affective relevance to current concerns might be particularly interesting in the case of these problematic behaviors. The affective relevance of an outcome depends on the importance of the concern for which its properties are relevant. In the hierarchy of priorities, some are more important than others because they determine how individuals define themselves, but are not associated with high expected pleasantness. Over time, individuals with psychological disorders involving compulsive reward consumption such as in binge eating, drug addiction or pathological gambling, begin to define themselves in relation to the reward that is compulsively sought after (e.g., binge eaters, drug addicts or gamblers), therefore rendering the reward highly relevant to their concerns. Such a process should increase the wanting triggered by reward-associated stimuli without increasing liking during the rewarding activity itself.

In this context, it could be interesting to note how social factors could also influence the prioritization of some particular concerns. For instance, in certain social groups, drinking or smoking is considered to be of value. By sharing the consumption of these rewards, the members of the group are able to bond. Therefore, if members of these groups find themselves in situations where social concerns (e.g., peer affiliation) are primed, the position of such concerns may be upgraded in the hierarchy of priorities and encountering a reward-associated cue (e.g., smoke or alcohol associated cue) might trigger amplified wanting peaks.

5. Conclusion

In conclusion, the present systematic review reveals that overall, the methodological procedures used to assess human wanting and/or liking have integrated key elements of the incentive motivation model, according to the main tenets of the incentive salience hypothesis. Most of the studies measured wanting after the presentation of a reward-associated cue and measured liking during or immediately after reward receipt or consumption. Nonetheless, a far from negligible number of studies used measures that do not reflect wanting and liking as defined in the animal literature. These studies generated confusion, since some of them operationalized wanting in ways that were similar to others that operationalized liking and vice versa. We suggest that these contradictions are driven by a major confound consisting of expected pleasantness. Expected pleasantness underlies cognitive desires and does not correspond either to animal liking, which is conceived as a hedonic experience, or to animal wanting, which relies on the interaction between the current physiological state of an organism and a cue associated with a relevant reward for the current physiological state of said organism. We argue that extending the concept of affective relevance to human specificities and its differentiation from expected pleasantness represents a solution to improve measures of human wanting and liking, constructs that might shed some light on a large variety of problematic and non-problematic human behaviors.

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Appendix A. : Summary of the studies included in the present systematic review

Note. cons.: consumption; EEG: electroencephalography; EMA: evaluative movement assessment; Exp.: experiment; fMRI: functional magnetic resonance imaging; freq.: frequency; mobil.: mobilized; PET: positron emission tomography; Physio: physiological; Pref.: preference; PRRT: progressive ratio reinforcement task; Quest.: questionnaire; QQ: quantitative question: Likert, visual analogue scale, buttons; QSS: questionnaire subscale; QUEST: questions from a questionnaire (not the entire subscale); RT: reaction time; U: correlated with; will: willingness.

Study	Type	Population	Wanting/incentive salience/incentive motivation					Liking/hedonic pleasure				
			Object	Reward	Cue	Measure	Time	Object	Reward	Cue	Measure	Time
Born et al. (2011)	fMRI	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ prefer	During cue
Born et al. (2009)	fMRI	Healthy	Food	–	Photo	Pref./choice	During cue	Food	–	Photo	Pref./choice	During cue
Born et al. (2012a)	fMRI	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ like	During cue
Born et al. (2012b)	fMRI	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ like	During cue
Buhler et al. (2010)	fMRI	Smoker	Nicotine	–	Symbol	Brain activity U effort mobil.	After cue	–	–	–	–	–
Bushman et al. (2011) Exp. 1)	Behavior	Healthy	Multiple	–	–	QQ want	–	Multiple	–	–	QQ pleasant	–
Bushman et al. (2011) Exp. 2)	Behavior	Healthy	Multiple	–	–	QQ want	–	Multiple	–	–	QQ pleasant	–
Bushman et al. (2012)	Quest	Healthy	Multiple	–	–	QQ want	–	Multiple	–	–	QQ pleasant	–
Cameron et al. (2008)	Physio	Overweight	Food	Sample	–	PRRT	Before cons.	Food	Sample	–	QQ appreciate	After cons.
Cameron et al. (2014) Measure 1)	Physio	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ appreciate	During cue
Cameron et al. (2014) Measure 2)	Physio	Healthy	Food	Sample	–	PRRT	Before cons.	–	–	–	–	–
Cowdrey et al. (2013) Measure 1)	Behavior	Problematic food cons.	Food	–	Photo	RT to choose	During due	Food	–	Photo	QQ like	During cue
Cowdrey et al. (2013) Measure 2)	Behavior	Problematic food cons.	Food	–	Photo	QQ want	During cue	–	–	–	–	–
Dagher et al. (2009)	fMRI	Smoker	Nicotine	–	Video	Brain activity U QQ crave	During cue	–	–	–	–	–
Dai et al. (2010) Exp. 1)	Behavior	Healthy	Attractive	Photo	–	Key pressing task	During cons.	Attractive	Photo	–	EMA	During cons.
Dai et al. (2010) Exp. 2)	Quest	Healthy	Attractive	Photo	–	QQ want to consume	After cons.	Attractive	Photo	–	QQ pleasant/attractive	During cons.
Dai et al. (2014) Exp. 1)	Behavior	Healthy	Imaginary romantic partner	–	–	QQ motivated to invest effort	–	Imaginary romantic partner	–	–	QQ positive feelings	–
Dai et al. (2014) Exp. 2)	Behavior	Healthy	Real romantic partner	Real date	–	QQ motivated to invest effort	After cons.	Real romantic partner	Real date	–	QQ positive feelings	After cons.
Dalton et al. (2013a)	Physio	Obese	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
Dalton et al. (2013b)	Physio	Problematic food cons.	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
Dawkins et al. (2006) Measure 1)	Physio	Smoker	Multiple	–	–	QSS expected pleasure	–	–	–	–	–	–
Dawkins et al. (2006) Measure 2)	Physio	Smoker	Money	–	Sample sight	RT of the instrumental action	After cue	–	–	–	–	–
Dawkins et al. (2006) Measure 3)	Physio	Smoker	Nicotine	–	Sample sight	QQ desire	After cue	–	–	–	–	–
Dawkins et al. (2006) Measure 4)	Physio	Smoker	Money	–	Symbol	RT of the instrumental action	After cue	–	–	–	–	–
Dermiki et al. (2015)	Physio	Healthy	–	–	–	–	–	Food	Sample	–	QQ like	After cons.
Dewitte (2015) Measure 1)	Behavior	Healthy	Sex	–	Video	Implicit association want	After cue	Sex	–	Video	Implicit association like	After cue
Dewitte (2015) Measure 2)	Behavior	Healthy	Sex	–	Video	QQ want	After cue	Sex	–	Video	QQ like	After cue
Epstein et al. (2011)	Physio	Obese	Food	Sample	–	PRRT	During cons.	Food	Sample	–	QQ like	After cons.
Epstein et al. (2015)	Physio	Children	Food	–	–	Will. to mobil. effort	–	Food	–	–	QQ like	–
Epstein et al. (2003) Measure 1)	Physio	Healthy	Food	Sample	–	PRRT	During cons.	Drink	Sample	–	Facial expressions	During cons.
Epstein et al. (2003) Measure 2)	Physio	Healthy	–	–	–	–	–	Drink	Sample	–	QQ like	After cons.
Epstein et al. (2004)	Physio	Smoker	Food	Sample	–	Will. to mobil. effort	After cons.	Food	Sample	–	QQ like	After cons.
Filbey et al. (2008)	fMRI	Alcohol-related	Alcohol	Sample	–	Brain activity U QQ urge	During/after cons.	–	–	–	–	–
Finlayson et al. (2011)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue

Study	Type	Population	Wanting/incentive salience/incentive motivation					Liking/hedonic pleasure				
			Object	Reward	Cue	Measure	Time	Object	Reward	Cue	Measure	Time
Finlayson et al. (2009) Measure 1)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
Finlayson et al. (2009) Measure 2)	Physio	Healthy	–	–	–	–	–	Food	Sample	–	QQ pleasant	After cons.
Finlayson et al. (2007a)	Physio	Healthy	Food	–	Photo	Pref./choice	During cue	Food	–	Photo	QQ expected pleasure	During cue
Goldstein et al. (2010)	Physio	Substance-related	Multiple	–	–	QQ want	–	Multiple	–	–	QQ expected pleasure	–
Gray et al. (2014) Reward 1)	fMRI	Smoker	Money	–	Photo	Brain activity	During cue	–	–	–	–	–
Gray et al. (2014) Reward 2)	fMRI	Smoker	Nicotine	–	Photo	Brain activity	During cue	–	–	–	–	–
Griffioen-Roose et al. (2010) Measure 1)	Physio	Healthy	Food	Sample	–	QQ want	After cons.	Food	Sample	–	QQ pleasant	After cons.
Griffioen-Roose et al. (2010) Measure 2)	Physio	Healthy	Food	–	Photo	PRRT	During cue	–	–	–	–	–
Griffioen-Roose et al. (2010) Measure 3)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
Grüsser et al. (2002)	Physio	Alcohol-related	Alcohol	–	Photo	Acoustic startle	During cons	–	–	–	–	–
Havermans et al. (2009)	Physio	Healthy	Food	–	Photo	PRRT	During cue	Food	Sample	–	QQ pleasant	After cons.
Hebert et al. (2015)	Physio	Healthy	Food photo	–	Symbol	Postauricular reflex	During cue	Food photo	Photo	–	Postauricular reflex	During cons.
Hebert et al. (2015)	Physio	Healthy	–	–	–	–	–	Food photo	Photo	–	QQ pleasant/arousal	During cons.
Heinz et al. (2004)	PET/fMRI	Alcohol-related	Alcohol	–	Photo	Brain activity U QSS craving	During cue	–	–	–	–	–
Jiang et al. (2008) Reward 1)	Physio	Healthy	Food	–	Photo	QQ want	After cue	Food photo	Photo	–	QQ like	After cons.
Jiang et al. (2008) Reward 2)	Physio	Healthy	Food	–	Odor	QQ want	After cue	Food odor	Odor	–	QQ like	After cons.
Jiang et al. (2010) Reward 1)	Physio	Problematic food cons.	Food	–	Photo	QQ want	After cue	Food photo	Photo	–	QQ like	After cons.
Jiang et al. (2010) Reward 2)	Physio	Problematic food cons.	Food	–	Odor	QQ want	After cue	Food odor	Odor	–	QQ like	After cons.
Jiang et al. (2015)	fMRI	Healthy	Food	–	Odor	QQ want	After cue	Food odor	Odor	–	QQ like	After cons.
King et al. (2015)	Physio	Alcohol-related	Alcohol	Sample	–	QQ want	After cons.	Alcohol	Sample	–	QQ like	After cons.
Krishnamurti and Loewenstein (2012)	Quest.	Healthy	Partner-specific sex life	–	–	QUEST: cons. freq./arousal	–	Partner-specific sex life	–	–	QUEST like/find exciting	–
Kumar et al. (2014)	fMRI	Healthy	Money	–	Symbol	Brain activity	During cue	Money	Symbol	–	Brain activity	During cons.
Kushnir et al. (2013)	fMRI	Smoker	Nicotine	–	Photo	Brain activity	During cue	–	–	–	–	–
Lambert et al. (2006)	Quest.	Substance-related	Drug	–	–	QSS want	–	Drug	–	–	QSS like	–
Lawrence et al. (2012) Measure 1)	fMRI	Healthy	Food	–	Photo	Brain activity	During cue	–	–	–	–	–
Lawrence et al. (2012) Measure 2)	fMRI	Healthy	Food	Sample	–	Consumed amount	After cons.	–	–	–	–	–
Lawrence et al. (2012) Measure 3)	fMRI	Healthy	Food	–	–	QSS physio craving	–	–	–	–	–	–
Lawrence et al. (2012) Measure 4)	fMRI	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ like	During cue
Lemmens et al. (2010)	Physio	Healthy	Food	–	Photo	Perf. + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Lemmens et al. (2011a)	Physio	Healthy	Food	–	Photo	Perf. + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Lemmens et al. (2011b)	Physio	Healthy	Food	–	Photo	Perf. + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Lemmens et al. (2011c)	Physio	Overweight	Food	–	Photo	Perf. + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Lemmens et al. (2009)	Physio	Healthy	Food	–	Photo	Perf. + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Leyton et al. (2002)	PET	Healthy	Drug	Sample	–	QQ want	Before/after cons.	Drug	sample	–	QQ like	Before/after cons.
Leyton et al. (2005)	Physio	Substance-related	Drug	–	Sample-sight	QQ want	Before/after cons.	–	–	–	–	–
Litt et al. (2010)Exp. 1)	Behavior	Healthy	Prize	–	–	Will. to pay	–	Prize	–	–	Pref./choice	–
Litt et al. (2010)Exp. 2)	Behavior	Healthy	Prize	–	–	Pref./choice	–	Prize	–	–	QQ attractive	–

Study	Type	Population	Wanting/incentive salience/incentive motivation					Liking/hedonic pleasure				
			Object	Reward	Cue	Measure	Time	Object	Reward	Cue	Measure	Time
Martens et al. (2012)	Physio	Overweight	–	–	–	–	–	Food	Sample	–	QQ like	During cons.
McCabe et al. (2009) Measure 1)	fMRI	Depression-related	Food	Sample	–	QQ want	After cons.	Food	Sample	–	QQ pleasant	After cons.
McCabe et al. (2009) Measure 2)	fMRI	Depression-related	Food	–	Photo	QQ want	After cue	Food	–	Photo	QQ pleasant	After cue
McCabe et al. (2011)	fMRI	Healthy	Food	Sample	–	QQ want	After cons.	Food	Sample	–	QQ pleasant	After cons.
McClernon et al. (2009)	fMRI	Smoker	Nicotine	–	Photo	Brain activity U QQ craving	During cue	–	–	–	–	–
McCloskey et al. (2010)	Physio	Healthy	Drug	Sample	–	QQ want	After cons.	Drug	Sample	–	QQ like	After cons.
McNeil et al. (2015a) Measure 1)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
McNeil et al.(2015a) Measure 2)	Physio	Healthy	Food	–	Photo	QQ want	During cue	–	–	–	–	–
McNeil et al. (2015b) Measure 1)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
McNeil et al. (2015b) Measure 2)	Physio	Healthy	Food	–	Photo	QQ want	During cue	–	–	–	–	–
McNeil et al. (2013)Measure 1)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	Food	–	Photo	QQ expected pleasure	During cue
McNeil et al. (2013)Measure 2)	Physio	Healthy	Food	–	Photo	QQ want	During cue	–	–	–	–	–
Newton et al., 2009 Newton et al. (2009) Measure 1)	Physio	Substance-related	Drug	–	–	QUEST: cons. because of craving	–	–	–	–	–	–
Newton et al., 2009 Newton et al. (2009) Measure 2)	Physio	Substance-related	Drug	–	–	QUEST: cons. because of cues	–	–	–	–	–	–
Ostafin et al. (2010)	Physio	Alcohol-related	Alcohol	–	Sample-sight	QQ urge	After cue	Alcohol	Sample	–	QQ pleasant	After cons.
Pool et al. (2015b)	Physio	Healthy	Food odor	–	Symbol	Effort mobil.	During cue	Food odor	Odor	–	QQ pleasant	After cons.
Powell et al. (2002)	Physio	Smoker	Nicotine	–	Sample-sight	QSS urge	After cue	–	–	–	–	–
Roemmich et al. (2008)	Physio	Children	–	–	–	–	–	Physical activity	Activity	–	QQ like	After cons.
Rueger et al. (2015)	Physio	Alcohol-related	Alcohol	Sample	–	QQ cons. more	After cons.	Alcohol	Sample	–	QQ like	After cons.
Rutters et al. (2012)	Physio	Healthy	Food	–	Photo	Performance + want cons.	During cue	Food	–	Photo	Pref./choice	During cue
Schrieks et al. (2015) Measure 1)	Physio	Healthy	Food	–	Photo	QQ want	During cue	Food	–	Photo	QQ pleasant	During cue
Schrieks et al.(2015) Measure 2)	Physio	Healthy	Food	–	Photo	RT to choose	During cue	–	–	–	–	–
Sescousse et al. (2013) Reward 1)	fMRI	Gambler	Erotic photo	–	Symbol	Brain activity	During cue	Erotic photo	Photo	–	Brain activity U QQ pleasant	During cons.
Sescousse et al.(2013) Reward 2)	fMRI	Gambler	Money	–	Symbol	Brain activity	During cue	Money	Photo	–	Brain activity U QQ pleasant	During cons.
Simon et al. (2010a)	fMRI	Schizophrenic	Money	–	Symbol	Brain activity	After cue	Money	Photo	–	Brain activity	During cons.

Study	Type	Population	Wanting/incentive salience/incentive motivation					Liking/hedonic pleasure				
			Object	Reward	Cue	Measure	Time	Object	Reward	Cue	Measure	Time
Simon et al. (2010b)	fMRI	Healthy	Money	–	Symbol	Brain activity	After cue	Money	Photo	–	Brain activity	During cons.
Small et al. (2003)	PET	Healthy	–	–	–	–	–	Food	Sample	–	Brain activity UQ pleasant	After cons.
Soussignan et al. (2010)	Physio	Problematic food cons.	Food	–	Photo	QQ desire	During cue	Food	–	Photo	QQ expected pleasure	During cue
Soussignan et al.(2012) Measure 1; Reward 1	Physio	Overweight children	Food	–	Photo	QQ want	After cue	Food photo	Photo	–	QQ like	After cons.
Soussignan et al(2012) Measure 1; Reward 2	Physio	Overweight children	Food	–	Odor	QQ want	After cue	Food odor	Odor	–	QQ like	After cons.
Soussignan et al. (2012) Measure 2)	Physio	Overweight children	–	–	–	–	–	Food	–	Photo	Pref./choice	During cue
Stenblom et al. (2015)	Physio	Healthy	Food	Sample	–	QQ want	Before/after cons.	Food	Sample	–	QQ pleasant	After cons.
Thalemann et al. (2007) Measure 1)	EEG	Video gamer	Video games	–	Photo	Brain activity	During cue	Video games	–	Photo	Pref./choice	During cue
Thalemann et al. (2007) Measure 2)	EEG	Video gamer	Video games	–	Photo	QQ crave	During cue	–	–	–	–	–
Tibboel et al. (2015a)	Behavior	Alcohol-related	Alcohol	–	–	Implicit association want	–	Alcohol	–	–	Implicit association like	–
Tibboel et al. (2011)	Behavior	Smoker	Nicotine	–	–	Implicit association want	–	Nicotine	–	–	Implicit association like	–
Touyarou et al. (2011)	Physio	Healthy	Food	–	Photo	QQ want	After cue	Food odor	Odor	–	QQ pleasant	After cons.
Triscoli et al. (2014a)	Behavior	Healthy	Touch	Caress	–	QQ want	After cons.	Touch	Caress	–	QQ pleasant	After cons.
Triscoli et al. (2014b)	Behavior	Healthy	Pleasant odors	Odor	–	QQ want	After cons.	Pleasant odors	Odor	–	QQ pleasant	After cons.
Vijayaraghavan et al. (2013)	Brain lesion	Brain lesion	Multiple	Photo	–	Key press task	During cons.	Multiple	Photo	–	QQ pleasant	After cons.
Vijayaraghavan et al. (2008)	Brain lesion	Brain lesion	Multiple	Photo	–	Key press task	During cons.	Multiple	Photo	–	QQ pleasant	After cons.
Wilner et al. (2005; Exp. 1)	Quest.	Alcohol-related	Alcohol	–	–	QSS desire/intention to cons.	–	Alcohol	–	–	QUEST positive effects of cons.	–
Wilner et al. (2005; Exp. 2)	Quest.	Substance-related	Drug	–	–	QSS desire/intention to cons.	–	Drug	–	–	QUEST positive effects of cons.	–
Wölfling et al. (2008)	EEG	Substance-related	Drug	–	Photo	Brain activity	During cue	–	–	–	–	–
Wölfling et al. (2011)	EEG	Gambler	Gambling	–	Photo	Brain activity	During cue	–	–	–	–	–

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