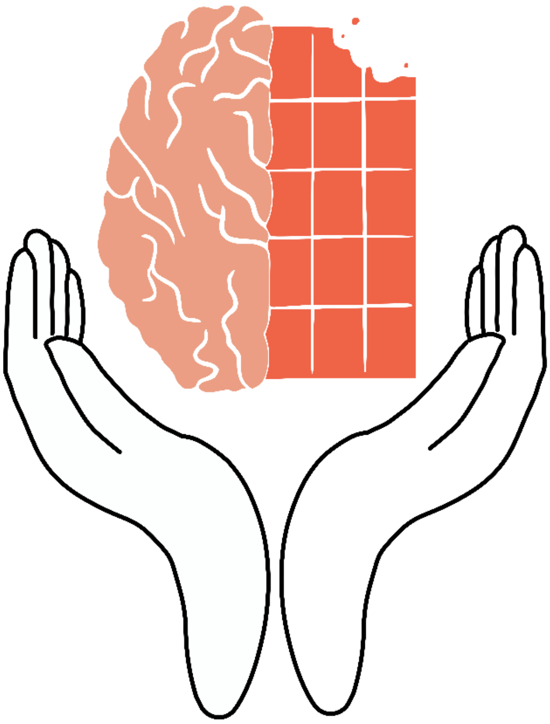

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UNIVERSIDAD DE GRANADA

Doctoral Thesis

Doctoral Program in Psychology

DECISION-MAKING IN EATING BEHAVIOUR

LEARNING PROCESSES AND INDIVIDUAL DIFFERENCES

Toma de decisiones en la conducta alimentaria:
Procesos de aprendizaje y diferencias individuales

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A mi madre y a mi padre

Introductory Note

The research included in this doctoral thesis was conducted at the laboratory of the Learning, Emotion, and Decision Group (CIMCYC) of the Universidad de Granada thanks to the following funding awarded to Felisa González Reyes as PI:

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The content of this doctoral thesis has been written according to the regulations of the University of Granada to obtain the Doctorate with International Mention in the Psychology Doctoral Programme. Therefore, it has been drafted entirely in English, except for a general summary written in Spanish. In addition, this work was supported by a grant funded by the Rectorate of the University of Fribourg (Switzerland) for foreign researchers for a four-month training stay at the Laboratory of Neurorehabilitation Sciences (University of Fribourg), supervised by Dr Lucas Spierer.

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SUMMARY IN SPANISH

Los alimentos altamente calóricos, ricos en azúcares y pobres nutricionalmente, como la bollería industrial y la comida basura, son omnipresentes, fácilmente accesibles y difíciles de resistir en las sociedades occidentales actuales. Nos encontramos en un entorno en el que debemos tomar continuamente decisiones relacionadas con la alimentación. En este ambiente repleto de claves que incentivan nuestra conducta de búsqueda de refuerzo, un control de la acción flexible y adaptativo es esencial para mantener un comportamiento alimentario saludable. La prevalencia de los problemas relacionados con la ingesta de alimentos no deja de aumentar año tras año. Teniendo en cuenta la dificultad de modificar directamente este contexto obesogénico, las elevadas tasas de prevalencia con el consiguiente aumento de los costes médicos y los graves problemas de salud subyacentes, es esencial desarrollar modelos potentes que identifiquen las variables implicadas en los comportamientos que contribuyen en esta problemática.

La conducta alimentaria está influida por factores biológicos (por ejemplo, las señales de saciación o las necesidades energéticas) y factores no biológicos, destacando entre estos últimos los procesos de condicionamiento y regulación emocional. Saber más sobre estos factores y cómo afectan al control y la selección del comportamiento alimentario es crucial para comprender, prevenir e intervenir en posibles trastornos psicológicos, así como para promover actitudes saludables. Además de la investigación clínica y básica, campos como el neuromarketing y la ciencia de los alimentos —donde es crucial comprender las necesidades y preferencias de los consumidores—, también se han comenzado a interesar por esta área de conocimiento.

El objetivo principal de la presente tesis doctoral ha sido evaluar la toma de decisiones en la conducta alimentaria desde una perspectiva de aprendizaje. Para ello, se han estudiado tres aspectos relacionados con este comportamiento: 1) el papel de la regulación emocional en el control y la selección de acciones (Capítulo 3); 2) cómo disminuir la saliencia de la claves contextuales que adquieren propiedades de incentivo ("wanting"), así como los comportamientos desadaptativos asociados en participantes que sufren frecuentemente episodios de craving por la comida (Capítulo 4); 3) el efecto del nivel de pericia en las medidas explícitas e implícitas (y la fuerza de su relación) del análisis hedónico y sensorial de alimentos ("liking") (Capítulo 5).

Para alcanzar este objetivo, se han llevado a cabo cinco experimentos en los que se han empleado distintas técnicas y metodologías, entre las que se incluye: el uso de paradigmas comportamentales como el *Pavlovian-to-Instrumental Transfer test* y el procedimiento de devaluación del reforzador; la implementación de novedosas estrategias basadas en la atención plena para reducir el craving por la comida en el laboratorio y en contextos naturales, gracias a la programación y empleo de una aplicación para *smartphones*; así como el análisis de experiencias sensoriales y hedónicas del consumo de bebidas (cervezas) utilizando medidas explícitas (juicios sensoriales y de calidad: niveles visual, olfativo, gustativo y el valor general hedónico) e implícitas (registros continuos de la actividad cerebral mediante electroencefalografía, EEG). Finalmente, cabe destacar la política de transparencia aplicada en los análisis estadísticos realizados a través de la deposición de los datos en OSF (*Open Science Framework*).

Los resultados de este conjunto de estudios tienen relevantes implicaciones teóricas y clínicas. Por un lado, en el Capítulo 3 se muestra que la impulsividad emocional afecta al sistema de toma de decisiones disminuyendo la eficacia en el control y la selección de la acción, así como capacidad de extraer información de las claves contextuales e integrarla en la conducta instrumental específica (efecto PIT específico del resultado). Nuestros datos sugieren que el efecto PIT específico del resultado está controlado por el sistema dirigido a meta y, además, este control se ve perjudicado por la impulsividad emocional (urgencia negativa). Futuras intervenciones clínicas o de promoción de la salud podrán adaptar sus estrategias incluyendo el entrenamiento en regulación emocional para individuos con condiciones clínicas que involucren dificultades para actualizar el valor actual del resultado (como por ejemplo ocurre en el trastorno por atracón o la obesidad).

Por otro lado, en el Capítulo 4, el uso de una breve intervención en atención plena (defusión cognitiva) de 3 minutos reduce la intensidad de los episodios de craving (*wanting*) y mejora la conducta alimentaria en mujeres vulnerables, tanto en el laboratorio como en episodios espontáneos generados en contextos reales. Esta estrategia podría aplicarse clínicamente a personas en las que la reactividad a las claves alimentarias suponga un potencial problema de salud. Además, las investigaciones futuras también podrán implementar esta herramienta de bajo coste y gran accesibilidad que permite recoger datos en tiempo real en contextos naturales a través del teléfono móvil.

Por último, en el Capítulo 5, los datos muestran que el nivel de pericia influye en la fuerza de la relación entre las medidas explícitas e implícitas que se han utilizado para evaluar sensorial y hedónicamente (*liking*) distintas cervezas.

Concretamente, expertos catadores en cerveza muestran un mayor número de correlaciones entre ambas medidas y un uso de estrategias más analíticas durante el análisis sensorial y hedónico —en comparación con participantes sin formación experta, quienes parecen confiar más en experiencias personales previas—. Futuras investigaciones sobre los mecanismos de *liking* asociados a la experiencia hedónica de consumir una recompensa alimentaria deberían considerar la experiencia previa de los participantes, especialmente la vinculada a la formación o conocimiento experto. Además, en campos como el neuromarketing podrán potenciar el uso de medidas implícitas, pues han resultado ser relativamente más sensibles que las explícitas.

THESIS PUBLICATIONS

Publications Included in the Thesis

This thesis is presented as a "Compendium of articles". Therefore, the published contributions included in each experimental section chapter are detailed below.

The Content of Chapter 3 has been published as:

Hinojosa-Aguayo, I., & González, F. (2020). Affect-driven impulsivity impairs human action control and selection, as measured through Pavlovian instrumental transfer and outcome devaluation. *Quarterly Journal of Experimental Psychology*, 73(4), 537–554. https://doi.org/https://doi.org/10.1177/1747021819883963

Impact Factor (JCR): 2,143 (Psychology, Experimental: Q3; 58/91)

The Content of Chapter 4 has been published as:

Hinojosa-Aguayo, I., & González, F. (2022). Cognitive Defusion as Strategy to Reduce the Intensity of Craving Episodes and Improve Eating Behavior. *The Spanish Journal of Psychology*, *25*, 1–12. https://doi.org/10.1017/sjp.2021.47

Impact Factor (JCR): 1,264 (Psychology, Multidisciplinary: Q4; 106/140)

The Content of Chapter 5 has been published as:

Hinojosa-Aguayo, I., Garcia-Burgos, D., Catena, A., & González, F. (2022). Implicit and explicit measures of the sensory and hedonic analysis of beer: The role of tasting expertise. *Food Research International*, 152, 1–11. https://doi.org/10.1016/j.foodres.2021.110873

Impact Factor (JCR): 6,475 (Food Science & Technology: Q1/D1; 9/143)

GENERAL THEORETICAL AND EMPIRICAL INTRODUCTION

CHAPTER 1:

Learning Processes and Behavioural Mechanisms Underlying Food Decision-Making

Decision-making is a complex process involving mechanisms of instrumental action control and selection. Our ability to extract and integrate information on causal relationships from the environment to guide and select the best choice among competing courses of action is a key component which encapsulates the core structure and function of action control (Balleine, 2015). From a learning-focused perspective, instrumental action control has been broadly dichotomised for years (Balleine, 2019; Bouton, 2021; A Dickinson, 1985; Morris et al., 2022).

1.1. Law of Effect Theory and Cognitive maps

Research on instrumental action control began with Thorndike's postulations on the well-known Law of Effect Theory (Thorndike, 1911). In one experiment, he placed cats in cages in which, to get out, they had to press a lever. After finding that animals improved their ability to escape by trial and error, the author discovered that, with repetition, the contextual stimuli of the cage (S) were associated with the response required to escape (R), whereby the pleasant outcome of escaping from the cage (O) was a mere reinforcer of the S-R association. From this associationist perspective, S-R theorists were able to offer, for the first time, a complete explanation of why reinforcers strengthened actions: the presence of a reinforcer, such as food, increases the strength of the bond between the stimulus that was present at the time the response occurred, and the response, without encoding any information about the outcome itself in the associative chain. The strengthening of the association would then lead to the formation of a hitherto new concept: the habit (Berridge, 2001). This definition of habit emphasises that its execution is independent of the current value of the outcome that reinforced the habit in the first place (Dickinson & Perez, 2018). Thus, once the association is created, the mere presence of the stimulus will reflexively generate a motor response.

A few years later, Hull provided a more refined version of the S-R framework in his famous book, *Principles of Learning* (Hull, 1943). According to Hullian theory, the probability of performing a particular action depends mainly on the drive and habit strength (Goodman, 2021). On the one hand, when we are, for example, hungry, we would be in a *drive state* that prompts us to seek food to reduce the drive of hunger. Hull considered that the reduction of this drive is the source of reinforcement. On the other hand, he defined *habit strength* as the degree to which a stimulus (S) has the capacity to activate a response (R) that reduces the intensity of the drive in a specific way. For example, if a hungry rat locked in a maze, wanders aimlessly until it finds a bowl of food, eating the food will lead to a reduction of the drive (i.e., less hunger) and thus to a strengthening of the association "see the food bowl" (S) and "walk to the food bowl" (R). Moreover, the strength of the habit increases with the repeated pairing of S with R. Over time, S can activate R automatically, even under conditions of low drive. Continuing with the rat example, once the association between "seeing the food bowl" and "walking to the food bowl" is established, the food itself (O) would not be reflected in this associative chain. According to Hull, the rat would never intentionally walk towards the food until it directly saw the stimulus (i.e. the food bowl) that would automatically trigger the previously associated response (Berridge, 2001).

Later, evidence emerged that could not be explained solely through this associative structure. In 1948, Edward Tolman was one of the first authors to argue strongly against S-R theories. Instead, he proposed that animals learned to escape from a maze by forming "cognitive maps", which included structural knowledge of the environment that could be flexibly consulted and recruited to pursue a current goal and make predictive decisions (Tolman, 1948). This alternative conceptualisation assumed the importance of the outcome representation and the significance of the expectation. Overall, this new conception brought to light results from several experimental paradigms — and promoted the emergence of new ones — that challenged the nature of instrumental learning originally proposed by S-R theorists (Muenzinger, 1938; Tolman & Honzik, 1930).

The irrelevant incentive effect provides a classic example. Krieckhaus and Wolf (1968), in the first phase of their experimental paradigm, trained two groups of thirsty but non-salt deprived animals. One group learned that by pressing a lever (R), they would receive a sodium-rich solution (O1), while the other group was taught that by pressing the lever, they would receive water (O2). In the second phase, when all animals had been salt-deprived, subjects in the first group pressed the lever more vigorously than those in the second group. Latent learning during the first phase occurred even when the outcome was irrelevant to the current drive state. These results demonstrated the existence of a different type of instrumental action that did not show the same properties as habits. The basis of these models began to set up a clear and attractive distinction between two instrumental behavioural control systems (Adams & Dickinson, 1981; Balleine & Dickinson, 1998; A Dickinson, 1985; A Dickinson & Balleine, 1994; Heyes & Dickinson, 1990; Perez & Dickinson, 2018). On the one hand, a more flexible and accessible control system based on cognitive maps assumes that the association is formed between the instrumental response (R) and the mental representation of the outcome (O), thus considering the expectation and the value of the outcome in the associative chain. This system is directly related to the execution of goal-directed actions. And on the other hand, a more rigid and reflexive system controlled by the S-R associative structure would lead to habit actions (Dolan & Dayan, 2013).

1.2. Goal-Directed vs Habitual Systems

In order to study these two systems, it was first necessary to establish a clear definition of what is understood by both types of instrumental actions. An action is considered to be mostly *goal-directed* when two criteria are met: i) the agent believes in the causal relationship between the response (R) and the outcome (O), and ii) the outcome is desired, that is, it is valuable. In associative terms, the response would be mediated mainly by the R-O relationship. Heyes & Dickinson (1990) used these criteria of belief and desire to describe the intentionality of responses in animals and these subsequently served to characterise goal-directed behaviour (De Wit & Dickinson, 2009).

Alternatively, when the ***habit system*** takes control over instrumental behaviour, the response fails to meet these joint criteria, even if it did in the past (Dolan & Dayan, 2013). With iteration, instrumental responses (R) begin to be reflexively elicited by the stimulus (S) through the S → R association, regardless of the current value of their outcome. Despite its apparent simplicity, the definition of *habit* is a rather complicated and unclear issue in the literature (Balleine & Dezfouli, 2019; De Houwer, 2019; Foerde, 2018; Watson & De Wit, 2018; Wood & Rünger, 2015). Moreover, demonstrating that an instrumental response is a habit is even more complex. A habit is often mistakenly asserted to be an action that fails to satisfy goal-directed action criteria. This form of definition does not consider, for example, omissions, confusion, forgetfulness, or individuals suffering from psychiatric disorders. In such cases, the behaviour may seem to be a habit when it is, in fact, ineffectively controlled by the goal-directed system. Balleine & Dezfouli (2019) made an excellent contribution to this issue. Based on a series of observations of responses considered habits, these authors suggest that they appear to have the following features in common: (1) they are deployed and executed relatively quickly, (2) they are relatively invariant in their topography, (3) they are embedded in fragmented action sequences, and (4) they are insensitive to changes in the relationship with their consequences and the value of those consequences.

1.2.1. How Can We Measure Instrumental Action Control?

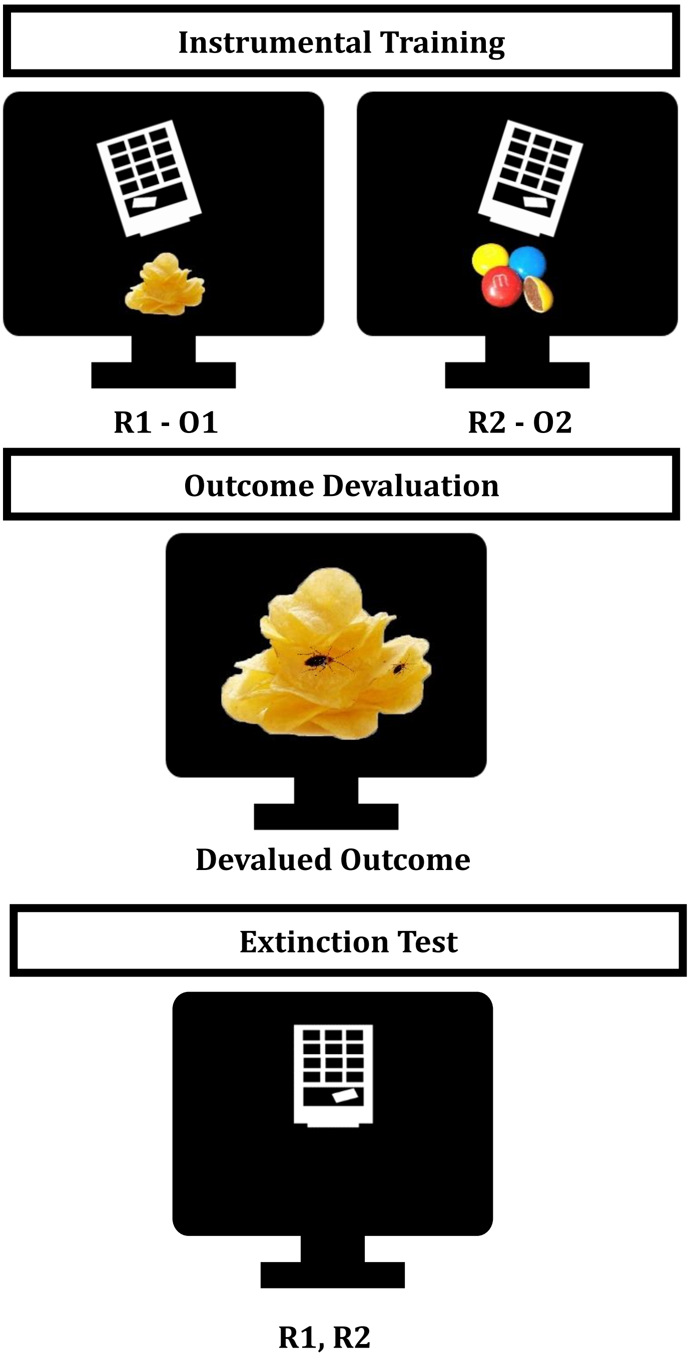
In summary, the evidence suggests that goal-directed and habitual actions differ in two main respects: (1) sensitivity to changes in outcome values previously associated with the action; and (2) sensitivity to changes in the causal relationship between the action and those outcomes. There are many empirical approaches to the study of these differences. However, the most widely used to date in human studies — and the one used in the experiments presented in Chapter 3 below — is the outcome devaluation paradigm (Balleine & O'Doherty, 2010; Corbit, 2018).

Adams and Dickinson (1981) were the first to demonstrate that rats could elaborately encode the value of the consequences of actions and modify their instrumental response based on that value. The authors devised an experiment in which, in the first phase, they trained rats to lever press (R) to obtain sucrose (O). Following the devaluation of sucrose by pairing its consumption with illness induced by an injection of lithium chloride, lever pressing was tested in extinction. As a result, the animals showed a significant decline in the number of lever presses, suggesting a modification in the performance of the instrumental response as a function of the new outcome value. This experiment therefore demonstrated that rats had acquired R-O contingency knowledge during instrumental training and subsequently integrated this learning into the performance of the instrumental action (Balleine & O'Doherty, 2010; De Wit & Dickinson, 2009).

This outcome devaluation effect has been widely replicated directly in humans. To give an example, Valentin et al. (2007) demonstrated that human participants reduced the number of responses trained to obtain a sugary drink (O) when they were previously allowed to consume this drink to satiety. In another study with humans (Morris et al., 2015), this effect was demonstrated through a "virtual devaluation" procedure. Using an instrumental learning computerized task similar to the one shown below in Experiments 1 and 2 (Chapter 3), participants simultaneously learned to perform two specific actions (R1, R2) to obtain two snacks (O1, O2) from a virtual vending machine. Subsequently, O1 or O2 was devalued by presenting a video depicting the snack infested with cockroaches before testing performance on R1 and R2 in extinction (see Figure 1.1). Participants were able to select the action associated with the outcome that had not been devalued, consequently demonstrating that they had acquired knowledge about R-O contiguity and could adapt the execution of the instrumental response according to the current value of the outcome.

Figure 1.1

Outcome Devaluation Procedure in the Morris et al. (2015) experiment.



Note. R = Response, O = Outcome

A broader comprehension of instrumental action control has critical theoretical implications, as developed so far, but is also clinically relevant. Indeed, deficits in the control of reward-seeking behaviour have been linked to clinical conditions such as nicotine addiction (Manglani et al., 2017), obsessive-compulsive disorder (Gillan et al., 2011), depression (Wen et al., 2022) and, particularly relevant to the focus of this thesis, to eating disorders associated with obesity and overweight (Horstmann et al., 2015; for a review on the relationship between a deficit in instrumental action control and problematic eating behaviour, see Pierce-Messick & Corbit, 2021; Wiers et al., 2017) or binge eating disorders (Reiter et al., 2017).

1.3. Role of Incentive Cues in Instrumental Action Control and Selection: Pavlovian-to-Instrumental Transfer

Adapting learned behaviours according to current needs, desires, and events is essential for effective decision-making, and Pavlovian learning plays a crucial role in this regard. When environmental cues are repeatedly associated with the presence (excitatory stimulus, CS+) or absence (inhibitory stimulus, CS-) of rewards, we can observe two important effects. First, the presence of the cue provides predictive information about the availability of the outcome, including the time and effort we must expend to obtain such an outcome (via S-O association, Pavlovian conditioning). Second, the cue acquires incentive properties that elicit desire and motivation related to the associated reward (Balleine, 2015).

Research on associative learning has shown that these incentive cues can influence, bias, and guide reward-seeking action control and selection by invigorating or suppressing these processes (Colwill & Rescorla, 1988; Estes, 1943; Mahlberg et al., 2021; Meemken & Horstmann, 2019). Indeed, cues help us to select which goals to follow and how to pursue them, but they can also lead us to make poor choices, especially in a world filled with highly desirable but potentially dangerous rewards (e.g., junk food) (Ostlund & Marshall, 2021). These cues can trigger a powerful drive to act almost irrepressibly (e.g., craving), leading to an uncontrolled reward-seeking behaviour (Berridge, 2001; Berridge & Robinson, 2016; see also point 1.4 below). Thus, there is great interest in identifying the mechanisms that govern cue-driven behaviour and determining which events may disrupt them.

The paradigm most widely used to study the effect of cues on instrumental action selection (and the one used in Chapter 3) is the *Pavlovian-to-Instrumental transfer (PIT) task* (for reviews on PIT, see Cartoni et al., 2016; Holmes et al., 2010). In its simplest form, a traditional PIT tasks is composed of three phases: *Instrumental training*, in which participants are trained to perform one or more responses (e.g., R1, R2) reinforced with different outcomes (e.g., R1 → O1, R2 → O2); a separate *Pavlovian training phase*, in which different Pavlovian stimuli (e.g., CS1, CS2) signal the delivery of the outcomes used in the previous phase (e.g., CS1 → O1, CS2 → O2); and finally, a *transfer test* phase, where participants are allowed to freely perform the instrumental responses in the absence (baseline response rate) and the presence (transfer) of the conditioned stimuli. This test is usually carried out under extinction (i.e., without delivering outcomes) so that ongoing outcomes do not modify instrumental behaviour.

The most common result is that the presence of a CS+ affects instrumental responding, producing an increase in response rate. This finding has been replicated in numerous human studies to examine the effect of environmental cues on eating behaviour (Colagiuri & Lovibond, 2015; Frank-Podlech et al., 2021; Watson et al., 2014), drugs (Hogarth & Chase, 2011; Manglani et al., 2017; Martinovic et al., 2014; van Timmeren et al., 2020), or on individual differences such as stress (Quail, Morris, et al., 2017) or impulsivity (Hogarth et al., 2012).

1.3.1. Outcome-Specific and General PIT effect

Two different forms of the PIT effect can be distinguished. In *outcome-specific PIT*, the reward-predicting stimulus (CS+) selectively enhances the performance of the instrumental response that predicts the same outcome. Alternatively, *the general PIT* effect refers to circumstances in which a CS+ elicits a general excitatory state that indiscriminately increases overall instrumental responding. This is produced by cues that signal an outcome different to the instrumental rewards, as long as they have the same motivational valence (Corbit et al., 2007).

For instance, Quail et al. (2016), using an adapted version of the experimental design described later in the studies in Chapter 3 and the scenario as shown in Figure 1.1, gave their participants the task of earning food from a virtual vending machine. In an instrumental training phase, participants learned the relationship between pressing two keys and selectively obtaining two snacks (R1 → O1; R2 → O2). During subsequent Pavlovian training, participants passively observed the relationship between different coloured lights on the machine and different food rewards. Two signals (CS1 and CS2) differentially predicted the same outcomes obtained during the instrumental phase (CS1 → O1, CS2 → O2); another signal predicted a third snack that had not been previously presented (CS3 → O3); and a fourth signal did not predict any outcome (CS4 → Ø). On the transfer test, participants were allowed to perform the two instrumental actions freely, and every so often, the four Pavlovian stimuli were presented.

The authors found the expected results: cues CS1 and CS2 specifically increased responses linked to the same outcome (i.e. R1 and R2, respectively), while stimulus CS3 elicited a general increase in the rate of both responses compared to CS4. Translating these results to the real world, the difference between the two effects could be seen, for example, with a television advertisement for hamburgers that either motivates a person to order a hamburger for dinner (outcome-specific PIT) or start cooking more generally (general PIT) (Mahlberg et al., 2021).

Both forms of Pavlovian-instrumental transfer have been reproduced in many studies. But interestingly, the most robust support for the dissociation of the PIT effect has come from research on the neurobiological basis of this phenomenon, which has revealed distinct neural mechanisms underlying the general and specific forms, mostly in rats (Corbit et al., 2007; Corbit & Balleine, 2005), but also in humans (Holmes et al., 2010; Prévost et al., 2012; van Steenbergen et al., 2017). However, there is currently some disagreement about the nature of the psychological mechanisms involved.

1.3.2. Behavioural Mechanisms Underlying the PIT Effect

The extent and circumstances under which we can control the influence of incentive cues on instrumental behaviour are of clinical relevance. The most frequently used procedure to shed light on this question has involved assessing the effect of outcome devaluation on the PIT effect. For example, Watson et al. (2014) trained participants to learn that following the performance of two responses, they could earn chocolate (R1→ O1) or popcorn (R2 → O2). During Pavlovian training, two cues were associated with the same outcomes as in the previous phase (CS1 → O1; CS2 → O2), a third released a new reinforcer, nuts (CS3 → O3), and the fourth cue was related to the absence of reward (CS4- → ∅). Before the transfer test, the sample was divided into three groups. The first two groups were allowed to consume O1 and O2, respectively, until satiation, while the last group received no experimental treatment. The data showed that both specific and general PIT effects remained intact, that is, Pavlovian cues increased the response associated with the same instrumental outcome compared to that associated with the opposite outcome (CS1: R1 > R2; CS2: R2 > R1), and CS3 increased the performance of both responses over CS4. This effect was equal across all three groups, implying insensitivity to devaluation in the PIT effect. In other words, the influence of incentive cues on instrumental behaviour was not — or at least not efficiently — controlled by goal-directed action mechanisms.

An observation to note from these analyses is that the PIT effect is usually measured relative to a baseline period of the same duration as the CSs (the preCS period) where Pavlovian cues do not appear (Experiment 1 in Seabrooke et al., 2017; Watson et al., 2014). However, by including a devaluation procedure before the transfer test, responding during this baseline period is often biased towards the valued outcome (Mahlberg et al., 2021; Seabrooke et al., 2018, 2019). In other words, if, for example, O1 is devalued, the overall response during the baseline period will tend to earn the still valuable outcome (i.e., a higher response rate for R2). This would consequently have two effects. First, if participants tend to choose the valuable outcome during the baseline, then the possibility of observing a PIT effect on the valuable outcome is hindered due to a possible ceiling effect.

Conversely, as the response for the devalued outcome is close to zero at baseline, the possibility of observing the PIT effect for the devalued outcome is multiplied since the response at baseline is almost at floor (Hogarth et al., 2018). Thus, when the outcome-specific PIT effect for the valued and devalued outcomes is directly compared, and no significant differences are found, this could just indicate differences in the sensitivity of the two tests (Mahlberg et al., 2021). This bias has been reproduced frequently in several studies where no devaluation effect on the PIT effect has been found.

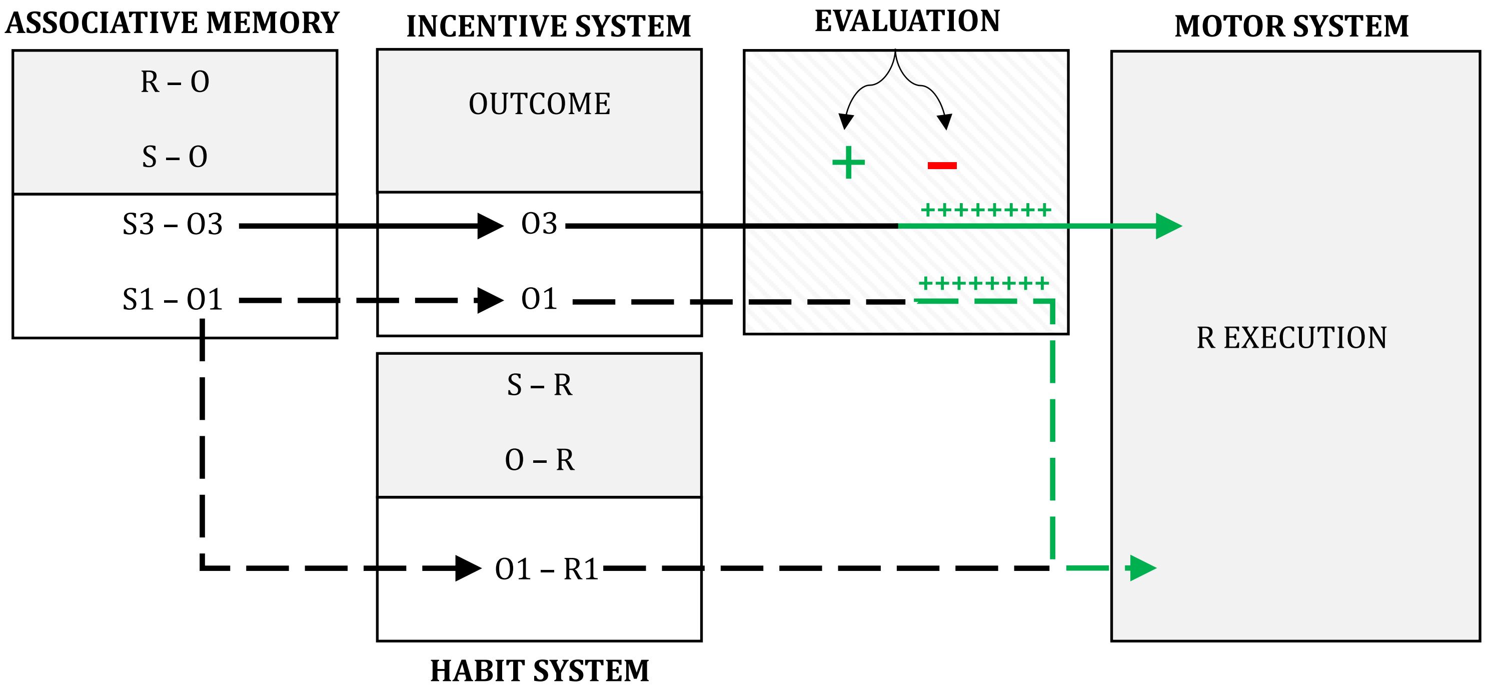
Indeed, controlling for baseline bias, Seabrooke et al. (2019) found very different results. During the experiment, participants learned to perform two responses that gained two of the previous outcomes each (R1 → O1, O3; R2 → O2, O4) after observing the association between four stimuli (CS1, CS2, CS2, and CS4) and four outcomes (O1 to O4), respectively. Then, one outcome associated with each instrumental response (e.g., O1 and O2) was devalued to avoid baseline bias. Results during the transfer test revealed a PIT effect for the valued but not the devalued outcomes, indicating PIT sensitivity to outcome devaluation when devaluation bias was taken into account (see Rose et al., 2018; Seabrooke et al., 2017 for similar results).

Various theories have been proposed to explain the behavioural mechanisms underlying the PIT effect that support goal-directed control. One of the most relevant is the *associative-cybernetic model* proposed by Dickinson and Balleine (see Figure 1.2). Although not exactly a model of the PIT effect, their ideas could explain how it works (Balleine & Dezfouli, 2019; Balleine & Ostlund, 2007; for a more comprehensive review, see Cartoni et al., 2013; Anthony Dickinson, 2012). It is an updated version of the Stimulus-Outcome-Response (S-O-R) associative mechanisms proposed by Trapold and Overmier (1972). In brief, the model suggests that, in General Transfer, the CS stored in "associative memory" (S3 in Figure 1.2) would trigger the representation of the associated O (learned during the Pavlovian phase) in the "incentive system". Normally, the incentive system would involve evaluating the outcome to be earned. If the expected outcome is evaluated positively, the activation of the general "motor system" guided by the motivational value of the reward would be facilitated (otherwise, the response would be less likely). In contrast, in Outcome-Specific Transfer, the CS stored in associative memory (S1 in Figure 1.2) would not only elicit the incentive system and the subsequent evaluation of the outcome, the outcome associated with the CS would also activate the so-called "habit system". In this system, only the specific sensory properties of the outcome and their relationship with the associated instrumental response are encoded. This would be sufficient to trigger a motor response independent of the motivational value of the outcome. However, the reward evaluation made in the incentive system would modulate the performance of the response triggered by the habit system.

Alternatively, the *propositional theory* offers a slightly different approach to explaining Outcome-Specific PIT (Mahlberg et al., 2021; Seabrooke et al., 2016, 2017, 2019). According to this model, the PIT effect depends on assumptions about the relationships between events rather than being based on a traditional associative view. Thus, it is suggested that participants would learn, through a cognitively demanding procedure, the S-O and R-O relationships during the early phases of Pavlovian and instrumental training, respectively. The model indicates that learned associations become conscious, verbalizable propositional beliefs. During the transfer test, participants infer that the Pavlovian stimuli signal which outcomes are most available and, hence, which instrumental response is most likely to be reinforced at a given time. Accordingly, PIT effects in humans reflect a decision-making process controlled by outcome expectancy in which responses are based on a function of the probability of earning the outcome and its value — resulting in intentional, goal-directed decisions. Interestingly, the authors predict other two results in line with those obtained in the experiments reported in Chapter 3 of the present thesis: 1) The effects of specific PIT reflect explicit knowledge of the S-O and R-O relationships so that participants can explicitly verbalise them; and 2) the effect of the specific PIT is highly flexible so that a mere change in the task instructions could serve to adapt the response according to the new information (Mahlberg et al., 2021).

Figure 1.2

The Associative-Cybernetic Model of Goal-Directed Behaviour



Note. The boxes with a grey background correspond to the formal model. In contrast, the white boxes represent an example that could explain the differential associative pathways that instrumental behaviours follow under the Outcome-Specific PIT effect (dashed lines) and the General PIT effect (solid lines) in the experimental design of Watson et al. (2014). The grated background of the Evaluation box indicates how, under certain circumstances, the influence of the outcome value may not be strong enough to affect the instrumental behaviour displayed by the habit system; S = Stimulus; R = Response; O = Outcome

1.3.3. Individual Differences in Instrumental Action and Selection: Impulsivity

Emotions can influence action control and selection (Balleine, 2021; Heffner et al., 2021). Following Braunstein's multi-level framework of emotional regulation (Braunstein et al., 2017), the inability to update the incentive or current affective value of the outcome (i.e., outcome revaluation) points to deficits in implicit-automatic emotion regulation.

More precisely, in humans, habit-prone or inefficiently goal-directed behaviour (i.e., instrumental actions with a poor capacity to adapt to the current outcome value) has been linked to individual differences in impulsivity as a trait. Dietrich et al. (2016) measured the influence of trait impulsivity on instrumental action control using self-reported measures of impulsivity and a devaluation sensitivity index representing the balance of goal-directed and habit-prone systems in action control, which was measured using the *slips-of-action* task. During the task, participants were trained to learn to perform specific responses to the occurrence of discriminative stimuli to gain outcomes (via an S-R-O association). In the test phase, some outcomes were devalued, and the participant's ability to adapt their response to the new reward value was measured. The authors found a lower sensitivity to the devaluation index related to higher impulsivity scores. These results suggested that trait impulsivity impairs efficient instrumental action control (see Hogarth et al., 2012 for similar results).

Impulsivity is a multidimensional construct comprising a broad framework of subdimensions, including emotional, cognitive and/or purely motor aspects of behaviour (Cyders, 2013). In particular, *negative urgency*, i.e. a dimension of emotional impulsivity associated with the tendency to act impulsively when experiencing negative emotions, has been related to disorders involving inefficient instrumental action control, such as problematic drinking (Willie et al., 2022; Wolkowicz et al., 2020), gambling (Quintero et al., 2020) and, interestingly, dysregulations in eating behaviour. For example, Fischer et al. (2018) reported that in women with high levels of NU, binge eating was triggered in response to smaller changes in negative mood than women with low levels of NU (for similar results, see Ralph-Nearman et al., 2020; Yan et al., 2022). Likewise, Mallorquí-Baqué et al. (2020) found that participants with eating disorders scored higher on NU than healthy control participants (with bulimic spectrum participants showing higher scores than patients with anorexia nervosa and healthy subjects). Positive associations have also been found between NU scores and waist-to-height ratio (Shell et al., 2021), palatable food consumption (Becker et al., 2016) and hedonic hunger (Mason et al., 2020).

Evidence suggests that the NU plays a key role in eating disorders and even risky food behaviour. It is important to determine whether this emotional impulsivity trait affects instrumental action control and selection previously linked to implicit-automatic emotion regulation. If we can establish whether individuals with high NU show maladaptive action control and selection, this could have significant implications for tailoring interventions for people with clinical conditions (Webb et al., 2012). For these reasons, Chapter 3 of the thesis will explore how negative urgency may influence instrumental action control and selection and how it might even modify the impact of incentive cues on instrumental behaviour (PIT effect).

1.4. Role of Reward Processing on Food-Seeking Behaviour: Wanting vs Liking Mechanisms

Rewards in general — and food rewards in particular — involve two psychological mechanisms that, although commonly positively correlated, are neural and behaviourally dissociated (Morales & Berridge, 2020). First, *wanting* is the motivation or incentive disposition to obtain the reward (e.g., food). Second, *liking* is the hedonic experience that arises when consuming the reward (see Pool et al., 2016 for a review).

Berridge and Robinson (2003) proposed that both components could be considered at the explicit and implicit levels (see Figure 1.3 for a schematic overview). *Explicit wanting*, also called cognitive desire, refers to the explicit cognitive expectation that we will like what we want. Computationally it conforms better to goal-directed systems, while psychologically it is based on past experiences with the outcome declaratively stored in episodic memory, which determines the pleasantness or sensory expectation (Berridge & O'Doherty, 2014). On the other hand, *implicit wanting* is known as incentive salience and involves motivational, 'magnetic' reactions — automatic or not so rational — triggered by Pavlovian cues that are predictive of rewards (see Section 1.4.1 for further elaboration of this issue). Since it is potentially independent of any hedonic aspect of reward (see Figure 1.3) it is possible to want what is not expected to be liked, what is not remembered as pleasant or what is not liked when acquired (Pool et al., 2016). Incentive salience is often experienced as temporary and transient spikes of desire, lasting from several seconds to minutes. Thus, incentive cues may vary in their ability to evoke wanting. For example, food-related cues are especially intense when a subject is hungry but less so when satiated (Berridge & O'Doherty, 2014). In addition, emotional states such as stress (Dicker-Oren et al., 2022; Pool et al., 2015; Wemm et al., 2020), or individual dispositions such as negative urgency (see Section 1.3.3), can increase the tempting power of incentive signals. Cognitive desire can be estimated through subjective ratings (e.g., scales assessing a participant's desire for a particular food), while incentive salience requires more complex measures such as the PIT task.

The liking component can also be classified according to its implicitness and explicitness. While *explicit*, *conscious liking* is a subjective affective reaction, *implicit liking* is an objective affective reaction. To measure explicit liking, we would again rely on self-reported measures (e.g., applied at a certain point after the sensory or hedonic experience). To measure implicit liking, we would use measures based on continuous recording of physiological process indicators, such as brain activity or facial expressions. Hedonic experience in food processing will be discussed in more detail in Section 1.4.2.

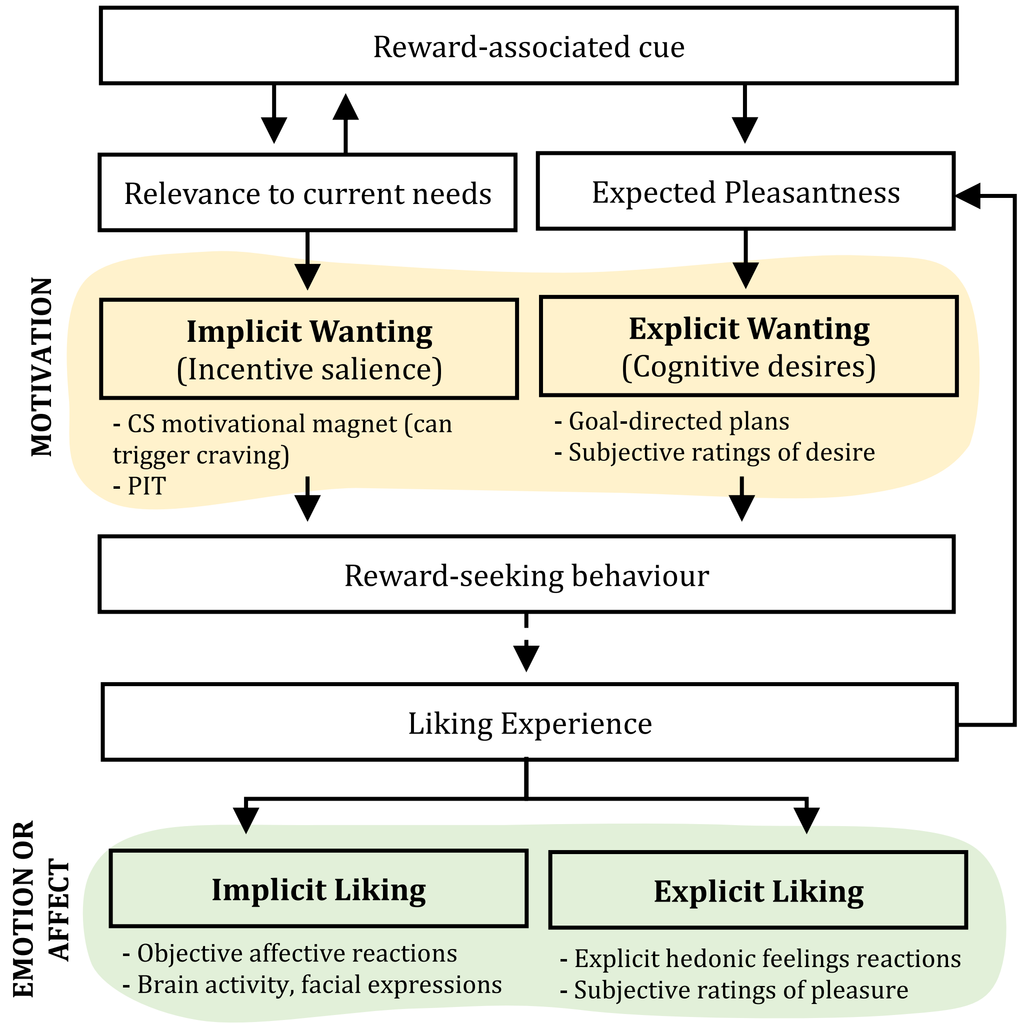
1.4.1. The 'Wanting' Mechanism in Eating Behaviour: Food Craving

So far, the evidence points to the possibility that incentive cues can influence reward-seeking behaviour with which it shares an outcome of at least the same valence (i.e., PIT effect). However, it remains to be determined to what extent individuals react differently *to food-related cues* (Mahlberg et al., 2018). This question has relevant theoretical and clinical implications. Humans living in western countries are currently faced with constant "obesogenic" environments that promote sedentary lifestyles with access to plenty of readily available high-calorie foods (van den Akker et al., 2018). According to the World Health Organization (WHO, 2015), this situation leads to an increase in the prevalence of problematic eating behaviours and obesity, which are associated with major health problems such as diabetes, cardiovascular disease, and cancer (Schnepper et al., 2019), as well as psychological issues and mental illnesses (van den Akker et al., 2018). Due to the urgency of the problem and the difficulty of directly modifying these obesogenic contexts, one of the main goals of interventions aimed at tackling obesity and related eating disorders is individual behaviour modification to promote healthy eating (Vallis, 2019).

Neurobiological evidence suggests that obese people exhibit functional alterations of the appetite system underlying the hedonic drive to eat, leading to enhanced salience of incentive cues and an increase of implicit wanting (typically manifesting as a strong desire or "craving") (Kanoski & Boutelle, 2022). *Food cue reactivity* has an important genetic component (van den Akker et al., 2018), but learning processes such as Pavlovian conditioning are also involved in its development (Berridge et al., 2010). In today's obesogenic environment, it is easy to associate internal (e.g., cognitions, emotions) and external (sight and smell of food) environmental cues (CS) with reinforcing effects when palatable food is consumed (US), leading to appetitive conditioned responses which promote reward-seeking behaviour and subsequent food intake (Frank-Podlech et al., 2021). In this context, appetitive conditioning occurs quickly, with relatively few CS-US pairings, after which exposure to food cues activates reactivity in terms of relevant psychological (e.g., food craving, expectations), physiological (e.g., salivation, activation of arousal), and neurocognitive (e.g., brain activation patterns) responses which, at increased levels, have been related to overeating, higher body mass index (BMI) or dieting failures (van den Akker et al., 2018).

Figure 1.3

Simplified Scheme of the Mechanisms Involved in Wanting and Liking Processes



Note. Implicit wanting is triggered by the interaction between 1) the perception of a cue indicating outcome availability and 2) potential outcome relevance to satisfying the individual's current needs. Implicit wanting generates an automatic and magnetic motivational reaction towards the object of desire. Moreover, the liking experience while consuming the reward influences the future expectation of pleasantness that will be expected to be reached with the outcome. Based on the past liking experience, a present expectation about how much we will like the desired object is developed. In yellow, the wanting components, which would involve motivational processes; in green, the liking components, which would involve affective processes. Adapted from Pool, E. R., Sennwald, V., Delplanque, S., Brosch, T., & Sander, D. (2016). Measuring wanting and liking from animals to humans: A systematic review. Neuroscience and Biobehavioral Reviews, 63, 124–142.

Food craving can be defined as an intense and difficult-to-resist desire to consume a specific type of food (Weingarten & Elston, 1990) that can be a precursor to uncontrolled eating (Vainik et al., 2019). It is sometimes associated with increased BMI and obesity (e.g. Chao et al., 2014), dieting (e.g. Hill, 2007), poorer weight control (Sitton, 1991), as well as negative mood and depression (Schumacher et al., 2018). This increase in the incentive salience of cues or craving reactions suggests that food becomes a powerful reinforcer for certain individuals, which promotes operant (i.e. habit-forming) and classical (i.e. cued eating) conditioning (Vallis, 2019).

However, food cravings are not only experienced by overweight or obese individuals, but also by people with a weight that could be considered normal and healthy (Hofmann et al., 2012). For example, in a nationally representative survey of Canadian adults, 62.6% of respondents reported having food cravings, and more than half of them reported losing control, overeating, and thinking about food until they ate (Vallis, 2019). In another study focusing on naturally occurring cravings, 67% reported cravings, and 48% reported specific food or drink cravings (Skorka-Brown et al., 2014). Indeed, cravings predict weight gain over time, even in lean people and those who are overweight and obese (Boswell & Kober, 2016). Food cravings may also be a precursor to binge eating in the general population (Gendall et al., 1998). Hence, food cravings represent a suitable target for interventions promoting healthy weight through improving eating patterns (see Chapter 4, where various strategies to reduce craving are tested in the laboratory and real-life contexts).

1.4.1.1. Strategies to Reduce Food Craving: The Elaborated Intrusion Theory of Desire

As noted, individuals differ in their sensitivity to food incentive cues that produce affective reactions shaped by cognition (van Dillen & Andrade, 2016). The *Elaborated Intrusion (EI) theory of desire* (Andrade et al., 2012; Kavanagh et al., 2005; May et al., 2012) considers craving a motivational process whereby people have an increased reactivity to food cues. This craving process could be divided into two distinct phases: First, craving-related cues (e.g., images or even memories of food) trigger intrusive thoughts. Second, these cues further elaborate the intrusions with vivid mental imagery of the desired object and its acquisition. This can eventually generate a powerful affective reaction or urge to consume that is experienced as craving (Tapper, 2018). This second elaboration phase is considered to be at the core of the craving process, as it leads to a negative affective state that ultimately motivates people to eat to reduce that state. Hence, targeting the underlying cognitive processes is essential to prevent or intervene in elaborating intrusive thoughts in vulnerable people with high sensitivity to hedonic food cues (Schumacher et al., 2018).

Visual images appear to figure centrally in craving (Kavanagh et al., 2009; May et al., 2004) since the motivation to use a drug or consume food is often driven by imagining the experience of achieving that goal (Skorka-Brown et al., 2015). Visual images place demands on the limited capacity of working memory. According to EI theory, one way to prevent or interrupt the elaboration of intrusive thoughts is by loading the visuospatial sketchpad of working memory with competing visual imagery, something that has proved to be effective in reducing both naturally-occurring as well as induced cravings for food and in improving snack choice (e.g., see Hsu et al., 2014; Skorka-Brown et al., 2014; van Dillen & Andrade, 2016), although this has not always been effective in reducing chocolate consumption compared with a control condition (e.g., Knäuper et al., 2011; Skorka-Brown et al., 2015; van Dillen & Andrade, 2016). Individuals with high sensitivity to hedonic food could benefit from a self-regulation strategy that involves engaging in a task that recruits cognitive resources and thus competes with the elaboration process (van Dillen & Andrade, 2016). For instance, playing Tetris, a task with high visuospatial demands, will selectively compete with intrusive thoughts for limited cognitive resources. Thus, it will reduce craving for food and other substances (e.g., drugs) or physical-activity cravings such as those related to practising sports (e.g., Skorka-Brown et al., 2015).

Imposing a cognitive load is not the only strategy derived from EI theory to weaken cravings. For decades, *mindfulness-based interventions* have been applied to treat food-related intrusions (for a review, see Tapper, 2022). The basis of these strategies is to change individuals' reactions to intrusions before they begin to be negatively elaborated (Schumacher et al., 2017). There is a consensus in the literature that mindfulness is characterized by three key components that build upon one another: 1) Present moment awareness. This consists of the ability to intentionally maintain attention on the present moment; 2) Acceptance. This involves not judging or trying to control thoughts, that is, accepting them without reacting; 3) *Decentering* or cognitive defusion. Thoughts are seen as interpretations of events fleeting and separate from oneself (Tapper, 2018, 2022). For example, if we are faced with an image related to chocolate consumption, an intervention with cognitive defusion could involve considering these images as simple "thoughts" and, subsequently, applying imagery about more general thoughts, such as goals related to healthy eating (Wilson et al., 2021). More specifically, Lacaille et al. (2014) suggest that cognitive defusion may be more effective in targeting these metacognitions than awareness and acceptance skills when considering the effects of all these skills independently. In this regard, Chapter 4 assesses the effectiveness of this strategy (e.g., acting on intrusions through cognitive defusion) in decreasing both laboratory-induced cravings and those experienced in real life.

1.4.2. The 'Liking' Mechanism in Eating Behaviour: Explicit and Implicit Measures

As shown in the diagram in Figure 1.3, prior experience with the outcome influences the expectancy about the future experience and cognitive desire, which, in turn, can affect reward-seeking behaviour and subsequent outcome liking evaluation (see Piqueras-Fiszman & Spence, 2015, for a review of this topic; Wilton et al., 2019). For instance, Yeoman et al. (2008) showed how predictive information about a food product and expectations could influence future hedonic and even sensory experiences. Employing explicit measures, the authors conducted a series of experiments in which participants tasted a novel food (salmon ice cream) presented through plausible but inaccurate food labels. The results showed that ratings were significantly more aversive and less pleasant when the product was labelled as "ice cream" than when it was labelled as "savoury frozen mousse". Additionally, participants who tasted the "ice-cream" product rated this as saltier and tastier. In another more recent experiment, Wang and Spence (2019) examined how wine colour (a very relevant attribute for wine quality assessment) could olfactorily bias professional wine tasters, affecting sensory and hedonic analyses (e.g., see Carvalho & Spence, 2019 for similar results). Prior knowledge of an added ingredient (Lee et al., 2006) or the wine brand tasted (Lick et al., 2017) also affects the assessment of reported flavour quality or pleasantness. Evidence suggests that extrinsic product properties (i.e., external characteristics which are not physical parts of the product, such as packaging or brand name) can affect the expectation and subsequent consumption of the food. However, the hedonic experience is also affected by intrinsic cues (i.e. characteristics referring to sensory properties, such as product smell or taste), which have received much less attention in the literature due to the difficulty of measuring these objectively (Honoré-Chedozeau et al., 2019; Sáenz-Navajas et al., 2016).

As mentioned above, we can use explicit and implicit measures to assess the hedonic and sensory experience of a food reward. While explicit measures are quick and easy to gather and analyse, measures of implicit liking processes are less affected by response biases, misinterpretation, and cross-contamination (Ariely & Berns, 2010; Berridge, 1996). Therefore, access to implicit valuation, complemented with explicit methods, provides a richer context for generally studying food and beverage decision-making and psychological processing. For this reason, implicit measures have recently attracted attention in food science (Lagast et al., 2017) and neuromarketing (e.g., Domracheva & Kulikova, 2020; Walsh et al., 2017). Research studies using fMRI have reported brand effects on behavioural preferences for soft drinks (sodas) as well as neural response (McClure et al., 2004). Likewise, an increase in the declared price of wine enhances the self-reported subjective value of its flavour's pleasantness and modulates the neural representation of the experienced pleasantness during sensory analysis (Plassmann et al., 2008). In a recent review, Songsamoe et al. (2019) examined the efficacy of electroencephalography in assessing sensory and hedonic responses to food taste and flavour. The main findings suggest that electroencephalography is a useful technique that provides insight into consumers' food-related cortical processes. For instance, a recent experiment assessed explicit and implicit liking after beer consumption. As an explicit measure they used subjective hedonic scales and for the implicit measure they used a portable electroencephalogram (EEG) from a single dry electrode that recorded brain activity while participants were drinking. Using machine learning techniques, they developed an artificial neural network model that accurately classified beers according to the level of liking explicitly reported by consumers (Gonzalez Viejo et al., 2019).

1.4.2.1. Role of Tasting Expertise in the Relation Between Explicit and Implicit Measures

The role of prior experience in an outcome's hedonic evaluation and selection seems clear. If this is the case, what will happen in individuals who have received a high degree of exposure to the same food stimuli? Will formal training or deliberate practice affect these processes? Consumer-related factors have been shown to be significant influencers of quality perception. Available evidence suggests that consumers' "consumption history" (Melo et al., 2011), gender, or age (Bruwer et al., 2011) or, indeed, level of experience are determinants of their cognitive construction of quality concepts (Parr, 2019; Spence, 2020). In this regard, Chapter 5 of this thesis sheds light on the high-order cognitive processes involved in expertise related to the hedonic and sensory evaluation of beverages by comparing groups with different levels of tasting expertise.

To date, studies in this area do not clarify how fundamental skills related to sensation and perception may be enhanced by experience (Chollet et al., 2005; Poupon et al., 2019). Some studies suggest that an essential cognitive effect of expertise is due to experts describing their perception better than novices, although not all published research agrees with this (Honoré-Chedozeau et al., 2019). Using implicit measures, Pazart et al. (2014) compared neural activation in experts and non-experts while tasting wine in a blind sensory analysis procedure. Common activation was found for areas involved in sensory integration (insula, operculum, OFC, and amygdala), although experts showed a relatively more efficient processing pattern than controls. Moreover, experts exhibited differential activity in hippocampal, para-hippocampal, anterior temporal regions and associative occipital areas, activating sensory and episodic memory, as well as semantic and working memory. This activation pattern suggests that, in addition to sensory quality evaluation, experts also worked on label recognition of wine (Pazart et al., 2014). Castriota-Scanderbeg et al. (2005) also compared brain activity in sommeliers with that of a control group. For experts, they found activation in a brain network including the left insula and adjacent areas of the OFC (olfactive-gustatory integration) as well as bilateral activation of the dorsolateral prefrontal cortex, which is involved in high-order cognitive processes such as working memory and selection of behavioural strategies (executive control). For controls, they found activation in areas of the primary gustative cortex and those involved in emotional processing, such as the amygdala.

The available evidence suggests that brain activity associated with sensory and hedonic analysis processes differs between experts and naive consumers, involving circuits related to memory processes and analysis in the former, and more affective processing in the latter. However, further evidence is required to determine the level of correspondence between the results reported by implicit and explicit measures. Furthermore, if formal training provides more reliable explicit measures, a stronger relationship between the two measures would be expected in experts compared with more naïve groups. This issue is clearly addressed in the experiments presented in Chapter 5.

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MOTIVATION AND AIMS

CHAPTER 2:

Motivation, Research Aims and Hypotheses

2.1. Motivation

High-sugar foods, such as soft drinks and pastries, are omnipresent, easily accessible, and challenging to resist. Their overconsumption leads to disorders ranging from cardiovascular disease to obesity. Moreover, the prevalence of problems related to food intake has been steadily increasing year after year. Since 1975, obesity rates have tripled, and 2.8 million people die each year from overweight or obesity (WHO, 2015). Considering these high prevalence rates, the resulting increase in medical costs and the severe underlying health problems, it is essential to develop powerful models that identify the variables involved in the behaviours that contribute to being overweight.

Eating behaviour is quite complex, as it is influenced by many biological factors (e.g. satiety and adiposity signals, energy needs) and non-biological factors (e.g. learning processes, emotional regulation, education), with conditioning and learning processes being one of the most important among them (Bouton, 2011). Knowing more about these factors and how they affect the control and selection of food-seeking behaviour is crucial to understanding, preventing, and intervening in possible psychological disorders, as well as promoting healthy attitudes. Furthermore, clinical and basic research are not the only fields that have been interested in providing a more in-depth understanding of eating behaviour. In the last decade, research has also gained ground in areas such as neuromarketing (e.g., Domracheva & Kulikova, 2020), where understanding consumers' needs and preferences is crucial.

2.2. Research Aims

The main purpose of this doctoral thesis is to evaluate food decision-making from a learning perspective. Specifically, we focus on studying how individual differences in emotional regulation, cue reactivity, and the degree of expertise (all of which may ultimately influence instrumental action control and selection) can advance our understanding of food-related reward-seeking behaviour. Five experiments were conducted and divided into the following chapters to address and shed light on this broad study framework to accomplish this central goal.

Chapter 3. Does Affect-Driven Impulsivity influence Action Control and Selection?

The specific goal of this chapter was to investigate the effects of individual differences in emotional impulsivity (emotion dysregulation) on 1) action control (using an outcome devaluation procedure); 2) action selection (using the PIT task, both addressed in Experiment 1); and 3) the interaction between them (i.e., the effect of outcome devaluation on the PIT effect), examined in Experiment 2. In Experiment 1, the outcome devaluation procedure occurred after PIT, whereas in Experiment 2 this occurred before PIT. Affect-driven trait impulsivity (i.e., negative urgency, NU) was estimated using a self-reported measure (questionnaire).

Hypothesis 1: The NU score will be associated with a poorer updating of the outcome value, that is, a weaker or absent outcome devaluation effect (Experiment 1).

Hypothesis 2: If the PIT effect is goal-directed in our task, a reduction in the outcome-specific PIT effect with high levels of NU is expected (Experiment 1).

Hypothesis 3: If the PIT effect is goal-directed in our task, and an outcome devaluation effect on outcome-specific PIT is found, the size of PIT devaluation will be inversely related to the NU score (Experiment 2).

Chapter 4. Can We Reduce Craving Experience in the Laboratory and Real-Life Contexts?

This chapter focuses on studying reactivity to incentive cues. Specifically, we examine the efficacy of brief mindfulness-based strategy training (cognitive defusion) in reducing the intensity of self-reported cravings and unhealthy food selection and consumption. For this purpose, craving was induced (Experiment 1) or measured in natural episodes (Experiment 2) in vulnerable individuals (young female participants selected for being chocolate cravers in particular —Experiment 1 — or food cravers in general — Experiment 2—). The strategies were applied in both the laboratory (Experiment 1) and a real-life context, using a smartphone app (Experiment 2) especially programmed for this purpose by the PhD candidate. Furthermore, we examine whether food craving as a trait and mindfulness skills could influence the success of this strategy (Experiment 1).

Hence, if craving episodes are the result of intrusive thoughts triggered by food incentive cues, which are subsequently elaborated (as predicted by the aforementioned Elaborated Intrusion Theory), in Experiment 1, we expect to find that:

Hypothesis 4: Cognitive defusion training mitigates reactions to intrusive thoughts, which will be associated with a reduction in **4a)** self-reported craving, **4b)** preference for less healthy snacks in a choice test, and **4c)** food consumption, compared to a control condition.

Hypothesis 5a) Cognitive fusion (the opposite of cognitive defusion) and trait craving are positively associated; **5b)** there is a negative relationship between mindfulness skills scores and both traits, i.e., craving and cognitive fusion.

As in Experiment 2, individuals implementing the cognitive defusion strategy using a smartphone app in real-life contexts (compared to the control condition) should report:

Hypothesis 6a) A greater reduction in self-reported craving; **6b)** fewer indulgence episodes (i.e., more episodes of not consuming the desired food; **6c)** a reduction in consumption pattern (i.e., consuming less than they initially desired or under-reporting having consumed more than they desired).

Chapter 5: Does Expertise Affect the Sensory and Liking Experience of Consuming a Food Reward?

This final chapter examines the sensory and hedonic experiences of beverage (beers) consumption using explicit (sensory and quality judgements: visual, olfactory, and gustatory levels; as well as general hedonic value) and implicit (continuous EEG brain activity recordings) measures. Data for three groups were compared: beer expert tasters, general beverage and food tasters, and beer consumers without formal training. The strength of the relationship between explicit judgements and EEG brain activity was also explored. Finally, we aimed to estimate the extent to which an explicit-implicit correlation differed according to beer tasting expertise.

According to the literature previously reviewed in Chapter 1, we expected to find:

Hypothesis 7 (Exploratory): Differences in sensory and hedonic judgements (i.e., explicit measures) between beer experts and all other groups, and between general tasters and consumers.

Hypothesis 8a) Differences in brain activity (i.e., implicit measure) between beer experts and general tasters in areas associated with flavour processing and higher cognitive processes (e.g., analysis and decision making). **8b)** In contrast, greater activation in consumers will rely on recognition memory and affective or hedonic processing areas.

Hypothesis 9a) A stronger relationship between explicit and implicit measures in beer experts compared to the other groups. **9b)** In beer experts, this stronger relationship between both measures will mostly occur in areas involved in working memory processing. **9c)** Consumers, in contrast, will show a stronger association between both measures in areas primarily involved in hedonic processing.

2.3. References

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EXPERIMENTAL SECTION

CHAPTER 3:

Does Affect-Driven Impulsivity influence Action Control and Selection?

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3.1. Abstract

Two experiments were designed to study the role of emotional impulsiveness in action control and selection, involving healthy young women participants. In Experiment 1, the effects of both outcome devaluation and Pavlovian-to- instrumental transfer (PIT) were assessed on instrumental responding. In Experiment 2, we further explored the effect of outcome devaluation on outcome-specific PIT. The role of emotional impulsivity, specifically negative urgency (NU), was also evaluated in both experiments using a self-reported measure (UPPS-P scale, Spanish short version). Experiment 1 showed both outcome devaluation and outcome-specific PIT effects, which were positively inter-correlated and negatively correlated with scores in NU. Experiment 2 found an effect of outcome devaluation on outcome-specific PIT, which was negatively correlated with scores on NU. These results highlight the relevance of considering individual differences in affect-driven impulsivity, specifically NU, when addressing failures in action control and selection (proneness to habit). Moreover, these findings suggest that, at least with the procedure used in these experiments, outcome-specific PIT may be based on a goal-directed process that is under the participant’s control.

3.2. Introduction

From a learning-focused perspective, adaptive reward- seeking behaviour involves the integration of two different pieces of knowledge: learning the actions that lead to the desired outcome (instrumental conditioning) and knowing which cues signal the availability of reward (Pavlovian conditioning). From a dual-process theory of instrumental learning (Dickinson, 1985), effective reward-seeking behaviour depends on the balance between goal-directed action and habitual systems that underlie instrumental responding. In addition, successful action control involves emotion regulation processes that help us to focus on long- term interests (e.g., healthy weight) over immediate emotional needs (e.g., craving). Impaired emotion regulation may lead to the development of emotionally impulsive personality traits that would make it difficult to resist temptations and delay gratification. Among these, negative urgency (NU), the tendency to act rashly when experiencing negative emotional states (Whiteside & Lynam, 2001), has been specifically linked to impairments in behavioural control such as those involved in eating disorders (e.g., Peterson et al., 2012).

Taking into account this general framework, in this study, we investigated whether cues associated with rewards through Pavlovian conditioning could bias action selection (i.e., the choice between instrumental responses associated with these or similar rewards) using the Pavlovian-to-instrumental transfer (PIT) paradigm (Estes, 1943). To estimate the degree to which instrumental behaviour was controlled by the goal-directed system, we made use of the outcome devaluation procedure (Adams & Dickinson, 1981), both for instrumental responding (Experiment 1) and cue-elicited responding using a PIT procedure

(Experiment 2). In addition, we investigated whether these effects were modulated by an affect-driven impulsivity trait, specifically that of self-reported NU.

3.2.1. Pavlovian to Instrumental Transfer (PIT) and Outcome Devaluation

Both reward-predicting actions (instrumental learning) and cues (Pavlovian conditioning) are important in guiding behaviour, and the interaction between them may be studied through the PIT paradigm (for recent reviews, see Cartoni et al., 2016; Holmes et al., 2010). A Pavlovian cue associated with an outcome is able to selectively promote actions linked to that outcome, referred to as specific transfer, as well as increase the motivation and vigour of instrumental responding linked to different outcomes of the same motivational or affective valence, known as general transfer. Therefore, when subjects are given the opportunity to perform two alternative actions, cues will bias the choice of action in favour of the one with which they share the specific outcome, or will increase general motivation for responding when they are linked to outcomes with similar motivational properties. Behavioural, lesion, and neuroimaging evidence all suggest that these effects (on response bias and on the vigour of responding) are distinct and dissociable (e.g., Quail et al., 2017).

The PIT effect has been linked to impulse control. For instance, in relation to eating behaviour, in western and related societies we are all immersed in an obesogenic environment with an abundance of rewarding and highly palatable food and are surrounded by multiple food related cues that can elicit food-seeking and consumption in a rather automatic way, even when sated (Colagiuri & Lovibond, 2015).

Regarding action control, the dual-system theory of instrumental learning (Dickinson, 1985) proposes that flexible behaviour is determined by the balance between goal-directed and habitual systems, which exhibit varying degrees of sensitivity to changes in the motivational value of the outcome (i.e., incentive learning). Neuroimaging studies appear to support this distinction, showing that dissociable corticostriatal circuits mediate goal-directed and cue-triggered habitual behaviour (van Steenbergen et al., 2017).

Effective action control requires consideration of the current motivational or incentive value of the outcome of an action (Balleine & O'Doherty, 2010). This is not static, and it may change over time, due to, for instance, a motivational shift from satiety to hunger. Therefore, the value of the outcome needs to be regularly updated. Thus, if the outcome loses its value, behavioural flexibility (i.e., goal-directed action) would cause a decrease in the frequency or vigour of responding. Habitual responses, however, are less sensitive to changes in the incentive value of the outcome and, as a consequence, the rate or frequency of behaviour will show little change, even when the outcome is no longer rewarding. Hence, one way to estimate the relative strength of one system over the other in action control, both in animals and in humans, makes use of the outcome devaluation procedure (see, for example, Watson & de Wit, 2018) which was employed in Experiments 1 and 2 of this study. In this procedure, the incentive value of the outcome changes (i.e., decreases) as a result of an experimental manipulation such as a motivational shift (e.g., satiation), pairing food with illness produced by a toxin or with a disgusting taste, or by instructions (e.g., an otherwise previously valuable outcome no longer equates to points or even makes the participant lose them).

One issue of interest is whether specific PIT is sensitive to outcome devaluation. Unfortunately, current research on this topic has yielded mixed evidence. While some studies have found, both in animals and humans, that specific PIT is observed even when the outcome is no longer desired indicating that it has an automatic component (e.g., Colagiuri & Lovibond, 2015; Colwill & Rescorla, 1990; De Tommaso et al., 2018; Hogarth & Chase, 2011; Holland, 2004; Watson et al., 2014), other studies with human participants have found an effect of outcome devaluation under specific circumstances (Allman et al., 2010; Eder & Dignath, 2016a, 2016b; Seabrooke et al., 2017, 2019). Therefore, it is still unclear how and when changes in outcome value may affect specific PIT, and one of the goals of the present experiments is to increase our knowledge with regard to this issue. This topic is of theoretical importance, because it could shed light on the associative structure underlying the effect (i.e., which particular outcome properties are recovered by the Pavlovian cue—sensory or motivational), while also having potential clinical implications.

In humans, insensitivity to outcome devaluation in instrumental responding has been linked to altered goal-directed control in neuropsychiatric disorders and other conditions (Corbit, 2018) such as addictions (Hogarth et al., 2013; Trick et al., 2011), obsessive-compulsive disorder (Gillan et al., 2011), obesity (Horstmann et al., 2015), stress (Quail, Morris, et al., 2017; Schwabe & Wolf, 2009), schizophrenia (Morris et al., 2015), tryptophan depletion (Worbe et al., 2015), and impulsivity (Hogarth, 2011; Hogarth et al., 2012; Hogarth & Chase, 2011) measured by the Barratt's Impulsivity Scale (BIS), which considers attentional, cognitive (non-planning), and motor dimensions of impulsiveness.

3.2.2. Affect-Driven Impulsivity: Negative Urgency

Impulsivity is a broad umbrella term comprising qualitatively different forms of impulsivity, which are often only moderately correlated (Whiteside & Lynam, 2003). Distinct forms of emotion-related impulsivity have been identified and distinguished from other forms in which emotions do not play a central role but are instead related to cognitive dimensions (e.g., the lack of premeditation or perseverance related to deficits in conscientiousness). Reflexive responses to emotions represent a core vulnerability to psychopathology, having been linked to the "P" factor (Carver et al., 2017) and both externalising and internalising behaviours (King et al., 2018), such as alcohol abuse, eating disorders, anxiety, and depression (Johnson et al., 2017).

More specifically, negative urgency—the tendency to act rashly while experiencing distress or negative mood (Whiteside & Lynam, 2001)—has been considered a predictor of stimulant and mobile phone dependence, proneness to compulsive behaviour (Cándido et al., 2012), self-harm behaviours, alcohol consumption, and eating problems (Dir et al., 2013) and has been proposed as an endophenotype candidate of genetic risk for the development of eating disorders (Peterson et al., 2012).

Individuals exhibiting higher levels of self-reported NU favour immediate solutions to negative emotions due to a depletion of the resources dedicated to impulse control (Cyders & Coskunpinar, 2010), and use non-adaptive cognitive strategies of emotion regulation in search of short-term emotional relief, which may lead to inefficient emotion regulation in the long term (King et al., 2018). NU may also be related to failures in incidental (implicit-automatic) emotion regulation strategies (Braunstein et al., 2017) such as outcome revaluation and extinction.

3.2.3. Goals and Predictions of the Present Study

To our knowledge, the effects of emotion-relevant impulsivity on action control (e.g., outcome devaluation) and selection (PIT), as well as the interaction between them (i.e., the effect of outcome devaluation on outcome-specific PIT), have not been addressed to date, even though this issue is of importance for control dysregulation. To this end, we used a PIT paradigm combined with the outcome devaluation procedure; the latter occurred after (Experiment 1) or before (Experiment 2) the PIT phase (see Tables 3.1 and 3.2). This allowed us to selectively assess the effect of outcome devaluation on instrumental responding (Experiment 1) without the effect of Pavlovian cues, or on cue-elicited responding (Experiment 2). We expected to find both outcome devaluation and PIT effects in Experiment 1.

The prediction regarding the effect of outcome devaluation on specific PIT in Experiment 2 was less clear, given the mixed results reviewed above. Taking into account the paradigm we used, which involved abstract rewards or secondary reinforcers (i.e., food images), which were not properly "obtained" or consumed (and thus may be thought to be relatively weaker), and the relatively more cognitive outcome devaluation procedure (seeing a gif image in which two cockroaches run over the snack instead of a "motivational" change, such as sensory specific satiation; see Cartoni et al., 2016), we expected to find an effect of outcome devaluation on PIT. Therefore, we implicitly considered that the specific PIT effect to be found using our procedure would be mediated by the representation of the motivational properties of the outcome, that is, mediated by a goal-directed process (see also

Seabrooke et al., 2017, 2019). If this were the case, the task might be useful for assessing the incentive salience of Pavlovian cues associated with rewards (which cannot be addressed using more conventional instrumental conditioning paradigms that involve only associations between responses and outcomes). In addition, the task might also be useful for evaluating the balance between a goal-directed process and one based on automatic responding (by way of the outcome devaluation procedure).

A noteworthy feature of our study is that it was carried out with young women who were not selected for their impulsiveness scores or any other condition. We were interested in looking for vulnerability or risk factors related to behavioural inflexibility in otherwise healthy people, such as habit propensity (Robbins et al., 2012). Given the fact that insensitivity to outcome devaluation—as well as NU—has been linked to several externalising behaviours associated with psychological disorders and other conditions, we reasoned that both of these might also be related in healthy people. If this is the case, a negative correlation between performance on the experimental tasks and self-reported NU should be expected. Thus, in the case of Experiment 1, we hypothesised that NU would be associated with poorer reward value updating, that is, we expected to find that the weaker the effect of outcome devaluation on responding, the higher the score on this impulsivity trait. In addition, if the PIT task is indeed goal-directed, we expected to find a reduction in specific PIT in participants with higher levels of NU, that is, for these participants there would be a smaller difference between performance in the presence of the cue that shares the outcome with that particular response and performance in the presence of the alternative cue. For Experiment 2, we hypothesised that the putative effect of outcome devaluation on PIT (if found) will be inversely related to NU, due to a failure in outcome value updating after the devaluation phase.

Experiment 1

One additional goal of Experiment 1 was to validate in our sample the adapted version of an instrumental computerised task (see the "Procedure" section for a detailed description of the modifications). The aim of this task was to study both the PIT and outcome devaluation effects, in that order (see Table 3.1). Participants first had to learn which one of two responses led to which of two different outcomes during the instrumental training phase and, afterwards, which cues (colours) signalled the availability of four different outcomes during Pavlovian training, before freely performing both responses in an extinction test in which the four cues were presented occasionally (PIT test). Three outcomes were images of several snacks that could hypothetically be gained (i.e., never delivered in reality) whereas the fourth outcome was an image with the message "empty." Two of the three outcomes had previously been used to reinforce the instrumental responses during the instrumental training phase. Finally, one of the two instrumental outcomes was devalued by presenting its picture in a gif image displaying two cockroaches running over it, before carrying out a second test in extinction, this time without cues (outcome devaluation test). Prior to the experimental session, participants completed several online questionnaires at home, one of which measured NU (the Spanish adaptation of the short version of the Impulsive Behavior Scale (UPPS-P), the details of which can be found in the "Materials" section).

3.3. Methods

3.3.1. Participants

Forty-eight young female undergraduate students from the University of Granada participated in the study in exchange for academic credit. The students' ages ranged from 18 to 30 years (M = 20.08, SD = 2.22), and their body mass index (BMI) ranged from 16.65 to 30.12 (M = 21.63, SD = 3.01). They provided written consent before the study and had normal or corrected vision. The study received ethical approval from the Human Research Ethics Committee of the University of Granada (#71/ CEIH/2015), and all procedures were conducted in accordance with the 1964 Helsinki Declaration and its later amendments.

3.3.2. Materials

3.3.2.1. Initial Level of Hunger and Outcome Rating.

Before starting the experimental task, participants rated their level of hunger and the pleasantness of the three outcomes to be used during the experiment using a 7-point Likert-type scale with responses ranging from 0 (*not at all*) to 7 (*extremely*).

3.3.2.2. Behavioural Task.

The computerised task was an adaptation of that used by Quail et al., (2017) and Morris et al., (2015), kindly provided by the authors. The task was programmed using PsychoPy Software (Peirce, 2007) and presented on two available PC desktops, one with a HD 21.5″ screen with a resolution of 1920 × 1080 pixels, and the other with a LCD 19″ screen with a resolution of 1440 × 990 pixels. Raw data from the task were extracted and organised using R scripts. The adaptation of the original task involved introducing the following slight modifications to the procedure: some of the outcomes were substituted to make them more familiar to Spanish participants; the specific instructions given to the participants were changed to describe the goal of the task (i.e., imagining collecting snacks for the birthday parties of impoverished children); an outcome devaluation phase was added at the end of the experiment, which made use of a gif picture instead of a video clip; and the items were translated into Spanish. All other details of the task were broadly similar to those of the original version.

3.3.2.3. Spanish Adaptation of the Short Version of the UPPS-P Questionnaire.

To obtain a measure of emotional impulsivity, we administered the Spanish short version of the UPPS-P questionnaire (Cándido et al., 2012), following the French short version of Billieux et al., (2012). The short version of the UPPS-P contains 20 items, four for each of the traits considered in the five-factor model of impulsive behaviour (Whiteside & Lynam, 2001): positive and negative urgency, sensation seeking, (lack of) premeditation, and (lack of) perseverance, all of which have been found to be only moderately correlated (Fischer et al., 2008). The first two are considered to be affect-driven dimensions, while the latter two are regarded as indicators of poor executive functioning or conscientiousness. This version of the questionnaire shows a factorial structure of five specific but related factors that fit with the five traits proposed by the original model and shows appropriate internal consistency. Its use shortens the time needed to complete the scales (the original version contains 59 items) without altering the psychometric properties of the original scales (Cándido et al., 2012). In addition, the Spanish short version of the UPPS-P shows adequate equivalence to the original 59-item Spanish version (Lozano et al., 2018). In this study, Cronbach's α of the different dimensions ranged from .56 to .84 (NU, .83) in Experiment 1 and from .62 to .83 (NU, .78) in Experiment 2.

3.3.3. Procedure

Because we are currently undertaking a wider unrelated research project, participants completed the Spanish short version of the UPPS-P in combination with other questionnaires (see online Appendix A.1 for more details) and responded to questions asking for demographic data. A link to the battery of questionnaires to be completed at home was sent by email to participants who had previously agreed to take part in our study. Once the battery had been completed, they were invited to take part in the experimental study in the laboratory. Upon arrival, participants read and signed the consent form. As part of the wider research project mentioned previously, they performed an unrelated task (Implicit Association Test, IAT) in the same experimental session (this only happened in Experiment 1). The order in which participants performed the IAT task, before or after the target tasks, was counterbalanced across participants. The target tasks (PIT and outcome devaluation in an appetitive instrumental task) involved a total of four phases (see Table 3.1). All instructions were presented on the screen and paraphrased by the experimenter if necessary (the specific instructions can be found in the Appendix A.2, translated into English).

Table 3.1

Experiment 1. Experimental Design for the PIT task and Outcome Devaluation Test

Instrumental training	Pavlovian training	Transfer test	Devaluation test
R1 - O1	S1 - O1	S1: R1 (Same), R2 (Diff)?	Outcome devaluation (either O1 or O2)
R2 – O2	S2 - O2	S2: R1 (Diff), R2 (Same)?	
	S3 - O3	S3: R1, R2? (CS+)	R1, R2?
	S4 – no outcome	S4: R1, R2? (CS-)	

Note. PIT = Pavlovian-to-instrumental transfer; R = response; O = outcome; CS = cues; CS+ = excitor CS; CS - = inhibitor CS. Adapted from "Stress associated changes in Pavlovian-instrumental transfer in humans", by S. L. Quail, R. W. Morris, and B. W. Balleine, 2016, *The Quarterly Journal of Experimental Psychology*, *70*(4), p. 678 (https://doi.org/10.1037/xan0000148)

3.3.3.1. Instrumental Training Phase.

The outcomes (Os) used during the task were images of three snacks (counterbalanced) acting as O1, O2, and O3. The three Os were images of: M&Ms chocolates, a popular chocolate cookie (Príncipe), and crisps; the latter two were substitutes for two others used in the studies by Quail et al., (2017), to make them more familiar to Spanish participants. After rating their level of hunger and the pleasantness of the three snacks, participants were given the instructions that explained their goal. They were told that their task was to obtain as many snacks as they could to support birthday parties for disadvantaged children with no resources (see the Appendix A.2 for more details). Therefore, an important difference between

Quail et al., (2017) task and ours is that participants did not receive any snack; the reward was symbolic (conditioned) in that they never obtained it or consumed it. An image of a schematic vending machine appeared on the screen. Participants were told that they had to press keys B and N of the QWERTY keyboard with the index finger of their dominant hand to tilt the machine left or right (responses R1 and R2) to obtain two different outcomes (O1 and O2). Therefore, in this phase participants concurrently learnt two different associations (R1 → O1; R2 → O2). Initially, there were six blocks of trials. In each block, participants freely performed R1 and R2, which were reinforced according to a random ratio reinforcement schedule so that the number of consecutive responses required for reinforcement varied randomly in an interval between 5 and 10 responses. This reinforcement consisted of the appearance of an image of the corresponding outcome for 1s. After three outcomes had been obtained, the participants were instructed to withhold responding for 1s and asked which key they should press to get the outcome whose image appeared on the screen (O1 or O2); this outcome was always the last one the participant had won. Participants were given feedback on their responses; the word "Correct" or "Incorrect" appeared on the screen for 1s. In total, they were asked six times about their outcome-action (O-R) knowledge. The procedure finished when the participant answered the six questions correctly. In the event that the participants failed to answer one question in any block, they were given a further six blocks, with a maximum of 25 blocks[1].

[1] However, this only occurred for one participant in Experiment 1 and another in Experiment 2; in both cases, they failed just one question in the first block, so they completed seven blocks in total.

3.3.3.2. Pavlovian Phase.

In this stage of the experiment participants did not perform any action. Instead, they had to observe the relationship between several stimuli (colours—see below) and the accidental delivery of one of the three outcomes or no outcome at all. They were told that the vending machine was full of one of the snacks that freely fell from the machine from time to time and that the colours gave predictive information about which outcomes would be delivered each time. On some occasions, the front panel of the machine was lit with one of four colours (red, green, blue, and yellow), which acted as Pavlovian cues or stimuli (S1, S2, S3, and S4). The assignment of stimuli to outcomes was as follows: S1:O1; S2:O2; S3:O3; S4: "no outcome" delivered, that is, the machine was empty. Thus, S1 and S2 shared the outcomes with R1 and R2, S3 (CS+) was predictive of a similarly pleasant snack not previously experienced (O3), and S4 (CS–) predicted no reward. There were 12 blocks of trials. In each one, the image of the vending machine remained on the screen in its original colour (black) for 3 s. The machine was then lit with one of the four colours (randomly selected) for 1s upon which the image of the corresponding outcome immediately appeared under the machine icon for 2 s during which the machine remained illuminated with the colour. After four trials, the vending machine was lit in one of the four colours while participants were given a multiple-choice question asking about which of the four outcomes would follow (random order). Feedback was given in a similar way to the previous phase. In total, the participants were questioned 12 times about their knowledge of the cue outcome relationship (S-O), three times for each outcome.

3.3.3.3. PIT.

In this phase participants had to tilt the vending machine again (freely performing R1 and R2), but in extinction, that is, no outcomes appeared on the screen. Participants were told that although no snacks would be delivered, they had to use the knowledge they had acquired during the previous phases to get as many snacks as they could. There were six blocks of trials with four trials each, one for each Pavlovian cue (colours). Each trial began with the appearance of the vending machine in its original colour (black) whose duration varied in an interval between 8 and 16 s according to a fixed sequence that varied from block to block. The final 6 s of this period was considered to be the pre-CS period. After this, the machine appeared in one of the four colours for 6s (again in a fixed sequence that varied from block to block); this period was considered to be the CS period. R1 and R2 responses were recorded for both intervals. The whole procedure lasted for 442 s. To evaluate the influence of specific PIT, we considered only the trials on which S1 and S2 had been presented. R1 and R2 responses were categorised as “Same” or “Different” according to the outcome (O1 or O2) they had been associated with during instrumental training. Therefore, R1 was the response “Same” when S1 was presented, but was considered to be the response “Different” when S2 was presented; the opposite was true for R2 (this was response “Same” when S2 was presented during the CS period, but “Different” if S1 was presented during that period). To determine the degree of general PIT, we considered R1 and R2 jointly as “responses” on trials in which S3 and S4 were presented. This was always true for the pre-CS period (no distinction between R1 and R2 was made).

3.3.3.4. Outcome Devaluation.

In this phase, one of the two outcomes used during instrumental training, O1 or O2 (counterbalanced across participants), was devalued. We modified the devaluation procedure used by Morris et al. (2015) for convenience. Instead of watching a video clip showing the outcome infected with cockroaches, participants observed a gif image in which two cockroaches run over the snack. The image lasted for approximately 10 s. After this, participants were given the outcome devaluation test, lasting 120 s, in which they could freely perform the two actions (R1 or R2) in extinction (no outcomes were delivered). Finally, they rated again the level of pleasantness of the three snacks and the level of hunger.

3.4. Results and Discussion

3.4.1. Statistics.

In this and the following experiment, repeated-measures (RM) analyses of variance (ANOVAs) were used to determine the locus of significant main effects and interactions. Greenhouse–Geisser correction for the violation of the sphericity assumption was applied when appropriate. Student's paired *t*-test (one-tailed in the case of directional a priori hypotheses) was used for testing pairwise mean differences, whereas Holm's correction was used for multiple comparisons. Estimated effect sizes were generated using Cohen's *d*, for *t*-tests, and η^2_p, for the ANOVAs. Pearson's correlation coefficients, with 95% confidence intervals, were computed to estimate the degree of relationship between the behavioural measures and the NU scores.

To provide evidence in favour of the null hypothesis in the case of non-significant differences, we computed Bayes factor (BF), estimated by using Jeffreys-

ZellnerSiow (JZS) prior (Rouder et al., 2009) and JASP (JASP Team, 2019) software. We followed the conventional interpretation of JZS values proposed by Wagenmakers et al., (2011) and the recommendations made by Schönbrodt et al., (2017) according to (Rouder et al., 2009), to incorporate prior knowledge, if available, by tuning the width of the Cauchy prior. Therefore, in Experiment 1, without prior evidence for the estimation of the effect size using our modified task, we selected the value of the Cauchy prior width corresponding to a small effect size ($r = \sqrt{2}/2$); in Experiment 2, taking into account the large effect sizes found in Experiment 1 for both outcome devaluation and outcome-specific PIT, we set the Cauchy prior width to $r = \sqrt{2}$. In the case of Bayesian correlations, we selected the value of the stretched beta prior width to 0.5, following the suggestions of (Quintana & Williams, 2018).

3.4.2. Preliminary analyses.

3.4.2.1. Initial Hunger Level and Pleasantness Outcomes Ratings.

Before starting the experiment, participants rated their hunger level (range = 1 – 7, M = 3.13, SEM = 0.26). The pleasantness ratings of the three outcomes used throughout the experiment (M&Ms, M = 4.73, SEM = 0.26; Chips, M = 5.33, SEM = 0.20; Cookies, M = 5.31, SEM = 0.16) were submitted to a RM one-way ANOVA that yielded a significant effect of outcome, $F(1.81, 85.03) = 3.88$, $p = .028$, $\eta^2_p = .076$. Holm's post hoc tests did not reveal any significant difference between the three means, although the difference between M&Ms and Cookies fell short of conventional levels of significance, $p = .051$, $BF_{s\,10} \leqslant 2.41$.

3.4.2.2. Instrumental Training.

As expected, the RM-ANOVA did not reveal differences between the total number of R1 and R2 responses made (R1: M = 119.85, SEM = 10.09; R2: M = 119.81, SEM = 9.26), or the number of O1 or O2 outcomes gained (O1: M = 9.06, SEM = 0.42; O2: M = 9.00, SEM = 0.43), both $F_s < 1$, $BF_{s\ 10} = 0.16$. All participants correctly answered the questions about explicit O-R knowledge (i.e., which response lead to which outcome); therefore, the average accuracy was 100%.

3.4.2.3. Pavlovian Training.

During this phase, participants observed the relationships between the four Pavlovian cues (CSs) and the four possible outcomes. Out of the 12 questions, two participants failed two of these, and eight participants failed one question. The remaining 38 participants answered each question correctly. The average number of correctly answered questions on explicit S-O knowledge was M = 11.75 (SEM = 0.08), that is, average accuracy was 98%.

3.4.3. Pavlovian-to-Instrumental Transfer (PIT):

3.4.3.1. Specific Transfer.

To evaluate the effect of the different Pavlovian cues on instrumental responding, we first determined a baseline rate by averaging for each participant the number of R1 and R2 responses made during the pre-CSs periods. Likewise, for each participant the total number of responses Same and Different was averaged over trials. The average preCS responses were then subtracted from these values to obtain a differential [CS-preCS] score for each condition, Same and Different, per participant. These scores were then submitted to an RM-ANOVA (see Figure 3.1, left-hand panel). There was a significant effect of PIT, $F(1, 47) = 13.68$, $p < .001$, η^2_p =

.226 ; the cue produced an increase in responding for the action associated with the same outcome during instrumental training (Same); correspondingly, this produced a decrease for the alternative action (Different). We therefore found an outcome-specific PIT effect.

3.4.3.2. General Transfer.

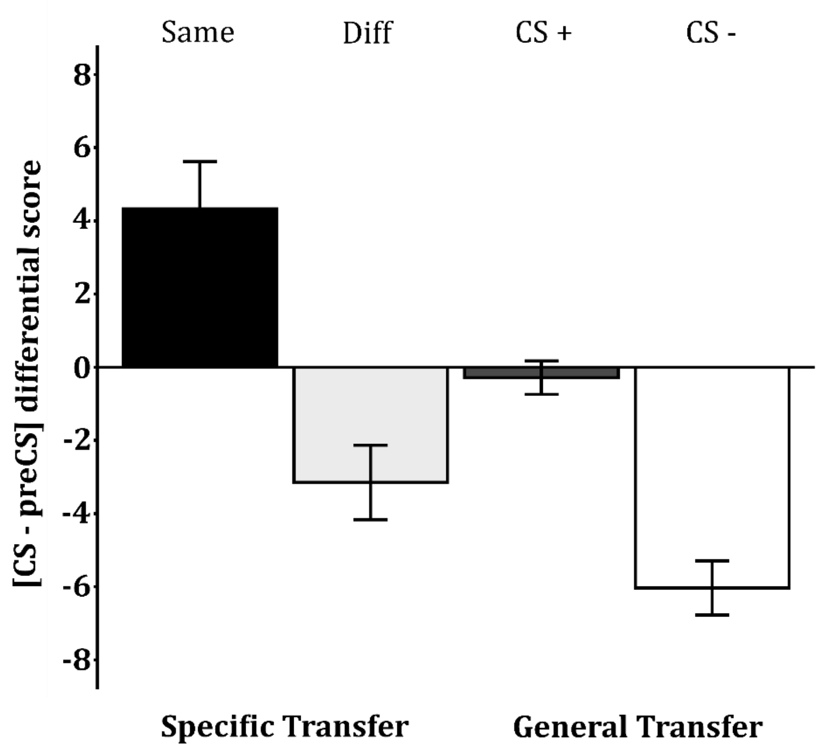
To assess the influence of cues S3 (CS+) and S4 (CS−) on the vigour of responding, we calculated a differential CS-preCS score by subtracting the average number of preCS responses computed previously from the number of responses made during each of these CSs averaged by trial (see Figure 3.1, right-hand panel). The RM-ANOVA conducted on the differential scores yielded a significant effect of CS, $F(1, 47) = 52.85$, $p < .001$, $\eta^2_p = .529$, thus finding a general transfer effect, at least when defined as a higher level of responding in the presence of CS+ in comparison with CS−.

3.4.3.3. Transfer on Baseline Responding.

To obtain a more direct index of the influence of the four cues on baseline responding, we compared the differential scores with the value of zero through several one-sample *t*-tests. We found significant differences for conditions Same ($p = .002$), Different ($p = .003$), and CS− ($p < .001$), but not in the case of CS+ ($p = .553$; $BF_{10} = 0.19$). Therefore, although the cues predicting the instrumental outcomes (O1 and O2) were able to produce a specific increase or decrease in the corresponding instrumental actions, R1 and R2 (i.e., specific transfer), above or below baseline, a cue (CS+) predicting a (motivationally) similar but different (in terms of sensory aspects) outcome (O3) did not produce any noticeable change in baseline responding. However, a cue predicting no outcome (CS−) induced response suppression. Therefore, we detected just a partial general transfer effect by which a cue predicting no reward decreased motivation for responding and, accordingly, lowered it below baseline.

Figure 3.1

Experiment 1. Specific and General Pavlovian-to-Instrumental Transfer (PIT)



Note. Mean CS-preCS difference score (compared with baseline) by condition during the PIT test. Same: response that shared the outcome with the Pavlovian stimulus presented during the test; Diff: alternative response; CS+: stimulus (S3), which during Pavlovian training, signalled a third outcome, not presented during instrumental training (O3); CS–: stimulus (S4) which signalled no outcome during Pavlovian training (O4). Bars represent ±*SEM*.

3.4.4. Effect of Outcome Devaluation on Instrumental Responding

The total number of responses for the non-devalued (*M* = 352.42, *SEM* = 23.05) and the devalued (*M* = 217.98, *SEM* = 21.21) responses were submitted to an RM-ANOVA, which yielded a significant effect of devaluation, $F(1, 47) = 10.85$, $p = .002$, $\eta^2_p = .188$, confirming that the devaluation treatment decreased responses for the action whose associated outcome during instrumental training was devalued before the test.

3.4.5. Effect of Outcome Devaluation on Outcome Pleasantness Rating Scores

We then analysed the differences in participants' reported pleasantness ratings before and after outcome devaluation in search for a decrement in the outcome that was devalued, which should be absent for the rest of the outcomes. The RM-ANOVA with outcome (devalued, nondevalued1, nondevalued2) and time (pre, post) yielded a significant Outcome × Time interaction, $F(1.43, 67.37) = 4.77$, $p = .021$, $\eta^2_p = .092$; the two main effects were not significant, largest $F(1, 47) = 3.17$, $p = .082$, for time. We explore the interaction through one-tailed *t*-test, finding a significant decrease in the case of the devalued outcome, $t(47)=3.19$, $p = .001$, $d = 0.46$, (*M* = 5.27, *SEM* = 0.19, and *M* = 4.71, *SEM* = 0.23; before and after devaluation, respectively). None of the two non-devalued outcomes showed a significant decrease in pleasantness, when comparing the scores pre and post the devaluation phase, $t(47) = –1.11$, $p = .863$, $d = –0.16$, $BF_{+0} = 0.08$ (M_{pre}= 4.77, *SEM* = 0.24; M_{post} = 4.98, *SEM* = 0.24); $t(47) = 1.43$, $p = .080$, $d = 0.26$, $BF_{+0} = 0.74$ (M_{pre} = 5.33, *SEM* = 0.184; M_{post} = 5.04, *SEM* = 0.19). Therefore, the devaluation treatment procedure we used in the present experiment (i.e., exposure to a gif image showing cockroaches running over the snack) was effective in reducing the incentive value of the outcome, and this reduction lead to a decrease in response rate for the action whose associated outcome was devalued, as well as a reduction in the reported pleasantness of the devalued outcome.

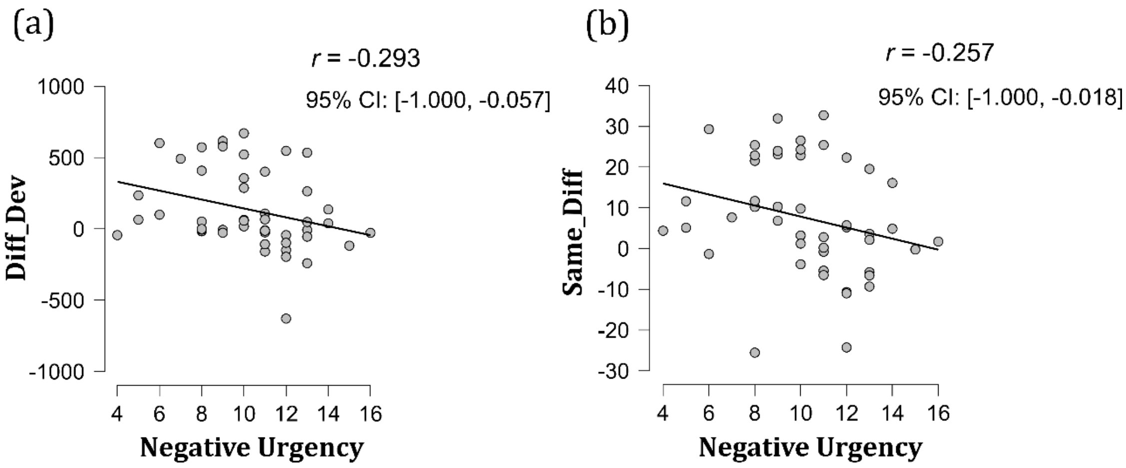
In summary, during instrumental training responding rates for R1 and R2 or the number of O1 and O2 gained did not differ, with the causal R-O knowledge of the participants being 100% accurate. Participants also learned the S-O relationships with an average accuracy of 98% during Pavlovian training. The outcome devaluation procedure was effective in reducing the pleasantness ratings of the outcome (liking), and, more importantly, the response rate for the action whose outcome had been previously devalued (wanting); that is, we found the outcome devaluation effect on instrumental responding, suggesting an underlying goal-directed process. On the PIT test, S1 and S2 cues selectively enhanced the response rate above baseline for the action with which they shared the outcome (Same condition), compared with the alternative action (Different condition), leading to a reliable specific PIT effect (see the left-hand panel of Figure 3.1). However, the CS+ (S3) did not increase responding above baseline, while S4 (CS–) had an impact on general performance, reducing responding below baseline (see the right-hand panel of Figure 3.1). Therefore, it appears that the adapted task employed in these experiments generated broadly similar effects to those found previously in the literature, at least with regard to outcome-specific PIT, although general PIT results were somewhat less conclusive. It is not clear why the CS+ did not increase the response rate above baseline. One possibility is that baseline responding might have been high, reducing the likelihood of detecting a positive transfer effect. Although we did find a specific transfer effect for stimulus Same, general transfer could simply be weaker and more difficult to detect in the case of CS+. It is also possible that the use of two reinforcers that shared motivational properties but differed primarily in terms of sensory attributes during instrumental training encouraged learning of an association between the two responses and the sensory attributes of their outcomes, with attention being focused on these properties rather than the motivational attributes (Holland, 2004). This could explain why the CS+ did not elevate performance above baseline. However, the general transfer effect was not completely absent, because the cue predicting no outcome (CS–) readily depressed responding below baseline. Inhibitory effects on PIT, specifically when using inhibitory training procedures (feature-negative conditioned inhibition), have previously been reported in humans (e.g., Alarcón & Bonardi, 2016; Laurent & Balleine, 2015; Quail, Laurent, et al., 2017). However, while no specific inhibitory procedures were used in the present experiment, the absence of an outcome in a context in which outcomes were expected may have provided the required conditions for inhibitory learning to take place (for similar results, see, for example, Colagiuri & Lovibond, 2015; Quail et al., 2017).

3.4.6. The Role of Negative Urgency

Following this overall analysis, we analysed the effect of NU on action control and selection. As a reminder, we anticipated that participants with higher NU scores would show insensitivity to outcome devaluation, making relatively more devalued responses than participants with lower scores. The implications for the PIT effect were less clear. If we consider that specific PIT is mediated by the outcome value (i.e., the effect depends on the updating of the motivational value of the outcome and is a goal-directed process), we might expect that participants with higher levels of NU should show poorer action selection, responding relatively less in the presence of the stimulus "Same" than participants with lower scores on NU.

Figure 3.2

Experiment 1. One-Tailed Correlational Analyses



Note. (a) negative relationship between difference in the number of non-devalued responses and devalued responses (Diff_Dev) and score on negative urgency. The negative relationship illustrates that the devaluation effect decreases with increases in Negative urgency score. (b) Negative relationship between difference in responding to the Same condition compared to the Diff condition (specific PIT, Same_Diff) and score on negative urgency. The negative correlation illustrates that the effect of specific PIT decreases with increases in Negative urgency score. (a) and (b) Scatterplots; one-tailed Pearson's coefficient, 95% confidence interval.

We conducted two one-tailed correlational analyses in accord with our hypotheses in which we expected to find negative correlations between NU scoring and measures of outcome devaluation and PIT. First, we calculated the correlation between the score on NU and the differential responding during the outcome-devaluation test (Diff_ Dev), number of responses associated with the non-devalued outcome minus number of responses associated with the devalued outcome (Figure 3.2a), which was negative and significant, as predicted, r=–.29, p=.022, 95% confidence interval (CI): [–1.000, –0.057], one-tailed. This result indicated that responding was less sensitive to the current value of the outcome (an index of habitual responding), the higher the score on NU.

No other impulsivity traits were significantly correlated, lowest r = –.18, p = .109, 95% CI: [–1.000, 0.062], BF_{-0} = 0.94, for positive urgency. Second, we computed the correlation between NU and specific PIT. To this end, we calculated the difference between the number of "Same" and "Different" responses made during the PIT test (Same_Diff). This correlation turned out to be negative and significant, r = –.26, p = .039, 95% CI: [–1.000, –0.018], one-tailed (Figure 3.2b), as was also the case for positive urgency, r = –.30, p =.017, 95% CI: [–1.000, –0.070]. Both emotional impulsiveness traits were linked to less specific PIT. Lack of perseverance, lack of premeditation, and sensation seeking showed no significant correlations with any of the measures, lowest r = –.22, p = .062, 95% CI: [–1.000, 0.017], BF_{-0}=1.48, for lack of perseverance. This pattern of results highlights the relevance of emotional impulsivity, as opposed to other forms of impulsiveness, in cued responding (specific PIT), and the uniqueness of NU in predicting failures in action control, measured by sensitivity to outcome devaluation. Given that both effects appear to be negatively correlated with emotional impulsiveness, the question arises as to whether the two effects could be related to each other. A two-tailed correlation analysis computed between Diff_Dev (sensitivity to outcome devaluation) and Same_Diff (outcome-specific PIT) scores found a significant positive correlation, r = .52, p < . 001, 95% CI: [0.283, 0.704], a result that is compatible with the notion that both effects could be underpinned by a common process. The correlation between Diff_Dev and CS+/CS– (general transfer index), however, turned out to be non-significant, r = .20, p = .174, 95% CI: [–0.090, 0.458], BF_{10} = 0.63, along with the correlation between specific and general PIT, r = .15, p = .318, 95% CI: [–0.143, 0.414], BF_{10} = 0.42.

These results suggest that in our task, and for participants with lower NU scores, the specific PIT effect might be mediated by the representation of the current motivational value of the outcome and therefore the underlying process could be goal-directed. This possibility makes testable predictions, one of which is that the PIT effect observed using our procedure should be sensitive to outcome devaluation, a prediction tested in Experiment 2.

Experiment 2

Experiment 1 showed that both outcome devaluation and specific PIT effects were impaired in young women with higher scores on NU in comparison with those who showed lower scores on this trait. In Experiment 2, we examined the interaction between these effects with a twofold aim. Our first goal was to add evidence to the current debate as to whether outcome devaluation has an effect on specific PIT, and second, if this indeed were the case, we aimed to investigate the role of NU in generating this effect. Regarding the first goal, the outcome devaluation procedure took place before the PIT test on this occasion (see Table 3.2). Taking into account the results of Experiment 1 (which indicate that the specific PIT effect found using our task was, unlike general PIT, linked to the current motivational value of the outcome, that is, goal directed), we predicted that outcome devaluation would decrease or eliminate this effect while having no impact on general PIT. In relation to the second goal, we aimed to replicate the findings of Experiment 1 with respect to NU. Given that we found a negative correlation between NU and specific PIT, we expected to observe an effect of outcome devaluation on specific PIT in participants with a lower score on NU, but not in those with higher scores on this trait; that is, we predicted a negative correlation between PIT devaluation and NU.

3.5. Methods

3.5.1. Participants

Forty-eight young female university students participated in the study in exchange for academic credit. The ages of the students ranged between 18 and 24 years (M = 19.69, SD = 1.56), and their BMI ranged between 16.81 and 28.40 (M = 21.76, SD = 2.78).

3.5.2. Materials

Measures, tasks, and questionnaires were the same as those used in Experiment 1, with the exception of minor details that are described in the "Procedure" section.

Table 3.2

Experiment 2. Experimental Design for the PIT Task, Outcome Devaluation Test, and Transfer Test

Instrumental Training	Pavlovian Training	Devaluation	Transfer Test
R1 - O1	S1 - O1	Outcome Devaluation (either O1 or O2)	S1: R1 (SameDev), R2 (DiffNonDev)? S2: R1 (DiffDev), R2 (SameNonDev)?
R2 – O2	S2 - O2		S1: R1 (SameNonDev), R2 (DiffDev)? S2: R1 (DiffDev), R2 (SameDev)?
	S3 - O3		S3: R1, R2? (CS+)
	S4 – no outcome		S4: R1, R2? (CS-)

Note. PIT = Pavlovian-to-instrumental transfer; R = response; O = outcome; CS = cues; CS+ = excitor CS; CS - = inhibitor CS. Adapted from "Stress associated changes in Pavlovian-instrumental transfer in humans", by S. L. Quail, R. W. Morris, and B. W. Balleine, 2016, *The Quarterly Journal of Experimental Psychology*, *70*(4), p. 678 (https://doi.org/10.1037/xan0000148)

3.5.3. Procedure

Table 3.2 summarises the design of Experiment 2. The instrumental and Pavlovian training phases were broadly similar to those described in Experiment 1. However, the outcome devaluation procedure took place before the PIT test, which was, as in Experiment 1, a test in extinction during which participants freely performed R1 and R2 while the four Pavlovian cues (colours) were presented from time to time. For half of the participants, the devalued response was R1, and for the remainder this was R2.

3.5.3.1. Outcome-Specific PIT.

To evaluate the influence of devaluation on specific PIT, we selected those trials on which S1 and S2 were presented. R1 and R2 responses were then categorised as “Same” or “Different,” according to the outcome (O1 or O2) with which they were associated during instrumental training. Because on this occasion the test was conducted after the devaluation procedure, one of the responses was associated with the now-devalued outcome and we thus added further labelling using the terms Devalued (Dev) or Non-Devalued (NonDev). For instance, consider those participants for whom O1 was devalued, and a particular trial in which S1 was presented. In this case, R1 would be labelled “Same,” because it shared the outcome with S1, and “Devalued,” because the shared outcome was devalued; thus, it would be labelled “SameDev.” Now consider a trial in which S2, instead of S1, is presented. Now R2 would be a “Same” response, but its associated outcome has not been devalued, and it would therefore be labelled as a “SameNonDev” response.

3.5.3.2. General PIT.

To estimate the magnitude of the general PIT effect, we followed Experiment 1 considering both R1 and R2 as "responses" on those trials in which either S3 (CS+) or S4 (CS–) were present. In this case, however, the calculation of the number of preCS responses as an estimation of baseline responding was complicated by the fact that one of the responses was already "devalued." For this reason, and because our hypotheses were more specifically linked to the specific PIT effect, we decided to analyse the PIT effect in two ways: one of these involved using the differential CS-preCS score, taking into account separately the preCS value for the devalued and the non-devalued response, while the other used the average number of responses made in the presence of the stimuli. Finally, participants were again required to rate the level of pleasantness of the three outcomes. It is important to note that, unlike Experiment 1, and to perform the PIT test immediately after the devaluation phase, this evaluation was conducted at the end of the experiment, and not after the devaluation procedure.

3.6. Results and Discussion

3.6.1. Preliminary Analyses:

3.6.1.1. Initial Hunger Level and Pleasantness Outcomes Ratings.

Before starting the experiment, participants rated their hunger level (range = 1–7, M = 3.06, SEM = 0.24). The pleasantness ratings of the three outcomes used throughout the experiment (M&Ms, M = 4.69, SEM = 0.26; Cookies, M = 4.75, SEM = 0.25; and Chips, M = 4.73, SEM = 0.24) were submitted to a one-way ANOVA that did not yield a significant effect, $F < 1$ (paired samples t-test $BF_{s\,10} < 0.10$).

3.6.1.2. Instrumental Training.

The number of responses made, both R1 and R2, did not differ[2] (M=111.60, *SEM*=6.97, and M=115.96, *SEM*=6.62, respectively), along with the number of outcomes gained, O1 and O2 (M=8.96, *SEM*=0.30, and M=9.10, *SEM*=0.30, respectively), both $F_s < 1$, $BF_{s\ 10} < 0.10$. All participants correctly answered the questions about explicit O-R knowledge (i.e., which response lead to which outcome); therefore, average accuracy was 100%.

3.6.1.3. Pavlovian Training.

During this phase, participants observed the relationships between the four Pavlovian cues (CSs) and the four possible outcomes. Out of the 12 questions, 14 participants failed one question, and one of the participants failed three questions. The remaining 33 participants answered each question correctly. The average number of correctly answered questions on explicit S-O knowledge was M = 11.69 (SEM = 0.07), thus indicating 97% accuracy.

3.6.2. Effect of Outcome Devaluation on Baseline Responding

Because the PIT task was performed after outcome devaluation, one of the two responses, R1 or R2, could be considered "devalued" (i.e., the one that was associated with the now-devalued outcome during instrumental learning). Indeed, the average number of instrumental responses performed in the presence of the stimulus whose associated outcome was devalued (the stimulus that was relevant to either the condition Same or Different) was significantly lower (M = 16.73, SEM = 1.54) than that of the alternative response (i.e., the one performed in the presence

[2] The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

of the stimulus whose outcome was not devalued, M = 23.48, SEM = 1.63), $t(47)$ = 3.54, p < .001, d = 0.51. Similar results were found when analysing the responses performed during the preCS period, where the average number of responses was lower for the response whose outcome had been devalued (M = 9.77, SEM = 0.88) than for the one whose outcome had not (M = 13.77, SEM = 1.45), $t(47)$ = 2.70, p = .010, d = 0.40. These results suggest that our outcome devaluation manipulation was, once again, effective.

However, these differences made it difficult to average responses to calculate a single "baseline" level of responding for the transfer test analyses. For this reason, as previously mentioned, separate preCS periods, for responses linked either to the devalued or the non-devalued outcomes, were taken into account. Note that this is a rather conservative test for our hypothesis, as responding was clearly biased towards the response associated with the still valued outcome. This may likely reduce the opportunity to observe an increase above baseline in the case of the SameNonDev condition (see, for example, Colagiuri & Lovibond, 2015; Seabrooke et al., 2019). However, it would still allow for comparing the effect of devaluation on the Same versus Diff contrasts depending on whether the relevant outcome was previously devalued or not. Specifically, if devaluation indeed has an impact on PIT, we anticipated that such a difference would emerge only in the non-devalued condition.

3.6.3. Effect of Outcome Devaluation on Pavlovian-to-Instrumental Transfer

3.6.3.1. Specific Transfer

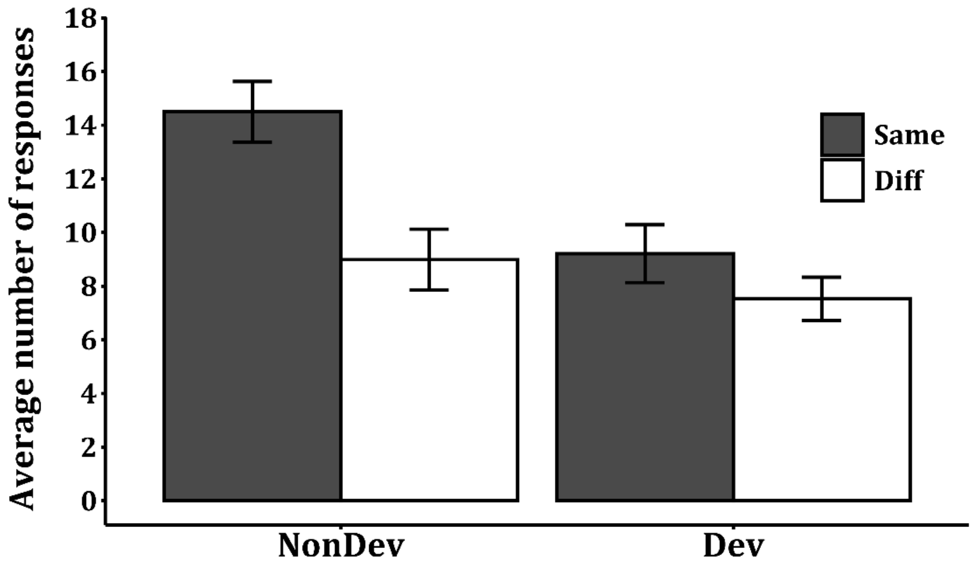
To evaluate the effect of outcome devaluation on specific transfer, we first computed the average R1 and R2 number of responses for each participant in the presence of both S1 and S2. As in Experiment 1, the number of R1 responses performed in the presence of S1 was referred to as Same and referred to as Different when performed during S2. Accordingly, R2 performed in the presence of S2 was referred to as Same and referred to as Different when performed during S1. Furthermore, as explained previously, R1 and R2 responses were also denoted as Devalued (Dev) or Non-devalued (NonDev), according to whether O1 or O2 was devalued (or not) during the outcome devaluation phase. To calculate the CS-preCS difference scores, the average number of responses performed during the preCS period for either the devalued response (preCS_Dev) or the non-devalued response (preCS_NonDev) was subtracted from the number of responses performed during the presence of the stimulus. In total, four difference scores were estimated for each participant: SameDev and DiffDev, using the preCS_Dev, and SameNonDev and DiffNonDev, using the preCS_NonDev. These difference scores were submitted to an RM-ANOVA with stimulus (Same, Different) and devaluation (Dev, NonDev) as factors, yielding a significant main effect of stimulus, $F(1, 47) = 12.26$, $p = .001$, $\eta^2_p = .207$, as well as an interaction between these variables, $F(1, 47) = 4.48$, $p = .040$, $\eta^2_p = .087$, while no significant effect of devaluation was found, $F < 1$. The simple main effects analysis showed that outcome-specific PIT was significant in the NonDev condition, $p < .001$, but there was no evidence of this in the Dev condition, $p = .141$,

BF_{10} = 0.24, means, SameNonDev, 0.72 (SEM = 0.90); DiffNonDev, −4.80 (*SEM* = 1.70); SameDev, −0.56 (*SEM* = 1.14); DiffDev, −2.45 (*SEM* = 0.98). As mentioned previously, although the Same versus Diff contrast was significant only in the case of the NonDev condition, providing that the outcome specific PIT effect did occur, it was difficult to detect an increase above baseline in the case of the SameNonDev condition, possibly due to the bias in responding towards the non-devalued instrumental response (see Seabrooke et al., 2019).

The pattern of results was, however, similar (and much clearer) when using the raw number of responses performed in the presence of the stimulus (Figure 3.3). The RM-ANOVA yielded main effects of both stimulus, $F(1, 47) = 12.27$, $p = .001$, $\eta^2_p = .207$, and devaluation, $F(1, 47) = 12.54$, $p < .001$, $\eta^2_p = .211$. Moreover, the interaction was also significant, $F(1, 47) = 4.48$, $p = .040$, $\eta^2_p = .087$. Inspection of Figure 3.3 (left-hand panel) suggests that there was an effect of specific transfer, that is, participants made a greater number of responses, on average, in the Same condition (in comparison with the Different condition), but only when the associated outcome had not previously been devalued. This impression was confirmed by statistical analyses. The simple main effects analysis showed that outcome-specific PIT was significant in the NonDev condition, $p < .001$, but there was no evidence of this effect in the Dev condition, $p = .141$, $BF_{10} = 0.24$. Moreover, the number of responses was significantly higher for SameNonDev compared with SameDev, $t(47) = 3.38$, $p < .001$, $d = 0.49$, while no such difference was found when comparing the two Diff conditions, $t(47) = 1.46$, $p = .152$, $BF_{10} = 0.23$. Therefore, the outcome devaluation procedure eliminated the effect of specific transfer, suggesting that this was mediated by a goal-directed process.

Figure 3.3

Experiment 2. Effect of Outcome Devaluation on Specific Pavlovian-to-Instrumental Transfer (PIT) during the Devaluation-PIT Test



Note. Average number of responses by condition. Same: response that shares the outcome with the Pavlovian stimulus presented during the test; Diff: alternative response; NonDev: response whose associated outcome had not been previously devalued; Dev: response whose associated outcome had been previously devalued. Bars represent ±SEM.

3.6.3.2. General Transfer.

To assess the influence of outcome devaluation on the ability of S3 (CS+) and S4 (CS–) to affect R1 and R2 responding, we considered the number of responses in the presence of each stimulus for the non-devalued and the devalued response (S3NonDev, S3Dev; S4NonDev, S4Dev). As in the previous specific PIT analyses, we subtracted the corresponding average, preCS_Dev or preCS_NonDev, to obtain difference scores (CS+NonDev, M = –1.90, SEM = 0.95; CS+ Dev M = 0.66, SEM = 1.26;

CS-NonDev, $M = -6.93$, $SEM = 1.27$; CS-Dev, $M = -2.55$, $SEM = 0.83$). An RM-ANOVA with devaluation (non-devalued, devalued) and general transfer (CS+ vs. CS–) as factors revealed significant main effects of general transfer (i.e., CS+ > CS-), $F(1, 47) = 22.70$, $p < .001$, $\eta^2_p = .326$, and devaluation, $F(1, 47) = 9.74$, $p = .003$, $\eta^2_p = .172$. The interaction was, however, not significant, $F(1, 47) = 1.25$, $p = .268$. Accordingly, and irrespective of devaluation, comparisons between CS+ and CS– scores, either in the non-devalued, $t(47) = 4.43$, $p < .001$, $d = 0.64$, or the devalued conditions, $t(47) = 2.59$, $p = .013$, $d = 0.37$, remained significant. The pattern of results obtained using the number of responses performed in the presence of the stimuli was similar, as the analyses yielded a main effect of stimulus, $F(1, 47) = 22.69$, $p < .001$, $\eta^2_p = .326$, but no effect of devaluation, $F < 1$, or an interaction, $F(1, 47) = 1.25$, $p = .268$, $\eta^2_p = .026$ (CS+NonDev $M = 11.88$, $SEM = 1.14$; CS+Dev $M = 10.43$, $SEM = 1.00$; CS-NonDev $M = 6.84$, $SEM = 0.69$; CS-Dev $M = 7.21$, $SEM = 1.00$). Differences between CS+ and CS– were significant both in the non-devalued condition, $t(47) = 4.43$, $p < .001$, $d = 0.64$, and in the devalued condition, $t(47) = 2.59$, $p = .013$, $d = 0.37$. These results suggest that general transfer is not mediated by a goal-directed process, and behaviour seems instead to be insensitive to changes in the current motivational value of the outcome with which it shares similar motivational properties (but from which it differs in terms of sensory properties).

3.6.4. Effect of Outcome Devaluation on Outcome Pleasantness Rating Scores:

After the PIT task, participants were asked again to rate the three outcomes. For the outcome that was devalued, we expected a decrease in outcome rating after devaluation, as was found in Experiment 1. The RM-ANOVA with outcome (devalued, nondevalued1, nondevalued2) and time (pre, post) yielded a marginally significant interaction, $F(1.47, 68.00) = 3.25$, $p = .060$, $\eta^2_p = .065$; the main effects were not significant, largest $F(1.94, 91.46) = 2.28$, $p = .110$, for outcomes. A one-tailed t-test, $t(47) = 1.85$, $p = .036$, $d = 0.27$, confirmed the expectation (M_{pre}= 4.50, SEM = 0.23; M_{post} = 4.14, SEM = 0.29). None of the non-devalued outcomes showed a decrease in pleasantness when comparing the pre and post devaluation scores, t_s < 1 ($M_{s\ pre}$ = 4.75 and 4.92, SEM_s = 0.26 and 0.25, respectively; $M_{s\ post}$ = 4.83 and 5.00, SEM_s = 0.28 and 0.26, respectively; BF_{s+0} < 0.10). The effect of outcome devaluation on this explicit measure seems to be weaker than the one found in Experiment 1. This could be due to the delay introduced between the outcome devaluation procedure and its explicit assessment: in this case, it took place after the behavioural devaluation test (and not immediately after the devaluation procedure). The data of the devaluation test, however, showed that baseline responding for the response that was linked to the devalued outcome was lower than that linked to the still valued one, while it was also shown to have an impact on specific PIT, at least in participants with lower NU scores. Although it could be possible that this might have negatively affected general PIT, in this study we were not able to specify how this might have occurred.

In summary, during instrumental training, there was no difference between R1 and R2 in terms of the number of responses made, or between gained outcomes, O1 and O2. Causal knowledge of the R-O relationships was 100% accurate, whereas it was again slightly lower (97%) in the case of the knowledge regarding the S-O relationship acquired during Pavlovian training. Regarding the PIT test conducted after outcome devaluation (see Figure 3.3), S1 and S2 cues selectively enhanced response rates for the action with which they shared the outcomes (Same condition), but only if they had not been previously devalued (NonDev condition, see Figure 3.3). Otherwise, the specific PIT effect was absent.

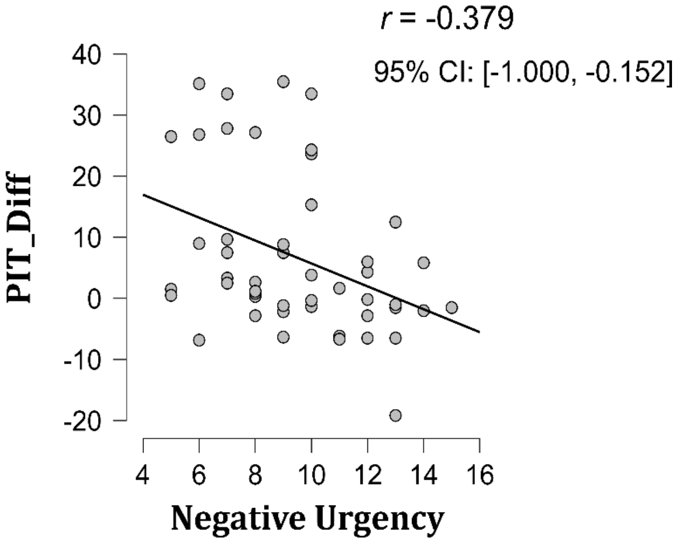
Therefore, on the basis of this preliminary analysis, it appears that the specific PIT effect found using our experimental procedure was sensitive to outcome devaluation and thus goal-directed. However, no differential effect of outcome devaluation was detected in general PIT. This latter result is consistent with the notion that the general PIT transfer found with our procedure is insensitive to changes in the motivational value of the outcome, although this conclusion might be premature, given that we did not observe a significant increase in responding at baseline in the case of S3 (CS+), only a decrease in the case of S4 (CS–). Whatever the precise mechanism underlying this pattern of results, its insensitivity to outcome devaluation is consistent with data from Experiment 1 showing that the difference in performance between CS+ and CS– was not significantly related to the effect of outcome devaluation found on instrumental responding.

3.6.5. The Role of Negative Urgency

Following these general analyses, we looked at the effect of NU on devaluation of the specific PIT. To estimate the effect of outcome devaluation on specific PIT, we considered the number of responses performed in the presence of the stimuli and two pairwise comparisons: SameNonDev versus DiffDev, and SameDev versus DiffNonDev. The extent to which they differed was determined using the following formula: PIT_Diff = [(SameNonDev – DiffDev) – (SameDev – DiffNonDev)], where the higher the devaluation effect, the higher the PIT_Diff value. The underlying rationale was that, if outcome devaluation affected PIT, an increase in responding would be observed only for the SameNonDev condition, but not for the SameDev condition, and, theoretically, the Diffs conditions would be much less affected, if at all, by the devaluation procedure. To recap, we did expect to find a lower specific PIT effect in those participants with higher NU scores, that is, we expected to find a significant negative correlation between both measures. To test this possibility, we calculated the correlation (one-tailed test) between the PIT_Diff score and the score on NU (Figure 3.4), which turned out to be negative and significant, as expected, $r = -.38$, $p = .004$, 95% CI: [−1.000, −0.152], that is, the higher the score on NU, the lower the effect of outcome devaluation on the specific PIT. The correlation with positive urgency was also found to be significant, $r = -.29$, $p = .024$, 95% CI: [−1.000, −0.051], while no other significant correlations were found for the remaining impulsiveness traits, $BF_{s-0} < 0.10$, lowest $r = .01$, $p = .532$, 95% CI: [−1.000, 0.252], for lack of premeditation.

Figure 3.4

Experiment 2. One-Tailed Correlational Analyses



Note. Negative relationship between PIT_Diff score [differential number of responses: (SameNonDev – DiffDev) – (SameDev – DiffNonDev)] and score on negative urgency. The negative relationship illustrates that the devaluation effect on outcome-specific PIT decreases with increases in Negative urgency score. Same: response that shares the outcome with the Pavlovian stimulus presented during the test; Diff: alternative response; NonDev: response whose associated outcome had not been previously devalued; Dev: response whose associated outcome had been previously devalued. Scatterplots; one-tailed Pearson's coefficient, 95% confidence interval.

3.7. General Discussion

One aim of the present research was to validate, in our sample, a modified appetitive instrumental task based on those used by Quail et al., (2017) and Morris et al. (2015) using abstract or conditioned rewards (images) instead of real rewards, to study the effects of outcome devaluation and PIT on action control and selection. In Experiment 1, we found the expected effect of outcome devaluation in which, during an extinction test, there was a decline in the response whose outcome had previously been devalued (in comparison with an alternative response), suggesting that instrumental behaviour was indeed goal-directed, as the instrumental response was mediated by the updated outcome value and modified accordingly (Dickinson, 1985). We also found a specific PIT effect by which the stimuli associated with the instrumental outcomes (S1 and S2) selectively biased action selection towards the one with which it shared the outcome (Same) in preference to the alternative action (Different) in a choice test in extinction.

A second goal of our study was to evaluate in healthy people (i.e., participants not selected for their scores on impulsiveness or other conditions) the impact of an affect driven impulsivity trait, specifically NU, on these effects. In Experiment 1 we found negative correlations between self-reported NU scores, measured by the UPPS-P, and indexes of both outcome devaluation and specific PIT. As reviewed in the "Introduction" section, NU has been linked to the "P" factor (Carver et al., 2017) and to both externalising and internalising behaviours (Johnson et al., 2017; King et al., 2018). These results therefore add to previous findings in the literature showing how PIT may be a reliable procedure that is useful for characterising pathologies such as schizophrenia, addiction, and major depressive disorders (Cartoni et al., 2016).

To the best of our knowledge, this is the first report linking affect-driven impulsiveness, specifically NU, to failures in updating the motivational value of the outcome (i.e., incentive learning), as well as in the adaptive ability to extract predictive information from environmental stimuli to make optimal choices, both of which form the basis of the PIT effect (Quail, Morris, et al., 2017). Therefore, a novel contribution of our study is that negative relations with measures of incentive learning and cue driven behaviour (action control and selection) can be observed in a non-clinical group varying in a single affect driven impulsivity trait dimension such as NU.

Another important aim of our study was to shed light on the ongoing debate over whether outcome devaluation affects specific PIT and thus whether the latter could be based on a goal-directed process. To this end, we scheduled the outcome devaluation phase before the PIT test in Experiment 2. Unlike what has often been found in both animal and human studies (see below), we observed an effect of outcome devaluation on specific PIT, the implications of which will be discussed later. In addition, we further studied the mediating effect of emotional impulsivity, finding a significant negative correlation between NU and the effect of outcome devaluation on specific PIT.

Taken together, these results have some important implications. First, we will consider the general effects, after which we will focus on the impairment in action control that seems to be induced by emotional impulsivity.

3.7.1. Effect of Outcome Devaluation on Specific and General PIT

The specific PIT effect was shown to be sensitive to outcome devaluation (Experiment 2), suggesting that the underlying mechanism is goal-directed. This is an interesting result in itself given that previous literature with animal or human subjects has reported insensitivity to outcome devaluation (or extinction) in specific PIT (e.g., Colagiuri & Lovibond, 2015; Colwill & Rescorla, 1990; De Tommaso et al., 2018; Delamater, 1996; Hogarth & Chase, 2011; P. Watson et al., 2014; see also Seabrooke et al., 2017, Experiment 1).

Indeed, PIT has been mostly considered as an instance of stimulus-bound (cue-triggered) outcome-insensitive behaviour that may be of relevance for research into habit formation (Watson & de Wit, 2018). This view suggests that the motivational or incentive value of the outcome is not encoded in the S-O-R associative chain by which the stimulus activates a representation of the associated outcome, inducing its anticipation, which in turn triggers the performance of the motor response with which it shares the outcome (for a recent description of the associative structures underlying PIT, see, for example, (Alarcón et al., 2017). The view that PIT is governed by a rather automatic system assumes that the cue activates a representation of the sensory —but not motivational—attributes of the outcome; thus, devaluation is ineffective in reducing the response rate. This possibility appears to be particularly likely when two, instead of one, different instrumental response-outcome relationships are trained concurrently (Holland, 2004). However, there is some disagreement about the underlying associative mechanisms involved in specific PIT, with this issue currently being a matter of ongoing debate (e.g., Alarcón et al., 2017; Cartoni et al., 2016; Holmes et al., 2010; Watson et al., 2018).

It has recently been suggested that the specific PIT effect could, at least in humans, have both implicit and explicit components, with the former ascribed to subcortical structures and the latter to more cortical frontal areas (Garofalo & di Pellegrino, 2017). Support for a goal-directed (explicit like) component was provided by the results of Experiment 1, in which we found a moderately high correlation between outcome devaluation (i.e., difference between non-devalued and devalued responses) and the specific PIT (i.e., difference between Same and Different responses). Specific PIT could be mediated by an association between the representation of the instrumental response and a detailed representation of the outcome. In the case of general PIT, an increase in responding could instead be driven by a more general facilitatory process, being greater when the response is controlled to a lesser extent by its specific consequences. In fact, both PIT effects have been dissociated at a neuroanatomical level in lesion studies with animals, and neuroimaging studies with humans (Quail, Morris, et al., 2017). Consistent with this view, which emphasises the difference between both PIT effects, no significant correlations were found between outcome devaluation and general PIT or between specific and general PIT effects. The effect of individual differences in emotional impulsiveness on outcome devaluation and specific (but not general) PIT found here contributes further evidence towards the investigation of the mechanisms underlying goal-directed action and habitual behaviour.

Evidence is also available showing sensitivity to outcome devaluation in specific PIT in humans (e.g., Allman et al., 2010; Eder & Dignath, 2016a, 2016b; see also Seabrooke et al., 2017, Experiments 2 and 3; Seabrooke et al., 2019). It has been claimed that some of these studies have used designs with "cognitive" devaluation strategies (Cartoni et al., 2016) that might encourage participants to use a more explicit strategy leading to reasoned outcome expectations rather than performance that is reliant on learned associations (see also Watson et al., 2018). Cue elicited behaviour could in this way be overridden by explicit strategies. In these specific circumstances, PIT might be sensitive to changes in goal-incentive value. However, the accuracy of explicit knowledge of the instrumental O-R contingency was 100% in both studies, and the degree of knowledge of the Pavlovian S-O contingency exhibited by participants in this study did not correlate with scores on NU, either in Experiment 1, r = –.12, p = .424, 95% CI: [–0.389, 0.172], BF_{10} = 0.35, or Experiment 2, r = –.16, p = .291, 95% CI: [–0.421, 0.135], BF_{10} = 0.44. Therefore, differences in performance may be attributable to other factors.

The results obtained in Experiment 1 suggest that emotional impulsivity is a key factor leading to failures in updating incentive learning, even if the incentive was effectively devalued. This result points to an impairment in the goal-directed process (see, for example, Corbit, 2018; Watson & de Wit, 2018). Specific PIT was also negatively correlated with NU. In spite of the fact that participants with higher NU were equally aware of the O-R and S-O contingencies, they appeared to show a failure to integrate these two pieces of knowledge. This prompts the suggestion that failures in both outcome devaluation and specific PIT could reflect the action of the habit system in these participants. Therefore, individual differences need to be taken into account when considering the mechanisms underlying PIT (see also Garofalo & di Pellegrino, 2015).

3.7.2. Affect-Driven Effects on Action Control and Emotion Regulation

Our results involving emotional impulsiveness may be relevant to the concept of *habit propensity* (Robbins et al., 2012), which proposes that individuals differ in the degree of balance between goal-directed actions and habit systems, being more prone to act out of habit by relatively faster habit formation or stronger habit expression. Linnebank et al., (2018) have recently explored this possibility, finding evidence for the hypothesis that habit propensity may be a stable personal characteristic, underlying both performance in experimental studies and real-life measures of habit propensity. However, they did not find complete correspondence between these two aspects. In this regard, the data from Experiments 1 and 2 suggest that subclinical impulsive participants with higher levels of emotional impulsivity— specifically NU—appear to be more prone to habitual responding (if we interpret the absence of a devaluation effect in this sense) than those with lower levels of this trait. This habit propensity in people exhibiting emotional impulsivity could be taken to reflect a “temperamental pre-existing vulnerability” or disposition towards habits (Linnebank et al., 2018), which might be linked to failures in automatic emotion regulation.

Normal performance following outcome devaluation requires updating the current value of the outcome, adjusting behaviour according to its most recently experienced consequences. Indeed, within a multi-level framework of emotion regulation, outcome revaluation has been characterised as a relatively automatic process of implicit emotion regulation (Braunstein et al., 2017) that does not involve a conscious desire to change emotions (i.e., there is no explicit goal to regulate emotions), as might be the case in situations involving chronically active goals that are important for survival, such as the goal to respond to, and accurately represent, the current value of a relevant outcome (Braunstein et al., 2017). Regarding the nature of the emotion change process itself, the devaluation of outcome, as well as extinction, may be considered as instances of affective (or incentive) learning by which an organism experiences shifts in the contingent outcome and learns to update its prior affective value, involving few or no top-down control processes.

Thus, failure to update the current incentive or affective value of the outcome (i.e., outcome revaluation) points to impairments in implicit-automatic emotion regulation. This may have important implications when tailoring interventions for people exhibiting clinical conditions and suggests the convenience of including emotion regulation training that incorporates metacognitive techniques to increase awareness and reconfiguration of responses to emotional states.

3.7.3. Limitations

One possible limitation of this study is that participants were young undergraduate women, and this could limit the generalisability of our conclusions to the male gender or other age groups. Measurement and structural invariance of the UPPS-P (original 59-item version) in healthy (non-clinical) undergraduate students have proved to be comparable between men and women, although men generally score higher on positive urgency and sensation seeking (but not on NU). In addition, the relationship between the five traits and risk outcomes has been found to be invariant across gender (Cyders, 2013). The impulsivity subscales of the short Spanish version of the UPPS-P used in this study, validated in undergraduate students of the University of Granada, have also not been found to show gender differences (Cándido et al., 2012), whereas age was found to correlate negatively with all facets of impulsivity, except for NU. However, additional research will be needed to determine whether the results observed in these studies can also be confirmed in young males as well as for older adults of both genders.

In addition, our procedure had some characteristics that may have affected the observed pattern of results. As explained in more detail in the "Introduction" section, we decided to maximise the likelihood of observing an outcome-devaluation effect on PIT by using abstract instead of real natural rewards. Our outcome devaluation procedure consisted of pairing the images of the outcome with some insects running over it, a procedure that can be considered more of a cognitive than a motivational change. Although both manipulations proved to be successful, we acknowledge that the pattern of results found in Experiment 2 (i.e., effect of outcome-devaluation on specific PIT) could be different in the case of using different kinds of outcomes and/or devaluation procedures, as previously found in the literature. Regarding general PIT, the CS+ failed to increase responding above baseline in both experiments, and a similar pattern was found for the SameNonDev condition in Experiment 2. Perhaps interposing an instrumental extinction session before the PIT test could have been of some help in reducing the baseline rate, thereby favouring the detection of an increment in responding (e.g., Dickinson et al., 2000).

Finally, although we followed previous designs aimed at studying both outcome-specific and general PIT, in our specific procedure S4 (CS−) seems to signal the absence of reward rather than not being associated with any of the outcomes, possibly acting as an inhibitor and thus decreasing responding below baseline. In future experiments, it might be worth considering the possibility of adding a novel, briefly pre-exposed stimulus in the PIT test as a further control condition (Dickinson et al., 2000).

3.8. Conclusions

Adaptive action control and selection involve the integration of knowledge about contingencies between actions and outcomes, as well as between cues and outcomes, to make optimal choices among various courses of action. In addition, updating the incentive value of the outcome is critically important for action flexibility and control. People exhibiting higher levels of affect-driven impulsivity—specifically NU—may fail in the integration of knowledge about the current value of the outcome, which they do indeed acquire along with action-outcome knowledge, showing performance that is insensitive to changes in incentive value. They also show an apparent failure to use predictive cue-outcome knowledge to guide action selection (outcome-specific PIT). This pattern of results suggests that NU causes automatic processes to control instrumental responding, impairing the goal-directed processes that are normally involved in both action control and selection in healthy people, and this impairment appears to be linked to failures in implicit emotion regulation (i.e., outcome revaluation).

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CHAPTER 4:

Can We Reduce Craving Experience in the Laboratory and Real-Life Contexts?

Publication:

Hinojosa-Aguayo, I., & González, F. (2022). Cognitive Defusion as Strategy to Reduce the Intensity of Craving Episodes and Improve Eating Behavior. *The Spanish Journal of Psychology*, *25*, 1–12. https://doi.org/10.1017/sjp.2021.47

4.1. Abstract

The elaborated intrusion theory of desire proposes that craving is a cognitive motivational process involving intrusive thoughts. Changing the way we react to them, cognitive defusion (CD), should limit thought elaboration and craving. We induced chocolate craving in female chocolate cravers before CD (Experiment 1). A decrease in craving measured by a single-item scale, Visual Analogical Scale (VAS; $p < .001$, $\eta^2_p = .449$) and as a state, State Food Craving Questionnaire (FCQ-S; $p = .029$, $\eta^2_p = .106$) were found in the experimental group, while similar results were also found in group control. The reduction in craving (VAS) in group CD correlated negatively with chocolate consumption on a bogus taste test ($r = –.439$, $p = .036$), while the correlation was positive in the case of group control ($r = .429$, $p = .047$). Food craving as a trait, measured by the Trait Food Craving Questionnaire (FCQ-T), showed negative correlations with measures of CD and mindfulness skills (lowest $r = –.313$, $p = .018$). In Experiment 2 participants made use of a smartphone application implementing the CD procedure in real contexts whenever they experienced food craving. A corresponding decline in self-reported craving was found, as well as in consumption of the craved food (indulgence) compared with the control condition. Our findings indicate that CD may be a promising intervention for tackling the elaboration of intrusive thoughts and eating behavior in young female food cravers, both in a controlled laboratory environment after a cue-food exposure craving induction procedure, as well as responding to naturally occurring food cravings in real-life settings.

4.2. Introduction

Food craving may be defined as an intense and difficult to resist desire to consume a specific kind of food (Weingarten & Elston, 1990) that may be a precursor of uncontrolled eating in the general population (Vainik et al., 2019). Therefore, food cravings represent an appropriate target for interventions aimed at promoting a healthy weight through improvements in eating patterns. However, conventional behavioral treatments may fail to achieve long-term weight reduction and, for some individuals, dieting might actually encourage eating problems. This has led to a shift away from dieting in favor of strategies centered on the actual process of eating (Schnepper et al., 2019).

For example, the elaborated intrusion (EI) theory of desire (Andrade et al., 2012; Kavanagh et al., 2005; May et al., 2012) proposes that food craving is a cognitive motivational process consisting of two distinct stages. First, food cues, as well as thoughts or memories, trigger intrusive thoughts. Second, these intrusions may be further elaborated, if for example they elicit a powerful affective reaction or a sense of deficit (Tapper, 2018), with vivid mental imagery (Schumacher et al., 2018), so that this cognitive elaboration is then experienced as craving. Therefore, the EI theory considers that craving is mainly a working memory process in which affective-laden sensory images are the object of further elaboration using internal or external information (Skorka-Brown et al., 2014). Elaboration fosters the growth of craving and the development of negative affective states that further fuel intrusions, giving rise to a cycle of intrusions and elaborations that are usually alleviated by eating the craved food (Schumacher et al., 2018).

4.2.1. Cognitive Defusion

Acceptance-based interventions (May et al., 2012) tackle intrusive thoughts or memories, changing how people react to them before they become elaborated. Mindfulness-based interventions have been used to treat cravings, although their effectiveness is often difficult to assess because such interventions often comprise mindfulness and non-mindfulness components (Tapper, 2018). In the present work, we selected one of the three key mindfulness components: Cognitive defusion—also referred to as decentering (Bernstein et al., 2015) or disidentification (Lacaille et al., 2014); hereafter, these labels may be considered as interchangeable in this context; however, we will use the term according to the one used in the referenced works—the other two mindfulness components are ‘present moment awareness’ and ‘acceptance’ (Tapper, 2018).

Cognitive defusion has been considered a core process of Acceptance and Commitment Therapy, where the objective is not to modify the content of thoughts but rather the way people react to them by helping individuals to separate themselves from their thoughts and emotions (Moffitt et al., 2012; for a review of the effects of mindfulness on craving and underlying mechanisms, see Tapper, 2018). In decentering, individuals are instructed to see their thoughts and feelings as transient events that are not part of themselves and that may not be a truthful reflection of reality (Tapper & Turner, 2018). In doing so, events become less believable and, as a consequence, they have a reduced capacity to trigger desire. In this vein, the Desire Thinking theory (Caselli & Spada, 2010) states that metacognitions play a role in the cycle of desire thinking, leading to stronger cravings, and considers the process of verbal perseveration (continual self-talk engaging the desired target) to be a component of the craving experience. Decentering could therefore represent a useful strategy for targeting these metacognitions.

4.2.2. The Present Work

In the present work, we examined the effectiveness of cognitive defusion in food cravers. We selected young female participants because women reportedly tend to experience stronger cravings than men (e.g., Lafay et al., 2001; Vallis, 2019; Weingarten & Elston, 1991) and this might be particularly true in young women (Skorka-Brown et al., 2015). In Experiment 1, we used a craving induction procedure involving actual exposure to chocolate before measuring self-reported craving and hunger, traits of food craving, and mindfulness skills, as well as objective measures of consumption in a covert way (bogus taste test) and healthy food choices (chocolate vs. fruit). In an attempt to extend the results of Experiment 1, and conduct a prelaminar feasibility assessment, in Experiment 2 participants used an application (app) for smartphones for a period of two weeks. The app was designed to reduce craving by following cognitive defusion instructions whenever they experienced a craving episode.

4.2.3. Hypotheses

If episodes of food craving are the result of intrusive thoughts prompted by external or internal food cues, which are further elaborated, we would expect to find in Experiment 1: (H_{1a}) Training participants in cognitive defusion in order to mitigate the reactions to intrusive thoughts should lead to a reduction in self-reported craving, unhealthy-snack preference on a choice test, and food consumption on the bogus taste test, compared with a control condition; (H_{1b})

Significant positive relationships between food craving as a trait and cognitive fusion (the opposite to cognitive defusion); and (H_{1c}) Significant negative relationships between scores of mindfulness skills and both food craving as a trait and cognitive fusion (Experiment 1).

Regarding Experiment 2, participants using the app should report: (H_{2a}) A greater reduction in self-reported craving; (H_{2b}) More episodes in which they had not eaten the craved food (i.e., lower indulgence); and/or (H_{2c}): A reduction in the pattern of consumption, that is, either more reports of consuming 'less food than initially desired' or less reports of consuming 'more than initially desired', compared with a control condition.

Experiment 1

During craving reduction, the experimental group listened to a 3-min audio clip instructing participants to 'decenter' from their thoughts and feelings in general, under the assumption that this targets the craving-related reactions elicited by the induction procedure. The audio clip in the control condition substituted the cognitive defusion instructions for a reading of selected fragments of a novel (see "Materials" section). Thus, both interventions involved a verbal format that, we reasoned, may interfere with the verbal perseveration (Caselli & Spada, 2010) of the desire thinking, but differed in the content, where only the experimental group were provided with specific instructions to target the way participants reacted to their thoughts.

The experiment was run in two phases, with the experimental group taking part first. We incorporated measures of both formal and informal mindfulness practice, as well as measures of trait-like mindfulness facets in order to control for any a priori differences between groups that could act as confounds in the interpretation of the results. Gathering this information would also allow us to estimate the strength of the relationship between mindful-like facets, including cognitive defusion, and 'trait food craving'.

4.3. Method

4.3.1. Participants

Forty-five[3] female undergraduate students from the University of Granada who craved chocolate 'often' or 'always/almost every day', according to their score in the chocolate item of the Food Craving Inventory, were recruited to participate in exchange for course credits (age, M = 20.02, SD = 2.55, range 18–29). Their average body mass index (BMI) was 22.59 (SD = 3.57, range 16.67–32.05), which is considered to be within the healthy weight range.

4.3.2. Design

To determine the effectiveness of the intervention in reducing craving, the study employed a 2 (group as between-subject factor: Cognitive defusion vs. control) x 2 (intervention as within-subject factor: Pre, post) mixed factorial design. The dependent variables were self-reported craving, food choice (healthy vs. unhealthy snack), and chocolate consumption (g) on the bogus taste test. For other analyses, the dependent variables were measures of craving, both as a state and as a trait, as well as of mindfulness skills, which are described in the next section. Power analyses were run using G*Power 3.1.

[3] An a priori power analysis for mixed design ANOVA was run, taking into account the effect size found in a previous study using a similar procedure (see Passive control study in Appendix B.3) which was rather large (η^2_p = .183, corresponding f = 0.47). With a significance level set at .05, the estimated minimal total sample size to achieve .80 power was 30 participants.

4.3.3. Materials

This study consisted of two phases. First, participants accessed a battery of questionnaires and sociodemographic questions (see Section "Questionnaires Completed Online before the Experimental Session") through an online survey programmed in Unipark[4]. Participants who met the inclusion criteria were later invited to participate in the laboratory study on subsequent days.

4.3.3.1. Questionnaires Completed Online before the Experimental Session

Sociodemographic questions. These included questions related to gender, age, and estimation of weight and height to calculate the approximate BMI. Participants stated what kind of chocolate they preferred: White, milk or dark. As part of a larger research project, the questionnaire contained other questions and scales not considered in the present study.

Food Craving Inventory. Spanish version FCI-SP (Jáuregui Lobera et al., 2010). FCI-SP assesses the frequency of craving in the last month using a 5-point Likert-type response scale (from '*never*' to '*always/almost every day*') for 28 food items of which we used that for chocolate.

Trait Food Craving Questionnaire, Spanish version FCQ-T-SP (Cepeda-Benito et al., 2000). The FCQ-T-SP is a 37-item measure of food craving using a 6-point Likert scale ranging from 'never' to 'always'. The items load onto nine factors: (a) Intentions and plans to consume food; (b) anticipation of positive reinforcement; (c) anticipation of relief from negative states and feelings; (d) lack of control over eating; (e) thoughts or preoccupation with food; (f) craving as a physiological state;

[4] www.unipark.de

(g) emotions that may be experienced before or during food cravings or eating; (h) cues that may trigger food cravings; (i) guilt from cravings and/or for giving in to them.

4.3.3.2. Questionnaires/VAS Completed during the Experimental Session

State Food Craving Questionnaire, Spanish version, FCQ-S-SP (Cepeda-Benito et al., 2000). The FCQ-S-SP measures craving for food at a given moment (state) by asking participants to indicate the extent to which they agree with 15 statements using a 5-point Likert-type response scale; we used a 6-point response scale though (from '*strongly disagree*' to '*strongly agree*'). The items load onto five factors: (a) Intense desire to eat; (b) anticipation of positive reinforcement; (c) anticipation of relief from negative states or feelings, (d) lack of control over eating; and (e) craving as a physiological state.

Visual Analogical Scale (*VAS)*. This consists of a slide-bar in which the moving point appears just in the center of the scale that had two extremes anchored with '*totally sated*' and '*totally starving'*, in the case of hunger, and '*none at all*' and '*absolutely*', in the case of the desire to eat the craved food (craving). These extremes corresponded to a continuous scoring scale from 0 to 100 (numbers were not shown to the participants).

Questions Related to Formal and Informal Mindfulness Practice. Regarding informal practice, we included five multiple-choice questions: e.g., Q1 *'Have you ever formally practiced mindfulness?'*, Q4 *'Have you ever informally practiced mindfulness?'* The questions and the response format are available in Appendix B.1.

Five Facets Mindfulness Questionnaire (FFMQ). Spanish adaptation by Cebolla et al., (2012). The FFMQ measures a trait-like tendency to be mindful in daily life. It consists of 39 items rated on a 5-point Likert scale ranging from '*never or very rarely true*' to '*very often or always true*', comprising five factors (Baer et al., 2008): (a) Observing (noticing or attending to internal or external experiences); (b) describing (labeling internal experiences with words); (c) acting with awareness (attending to one´s activities at that moment instead of using 'automatic pilot'); (d) non-judging (taking a non-evaluative perspective of one's own thoughts and feelings); and (e) non-reacting (tendency to allow thoughts and feelings to come and go, without getting caught up in or carried away by them).

Mindfulness Attention Awareness Scale (MAAS). Spanish adaptation by Soler et al., (2012). This scale assesses differences in the frequency of conscious states (presence of attention to and awareness of what is occurring in the present) through 15 negatively worded items, according to a 6-point Likert-type response scale ranging from '*almost never*' to '*almost always*'.

Cognitive Fusion Questionnaire (CFQ). Spanish adaptation by Romero-Moreno et al., (2014). The CFQ is composed of 7 items measured on a 7-point Likert scale ranging from '*never true*' to '*always true*' that measures general cognitive fusion (the opposite to cognitive defusion), which is the tendency for behavior to be overly dominated by cognitive events as opposed to other sources of behavioral regulation (Gillanders et al., 2014). The Spanish adaptation of the CFQ shows a one-factor structure with good internal consistency, and shows negative correlations with measures of mindfulness skills (Ruiz et al., 2017).

4.3.3.3. Audio Clips

Two audio clips of approximately 3 min (featuring the same female voice) were specifically recorded for this study. The cognitive defusion content was a

Spanish adaption of the one used by Schumacher et al. (2018). For the control condition, we selected some fragments of the beginning of the novel by Leo Tolstoy *Anna Karenina*. The audio clips are available at the OSF[5], and the transcriptions (Spanish) and descriptions (English) in Appendix B.2.

4.4. Procedure

Upon arrival to the laboratory, the participants gave informed consent and completed the battery of questionnaires programmed in Unipark (see "Questionnaires/VAS Completed during the Experimental Session" section). After this, the experimental session took place, which consisted of the following phases: Chocolate craving induction, cognitive defusion (or control condition), snack choice-test, and bogus taste test. The experimental session always took place in the afternoon, when people are known to experience a strong desire for tasty snacks (van Dillen & Andrade, 2016), between 12 p.m. and 3 p.m., to facilitate compliance with two-hour fasting taking into account the usual lunch time in Spain. All procedures used in this and the following study were approved by the Ethics Committee of the University of Granada (#71/CEIH/2015).

4.4.1. Fasting Check, Initial Hunger, and Craving for Chocolate Assessments

Participants reported their initial level of hunger using a VAS, the time elapsed since their last meal (more or less than two hours). Craving was measured using the VAS at the following timepoints: Before craving induction (VAS 1), after craving induction but before the intervention (VAS 2), and after the

[5] https://osf.io/p2fv9/

experimental/control intervention (VAS 3). We also measured the state of craving using the FCQ-S, before craving induction (FCQS1), immediately before the craving VAS 1, and before the snack-choice test (FCQS2), immediately after the craving VAS 3.

4.4.2. Induction of Craving for Chocolate: Visual and Olfactory Sensory Analysis

First, after completing the VAS 1 and FCQS1 measures, participants were presented with a bowl containing 100 g of a popular Spanish sweet snack (‘Conguitos’, Lacasa, Zaragoza, Spain) consisting of peanuts coated with a thick cover of chocolate of their preference (white, milk, or dark chocolate, according to their response to the online questionnaire). To induce craving, we used a sensory analysis procedure in which participants had to evaluate, without tasting, the visual and olfactory properties of the chocolate using an online questionnaire programmed as a survey in Unipark (for a similar procedure involving the analysis of chocolate bars, see Andrade et al., 2012). More detailed information of this procedure is available in Appendix B.1. Immediately after completing the sensory analysis, the chocolate was withdrawn and, unknown to the participants, weighed to check whether they had complied with the requirement of not eating the chocolate. Participants were then assessed again for the level of chocolate craving experienced using the VAS scale (VAS 2).

4.4.3. Craving Reduction Procedure: Cognitive Defusion Audio Clip/Control Condition

Participants in the cognitive defusion group listened to a 3-min audio clip instructing them to sit comfortably, close their eyes, and pay attention to their breathing and to the present moment. They were invited to consider their thoughts as transient entities that are not necessarily a true reflection of reality. Participants in the control condition were also instructed to sit down and pay attention to the audio clip, but instead of receiving instructions to cognitively defuse from their thoughts, they listened to the fragments of the novel. Afterwards they complete the VAS 3 and FCQS2 measures.

4.4.4. Snack-Choice Test

Food choice was measured covertly by offering participants a snack to take home as a gift to thank them for their participation (for a similar procedure, see van Dillen & Andrade, 2016). They were invited to take either a KitKat bar (41.5 g), their preferred chocolate, or a pack of dehydrated fruit snacks, approximately 20 g of crunchy pieces of sliced fruit (Frubis, Luis Vicente, Portugal) of three different flavors: Green apple, rocha pear, and strawberry They kept the snack, but did not consume it at that moment.

4.4.5. Bogus Taste Test

Finally, the participants were invited to complete a second sensory analysis procedure (flavor). The bowl containing 100 g of the chocolate snack was presented again. They were asked to taste the chocolate and answer a set of questions related to several sensory attributes (for a similar procedure, see Schumacher et al., 2017). Detailed information of the procedure is available in Appendix B.1. They were also told that the uneaten chocolate would be thrown away for hygiene reasons, so they were free to eat it all or even take the leftovers away. Once the participant left the laboratory, the experimenter estimated the amount of chocolate consumed by weighing the remaining chocolate. If a participant kept the remains of the chocolate, they were recorded as having eaten the whole amount.

4.5. Results

Significance was determined according to an alpha level of .05. Size effects were estimated by using partial eta-squared for analyses of variance (ANOVAs) and Cohen's *d* in the case of *t*-tests for pairwise contrasts. For repeated measures (RM) ANOVAs, Greenhouse–Geisser correction was applied in case of violation of the assumption of sphericity. Simple main effects were computed in factorial designs to assess predicted changes within conditions involving an interaction between factors. One-tailed tests were used to examine *a priori* hypotheses outlined in the Introduction regarding between-condition differences (Student's *t*-test) or relationships between variables (Pearson's correlations, *r* coefficient with 95% CI), and two-tailed otherwise. Statistical analyses were conducted using JASP software[6].

[6] https://jasp-stats.org

Table 4.1

Experiment 1. FCQ-T Descriptive Statistics According to Group

	Group	Mean	SD
Intentions and plans to consume food	Defusion	21.21	5.26
	Control	16.45	5.28
Anticipation of positive reinforcement	Defusion	17.47	4.23
	Control	17.81	4.61
Anticipation of relief from negative states and feelings	Defusion	10.08	3.20
	Control	10.45	4.02
Lack of control over eating	Defusion	20.91	7.36
	Control	18.36	6.09
Thoughts or preoccupation with food	Defusion	12.91	4.24
	Control	10.72	4.35
Craving as physiological state	Defusion	16.43	4.63
	Control	15.81	3.51
Emotions that may be experienced before or during food cravings or eating	Defusion	7.21	2.41
	Control	7.50	2.79
Cues that may trigger food cravings	Defusion	15.87	4.48
	Control	15.04	4.52
Guilt from cravings and/or for giving in to them	Defusion	8.69	3.91
	Control	9.68	4.20

4.5.1. Discarding a priori Between-Group Differences

We checked for between-group differences in the following variables: Age, BMI, hunger and craving levels at the beginning of the experiment, and scores on the FCQ-T (mean scores in FCQ-T, according to craving factor and group, are displayed in Table 4.1).

The groups did not differ in most of these variables, t_s (43) < 1, p_s > .343, with the exception of BMI, which was significantly higher in group control (*M* = 23.94, *SD* = 3.41) than in cognitive defusion (*M* = 21.30, *SD* = 3.28), *t*(43) = 2.64, *p* = .011, *d* = 0.80, although both means fell within the range of conventional values corresponding to a healthy weight.

No differences were found between groups in any of the five factors of the FFMQ, largest *t*(43) = 1.36, *p* = .181, or the MAAS scores, *t* < 1, *p* = .807. There were also no group differences in CFQ scores, Welch's correction, *t*(34.566) = 0.879, *p* = .386 (mean scores for each scale and factor, according to group, are depicted in Table 4.2).

There were no differences either between groups in formal, $\chi^2(2)$ = 1.11, *p* = .574, as well of informal, $\chi^2(2)$ = 0.43, *p* = .807, mindfulness practice (for more details, see Appendix B.1).

4.5.2. Exploratory Analyses: Relationships between Mindfulness Skills, Cognitive Fusion, and Craving for Food as a Trait

4.5.2.1. Mindfulness skills.

The FCQ-T score showed negative correlations with two factors of the FFMQ, 'acting', *r* = –.313, 95% CI [–1.000, –.069], *p* = .018, and 'non-judging', *r* = –.334, 95% CI [–1.000, –.093], *p* = .012, (both close to the *p*-value adjustment for multiple comparisons using Bonferroni correction, *p* = .01), as well as for the mindfulness and awareness state measured by the MAAS, *r* = –.374, 95% CI [–1.000, –.139] *p* = .006.

Table 4.2

Experiment 1. Mindfulness Skills (FFMQ and MASS) and Cognitive Fusion (CFQ) Descriptive Statistics According to Group

	Group	Mean	SD
FFMQ			
Observing	Defusion	27.60	5.77
	Control	27.59	5.65
Describing	Defusion	26.26	5.95
	Control	27.27	4.83
Acting with awareness	Defusion	26.56	5.03
	Control	24.22	6.44
Non-judging	Defusion	24.73	7.92
	Control	23.86	7.91
Non-reacting	Defusion	20.60	4.53
	Control	19.31	3.99
MAAS	Defusion	54.87	12.33
	Control	54.00	11.33
CFQ	Defusion	25.91	6.88
	Control	28.36	11.21

4.5.2.2. Cognitive fusion.

There was a significant positive correlation between the FCQ-T score and the measure of cognitive fusion (CFQ), the opposite to cognitive defusion, r = .345 95% CI [0.105, 1.000], p = .010. The CFQ score, also showed significant negative correlations with measures of mindfulness skills, including the MAAS score, r = –.403, 95% CI [–1.000, –.171], p = .003, or the FFMQ factors ‘acting’, r = –.631, 95% CI [–1.000, –.454], p < .001, ‘non-judging’, r = –.673, 95% CI [–1.000, –.510], p < .001, and ‘non-reacting’, r = –.387, 95% CI [–1.000, –.154], p = .004 (Bonferroni corrected p-value for multiple comparisons, p =.01.).

4.5.3. Manipulation Check: Chocolate Craving Induction

Self-reported craving, as measured by the VAS (VAS 1 vs. VAS 2) increased after the induction procedure, $t(44) = -3.99$, $p < .001$, $d = -0.59$ ($M_{pre} = 64.53$, $SD = 23.01$; $M_{post} = 80.00$, $SD = 18.17$). Including group as a between-subjects factor in a RM-ANOVA, as a check for potential a priori differences due to the lack of randomized group assignment, showed no main effect of group or a group x timepoint interaction (pre, post), $F_s < 1$.

4.5.4. The effect of Cognitive Defusion on Induced Craving

The RM-ANOVA on self-reported craving (VAS) with group (cognitive defusion and control) as the between-subject factor, and timepoint (before and after listening to the audio clip, VAS 2 vs. VAS 3) as the within-subject factor, yielded a main effect of timepoint, $F(1, 43) = 34.99$, $p < .001$, $\eta^2_p = .449$ (cognitive defusion: $M_{pre} = 79.65$, $SD = 19.61$, M_{post} =, 63.30, $SD = 23.75$; control: M_{pre} =80.36, SD =17.00; $M_{post} = 68.54$, $SD = 19.15$). No other main effect or interaction was significant, largest $F < 1$.

The RM-ANOVA conducted on FCQ-S scores, with group as between-subjects factor and craving factor (desire, positive reinforcement, negative affect, control, physiological state), and timepoint (pre, post intervention) as within-subject factors, yielded a main effect of timepoint, $F(1, 43) = 5.11$, $p = .029$, $\eta^2_p = .106$, craving factor, $F(2.749, 118.214) = 18.22$, $p < .001$, $\eta^2_p = .298$, and an interaction between these two variables, $F(4, 172) = 2.58$, $p = .047$, $\eta^2_p = .057$. No other main effect or interaction was significant, largest, $F(2.749, 118.214) = 2.23$, $p = .094$. Simple main effects analysis revealed a decrease in positive reinforcement ($p = .015$) and negative affect

(p = .007) after listening to the audio clips (Figure 4.1). Mean scores according to craving factor and timepoint are displayed in Table 4.3.

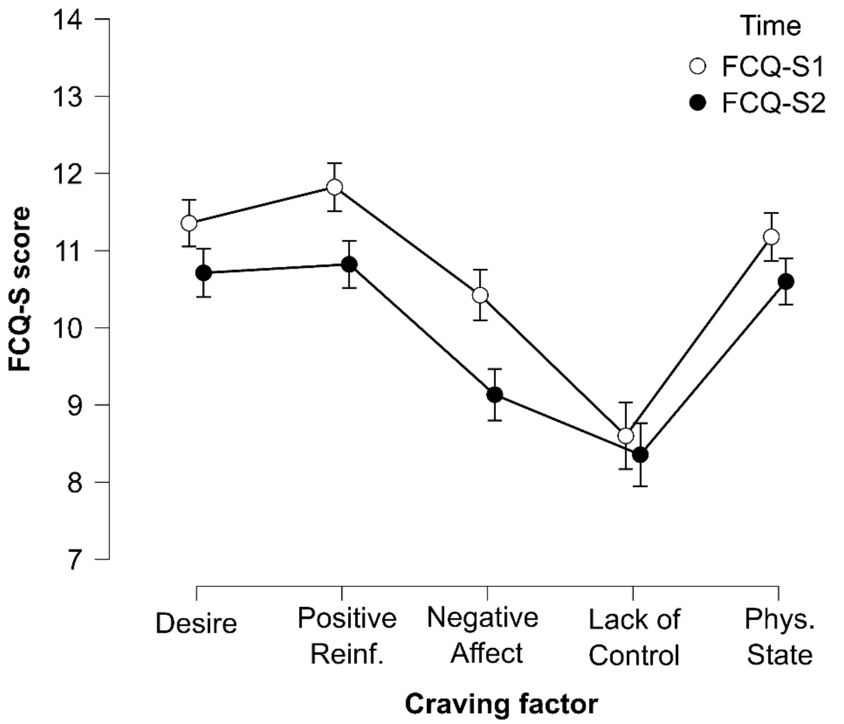
Table 4.3

Average FCQ-S Descriptive Statistics According to Group, Factor and Time: Before (FCQS1) and After (FCQS2) Listening to the Audio Clip.

Factor	Group	Mean	SD
FCQS1			
Desire to eat	Defusion	11.04	3.96
	Control	11.68	2.76
Anticipation of positive reinforcement	Defusion	11.69	3.41
	Control	11.95	2.78
Anticipation of relief from negative states or feelings	Defusion	10.73	3.80
	Control	10.09	2.58
Lack of control over eating	Defusion	9.08	3.67
	Control	8.09	2.97
Craving as a physiological state	Defusion	10.69	3.59
	Control	11.68	2.85
FCQS2			
Desire to eat	Defusion	10.43	4.17
	Control	11.00	3.16
Anticipation of positive reinforcement	Defusion	10.17	4.29
	Control	11.50	2.44
Anticipation of relief from negative states or feelings	Defusion	8.78	4.39
	Control	9.50	2.82
Lack of control over eating	Defusion	8.69	4.01
	Control	8.00	3.39
Craving as a physiological state	Defusion	9.78	3.69
	Control	11.45	2.24

Figure 4.1

Experiment 1. Mean FCQ-S Score According to Craving Factor and Timepoint



Note. FCQ-S1 was administered at the beginning of the experimental session while FCQ-S2 was completed after the craving reduction procedure, immediately before the snack-choice and consumption tests. Positive Reinf: Positive Reinforcement; Phys. State: Physiological State. Bars represent ±SEMs.

4.5.5. Snack-Choice

Choice of healthy snacks (dehydrated fruit) was codified as “1” and the selection of chocolate was codified as “0”. The percentages of participants who chose the healthy snacks were 26.09% and 9.09% in group cognitive defusion and control respectively, but this difference was not significant, $\chi^2(1) = 2.22$, $p = .136$.

4.5.6. Chocolate Consumption

Contrary to our expectations, the groups did not differ in the amount of chocolate consumed during the bogus taste test, $t(43) < 1$, $p = .750$, one-tailed; mean consumption for group cognitive defusion was 30.65g ($SD = 16.68$) and for group control, this was 27.23 g ($SD = 17.15$).

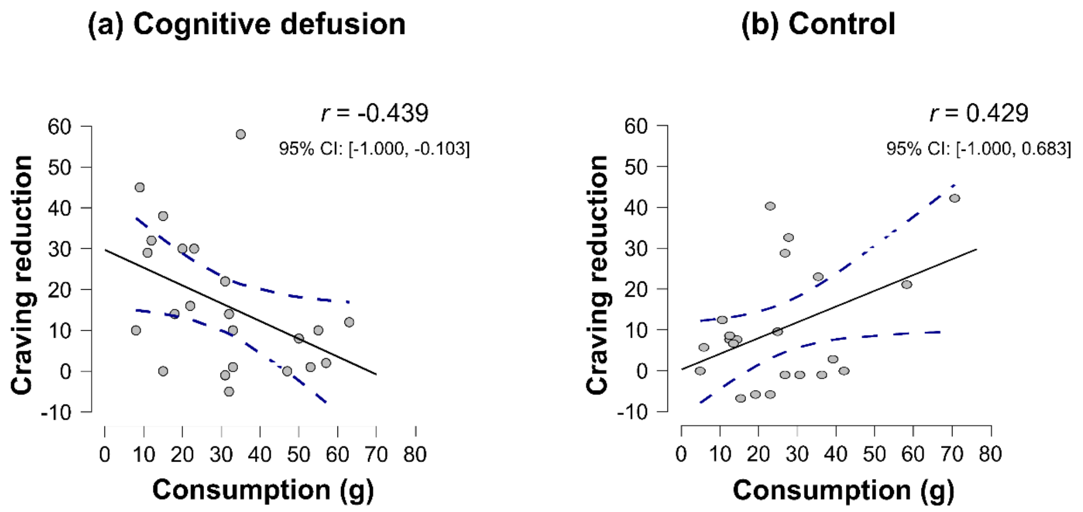
However, an exploratory analysis revealed that the decrement in self-reported craving after the intervention (VAS 2 vs. VAS 3) was negatively correlated with chocolate consumption in group cognitive defusion, $r = -.439$, 95% CI [–.721, –.033], $p = .036$, whilst this correlation was positive in group control, $r = .429$, 95% CI [.009, .720], $p = .047$ (Figure 4.2). Moreover, the two correlations differed significantly according to Fisher's transformation, $z = -2.90$, $p = .004$.

4.6. Discussion

Listening to a 3-min audio clip that featured either the cognitive defusion instructions or the reading of a narrative, was effective in reducing self-reported craving after induction, as measured through a change in the VAS, as well as a decrease in craving as a state measured by the FCQ-S. In particular, the expectation of positive reinforcement and the reduction in negative affect, both of which might be regarded as core motivational aspects of craving related to reinforcement, were lower than at the beginning of the study. This result in the cognitive defusion group adds to the findings in the literature showing the benefits of this intervention for reducing food cravings (e.g., Forman et al., 2007; Lacaille et al., 2014; Moffitt et al., 2012; Schumacher et al., 2017, 2018) and partially confirms our first hypothesis (H_{1a}).

Figure 4.2

Experiment 1. Scatter Plots Showing Pearson's Coefficients for the Correlation between Craving Reduction (Measured as VAS-2 Minus VAS-3 Score) and Chocolate Consumption on the Bogus Taste Test for Groups Cognitive Defusion (a) and Control (b)



Note. One-tailed Pearson's coefficient, dashed blue lines represent 95% confidence interval.

The observation that the control condition successfully reduced self-reported craving raises doubts about the effectiveness of cognitive defusion *per se*. An obvious alternative explanation is that the intensity of craving declines with the mere passage of time. However, unpublished data from our laboratory (see Passive control condition, in Appendix B.3) suggest that this is not necessarily the case. Using distraction (playing Tetris) effectively reduced self-reported craving compared to a passive control condition (3 min waiting without performing any explicit task) in which no change of craving intensity was found. Despite the similar decline found in self-reported craving in both groups in the present study (the change in craving levels produced by the intervention after the induction measured by the VASs), this correlated negatively with chocolate consumption only in the cognitive defusion group whilst, quite unexpectedly, the opposite pattern of results was found in the control condition. Both of these issues will be taken up in the General Discussion.

The correlation patterns showed, as predicted, that craving as a trait and cognitive fusion were positively correlated (H_{1b}), and that scores on several mindfulness skills were negatively correlated with both craving as a trait and cognitive fusion (H_{1c}). These results confirm that cognitive fusion and food craving are related to each other.

Taken together, these results suggest that cognitive defusion could be a promising strategy for reducing craving, and this reduction appears to be, potentially, predictive of lower consumption of the craved food. However, participants in this study received a single 3-min intervention, which might be of limited effect. Therefore, we wondered whether the 3-min brief cognitive defusion intervention, practiced repeatedly in a real-life context whenever food craving naturally arises, will be equally effective in reducing the intensity of craving as well as in improving eating behavior.

Experiment 2

Therefore, to determine whether regular practice of this brief cognitive defusion experience may be effective in reducing craving and food consumption in a real context, we designed and programmed a smartphone application that could be used by the participants whenever they needed it. In this case, we recruited young female food cravers (not specifically chocolate cravers) and invited them to participate in the study for a two-week period.

4.7. Method

4.7.1. Participants

Forty-four young female undergraduates with a FCQ-T score above 100, who were users of an Android smartphone (Version 1.6 Donut, API level 4 or later) and met the inclusion criteria, agreed to participate in the two-week study in exchange for course credits. Of these, 24 were then excluded due to uncompleted records or frequencies of use lower than three entries per week. The final study sample included 20 participants[7] (n = 10 in each group) with a mean age of 20.15 years (SD = 2.27, range 18–26), an average BMI considered to be within the healthy weight range (M = 22.24, SD = 2.99, range = 18.34–29.43) and a high score on the FCQ-T, (M = 139.25, SD = 29.15).

4.7.2. Design

To assess the effect of cognitive defusion on the reduction of self-reported craving we used a 2 (group as between-subject factor: Cognitive defusion vs. control) x 2 (craving measure as within-subject factor: Pre, post audio clip listening) mixed factorial design with the mean score of craving intensity across entries as the dependent variable. Other variables of interest were frequency of use, hunger level, indulgence (having eaten the craved food or not after using the app), and estimated

[7] An a priori power analysis for mixed design ANOVA, taking into account the effect size found in Experiment 1 (η^2_p = .449, corresponding f = 0.91) with the minimum number of entries set as a criterion (seven) as number of measures and a significance level of .05, established that the minimum total sample size to achieve .80 power was 8.

amount eaten (if applicable) compared with the quantity initially desired before listening to the audio clip.

4.7.3. Materials

Participants were provided with a link to download the corresponding MIT App Inventor[8] mobile application, depending on the assigned condition (cognitive defusion or control). Both versions are available at the OSF. The applications included the two 3-min audio clips used in Experiment 1.

4.8. Procedure

Participants were invited to visit the laboratory for an information session and were provided with written instructions detailing how to register a new craving episode and proceed with each one. They were asked to use the app for a period of two weeks, and as often as they experienced cravings for a particular food. The procedure was as follows. They chose 'register a new craving episode' from the main menu and specified the food they craved, as well as the level of hunger and craving intensity they experienced at that moment using a slide bar anchored with 0 ('*very low*') and 100 ('*very high*'). Afterwards, they played the 3-min audio clip according to the group (cognitive defusion or control) before reporting craving intensity for a second time. Five minutes later, the app sent a notification reminding participants to enter again and choose the option 'report the last craving episode' from the main menu. They were required to report 'indulgence' (e.g., Skorka-Brown et al., 2015), specifying whether or not they finally ate the food; if they did, they had to further specify the food and estimate how much they consumed in comparison with the

[8] https://appinventor.mit.edu/

quantity that they initially desired before using the application (less, equal, or more).

Table 4.4

Experiment 2. FCQ-T Descriptive Statistics According to Group.

	Group	Mean	SD
Intentions and plans to consume food	Defusion	19.60	4.27
	Control	23.10	5.44
Anticipation of positive reinforcement	Defusion	19.80	3.93
	Control	17.50	4.17
Anticipation of relief from negative states and feelings	Defusion	11.40	3.06
	Control	11.10	3.69
Lack of control over eating	Defusion	19.90	6.15
	Control	25.30	7.04
Thoughts or preoccupation with food	Defusion	11.00	3.43
	Control	12.80	6.23
Craving as physiological state	Defusion	18.10	3.72
	Control	17.60	3.80
Emotions that may be experienced before or during food cravings or eating	Defusion	6.500	2.06
	Control	7.70	3.62
Cues that may trigger food cravings	Defusion	16.00	4.32
	Control	19.30	3.36
Guilt from cravings and/or for giving in to them	Defusion	10.60	4.90
	Control	11.20	4.07

4.9. Results

4.9.1. Sociodemographic and Questionnaire Data

The groups did not differ in terms of mean age or FCQ-T scores, $t_s < 1$. Further, there were no group differences in scores on any of the nine FCQ-T subscales, largest

$t(18) = -1.90$, $p = .073$ (Table 4.4 displays the mean scores and standard deviations according to group and factor).

4.9.2. Frequency of Use of the App

Participants in both groups made use of the app with a similar frequency during the two-week period, without differences between them, $t(18) = -0.72$, $p = .479$ ($M_D = 11.90$, $SD = 3.51$; $M_C = 13.20$, $SD = 4.47$). There were also no differences in the number of complete notifications regarding food consumption, $t(18) = -1.26$, $p = .223$ ($M_D = 9.11$, $SD = 3.66$; $M_C = 11.30$, $SD = 4.11$).

4.9.3. Craving Assessment

A RM-ANOVA conducted on the mean reported craving assessments across entries, with group (cognitive defusion and control) as the between-subject factor and timepoint (pre and post audio listening) as the within-subject factor, yielded a significant effect of timepoint, $F(1, 18) = 39.59$, $p < .001$, $\eta^2_p = .687$ (cognitive defusion: $M_{pre} = 68.39$, $SD = 18.04$, $M_{post} = 47.89$, $SD = 18.92$; control: $M_{pre} = 74.27$, $SD = 10.60$; $M_{post} = 57.29$, $SD = 16.01$). There was no significant effect of group or a group x time interaction, $F_s < 1$.

4.9.4. Consumption of Food after the Craving Episodes

For these analyses, we computed the frequency of indulgence by summing the number of uses of the app in which participants reported having eaten the desired food after the craving episode. Participants in group cognitive defusion reported having eaten the craved food with a significantly lower average frequency than participants in group control $t(18) = -1.82$, $p = .042$, one-tailed, $d = -0.82$ ($M_D = 4.70$, $SD = 3.20$; $M_C = 7.40$, $SD = 3.41$). In addition, when they confirmed having eaten, they chose “more food than desired” with a lower average frequency than group control, $t(18) = -2.28$, $p = .018$, one-tailed, $d = -1.02$ ($M_D = 0.60$, $SD = 0.97$; $M_C = 1.90$, $SD = 1.52$). There were no differences in the reported average frequency of the "less than desired" option, $t(18) = -1.27$, $p = .110$ one-tailed ($M_D = 1.10$, $SD = 1.37$; $M_C = 2.10$, $SD = 2.08$) or "equal to desired" $t(18) = -0.22$, $p = .413$, one-tailed ($M_D = 3.00$, $SD = 1.83$; $M_C = 3.20$, $SD = 2.15$).

4.10. Discussion

In both groups, listening to the 3-min audio clip produced a decrease in self-reported craving in participants using the app for a two-week period, confirming only partially our hypothesis H_{2a}. This replicates the pattern of results found in Experiment 1, and suggests that the control condition may share some characteristics with the cognitive defusion condition, an issue that we will return to in the General Discussion.

Participants in the cognitive defusion group reported experiencing a higher number of occasions on which they did not eat the craved food and, when they did, the option of eating "more than desired" was chosen significantly fewer times, even if over the two-week period participants in both groups used the app with the same frequency. This pattern of results, confirming our hypothesis H_{2b} and H_{2c}, respectively, is congruent with previous studies reporting that cognitive defusion may reduce the undesired impact of food craving on eating behavior without lowering the number of cravings experienced (Forman et al., 2007; Hooper et al., 2012).

4.11. General Discussion

Elaboration is at the core of the craving process, according to the EI theory (Kavanagh et al., 2005), leading to a negative affective state that ultimately motivates people to eat as a way of reducing such a state. Cognitive defusion tackles the way in which participants react to intrusive thoughts by increasing attention and awareness while considering these thoughts as transient cognitive phenomena thus preventing further elaboration. We measured self-reported craving as well as eating behavior (snack-choice and chocolate consumption) following a naturalistic induction procedure in the laboratory involving food-cue exposure (Experiment 1) and in real-life contexts, using a smartphone application implementing cognitive defusion to be used whenever a craving episode was experienced (Experiment 2).

Cognitive defusion decreased the intensity of craving measured by the VAS and also the craving state, measured by the FCQ-S. The question remains as to why these outcomes were also found in the control group. Instructing participants to attend to the narration could have prompted receptive awareness and attention to the present moment, which are two of the key mindfulness skills. Lacaille et al., (2014), reported that a non-mindful intervention, such as distraction, led to increments in awareness and acceptance to a similar extent as those produced by mindful training, but did not produce an increase in disidentification (cognitive defusion). Another potential explanation could be that in both groups, paying attention to the verbal content of the audio-clip interfered with craving-related metacognitions in the form of verbal perseveration which, according to the desire thinking theory (Caselli & Spada, 2010), involves a continual self-talk that engages with the desired target. Cognitive defusion may have targeted these metacognitions in a more effective way than following the content of a story in the control condition, since it explicitly involves a metacognitive strategy.

Although we did not find between-group differences in chocolate consumption, which is consistent with the results of previous research (Schumacher et al., 2017), the groups differed in terms of the pattern of relationship between craving reduction measured by the VAS and the amount of chocolate consumed, being negative, as expected, in the cognitive defusion condition and positive, rather surprisingly, in the control group. Again, we can only speculate about the reasons for this discrepancy. Our participants were chocolate cravers that had been subjected to a rather strong food-exposure craving induction procedure. Without the protective effect of cognitive defusion, they might have suffered a greater craving reactivity during the bogus taste test (i.e., a rebound-like effect). Whilst awareness prompted by paying attention to the narration may have reduced craving intensity after induction, cognitive defusion might have reduced this reactivity with re-exposure to chocolate; this component was missing in the control condition.

Acceptance-based strategies, such as cognitive defusion, have been reported to engender behavioral effects even without a reduction in craving (Hooper et al., 2012), and to prompt decoupling of the relationship between craving measure and craving-related behavior (Tapper, 2018). In our study we found that food as a trait correlated positively with cognitive fusion, confirming that this could be an important target in craving-reduction strategies. Measures of awareness and acceptance (non-judging) correlated negatively both with food craving as a trait and cognitive fusion (which also correlated negatively with 'non-reacting'). This pattern of outcomes could be useful in guiding mindfulness interventions, particularly in selecting those mindfulness skills that may be more relevant to tackle food craving, although due to the reduced sample size we must interpret these findings with caution.

According to some theories (e.g., Buddhist-based), craving is thought to arise when pursuing or avoiding certain experiences, such as distress or discomfort (Lacaille et al., 2014; Moffitt et al., 2012). Therefore, cognitive defusion may be more effective in relieving distress and increasing tolerance to these experiences than strategies aimed at merely reducing the craving episodes (Forman et al., 2007). This is consistent with the reduction found in craving as a state, both in the anticipation of positive reinforcement (pleasure) and the reduction in negative affect (avoiding unpleasantness) in Experiment 1. Moreover, using the app during a two-week period reduced self-reported indulgence and reports of having eaten a lower amount of food when they did.

Obesity has become a pandemic, partly because we live in an obesogenic environment in which food cues generate thoughts that are immediate and automatic, giving reasons to eat more in individuals with poor executive control resources or those suffering from conditions such as stress, fatigue, or negative mood (Vallis & Macklin, 2021). Behavioral and psychological therapies in this context are concerned with providing individuals with the skills to improve executive control in a person-centered manner, increasing adherence, self-efficacy, and intrinsic motivation. In this vein, previous works have showed that training in cognitive defusion (disidentification) may be more successful than training in other mindfulness skills. It might be easily taught (Lacaille et al., 2014) which may increase usability in people who are unable or unwilling to practice more formal meditation of mindfulness programs (Fisher et al., 2016). Our results add to the evidence showing that even brief cognitive defusion sessions could have potentially beneficial effects and might be implemented in smartphone applications to be used whenever is needed. The advantages of these types of procedures include their low cost, along with good accessibility and feasibility, whilst helping individuals to overcome food cravings and eating behavior by implementing a strategy built on evidence-based theories (A. Hsu et al., 2014).

Experiment 1 used quasi experimental methodology, with non-randomized healthy-student groups. However, measures were taken to examine *a priori* between-group differences in variables thought to be relevant for the hypotheses to be tested. In addition, the groups were specifically composed of young female participants selected for their food-craving tendencies, which could limit the generalizability of our results and impose limits on the sample sizes. Another limitation of our work could be that the manipulation used in Experiment 1 to reduce self-reported craving was very short. However, it is true that longer interventions are impractical in terms of time and cost. To achieve feasibility and widespread use in real-world settings, interventions must be easy to implement, with low cost, intensity, and complexity, such as those provided by applications for smartphones, allowing users to access evidence-based strategies (Chapman et al., 2018). However, due to the small size of the sample used in Experiment 2, it would be worthwhile to replicate these findings with a larger sample, along with a longer timeframe. Another limitation is that, for procedural reasons, we did not measure changes in mindfulness skills after the intervention in Studies 1 and 2. In particular, because these questionnaires take a long time to complete, they might have interfered with other measures in Experiment 1, making the application in Experiment 2 unmanageable, discouraging people to use it.

Food craving as a trait was found to be linked to poor awareness as well as to cognitive fusion, that is, the tendency to react to thoughts and emotions. The results of the present studies show the promising beneficial effects of practicing cognitive defusion on self-reported craving and eating behavior in young female cravers, both in the controlled environment of the laboratory as well as in real-life context using a smartphone application. These results support theories of craving such as the elaborated intrusion theory, the desire thinking theory, or Buddhist-based theories, that focus attention on the cognitive elaboration of intrusive thoughts, self-talking verbal perseveration of craving-related content, and distress-avoidance behaviors linked to poor mindfulness skills such as awareness, acceptance and, particularly, cognitive defusion.

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CHAPTER 5:

Does Expertise Affect the Sensory and Liking Experience of Consuming a Food Reward?

Publication:

Hinojosa-Aguayo, I., Garcia-Burgos, D., Catena, A., & González, F. (2022). Implicit and explicit measures of the sensory and hedonic analysis of beer: The role of tasting expertise. *Food Research International*, *152*, 1–11. https://doi.org/10.1016/J.FOODRES.2021.110873

5.1. Abstract

Measures of drinking and eating behaviors may be assessed both explicitly (e.g., sensory and quality judgments) and implicitly (e.g., Electroencephalography, EEG), although the relationship between the results of both approaches remains unclear and each might be differentially affected by acquired knowledge. The main aim of the present study was to determine the strength of the relationship between these measures in sensory and hedonic processing of beers depending on the degree of tasting expertise. Beer experts, experts in non-beer beverages or edibles, and non-expert consumers took part in a sensory analysis procedure where they rated beers in terms of their sensory attributes and general quality—visual, olfactory, and gustatory phases—as well as their global hedonic value while their brain activity was recorded. The results suggest that participants evaluated the sensory properties of the beers in a rather similar manner. However, during the gustatory phase, experts and general tasters differed in terms of the activation of brain areas related to memory processes, while general tasters and consumers differed in brain activation related to hedonic processing. The relationship between self-reported quality judgments and EEG activity — particularly in relation to recognition and working memory components — appeared to be stronger in experts in comparison with the other groups (lowest $|r| = .67$, $p < .01$). Although lower in number, significant relationships were also found in general tasters and consumers, primarily involving hedonic processing (lowest $|r| = .58$, $p < .01$) and recognition memory (lowest $|r| = .57$, $p < .01$) components. Moreover, those relationships differed significantly, mostly between experts and consumers (lowest $|z| = 2.68$, $p < .01$), in terms of the involvement of working memory components. Taken together, the results of this study suggest that beer experts have a

more efficient pattern of gustatory processing and show a better fit between explicit (judgments) and implicit (EEG) measures of sensory and hedonic quality of beers.

5.2. Introduction

Eating and drinking are actions that are open to awareness, with the underlying psychological processes being both explicit and implicit. Instruments for measuring such processes can also be divided into explicit, including self-reported measures at a certain point after the sensory or hedonic experience, or implicit, which are based on continuous registration of physiological measures, such as brain activity. Even if explicit measures are quick to gather and easy to use and analyze, they can also be cognitively biased, and it is for this reason that implicit measures have recently attracted attention in food science (Lagast et al., 2017) and neuromarketing (e.g., Domracheva & Kulikova, 2020; Walsh et al., 2017). The main goal of the present study was to use both types of measures to evaluate differences in the explicit (sensory and quality judgments) and implicit (brain activity) sensory and hedonic assessment of beers, as well as to explore the strength of the relationship between such measures depending on beer tasting expertise (for recent reviews regarding beverage testing expertise, as well as implicit and explicit methods of assessing emotions elicited by food, see e.g., de Wijk & Noldus, 2021, and Honoré-Chedozeau et al., 2019; Lagast et al., 2017, respectively).

5.2.1. Brain Activity

Neuroimaging techniques are useful for studying sensory processing and the implicit physiological responses to food odors in connection with food-related emotions or preferences (Han, 2021). Measures of brain activity are good implicit indexes of affective evaluation in the cases where people are unable (or unwilling) to explain their preferences when explicitly asked about them (Vecchiato et al., 2011). Surprisingly, the use of neuroimaging techniques for studying affective reactions to flavors in food science is relatively novel (de Wijk & Noldus, 2021; for a recent review on the latest research on food odors using non-invasive neuroimaging techniques see Han, 2021). Nonetheless, there is now considerable evidence showing that flavor experience is influenced by the external features of food, or the so-called extrinsic cues. The available psychological and neuroscientific evidence suggests that information about extrinsic cues not only leads to expectations with regard to a beverage, but also affects stimulus processing, modifying the perception of a flavor (Okamoto & Dan, 2013) and modulating the neural representation of the experienced pleasantness (Plassmann et al., 2008), affecting consumers' purchase intentions toward food products (Samant & Seo, 2020).

Electroencephalography (EEG) has an excellent temporal resolution that allows, at the millisecond scale, for determining differences in brain responses between experimental conditions. Another neuroimaging technique commonly used in the field, functional magnetic resonance imaging (fMRI), allows subjects to taste only small amounts of solutions (e.g., less than 1 ml) in a supine position with a strong restriction on head movements, which may produce differences in flavor perception in comparison with natural conditions (Okamoto & Dan, 2007). In contrast, EEG allows for an examination of the olfactory and gustatory processing of foods and beverages that can easily be consumed without the need to use canulae fixed to the oral cavity or imposing immobility, providing a more naturalistic approach to the study of flavors and other complex evaluations of stimulus pleasantness. In this vein, the index of frontal alpha hemispheric asymmetry has been used to determine the pleasantness of flavors (Di Flumeri et al., 2017), finding significant correlations with explicitly reported subjective judgments. In another study using EEG with one dry electrode sensor placed on the participants' forehead, (Hsu & Chen, 2020) found differential brainwave oscillations in alpha and beta bands when drinking coffee with and without latte art, although no differences in explicit taste evaluations. More relevant to the goals of the present study, EEG has also been used to assess consumers' acceptability of beers. In their study, Gonzalez Viejo et al., (2019) used a single dry electrode (positioned on the forehead) that can register all brainwaves to construct an artificial neural network model using machine learning to classify beers according to overall liking.

Although EEG does not offer good spatial resolution, there are validated methods for localizing the source of brain activity and its cortical three-dimensional distribution based on multichannel surface of EEG recording, such a sLORETA (Standardized Low Resolution Brain Electromagnetic Tomography, Pascual-Marqui, 2002), which has recently been used in sensory research, to study, for instance, the effects of expectations on the subjective sensory and hedonic ratings of tastes (Wilton et al., 2019).

5.2.2. Studies of Sensory Analysis Involving Brain Activity in Expert and Non-Expert Participants

Past research has primarily focused on understanding the impact of extrinsic cues on the perceived quality of a beverage and, as a consequence, rather less is known about the influence of intrinsic sensory cues (Sáenz-Navajas et al., 2013; for a recent review of instrinsic and extrinsic factors affecting beer choice, see Betancur et al., 2020). Although it is known that olfactory and reward brain regions are involved in food odor and taste processing (Han, 2021), beverage-tasting expertise — which depends on both declarative knowledge and ortho as well as retronasal olfaction — has received relatively little scholarly attention (Honoré-Chedozeau et al., 2019), possibly because olfaction is the least readily categorizable and recognizable sensory modality (Richardson & Zucco, 1989). Thus, the available evidence is somewhat equivocal, with certain unresolved questions, including the role played by several kinds of memory processes (see e.g., Pazart et al., 2014). Given that evaluating brain activity could provide a useful and objective tool for investigating this issue, one of the aims of this study is to contribute to the literature by adding further evidence regarding the higher-order cognitive processes involved in beverage tasting in general, and beverage (beer) tasting expertise, in particular.

To our knowledge, no EEG studies have yet been reported including participants with different degrees of expertise in the sensory analysis of beer. Thus, the present study specifically aims to use implicit and explicit sensory and hedonic measures in response to visual, olfactive, and gustatory cues, to estimate the degree of correspondence between such measures as a function of formal beer-testing experience. This approach, using explicit and implicit measures of hedonic and sensory processing, has been scarce in the literature. In a recent systematic review (Lagast et al., 2017), out of 70 studies, only 6 combined both kinds of measures focusing on a single sensory modality (either appearance, aroma or flavor). Moreover, none of these studies measured brain activity.

5.2.3. The Present Study

Explicit (sensory, quality, and hedonic judgments) and implicit (EEG brain activity) measures of sensory and hedonic processing of beers of different qualities were compared in three groups of participants: beer-expert tasters; general food and beverage tasters with no particular specialization in beer sensory-analysis; and beer consumers without formal training or experience in food or beverage tasting. We expected to find differences in the explicit sensory and hedonic ratings of beers between experts and both general tasters and consumers, as well as between general tasters and consumers. Regarding brain activity, we expected to find differences between experts and general tasters in the activation level of areas related to further flavor processing, such as flavor labelling (semantic memory) as well as higher cognitive processes (analysis and decision making), while the activation pattern shown by consumers was expected to rely more on areas related to recognition memory and affective or hedonic processing. Predictions in the case of the quality and hedonic judgments involving EEG activity were less clear, and therefore this objective may be considered as exploratory.

Finally, we aimed to estimate the extent to which there is a correlation between explicit and EEG brain activity measures, and whether these correlations differed between groups. For the sake of simplicity, we conducted correlational analyses between brain activity and self-reported measures of sensory quality (visual, olfactory, and gustatory) and hedonic value judgments. If formal training leads to more reliable and valid explicit measures, we would expect to find a stronger relationship between explicit and implicit measures in experts in comparison with general tasters and consumers. We would also expect to find stronger relationships between areas involved in memory processing — particularly working memory — in experts when compared with consumers, who might instead exhibit a stronger relationship between judgments and brain activity in areas involved in hedonic processing.

5.3. Material and Methods

5.3.1. Participants.

Fifty-four right-handed participants (25 women) with a mean age of 40.9 years, *SD* = 12.4; range 20-64 (see Table 5.1, for more detailed demographics). They comprised three groups: Experts (*n* = 18) from the expert panel of the brewing company Mahou S. A. (Madrid, Spain); generic food and beverage expert tasters General tasters (*n* = 13) belonging to the multidisciplinary tasting panel from the University of Granada (SEGE in its Spanish acronym), with no particular expertise in beer tasting (members of both panels have participated in sensory studies on a regular basis); and Consumers (*n* = 23) a convenience sample of non-expert beer consumers with no previous experience in beer tasting. In the last two groups, gender and age distributions were matched to that of experts whenever possible. Exclusion criteria for participation in this study were being left-handed; suffering from food or beer-related allergies or intolerances, metabolic or hormonal disorders, having suffered from episodes of gastrointestinal or respiratory disease in the last seven days; presence of nasal mucositis; being in receipt of medical treatment; and, in the case of females, being pregnant or reporting breast feeding during the last 12 months. The inclusion criteria for consumers were being beer likers and being average or above-average beer consumers of legal alcohol drinking age (18 years old or above).

Table 5.1

Demographic Data According to Expertise Group

	Beer Experts *n = 18*	**General Tasters** *n = 13*	**Non-expert Consumers** *n =23*	p-*value* (ANOVA, χ^2)
Age	41.17 (12.17)	46.15(10.67)	36.52 (12.71)	.077
Females	50.00%	38.50 %	47.80%	.802
Testing experience (years)	7 .41 (6.87)	8.87 (6.14)	—	.555
Beer hedonic value (1-10)	8.39 (1.46) ^{b}	6.08 (2.31 ^{a}	8.43 (2.15) ^{b}	**.003**
University studies	75.00%	61.50 %	69.60%	.736

Note. The table shows the mean (standard deviation) for continuous variables and percentages for categorical variables. Significant *p*-values ($p < .05$) are in bold. For educational level, Degree, Postgraduate and Doctoral studies were labelled together as "University studies".

5.3.2. Beverages and Measures

5.3.2.1. Beers and Mineral Water

The four beers and the still mineral water used in the study were provided by Mahou S. A: two popular lagers consumed in Spain (Lager 1 and Lager 2), both with 5.5% alcohol, and two extra dark (ale) beers (Extra 1 and Extra 2), both with 7.2% alcohol. They were kept refrigerated and taken from the fridge approximately 10 minutes before serving. The beers were served in transparent 250-ml plastic glasses and presented to the participants covered by an opaque paperboard cylinder of lavender color to prevent initial visual inspection until instructed to remove this at the beginning of the visual phase. Brands and other commercial details were unknown to the participants.

5.3.2.2. Explicit Measure

Sensory and Hedonic Beer Evaluation. In order to simplify the sensory analysis, the number of sensory attributes normally included in the profile form used by the beer expert tasters in their regular job (approximately 70) was substantially reduced, and some of the selected to-be-evaluated attributes were renamed, using everyday consumer-based language. We also added measures of sensory quality and hedonic value. Specifically, the attributes for each phase were (in the following order): visual (brilliancy, color, the creaminess and adhesion of the foam, and visual quality); olfactory (fruity, cereal, floral, alcohol, olfactory quality); and gustatory attributes, including retronasal aroma (fruity, cereal, floral, alcohol), taste (bitterness, sweetness, sourness) touch (body, astringency, bitter persistence, balance), and gustatory quality. The participants rated each attribute using a 0-5 subjective intensity scale (0 = "absent", 1 = "quite low", 2 = "low", 3 = "regular", 4 = "high", 5 = "quite high"). They finally judged the hedonic value or general satisfaction with the beverage (*Please, use the provided response scale to specify the extent to which you like the beverage')* using a 0-5 scale (0 = "I dislike it immensely", 1 = "I dislike it very much", 2 = "I slightly dislike it", 3 = "I slightly like it", 4 = "I like it very much", 5 = "I like it immensely").

5.3.2.3. Implicit Measure: Electroencephalography (EEG)

The whole study was conducted inside an electrically shielded recording chamber to reduce sources of electromagnetic interference.

Brain activity recording. A 64-channel actiCap Brain Vision electrode system (Brain Products, Inc.) was used for EEG recording using the standard extended 10-20 system, referenced online to the electrode FCz. Impedances were maintained below 5kΩ. The EEG was sampled at 1000 Hz and was amplified using a 0.016-1000 Hz band-pass filter.

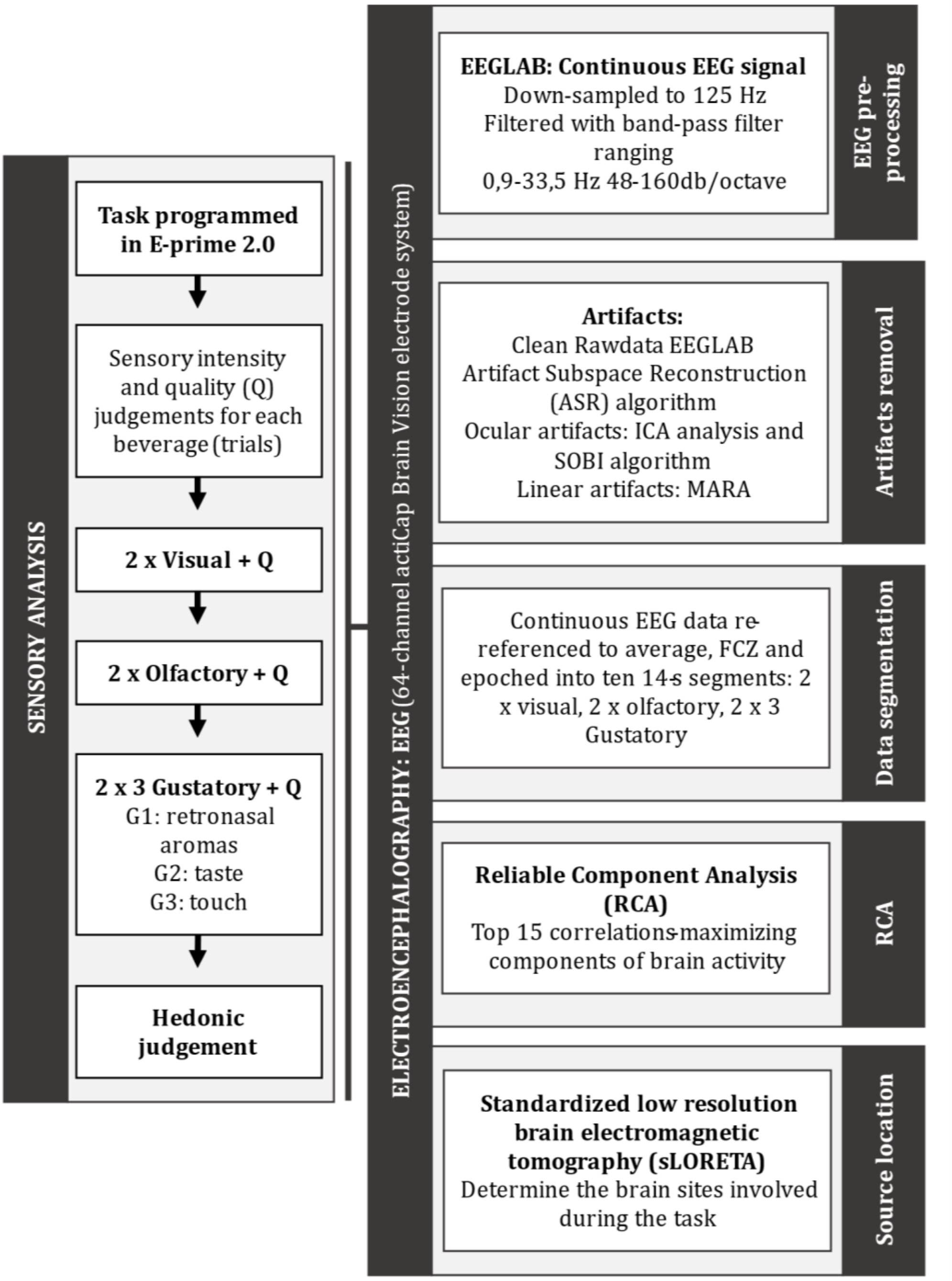
EEG Pre-Processing. Continuous EEG signals were pre-processed offline using EEGLAB (Delorme & Makeig, 2004) down-sampled to 125 Hz and filtered with a band-pass filter ranging between 0.9-33.5 Hz 48-160db/octave. Artifacts were identified and removed using Clean Rawdata EEGLAB plug-in based on the following criteria: a) High-pass filter was established at 0.2; b) channels with 5 s plus flatline, with more line noise from their signal than 4 standard deviations relative to the overall channel population mean, or with 0.8 -minus correlation from their reconstruction based on neighboring channels for more than a half of the recording, were identified as abnormal and were removed; c) segments of the recording in which activity was 5-plus standard deviations compared with previously computed clean reference EEG data were detected and reconstructed by Artifact Subspace Reconstruction (ASR) algorithm (Chang et al., 2018). A mean of 8.93 (SD = 7.32) channels per subject was removed and reconstructed by the spherical spline interpolation method (Perrin et al., 1989). Ocular artifacts and residual noise were then reduced by using Independent Component Analysis (ICA), applying the Second Order Blind Source Identification algorithm (SOBI, Belouchrani et al., 1993; Belouchrani & Abed-Meraim, 1997; Joyce et al., 2004) and a lineal artefacts classificatory "Multiple Artefact Rejection Algorithm" (MARA, Winkler et al., 2011). Continuous EEG data were then re-referenced to the average, FCz was recovered, and data were epoched into segments of 14 s, comprising the period from - 2 to 12 s during the different phases of sensory and hedonic assessment. Baseline correction was conducted using the first 2 s. For each participant, 10 epochs were obtained: 2 for the visual phase, 2 for the olfactory phase, and 6 for the gustatory phase (2 for each subphase: retronasal aroma, taste, and touch). Finally, epochs were submitted to Reliable Component Analysis (RCA, Dmochowski et al., 2012; Parra et al., 2019) in order to determine brain components common to all participants. This technique is suitable for natural stimuli such as those employed in sensory analysis, where there could be no well-defined epochs. RCA assumes that the signal-of-interest is spatiotemporally reproducible across subjects, and hence proposes carrying out dimensionality reduction by finding linear combinations of sensors that are maximally correlated between participants (reliable components). The result could be conceptualized as a set of virtual electrodes located intracranially at the brain sites involved in processing. We selected only the top 15 correlation-maximizing reliable components (RC) of brain activity, which were used, on the one hand, to determine the precise brain sites involved during the task using sLORETA software (Pascual-Marqui, 2002) and, on the other hand, to compute the effects of experimental manipulations, including the between-subject factor of group, and the within-subject factors of beverage (four beers and water as baseline) and phase (visual, olfactory, gustatory).

5.3.3. Procedure

The procedure received ethical approval from the Human Research Ethics Committee of the University of Granada (#227/CEIH/2016) and was conducted in accordance with the 1964 Helsinki Declaration and its later amendments. A flow-chart of the general procedure is available in Figure 5.1.

Figure 5.1

Procedure Flowchart



Participants were asked to fast (including water) for at least one hour before the session. Upon arrival at the laboratory, participants read and signed an informed consent form and self-administered a demographics questionnaire. The experimenter then assessed their laterality using the Spanish version of the Edinburgh Handedness Inventory (Oldfield, 1971). The participant sat down comfortably in an armchair while the experimenter proceeded to secure the EEG cap. A small window situated at the top of the wall behind the participant was used to project the instructions and task displays on the opposite wall. Before starting the procedure, the experimenter provided participants with specific instructions about the tasks they had to complete, and they were given the opportunity to ask as many questions as necessary before starting.

Participants completed the sensory analysis procedure using a QWERTY keyboard. The entire assessment procedure was programmed using E-prime® 2.0 (Psychology Software Tool, Pittsburgh, PA). As shown in Figure 5.1, participants were asked to mentally evaluate each sensory attribute more than once for each beverage before giving the sensory judgment, to mimic the experts' beer tasting procedure, which usually involves more than one assessment to reach a judgment. To make the session manageable in terms of length and reduce sensory habituation, we decided to limit the number of these evaluations to two for each sensory category (visual, olfactory, retronasal aroma, taste, and touch).

Participants rated five beverages in succession; water (baseline) was always tasted first, followed by the four beers in a pre-specified and distinct order for each participant, matched across the three groups whenever possible. For each beverage, the participants evaluated the three sensory phases in the following fixed order:

visual, olfactory, and gustatory (comprising retronasal aroma, taste, and touch subphases). Before starting each phase, they were reminded of the sensory attributes they were required to evaluate through the instructions projected on the screen. During each assessment, following specific instructions, participants looked at, smelled, or tasted the beverage twice, for 15s each time, in order to mentally evaluate the sensory and quality attributes. The end of each of these periods was signaled by the display screen briefly turning red, producing a decrease in the illumination of the room that was easily perceived by the participants. After each of these two 15-s periods, the wall-projected screen displayed the corresponding attributes listed in the Methods section (see Section 5.3.2.2), one at a time, and participants rated the intensity of each attribute of the corresponding phase, responding at their own pace using the keyboard. As shown in Figure 5.1, each of the three phases (visual, olfactory, and gustatory) ended with a sensory quality judgment and the evaluation of each beverage finished with a general hedonic judgment.

They proceeded in this way, from drinking water to tasting each of the beers until the fourth and final beer. Participants had a glass of tap water available to wash out their mouth between beer samples. The onset of each of the events or periods described above sent a trigger signal to the EEG recorder.

5.3.4. Statistical analysis.

5.3.4.1. Explicit Measure (Sensory, Quality, and Hedonic Judgments).

Mixed-design Analyses of Variance (ANOVAs) were conducted to assess the effects of the between-group and within-subject factors, as well as their interactions, using JASP software (JASP & JASP Team, 2019). Effect size was estimated using eta partial square (η^2_p). The level of significance was set at $p < .05$. If violation of the assumption of homoscedasticity was detected by the Levene's test, pairwise comparisons were conducted using Student's *t-test* assuming unequal variances; and Cohen's *d* was used to estimate effect size. For deviations from the assumption of sphericity, Greenhouse-Geisser correction was applied. Following the one-way ANOVAs, multiple comparison tests were corrected according to the Holm-Bonferroni procedure.

5.3.4.2. Sources of Brain Activation (RCA Analysis).

As mentioned above (see Section 2.2.3.2), after EEG signal pre-processing, epochs were submitted to Reliable Component Analysis (RCA, Dmochowski et al., 2012; Parra et al., 2019) and the top 15 correlation-maximizing components of brain activity were analyzed using sLORETA software (Pascual-Marqui, 2002) to determine the precise brain sites involved during the task.

5.3.4.3. Between-Group Differences in Reliable Component Activation.

To detect between-group differences in components activation, differences in activation level between group pairs were calculated for each beverage and tasting phase. To estimate significance, a permutation test was applied whereby random samples were created based on 2500 permutations ('tmax' corrected, Blair & Karniski, 1993).

5.3.4.4. Correlations Between Explicit and Implicit Measures in Each Group.

To determine the strength of the relationship between component activation and explicit measures, Pearson's correlation coefficients were calculated between quality and hedonic judgments and components activity for each group. The level of significance for this analysis was set at $p < .01$.

5.3.4.5. Between-Group Differences in Correlations Between Explicit-Implicit Measures.

To test whether the correlations between RC activity and explicit quality judgments detected in the previous analysis differed between pairs of groups, Pearson's correlation coefficients between RC activity and quality measures that reached significance were compared between groups using Fisher's r to z transformation. As in the previous analysis, the level of significance was set at $p < .01$.

5.4. Results

Table 5.1 displays the sociodemographic data. Groups did not differ in age, female/male ratio, or educational level. Expert and General tasters did not differ in testing experience (number of years). The only evident difference among groups was that General tasters rated beer with a lower average hedonic value in comparison with both Experts and Consumers.

5.4.1. Explicit measures

5.4.1.1. Sensory Analysis: Subjective Intensity of Sensory Attributes

Several mixed-design ANOVAs were conducted with group as the between-subject factor and attribute as the within-subject factor. For each beverage, radar charts showing the means of the sensory intensity evaluations, for each attribute and group, are available in Appendix C.1 (Figures C.1.1 to C.1.5). Given that we were primarily interested in between-group differences, in this section we report detailed analyses of the main effect of group and the Group x Attribute interactions (Table 5.2 also includes relevant information on the main effect of attribute for each phase and beverage).

Table 5.2

Summary of the ANOVA Results. Post-Hoc Exploration of the Main Effect of Sensory Attribute for each Phase (Visual, Olfactory and Gustatory) and Beverage, as well as the Group x Attribute Interaction

	Visual	**Olfactory**	**Gustatory**		
			Retronasal Aroma	**Taste**	**Touch**
Water	brilliancy > rest	n.s.	n.s.	n.s.	balance > rest
Lager 1	brilliancy > rest	n.s.	floral < cereal, alcohol	bitterness > sourness > sweetness	*body:* ***Exp > Con*** *astringency:* ***Exp < Con***
Extra 1	brilliancy < rest color > rest	cereal: ***Exp > Con, Gen***	fruity, floral < cereal, alcohol	bitterness > sourness > sweetness	*body:* ***Exp > Con*** *bitter persistence:* ***Exp < Con, Gen***
Lager 2	brilliancy > rest	fruity > floral, cereal	fruity, floral < cereal floral < alcohol	bitterness > sourness > sweetness	*body:* ***Exp > Con***
Extra 2	color > creaminess & foam adhesion	* n.s. post hoc (attributes)	fruity, floral < cereal, alcohol	***Exp:*** *bitterness > sourness, sweetness* ***Con:*** *bitterness, sourness > sweetness*	*bitter persistence:* ***Exp < Con***

Note. For a visual representation of this data sorted by group, please see Figures C.1.1 to C.1.5 in Appendix C.1. Significant main effects or interactions detected by the ANOVAs involving group are shown in **bold**. Exp = Beer-experts; Gen = General tasters; Con = Consumers; n.s. = non-significant differences when corrected for multiple comparisons.

With respect to water, the groups did not differ in their evaluations of any of the sensory attributes, Fs < 1. For the beers, there were no between-group differences in either visual or retronasal aromas, largest $F(2, 51) = 2.42$, $p = .099$. However, the groups differed in one of the olfactory attributes (Cereal) in the case of beer Extra 1, $F(2, 51) = 6.17$, $p < .01$, $\eta^2_p = .195$; experts rated the intensity of the cereal smell higher than the remainder, smallest $t = 2.65$, $p < .05$, $d = 1.14$. In the case of Taste, the ANOVA yielded a significant Group x Attribute interaction for beer Extra 2, $F(3.78, 96.33) = 2.59$, $p < .05$, $\eta^2_p = .092$. Further exploration of this interaction revealed different patterns of relationships among the three tastes (Bitter, Sour, and Sweet). The experts rated this beer to be higher in bitterness than both sourness and sweetness, lowest $t(17) =4.74$, $p < .001$, $d = 1.12$, whilst the consumers considered this beer to be lower in sweetness than bitterness and sourness, lowest $t(22) = 4.12$, $p < .001$, $d = 0.83$.

More consistent differences were found in the case of Touch, for which the evaluation differed between experts and consumers for each of the four beers, with significant Group x Attribute interactions in all cases, smallest $F(5.18, 126.97) = 2.80$, $p < 0.02$, $\eta^2_p = .103$.

To explore these interactions, one-way ANOVAs were conducted for each Touch attribute. In the case of Body, there were between-group differences for Lager 1, Lager 2, and Extra 1, smallest $F(2, 50) = 3.39$, $p < .05$, $\eta^2_p = .120$; in all cases, beer experts rated Body as being more intense in comparison with consumers (largest $p = .032$). Astringency intensity ratings also differed for Lager 1 $F(2, 51) = 4.57$, $p < .05$, $\eta^2_p = .152$, being higher for consumers than for experts ($p = .011$). There were also differences in Bitter Persistence for beers Extra 1 and Extra 2, smallest $F(2, 51)$

= 5.87, $p < .01$, $\eta^2_p = .187$; in both cases, experts gave lower ratings of this attribute than consumers, and these ratings were also lower than those of general tasters in the case of Extra 1, largest $p = .019$.

5.4.1.2. Sensory Analysis: Sensory Quality, and Hedonic Judgments

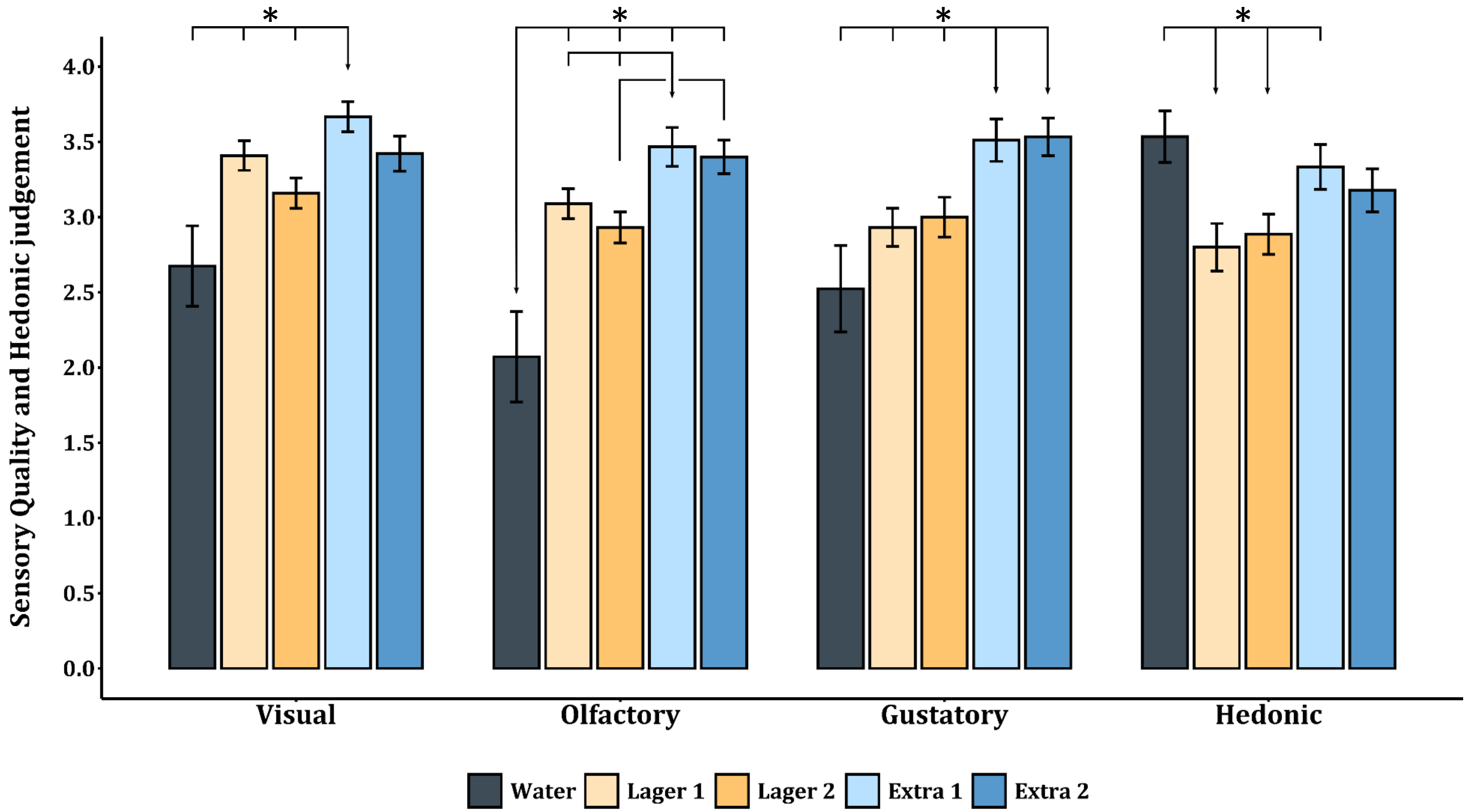
For each beverage, three quality judgments (visual, olfactory, and gustatory), as well as one hedonic value judgement, were subject to a mixed-design ANOVA. Beverage (water and the four beers) and judgement (visual, olfactory, gustatory, global hedonic) were included as within-subject factors, and group was the between-subject factor (see Figure 5.2 for a summary of the main results, and Table C.1.1 in Appendix C.1 for average judgments according to group and beverage). The ANOVA yielded significant main effects of beverage, F (1.83, 84.07) = 7.27, $p < .01$, $\eta^2_p = .137$, and judgment, F (2.67, 123.02) = 5.80, $p = .001$, $\eta^2_p = .112$, as well as a Beverage x Judgment interaction, F (6.12, 281.71) = 8.90, $p < .001$, $\eta^2_p = .162$. No other main effects or interactions were significant.

We considered it worth exploring the Beverage x Judgment interaction by kind of judgment. The obtained pattern would allow us to estimate the relative hedonic value of each beverage (extra beers are thought to be *better* than the lagers) that could be related to brain activity. To this end, we conducted one-way ANOVAs for each sensory-quality judgment, as well as for the hedonic-value assessment (Figure 5.2).

Visual quality. The ANOVA yielded an effect of beverage, F (1.97, 98.53) = 6.43, $p < .01$, $\eta^2_p = .114$, indicating that the visual quality of beer Extra 1 was judged to be superior to that of water, Lager 1, and Lager 2 (largest $p = .011$).

Figure 5.2.

Average Sensory Quality and Hedonic Judgements by Beverage



Note. Bars represent ±SEMs. Asterisks depict statistically significant differences ($p < .05$). For more detailed data sorted by group, please see Table C.1.1 in Appendix C.1.

Olfactory Quality. The ANOVA yielded an effect of beverage, F (1.61, 80.85) = 12.64, $p < .001$, $\eta^2_p = .202$, which, upon further exploration, revealed that there were lower ratings for water compared with all of the beers (largest $p = .034$), lower ratings for Lager 1 and Lager 2 compared with Extra 1 (largest $p = .022$), and lower ratings for Lager 2 compared with Extra 2 ($p = .005$).

Gustatory Quality. The ANOVA revealed a main effect of beverage, F (2.16, 107.951) = 8.90, $p < .001$, $\eta^2_p = .151$. The two extra beers were evaluated more positively than water, Lager 1, and Lager 2 (largest $p = .003$).

Hedonic Evaluation. The ANOVA revealed significant differences among the beverages, F (3.51, 179.23) = 6.33, $p < .001$, $\eta^2_p = .110$, with lower evaluations for the two larger beers in comparison with water and beer Extra 1 (largest $p = .044$).

5.4.2. Implicit Measure

5.4.2.1. EEG Analysis

After pre-processing, the data of four beer-experts (n = 14), two non-expert consumers (n = 21) and four general tasters (n = 9) obtained from the initial sample were excluded from the subsequent analysis due to poor data quality. Therefore, the final sample for these analyses was N = 44.

Source Location. The result of the sLORETA localization analysis, shown in Table 5.3 (for brain section images, see Figures C.2.1, C.2.2, and C.2.3 in Appendix C.2), resulted in *five functional groups*. Components 1, 7 and 11 (involving Brodmann's area 6) suggest a possible source in the bilateral superior frontal gyrus, which is involved in the execution of tasks involving working memory and attention, motor tasks, and cognitive-related processing (Li et al., 2013; Martino et al., 2011), and we will thus refer to its general function as *Working memory*. Analysis of activity in Components 2, 3 (left hemisphere) and 4, 12, and 13 (right hemisphere) (Brodmann's areas 10, 11, and 47) revealed possible sources in the medial prefrontal cortex and orbitofrontal cortex, which have been linked to the hedonic value of food, gustatory processing, smell/taste integration and decision making based on flavor pleasantness (Rolls, 2004; Rolls et al., 2010; Simmons et al., 2005; Small et al., 2007) and we will thus label its function as *Hedonic*. Components 5, 6, 8, 10 and 15 (involving Brodmann's 20 and 37) signal a source of activity in the right or left fusiform gyrus, which has been associated with object naming, word recognition, visual discrimination, and multisensory integration (Butler et al., 2011; Roberts et al., 2013); and we will thus consider its main function to be *Recognition memory*. The activity source in Component 9 (involving Brodmann's areas 38 and 47) suggests a localization in the right inferior frontal gyrus/ superior temporal gyrus, which has been linked to memory judgments on tasks requiring active retrieval processes (Kostopoulos & Petrides, 2003; Petrides & Pandya, 2001) or declarative memory, particularly semantic memory (Blaizot et al., 2010); we will therefore consider its main function to be *Retrieval memory*. Finally, source analysis of activity in Component 14 (involving Brodmann's areas 17 and 18) reveals a possible origin in the left lingual gyrus, a perceptual component of visual processing (Mangun et al., 1998; Rombouts et al., 2002); and we will thus refer to its function as *Visual* processing.

Table 5.3

Reliable Components (RC): sLORETA Localization Analysis. *Functional Group, Components, Estimated Source of Activation and Brodmann Areas*

Functional group	**RC**	**Source of activation**	**Brodmann area**
Working Memory	1, 7, 11	Bilateral superior frontal gyrus	6
Hedonic	2, 3, 4, 12, 13	Right/left medial prefrontal cortex; orbitofrontal cortex	10, 11, 47
Recognition Memory	5, 6, 8, 10, 15	Right/left fusiform gyrus	20, 37
Retrieval Memory	9	Right inferior frontal gyrus; superior temporal gyrus	38, 47
Visual processing	14	Left lingual gyrus	17, 18

Note. See also Figures C.2.1, C.2.2, and C.2.3 in Appendix C.2 for more detailed information about the brain locations of the components.

Between-Group Differences in Reliable Component Activation. RCs comprise a brain network activated differentially during sensory analysis. Table 5.4 shows the significant between-group differences in the activation of components during sensory analyses. Main differences were found between experts and general tasters during the gustatory phase for Lager 1 (Experts: M = 1.05, SD = 0.08; General tasters: M = 0.95, SD = 0.06) and Lager 2 (Experts: M = 0.96, SD = 0.06; General: M = 1.04, SD = 0.06), and between general tasters and consumers for Extra 2 (General: M = 0.97, SD = 0.03; Consumers: M = 1.01, SD = 0.03) during the gustatory phase.

Table 5.4

Statistically Significant Differential Activation of Components (RC) Detected in the Pair-Wise Contrasts between Groups for each Beverage and Phase

Beverage	**Phase**	**RC (Function)**	**Significant contrast**	***t-value***	***p-value***
Lager 1	G1	6 (Recognition Memory)	E-G	3.28	.04
Lager 2	G2	7 (Working Memory)	E-G	-3.38	.03
Extra 2	G2	13 (Hedonic processing)	G-C	-3.45	.02

Note. E = Experts; G = General; C = Consumers; G1 = retronasal aromas; G2 = taste. See also Figures C.2.1, C.2.2, and C.2.3 in Appendix C.2, for more detailed information about the brain locations of the components.

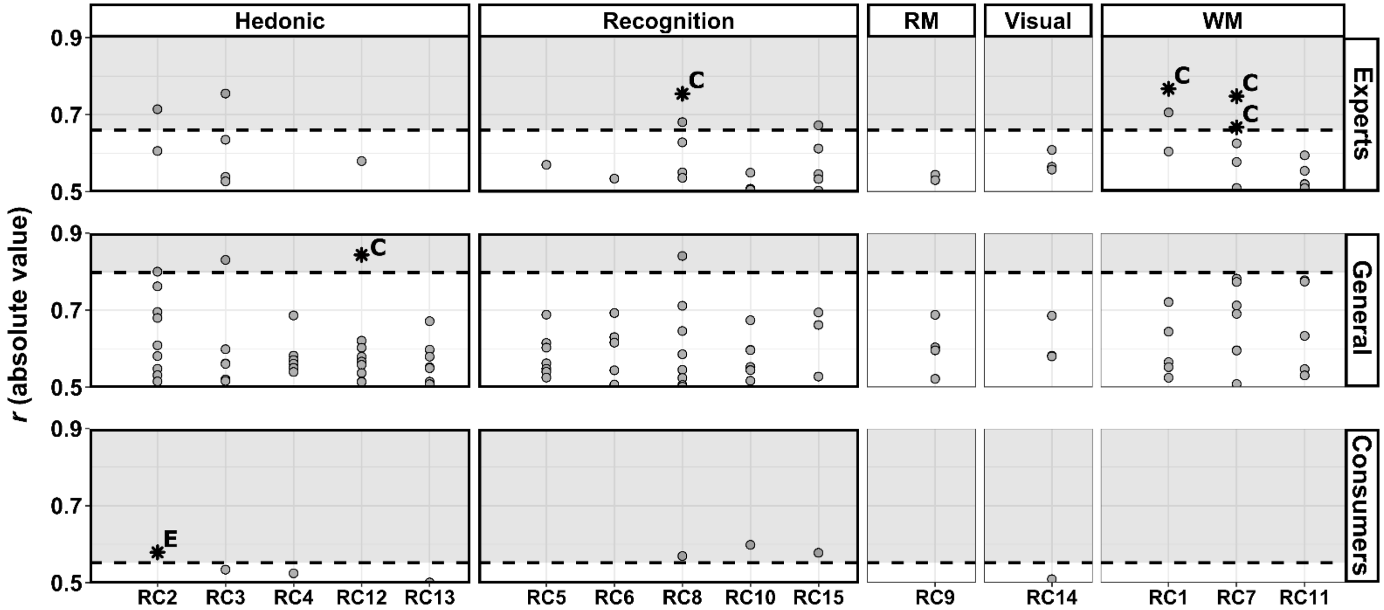
Correlations Between Explicit and Implicit Measures in Each Group. Only activity in RCs phases that may influence subsequent judgments for the same beverage during sensory analysis were selected (e.g., RC activity during the olfactory phase could significantly correlate with olfactory, gustatory, or hedonic judgments, but not with visual quality, which was judged before the olfactory analysis).

Figure 5.3 shows the significant correlations between RC activity and quality and hedonic judgments, for functional RC category and group (see Table C.1.2 in Appendix C.1 for more detailed statistical data). In general, RCs correlating with measures of quality were related to recognition and working (but not retrieval) memory and hedonic processing, while no relationship was found with visual processing. Beer experts showed the largest number of significant explicit-implicit measures correlations which mainly involved working and recognition memory components

Between-Group Differences in Correlations Between Explicit-Implicit Measures. As shown in Figure 5.3 (see Table C.1.3 in Appendix C.1 for more detailed statistical data), significant between-group differences in the RC activity-quality judgment correlations (marked with asterisks) were found mainly between experts and consumers.

Figure 5.3

Statistically Significant Correlations (as Absolute Values of r-Pearson Coefficients) between Reliable Components (RC) Brain Activity (Implicit Measure) and Quality Judgements (Explicit Measure) for each Group



Note. The y-axis scale ranges between 0.5 and 0.9. The shaded background shows the area within which p-values < 0.01 in each group. The bold-bordered squares mark the functional groups of RC where correlations between explicit and implicit measures are significant. Asterisks depict statistically significant between-group pair-wise contrasts; the letter above the asterisk indicates the alternative group comparison for which the difference between correlations is significant. WM = working memory; RM = retrieval memory; C = Consumers; E = Experts. For more detailed statistical information, see Tables C.1.2 and C.1.3 in Appendices corresponding.

5.5. General Discussion

Three groups of participants that differed in terms of their expertise in the sensory analysis of beers explicitly evaluated two kinds of beers (Lager and Extra) in terms of subjective sensory intensity, as well as sensory quality and hedonic value, whilst their brain activity was registered (EEG, implicit measure).

Regarding *sensory attributes*, the groups gave somewhat similar ratings for water and most of the beers, with the exception of attributes corresponding to the category of *Touch*, where differences between experts and consumers were found for all beers (Table 5.2). This result suggests that sensory evaluation — at least at the behavioral level of sensory intensity judgments and with the attributes and measurement scale employed in this study — was broadly similar across the three groups, and that participants understood instructions and assigned labels to each attribute in a rather comparable way. However, expertise also played a role. Touch seems to be a sensory category that distinguishes beer experts from non-expert consumers (although not from general experts). While the possible mechanisms responsible for this difference are not immediately clear (as our experimental design does not allow for discriminating among the various alternatives) certain accounts may be considered.

Differences could be due to the greater difficulty exhibited by consumers when it comes to discriminating between various degrees of intensity of this attribute using the provided verbal description and response scale. However, we found no differences in brain components related to retrieval or semantic memory (Table 5.4). Alternatively, consumers may have had no particular difficulty in understanding the attributes described within this category, but they simply rated these attributes differently. This would be unsurprising, given that they are less frequently exposed to these during their day life experience, and thus may be less habituated, experiencing a greater degree of bitter persistence or astringency. It is also possible that experts and consumers did not differ at all in terms of flavor perception, but that they instead used different perceptual or cognitive strategies (e.g., Pazart et al., 2014) when assessing abstract qualities such as complexity, harmony, or balance, giving different weight to the attributes of touch in a number of ways. For instance, consumers appear to perceptually judge these attributes in a rather global way, considering, for example, wine as an integrated whole, while experts use analytical evaluations by separating its constituent elements (Parr, 2019). Additionally, consumers and experts may use different strategies when judging the perceived quality of a wine based on this more abstract category of properties. A study comparing the ratings of Spanish consumers and experts in the perceived quality of red wines based on intrinsic sensory cues found that the ratings did not depend chiefly on taste properties; consumers assessed less astringent wines as being of higher quality, whereas for experts this cue was not important, and they instead rated more balanced and complex wines as being higher in quality (Sáenz-Navajas et al., 2013). Concerning beer, color cues appear to be a relevant factor for Spanish consumers, where gold or red beers are good predictors of consumer preferences (Donadini et al., 2016). Thus, our result could add to the body of evidence pointing to differences in the underlying higher-order cognitive processes (such as categorization) when assessing beverages depending on tasting expertise, something that still remains unclear when perceptual phenomena are involved (Honoré-Chedozeau et al., 2019).

Regarding *quality and hedonic* judgments, extra beers were evaluated more positively than lagers, as expected (Figure 5.2). Extra 1 was rated as having greater visual, olfactory, and gustatory qualities, as well as hedonic value, while Extra 2 elicited good olfactory and gustatory evaluations. Lager beers were considered mostly “visual”, with lower scores on olfactory and gustatory qualities, or hedonic value. There were no differences among groups with respect to explicit measures. Taken together, the quality judgments analyses allow us to conclude, with certainty, that explicit measures of sensory quality and affective value accurately capture the differences in quality between beers, with the extra beers outperforming the lagers.

We detected relatively few between-group differences in the level of *brain activation* during sensory analysis (Table 5.4), which is consistent with the relatively few differences found among groups in the explicit measures. The group of general tasters showed significant differences when compared with both experts and consumers, but only in components involving distinct functions. Beer experts and general tasters differed mostly in memory components (except those of retrieval memory) when analyzing lager beers, with recognition memory being more active in the case of experts during the evaluation of retronasal aromas, while working memory and attention components were less active during taste assessment, suggesting that a relatively more efficient, effortless, and spontaneous form of taste processing is engaged in beer experts (see, for example, Pazart et al., 2014). The lower implication of working memory and attention components in experts is consistent with the findings of previous studies showing that wine testing expertise correlated negatively with the activation of regions involved in memory (Royet et al., 2013). General tasters also differed from consumers, showing lower activation when evaluating one of the extra beers (Extra 2) in a component involved in the processing of hedonic or reward value, which is consistent with the lower hedonic rating of beer as a liked beverage shown by general tasters compared with both experts and consumers (Table 5.1), although no differences were found using quality and hedonic judgments. In this sense, brain activity might be a more sensitive (or less cognitively biased) measure of hedonic processing than explicit judgments. In fact, it has been suggested that implicit measures might be more sensitive to different factors or dimensions affecting the evaluation of food, particularly when conducting real-life testing, being more dynamic and able to capture a temporal window in which un- or subconscious processes could occur (de Wijk & Noldus, 2021).

In spite of the relatively few between-group differences found in explicit judgments, as well as in the activation of brain components, beer experts exhibited more significant correlations between quality and hedonic judgments and component activation than any other group, which suggests a better match between explicit and implicit measures (Figure 5.3, and Table C.1.2 in Appendix C.1). Thus, we found evidence in favor of our hypothesis of detecting stronger relationships between areas involved in memory processing in experts when compared with consumers, albeit only with respect to beer-tasting experts. Correlations between quality and hedonic judgments mostly involved working as well as recognition memory components. This agrees with reported evidence showing that beer experts outperform novices in odor recognition memory tasks, albeit only with familiar beers (Valentin et al., 2007). Differences in the structure of acquired knowledge (more efficient categorization thought mechanisms such as prototype extraction or the use of scripts with a larger number of precise steps) have also been proposed to account for this pattern of results in the field of wine testing (Honoré-Chedozeau et al., 2019). The fact that working memory components were not significantly related to judgments in the other two groups suggests that, for experts, formal training in the sensory analysis of beer may prompt the use of a more analytic strategy, using abstract or conceptual terms when evaluating quality beers, while novices use information based on specific information derived from everyday life, such as personal feelings. All this is compatible with studies reporting that wine experts use top-down processes based on their knowledge while novices use bottom-up processes based on perception (Honoré-Chedozeau et al., 2019). Indeed, the quality/hedonic judgments of general tasters relied mostly on hedonic processing components, and rather less on memory recognition, unlike consumers, whose judgments were related to components linked to recognition memory rather than hedonic processing, which could indicate that general tasters used a strategy based more on the immediate hedonic reaction to the beers, while the assessments of consumers seemed to be based more on past experience or recognition memory.

This general pattern of results is in accord with previously reported fMRI results (Castriota-Scanderbeg et al., 2005; Pazart et al., 2014) showing differential activity in brain areas involved in the flavor integration circuit between wine-expert tasters and non-experts during sensory analysis, particularly in semantic and episodic memory brain areas, as well as those involved in working memory and executive control. Our results add further evidence demonstrating that there are also differential patterns of activation of brain regions involved in working memory in the case of tasting beer, the most consumed alcoholic beverage in the world (Betancur et al., 2020).

5.6. Limitations

Olfaction is the least easily categorizable and recognizable sensory modality (Richardson & Zucco, 1989), being heavily involved in flavor processing, and, as in all studies of this sort, this could have produced greater variability in our findings, particularly among non-beer-experts. This might have made it more difficult to detect differences among groups, which may be considered as an added difficulty for any cross-sectional investigation. Further, other factors might have affected the results of the study. For instance, although the order of testing the beers was different for each participant, a cumulative effect of alcohol consumption on brainwaves throughout the tasting process cannot be ruled out. Other factors such as the nature of the stimuli, type of tasks, expertise types, and even genetic differences such as sensitivity to bitterness (Honoré-Chedozeau et al., 2019) may also have played a role in generating the results reported here. In addition, as in other studies using EEG, limited samples due to practical issues, including the availability of panelists, may lead to a lack of statistical power, although this would have less impact on within-group assessment such as correlation analyses between component activation and quality judgments.

5.7. Conclusions

Our results suggest that experts and consumers explicitly rated the beers in a rather similar way, with the exception of the category Touch. In accord with this, no major differences in brain activity were found, with beer experts relying more on memory components when assessing aromas and showing more efficient and effortless patterns of working memory related-activity when processing taste. When evaluating the strength of the relationship between both quality and hedonic judgments with brain activity, we found a larger number of significant correlations in the case of beer experts. Taken together, these results suggest that there may be a closer relationship between quality and hedonic judgments and underlying brain activity in beer experts, particularly in the case of working memory components, which seemed to involve mainly analytical strategies when assessing general visual, olfactory, and gustatory qualities, as well as the hedonic value of the beers.

5.8. References

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CONCLUSIONS SUMMARY

CHAPTER 6:

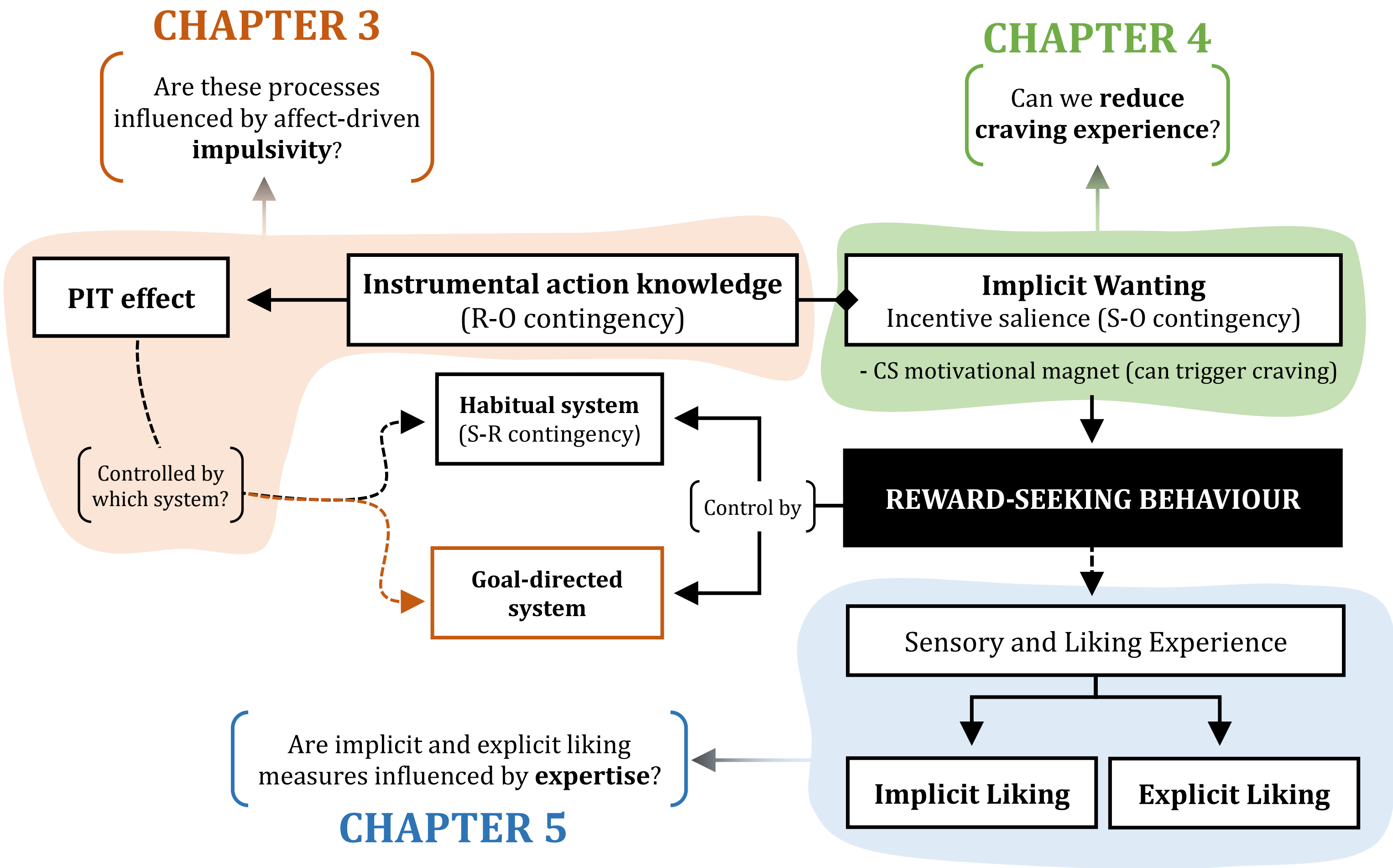
General Discussion and Conclusions

The main aim of this thesis was to increase our knowledge about food decision-making and food-seeking behaviour from a learning perspective. Specifically, three areas were investigated in the three experimental chapters (see Figure 6.1):

- How differences in affect-driven impulsivity influence action control and selection as well as the interaction between these two processes (i.e., control over action selection).
- How to reduce self-reported food craving (“wanting”) and related unhealthy eating behaviour (maladaptive effect of incentive cue salience) using a brief mindfulness-based intervention in young female cravers, both in the laboratory and a real-life context.
- How differences in formal training (‘expert’ knowledge) influence brain activity as well as the strength of the relationship between implicit (EEG) and explicit (general sensory quality: visual, olfactive, and gustatory, as well as hedonic value judgments) measures of “liking” during the sensory and hedonic processing of beer.

Figure 6.1

Overview of the main processes analysed in the experimental chapters of the thesis.



6.1. Chapter 3: Does Affect-Driven Impulsivity influence Action Control and Selection?

In this first chapter of the experimental section, the most relevant findings indicate a negative relationship between emotional impulsivity (negative urgency, NU) and: 1) The ability to adapt the instrumental action according to the current outcome value (Experiment 1; Hypothesis 1); 2) the ability to extract predictive information from incentive cues, integrate such knowledge into action selection (Experiment 1; Hypothesis 2) and do so flexibly as a function of the current value of the outcome shared by the action and the cue (Experiment 2; Hypothesis 3).

To the best of our knowledge, this is the first report to link inflexibility and inefficiency and integrate predictive knowledge into action selection with NU. This result has important theoretical and clinical implications. On the one hand, it sheds light on the ongoing debate about whether the outcome-specific PIT mechanism is goal-directed. The previous literature on humans has yielded ambiguous results on the sensitivity (Eder & Dignath, 2016a, 2016b; Mahlberg et al., 2021; Seabrooke et al., 2017, 2019) or insensitivity (Colagiuri & Lovibond, 2015; Colwill & Rescorla, 1990; De Tommaso et al., 2018) to outcome devaluation in the Outcome-Specific PIT effect in humans (see section 1.3.2). However, current mainstream theories argue that goal-directed mechanisms figure centrally in the effect of incentive cues on action-specific selection. Nonetheless, this greater involvement of the goal-directed system may be impaired under certain circumstances such as dysregulation of emotional responding (Webb et al., 2012), stress (Pool et al., 2022; Quail et al., 2017), interval schedules in instrumental training (Perez & Dickinson, 2020), sleep deprivation (Chen et al., 2017), hyper-reactivity to incentive cues (Eder & Dignath, 2016a; Mahlberg et al., 2018), or neuropsychiatric disorders (Dayan et al., 2017; Gillan et al., 2011; Morris et al., 2015).

On the other hand, in the multilevel framework proposed by Braunstein et al. (2017), the authors define *reinforcer revaluation* as an implicit and automatic emotion regulation strategy because: 1) updating the value of the outcome elicits behavioural changes indicative of an emotional response; 2) no explicit goal is pursued to regulate emotion; and 3) automatic processes primarily trigger the emotional response. Our data are in line with these assertions. In particular, our findings suggest that inefficient instrumental action control and selection (assessed or influenced by the ability to update the outcome value) are related to emotional dysregulation, as measured by emotional impulsivity. Taken together, it appears that emotional regulation strategies should be worked on in future interventions targeting disorders associated with a propensity towards habit formation or impaired use of the goal-directed system. In this regard, the current literature relates problems in eating behaviour with increased habitual control (see Pierce-Messick & Corbit, 2021 for a review of this topic). Moreover, there seems to be a link between eating disorders and an enhanced reliance on negative and maladaptive emotion regulation strategies (Brockmeyer et al., 2014; Dingemans et al., 2017; Prefit et al., 2019). Thus, future studies should examine whether training in emotional regulation is an effective tool that should be considered in prevention and/or intervention programmes aimed at tackling problems such as binge eating disorder or obesity (see Hartogsveld et al., 2022; Horstmann et al., 2015; Reiter et al., 2017, where the link between these disorders and insensitivity to outcome devaluation are analysed).

6.2. Chapter 4: Can We Reduce Craving Experience in the Laboratory and Real-Life Contexts?

As discussed above, incentive cues affect instrumental action control and selection and the interaction between both processes. Additionally, predictive reward cues involve "wanting" mechanisms, generating motivation and a predisposition toward obtain the desired outcome (see Section 1.4). Chapter 4 of the experimental section addresses the processes underlying implicit wanting (i.e., the magnetic and mostly automatic reaction triggered by incentive cues often manifested as intense craving or desire) in young female chocolate cravers. In particular, after applying a procedure to induce craving, devised in our laboratory (Experiment 1), or after naturally occurring craving episodes (Experiment 2), participants were given brief cognitive defusion training to reduce craving intensity and improve food selection and eating behaviour. The underlying mechanism of this strategy involves intervening in the negative emotional reaction triggered by intrusive thoughts by increasing attention and awareness of the agent while attempting to consider these thoughts as temporary and transient. According to Elaborated Intrusion Theory, this would prevent the craving process from further elaborating (Kavanagh et al., 2005).

We examined the efficacy of the cognitive defusion strategy in reducing both laboratory-induced craving (Experiment 1) and craving episodes experienced in real-life contexts using a mobile application that implemented this strategy and recorded real-time data (Experiment 2).

The most important results of Experiment 1 revealed that cognitive defusion was related to:

- A decrease in the intensity of self-reported craving (Hypothesis 4a). However, contrary to our expectations, these results were also found in the control group.
- A tendency (non-significant) to choose the healthy option on the "snack-choice test" in the cognitive defusion group (26%) compared to the control group (9%) (Hypothesis 4b).
- A differential chocolate consumption pattern. Although the groups did not differ in the amount of chocolate consumed during the bogus taste test (Hypothesis 4c), the reduction in self-reported craving after the intervention was found to be associated with lower consumption in the experimental group and, interestingly, with higher consumption in controls.

Moreover, the cognitive fusion trait (the opposite of cognitive defusion) was found to:

- Be positively associated with craving for chocolate as a trait (Hypothesis 5a) and negatively associated with measures of mindfulness skills such as awareness and acceptance (Hypothesis 5b).

Finally, the use of the mobile application applying the cognitive defusion strategy over two weeks yielded the following:

- A decrease in self-reported craving (Hypothesis 6a).
- A reduction in self-reported indulgence (Hypothesis 6b) along with reports of eating less food than initially desired (Hypothesis 6c).

As mentioned throughout this thesis, tackling the problems arising from reactivity to incentive cues is of critical importance, given the highly obesogenic environments in which today's Western society operates. Finding easily usable practical strategies with immediate results is of utmost relevance, considering that craving is typically experienced as temporary peaks of desire that last only seconds or minutes (Berridge & O'Doherty, 2014) but can trigger unhealthy and potentially dangerous eating behaviours. Overall, while the pattern of results revealed could help guide future mindfulness interventions, these findings should be interpreted with caution due to the small sample size. Nonetheless, the experimental results summarized above echo previous research showing the success of cognitive defusion training in reducing the impact of craving experiences. Furthermore, these findings indicate the efficacy of a brief 3-minute intervention that can be easily applied to real-life contexts whenever necessary. In addition to its good accessibility and viability, the strategy applied in real-life contexts in Experiment 2 has the advantage of being low cost while helping individuals overcome craving and maladaptive eating behaviour by applying a strategy based on proven theories (Hsu et al., 2014).

6.3. Chapter 5: Does Expertise Affect the Sensory and Liking Experience of Consuming a Food Reward?

Finally, when a food reward contingent to the instrumental action is experienced, it triggers the liking mechanism associated with the hedonic experience of consuming the outcome (see Section 1.4). Expectations generated by past events influence the pleasantness and sensory features of this experience (see Figure 1.3). Thus, previous experience is a crucial factor in liking and sensory reward evaluation, so the question arises as to what will happen to individuals who have undergone formal training and who have been repeatedly exposed to the same category of food stimuli. In this vein, the final chapter of the experimental section assesses the impact of hedonic and sensory experience on the consumption of beverages (beers) using implicit (continuous recording of EEG brain activity) and explicit (visual, olfactory, and gustatory quality and sensory, as well as hedonic, judgments) measures. To this end, three groups with different levels of formal expertise in the sensory analysis of beers participated in the experiment to determine how the degree of expertise could impact both explicit and implicit measures of liking, and the strength of these relationships.

Regarding the *explicit measures*, the main results revealed a similar pattern across all groups in sensory experiences regarding both quality and hedonic judgements. Significant differences were found only in the sensory evaluation of more complex attributes related to taste assessment (Exploratory Hypothesis 7). Concerning *implicit measures* of brain activity (Hypotheses 8a and 8b), there were again few between-group differences. The most relevant findings indicated that beer experts differed from consumers in activation of brain areas associated with memory processes, whereas general tasters differed from consumers on components associated with hedonic judgements. Finally, despite the few between-group differences in explicit and implicit measures, the most novel and relevant finding was that beer experts exhibited a higher number of correlations between sensory and hedonic quality judgments and brain component activation (Hypothesis 9a). Moreover, in this group, the correlations mainly involved brain components related to recognition and working memory processes compared to the group of consumers (Hypothesis 9b), while in the latter, a stronger association was observed between both measures and activation of brain areas involved in hedonic judgements (Hypothesis 9c).

Overall, these results show that, although there were no significant influences of expertise on the hedonic and sensory experience of consuming a beverage at the explicit and implicit levels using the simplified set of attributes selected for our study, there were differences regarding the strength of the relationship between these two measures. These data suggest that, for beer experts, expertise may promote more analytical strategies during the sensory analysis of the product, whereas non-experienced participants could use information based on their previous personal experiences. Such insights would align with previous research reporting that sommeliers are more prone to using top-down processes derived from their prior knowledge, while novices use bottom-up mechanisms driven by their perception (Honoré-Chedozeau et al., 2019).

6.4. General Conclusions

This thesis aimed to advance our knowledge about decision-making in reward-seeking behaviour — specifically eating behaviour — by examining three related processes or groups of processes: 1) How individual differences in emotional dysregulation influence action control and selection; 2) How to decrease reward-associated cue salience ("wanting") and associated maladaptive behaviours in participants frequently suffering food craving episodes; and 3) How differences in expertise can influence explicit and implicit measures (and the strength of their relationship) of hedonic and sensory analysis of beverages ("liking"). The results reported here may have important theoretical and clinical implications for future research and interventions.

First, these data indicate that emotional impulsivity decreases the efficacy or control of the goal-directed system on instrumental behaviour and the effect of reward-related cues on instrumental behaviour (PIT effect). Our data suggest that, at least in our experimental paradigm, Outcome-Specific PIT is controlled by the goal-directed system, and, in addition, this control is impaired by emotional dysregulation. Thus, future clinical interventions or preventions could tailor their strategies by including training in emotional regulation for individuals with clinical conditions related to difficulties in updating the value of a current outcome.

Second, we found that a brief 3-minute cognitive defusion intervention reduced the intensity of craving episodes and improved eating behaviour in laboratory and real-world settings. Strategies like the one proposed and analysed could be of considerable benefit due to their ease of application and low cost. These strategies and methodologies can be clinically applied to individuals for whom cue reactivity could become a relevant health problem. It might also be of interest for future research to apply this intervention by collecting real-time data in natural contexts using such an accessible and daily tool as the mobile phone.

Finally, although almost no differences were found in the explicit and implicit measures of hedonic and sensory beverage evaluation as a function of expert knowledge, significant differences were found in the relationship between both measures. Specifically, beer experts showed the highest number of correlations between explicit and implicit assessments. Moreover, the pattern of these correlations also differed between the groups. While beer experts exhibited more analytical strategies during sensory and hedonic analysis, non-expert participants seemed to rely more on previous personal experiences. Once again, the above data have theoretical implications, as future research on liking mechanisms associated with the hedonic experience of consuming a reward (e. g., food or certain beverages) should consider participants' prior experience, particularly that linked to formal training or expert knowledge. Moreover, in fields such as neuromarketing or food science, it might be of interest to consider that implicit measures are more sensitive than explicit measures when evaluating the hedonic and sensory properties of beverages.

6.5. References

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APPENDICES

Appendix A:

Does Affect-Driven Impulsivity influence Action Control and Selection?

Appendix A.1: Composition of the Battery of Questionnaires Answered Online by Participants in Experiments 1 and 2

As part of a wider unrelated research project aimed at studying several variables related to eating styles and personality traits, participants responded to a battery that was composed of, in addition to the UPPS-P, the following questionnaires or items: Spanish Revised Restraint Scale; Power of Food Scale, PFS, translated to Spanish by one of the authors and one English (American) native speaker; Spanish Version of the Shortened Sensitivity to Punishment and Sensitivity to Reward Questionnaire SPSRQ-20; Spanish Version of the Three-Factor Eating Questionnaire-R18; Item 26 of the Spanish Version of the Yale Food Addiction Inventory Scale, YFAS-S, and the three items of the Perceived Self-Regulatory Success measure applied to dieting, translated to Spanish by one of the authors and one English (American) native speaker. Participants responded online before being invited to participate in the experimental task of the present study.

Appendix A.2: Instructions of Experiments 1 and 2 (Translated from Spanish)

Experiments 1 and 2 (Instrumental and Pavlovian training were identical)

1. *Instrumental Training*

‘You form part of a group whose aim is to obtain goodies to help impoverished children to celebrate their birthday parties. Each piece of food obtained will be of great utility. There is a rumour saying that it is possible to get free snacks from a vending machine. Press Key B in order to tilt the machine to the left, and Key N to tilt the machine to the right. Use only the pointing finger of your dominant hand. Tilt the machine until a product falls. You have to learn which snack falls when you tilt the machine to the right and which one falls when you tilt it to the left. Occasionally a question about this relationship will appear in order to check your knowledge about it. Press the space bar to continue’.

2. *Pavlovian Training*

‘Your group has discovered that, when the machines are completely full of products, it is easier for products to fall freely. The lights on the front panel of the machine will signal when the machine is too full. You should just observe and pay attention in order to learn how the colours of the lights are related to each product. Again, you will occasionally be asked about these relationships. Use the keyboard [keys a, b, c, d] in order to select the correct answer. Press the space bar to continue’.

Experiment 1 (PIT first, Devaluation afterwards)

3. Pavlovian-to-Instrumental Transfer

'Now you and your group are going to be tested about the knowledge you have acquired so far. The aim of this phase is to optimize the process before going to the street to obtain products. Remember that you will be able to get them by tilting the machine to the left (Key B) or the right (Key N) in the way that you learnt in the first phase. Again, use only your dominant hand. Depending on the key you press, you will get one product or the other. However, in this phase you will not see images on the screen, although your task is still to obtain as many snacks as you can in the most efficient way. Additionally, consider the colour that the machine occasionally shows because this will give you a clue about which product is more likely to fall in a given time, as you learnt during the second phase. In summary, press keys 'B' and 'N' during the task in order to get products, as you did during the first phase. Likewise, take into account the colours that will occasionally light up in the machine in order to know which product is more likely to fall, according to what you have learned during the second phase. Finally, note that the task will last for approximately 7 minutes. Use this time to gain as many products as you can so the impoverished children can have the best birthday party of their lives. Press the space bar to continue'.

4. Outcome Devaluation

'Congratulations, you have successfully passed the test and are now on the street with your group trying to get goodies for the impoverished children. You and your group are in an area with plenty of vending machines, thus it looks like a good place to start. However, one of you has discovered that the machines are infested!

Disgusting insects have invaded some of the snack packages. When you tilt the machine, one of the products will be shared with these new inhabitants. Not all the snack packages, but half of them. Next you can see an image showing an instance of the state of half of the packages of that specific product. Pay close attention during the time the image is presented.

(After watching the image)

This is really a problem because, on the one hand, you need to get as many products as you can and, on the other, half of the packages of one of the products are infested with the insects. Remember that you will keep getting snacks by tilting the machine to the left (Key B) or to the right (Key N), as you learnt during the first phase. Again, use only the pointing finger of your dominant hand. Depending on which key you press, you will get one product or the other. However, in this phase you will not see the images of the products on the screen, although your task is still to obtain as many products as you can in the most efficient way. Go ahead, press the space bar to continue and get goodies for the impoverished children'.

<u>Experiment 2 (Devaluation first, PIT afterwards)</u>

'Congratulations, you have successfully passed the test and are now on the street with your group trying to get goodies for the impoverished children. You and your group are in an area with plenty of vending machines, thus it looks like a good place to start. However, one of you has discovered that the machines are infested! Disgusting insects have invaded some of the snack packages. When you tilt the machine, one of the products will be shared with these new inhabitants. No all the snack packages, but half of them. Next you can see one image showing an instance of the state of half of the packages of that specific product. Pay close attention during the time the image is presented.

(After watching the image)

This is really a problem because, on the one hand, you need to get as many products as you can and, on the other, half of the packages of one of the products are infested with the insects.

Now you get snacks by tilting the machine to the left (Key B) or to the right (Key N), as you learnt during the first phase. Again, use only the pointing finger of your dominant hand. Depending on which key you press, you will get one product or the other. However, in this phase you will not see the images of the products on the screen, although your task is still to obtain as many products as you can in the most efficient way. Depending on the key you press, you will get one product or another. Additionally, consider the colour that the machine occasionally shows because this will give you a clue about which product is more likely to fall in a given time, as you learnt during the second phase.

In summary, press the keys 'B' and 'N' during the task in order to get products, as you did during the first phase. Likewise, take into account the colours that will occasionally light up in the machine in order to know which product is more likely to fall, according to what you learned during the second phase.

Finally, note that the task will last for approximately 7 minutes. Use this time to gain as many products as you can so the impoverished children may have the best birthday party of their lives. Press the space bar to continue'.

Appendix B:

Can We Reduce Craving Experience in the Laboratory and Real-Life Contexts?

|Appendix B

Appendix B.1: Procedural Details in Experiment 1

1. Induction of Craving for Chocolate: Visual and Olfactory Sensory Analysis.

First, participants assessed *brightness* using a slide bar (VAS) anchored by 'dull' and 'extremely bright'. Second, they evaluated the *colour* by choosing one of the provided options (light ivory, yellow, cinnamon, reddish brown, dark brown, black, 'other', to be specified by the participant); *texture* was evaluated by encouraging the participant to touch the chocolate bean if needed (smooth, rough, grainy, other); and *odour* was evaluated using a number of options (wood, cinnamon, cacao, milk, vanilla, nuts, fruit, roasted, plastic, other); whilst they were asked to select all the options that applied when imagining the *flavour* they believed would correspond to this specific chocolate based on the visual and olfactory features (alcohol, cereal, creamy, milky, hot, easily melted, fruity, toffee, almond, sweet, salty, sour, other). To this end, we constructed a specific online questionnaire adapted from one previously used by the authors to accomplish a rather different goal involving an actual sensory analysis procedure. Participants completed the questionnaire at their own pace. They were encouraged to take all the time they needed to look, smell, and touch the chocolate in order to obtain as much information as they needed to make the evaluation. Importantly, they were warned they should not taste or eat the chocolate. These data were not analysed.

2. Consumption: Bogus taste test procedure

Participants completed the online questionnaire at their own pace. First, they had to evaluate the intensity of the *taste* using a slide-bar anchored with 'not intense at all' and 'extremely intense'. Second, they had to decide which of the following *flavour* features were 2 present in the chocolate: flavours of alcohol, cereal, diary, fruit, almond, toffee, 'other '(to be specified by the participant), or whether it melted easily. Third, they focused on *taste*: salty, sweet, sour, acid, hot, or other. Finally, they assessed the *texture* or sensation in the mouth (smooth, rough, grainy, crunchy, foamy, creamy, soft, or 'other'). The participants were encouraged to take the time they needed and taste (eat) as much chocolate as they needed or wanted in order to answer each question.

3. Mindfulness Formal and Informal Practice

Few participants practice mindfulness either in the present or in the pass. Most of the participants had not previously practiced *formal* mindfulness, Q1, either in group experimental (n = 17) or control (n = 13), whilst some of them had in the past, (experimental, n = 4; control, n = 6); and even fewer reported practicing it at the moment (experimental, n = 2; control, n = 3). There were no between-group differences in the percentages, $\chi2$ (2) = 1.11, p = .574. A few of the participants reported being involved in *informal* mindfulness practice, Q4, (experimental, n = 1; control, n = 2), or had done so in the past (experimental, n = 4; control, n = 4). The remainder reported no previous experience in informal mindful practice (experimental, n = 18; control, n = 16).

Appendix B.2: Audio Clips Descriptions

1. English Version

Cognitive Defusion[9]

Now that your headphones have been fitted comfortably, please close your eyes. Sitting on your chair, feet flat on the floor and hands resting in your lap.

Focus on your breath, feeling how the air moves in and out of your body. You may feel sensations in your body, notice them but allow them to pass. Notice any thoughts that come to your mind, staying within the present moment. Try to focus all of your attention on any thought you have in mind. Sometimes, we are able to see thoughts more clearly if we take a step back from them. We can become fused to our thoughts, when we believe our thoughts to be true without questioning them. But this is not always the case. Sometimes it is useful to take a step back from your thoughts, to consider whether they align with your goals, values and beliefs. It can be helpful to think of yourself as different or separate to your thoughts. They are creations of your mind, and can sometimes be different to your intentions. Sometimes we believe that thoughts are causal to actions, that because our thoughts are true, we must act on them. But this is not always the case. Notice the thoughts you are having now. Take a moment to step back from them, viewing them as merely thoughts. When you become more aware that you are having a thought, you will notice that it will soon fade, similar to the way leaves might float away on a stream. Whatever thoughts you are having at this moment, stay present with them. Do not try to change or challenge them, just let them exist. Consider your thoughts as

[9] From Schumacher, S., Kemps, E., & Tiggemann, M. (2018). Cognitive defusion and guided imagery tasks reduce naturalistic food cravings and consumption: A field study. Appetite, 127, 393–399. https://doi.org/10.1016/j.appet.2018.05.018 (Appendix A).

merely thoughts, and do not judge them. If you sit with your thoughts, you will be able to ride them like a wave, even if they become stronger and more powerful, eventually they will fade. You are in control of your actions, and you do not need to act on your thoughts. You are in charge of your own thoughts, just like you are separate from them. You can decide whether you will act on them or not. Notice any thoughts you are having at this moment. Step back from them and view them for what they are, just thoughts. Focus your attention again on your breathing. Notice the way your breath moves in and out of your lungs. And when you feel ready, open your eyes and once again take in the room.

Control[10]

Now that your headphones have been fitted comfortably, please close your eyes. Sitting on your chair, feet flat on the floor and hands resting in your lap. Now you will listen a narration Please, pay attention until its end.

Happy families are all alike; every unhappy family is unhappy in its own way. Everything was in confusion in the Oblonskys' house. The wife had discovered that the husband was carrying on an intrigue with a French girl, and she had announced to her husband that she could not go on living in the same house with him. This position of affairs had now lasted three days, and not only the husband and wife themselves, but all the members of their family and household, were painfully conscious of it. Every person in the house felt that there was no sense in their living together, and that the stray people brought together by chance in any inn had more in common with one another than they. The wife did not leave her own room, the

[10] Selected fragments from the English version of the beginning of the novel *Anna Karenina* by Leon Tolstoy available at https://www.weblitera.com/sync/?id=15&l1=5&l2=1&l=ru

husband had not been at home for three days. The children ran wild all over the house; the English governess quarreled with the housekeeper, and wrote to a friend asking her to look out for a new situation for her; the man-cook had walked off the day before just at dinner time; the kitchen-maid, and the coachman had given warning. Three days after the quarrel, Prince Stepan Arkadyevitch Oblonsky—Stiva, as he was called in the fashionable world—woke up at his usual hour, that is, at eight o'clock in the morning, not in his wife's bedroom, but on the leather-covered sofa in his study. He turned over his stout, well-cared-for person on the springy sofa, as though he would sink into a long sleep again; he vigorously embraced the pillow on the other side and buried his face in it; but all at once he jumped up, sat up on the sofa, and opened his eyes. And at this recollection, Stepan Arkadyevitch, as is so often the case, was not so much annoyed at the fact itself as at the way in which he had met his wife's words. There happened to him at that instant what does happen to people when they are unexpectedly caught in something very disgraceful. He did not succeed in adapting his face to the position in which he was placed towards his wife by the discovery of his fault. Instead of being hurt, denying, defending himself, begging forgiveness, instead of remaining indifferent even--anything would have been better than what he did do--his face utterly involuntarily utterly involuntarily assumed its habitual, good-humored, and therefore idiotic smile.

These are the final words of the narration. When you feel ready, open your eyes and once again take in the room.

2. Spanish Version

<u>Cognitive Defusion</u>[11]

Ahora que ya te has colocado confortablemente los auriculares, por favor cierra tus ojos. Sentada en la silla, apoya con las plantas de los pies en el suelo y deja tus manos reposar sobre tu regazo.

Concéntrate en tu respiración. Siente cómo el aire entra y sale por tu nariz. Puede que notes sensaciones en tu cuerpo, fíjate en ellas un momento, pero permítelas ir. Fíjate también en cualquier pensamiento que acuda a tu mente, permaneciendo en el momento presente. Trata de focalizar toda tu atención en cualquier pensamiento que tengas en mente. Algunas veces, somos capaces de ver los pensamientos más claramente si damos un paso atrás y nos distanciamos de ellos. En ocasiones, podemos sentirnos fundidos con nuestros pensamientos, como cuando creemos que son verdaderos sin cuestionarlos. Pero no siempre es así. A veces es útil distanciarse de ellos para considerar si se alinean con nuestros objetivos, valores y creencias. Puede ser útil que te consideres a ti misma como algo separado de tus pensamientos. Son creaciones de tu mente y pueden, en ocasiones, diferir de tus intenciones. A veces, creemos que los pensamientos son causa de nuestras acciones, que porque creemos que son verdaderos debemos actuar conforme a ellos. Pero no es así siempre. Fíjate en los pensamientos que tienes ahora. Toma un momento para distanciarte de ellos considerándolos meramente como pensamientos. Cuando te vuelves más consciente de que estas teniendo un pensamiento, notarás que pronto se desvanecerá, de manera similar a como una

[11] From Schumacher, S., Kemps, E., & Tiggemann, M. (2018). Cognitive defusion and guided imagery tasks reduce naturalistic food cravings and consumption: A field study. Appetite, 127, 393–399. https://doi.org/10.1016/j.appet.2018.05.018 (Appendix A).

hoja se desprende de una rama. Cualesquiera que sean los pensamientos que tienes en este momento, permanece presente con ellos. No trates de cambiarlos o desafiarlos, solo déjalos estar. Considera tus pensamientos meramente como pensamientos, y no los juzgues. Si permaneces atenta a tus pensamientos, serás capaz de cabalgarlos como una ola, incluso si se vuelven más fuertes e intensos, en algún momento se desvanecerán. Tienes el control de sus acciones y no necesita actuar en base a ellos. Estás al mando de tus pensamientos, igual que estás separada de ellos. Puedes decidir actuar conforme a tus pensamientos o no. Fíjate en cualquier pensamiento que tengas ahora mismo. Da un paso atrás y distánciate de él, y considéralo como lo que son, son solo pensamientos.

Ahora, pon otra vez tu atención en la respiración. Nota cómo el aire entra y sale de tus pulmones. Y, cuando estés preparada, abre tus ojos y vuelve a la sala.

Control[12]

Ahora que ya te has colocado confortablemente los auriculares, por favor cierra tus ojos. Sentada en la silla, apoya con las plantas de los pies en el suelo y deja tus manos reposar sobre tu regazo. A continuación, escucharás una narración. Por favor, presta atención hasta que se te indique su final.

Todas las familias felices se parecen unas a otras; pero cada familia infeliz tiene un motivo especial para sentirse desgraciada. En casa de los Oblonsky andaba todo trastrocado. La esposa acababa de enterarse de que su marido mantenía relaciones con la institutriz francesa, y se había apresurado a declararle que no podía seguir viviendo con él. Semejante situación duraba ya tres días y era tan

[12] Selected fragments from the English version of the beginning of the novel *Anna Karenina* by Leon Tolstoy available at https://www.weblitera.com/sync/?id=15&l1=5&l2=1&l=ru

dolorosa para los esposos como para los demás miembros de la familia. Todos, incluso los criados, sentían la íntima impresión de que aquella vida en común no tenía ya sentido, y que, incluso en una posada, se encuentran más unidos los huéspedes de lo que ahora se sentían entre ellos. La mujer no salía de sus habitaciones; el marido no comía en casa desde hacía tres días; los niños corrían libremente de un lado a otro sin que nadie les molestara. La institutriz inglesa había tenido una disputa con el ama de llaves y escribió a una amiga suya pidiéndole que le buscase otra colocación; el cocinero se había ido dos días antes, precisamente a la hora de comer; y el cochero y la ayudante de cocina manifestaron que no querían continuar prestando sus servicios allí y que solo esperaban que les saldasen sus haberes para irse. El tercer día, después de la escena tenida con su mujer, el príncipe Esteban Arkadievich Oblonsky –Stiva, como le llamaban en sociedad–al despertar a su hora de costumbre, es decir, a las ocho de la mañana, se halló, no en el dormitorio conyugal, sino en su despacho, tendido sobre el diván de cuero. Volvió su cuerpo, lleno y bien cuidado, sobre los flexibles muelles del diván, como si se dispusiera a dormir de nuevo, a la vez que, abrazando el almohadón, apoyaba en él la mejilla. De repente se incorporó, se sentó sobre el diván y abrió los ojos. Y ahora, al recordarlo, lo que más contrariaba a Esteban Arkadievich en aquel asunto no era el hecho en sí, sino la manera cómo había contestado entonces a su esposa. Le había sucedido lo que a toda persona sorprendida en una situación demasiado vergonzosa: no supo adaptar su aspecto a la situación en que se encontraba. Así, en vez de ofenderse, negar, disculparse, pedir perdón o incluso permanecer indiferente –cualquiera de aquellas actitudes habría sido preferible–hizo una cosa ajena a su voluntad sonreír, sonreír con su sonrisa habitual, benévola y, en aquel, caso necia.261

Con estas palabras, finaliza la narración. Por favor, cuando estés preparada, abre tus ojos y vuelve de nuevo a la sala.

Appendix B.3: Passive Control Condition (Unpublished Data).

Visuospatial Sketchpad Load: The Effect of Playing Tetris on Induced Craving Against a Passive Control Condition

1. *Participants*

The final sample consisted of 42 participants (age, *M* = 20.93, *SD* = 2.23, range 18-30). Their average BMI was 22.04 (*SD* = 4.58, range 15.57 – 44.06), which is considered to be within the healthy weight range. Using BMI weight categories for 3 classification, five participants (11.90%) were underweight (BMI < 18.5), twenty-nine (69.05%) were in the healthy weight range (BMI of 18.5 – 24.9), seven (16.67%) were overweight (BMI of 25-30), and one (2.38%) was obese (BMI > 30). The sample was split into two-halves.

2. *Procedure*

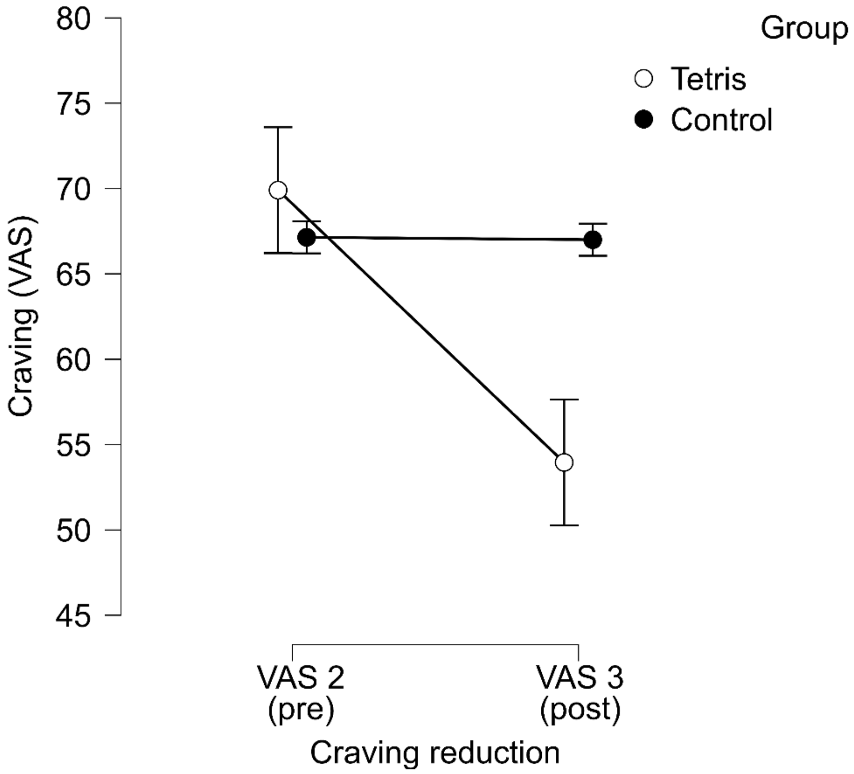
After craving induction [identical to that described in the case of cognitive defusion in Experiment 1] and craving assessment (VAS 2), participants were asked to play Tetris on the computer. In the case of the control group, the program never loaded (for a similar procedure, see Skorka-Brown et al., 2014) and they were told that "today we are having problems with the connection; do not worry and keep going with the rest of the experiment if this fails". After 3 mins of playing/waiting, participants were asked to complete the last VAS craving assessment (VAS 3).

3. *Results*

The RM-ANOVA conducted on the craving scores with group (Tetris vs. control), as the between-subject factor, and timepoint with respect to the craving-reduction intervention (pre: VAS 2 vs. post: VAS 3) as the within-subject factor, yielded a significant main effect of timepoint, $F(1, 40) = 8.95$, $p = .005$, $\eta^2_p = .183$, as well as a group x timepoint interaction, $F(1, 40) = 8.63$, $p = .005$, $\eta^2_p = .177$ (Figure B.2.1). Simple main effects analysis confirmed that the reduction in craving was significant in group Tetris, $p = .006$, but not in group control, $p = .915$. The main effect of group was not significant, $F < 1$.

Figure B.2.1

Mean Self-Reported Level of Craving for Chocolate, as Measured by VAS Following Craving Induction (VAS 2, pre) and Following the Craving Reduction Procedure (VAS 3, post) for Groups Tetris and Control



Note. Bars represent ±SEMs.

Appendix C:

Does Expertise Affect the Sensory and Liking Experience of Consuming a Food Reward?

Appendix C.1: Sensory Analysis

Table C.1.1

Explicit Measures: Mean Quality and Hedonic Judgments (range 0–5) According to Group and Beverage (Standard Deviation)

Quality judgment	Visual	Olfactory	Gustatory	Hedonic
Water				
Experts	2.88 (1.73)	2.44 (1.92)	2.56 (1.82)	3.39 (0.85)
General	2.50 (1.93)	2.00 (1.86)	2.42 (1.73)	3.58 (0.67)
Consumers	2.77 (1.72)	1.86 (2.10)	2.67 (2.08)	3.59 (1.37)
Lager 1				
Experts	3.50 (0.51)	3.17 (0.38)	3.17 (0.62)	3.11 (0.58)
General	3.08 (0.66)	3.00 (0.58)	2.83 (0.71)	2.77 (0.60)
Consumers	3.39 (0.72)	3.04 (0.82)	2.83 (0.98)	2.57 (1.31)
Lager 2				
Experts	3.28 (0.75)	3.11 (0.68)	2.94 (0.42)	3.00 (0.59)
General	3.31 (0.48)	2.77 (0.60)	2.85 (0.69)	3.00 (0.58)
Consumers	3.18 (0.80)	2.86 (0.71)	3.18 (1.14)	2.91 (1.15)
Extra 1				
Experts	3.83 (0.51)	3.56 (0.62)	3.89 (0.68)	3.72 (0.67)
General	3.62 (0.51)	3.31 (0.63)	3.31 (0.75)	3.15 (0.69)
Consumers	3.52 (0.79)	3.39 (1.08)	3.48 (1.08)	3.26 (1.21)
Extra 2				
Experts	3.67 (0.77)	3.61 (0.61)	3.72 (0.75)	3.61 (0.70)
General	3.62 (0.51)	3.38 (0.65)	3.38 (0.51)	3.23 (0.83)
Consumers	3.26 (0.81)	3.22 (0.80)	3.52 (0.95)	2.87 (1.10)

Table C.1.2

Statistically Significant Correlations Between Reliable Components (RC) Activity and Quality Judgment for each Group

Group	RC Function	RC	Quality judgement	Beverage	*r*
E	Hedonic	3	Gustatory	Extra 1	-.76
	Hedonic	2	Hedonic	Extra 1	.71
	Recognition	15	Hedonic	Extra 1	-.67
	Recognition	8	Hedonic	Lager 2	-.68
	Recognition	8	Gustatory	Extra 2	.75
	WM	1	Gustatory	Lager 2	-.77
	WM	7	Hedonic	Lager 2	-.75
	WM	7	Gustatory	Lager 2	-.67
	WM	1	Hedonic	Lager 1	.71
G	Hedonic	3	Hedonic	Lager 2	.83
	Hedonic	12	Gustatory	Lager 1	-.84
	Hedonic	2	Gustatory	Lager 1	.80
	Recognition	8	Visual	Lager 2	.84
C	Hedonic	2	Hedonic	Extra 2	-.58
	Recognition	15	Gustatory	Extra 1	-.58
	Recognition	8	Gustatory	Lager 2	.57
	Recognition	10	Olfactory	Extra 2	.60

Note. **E = Experts, G = General, C = Consumers; WM = working memory.**

Table C.1.3

Statistically Significant Pair-Wise Contrasts Found for the Relationship between RC Activity and Quality Judgements

Contrast (Group 1- Group 2)	**RC Function**	**RC**	**Quality judgment**	**Product**	**Explicit-Implicit correlation**		**z**
					Group 1 r	Group 2 r	
E-C	Hedonic	2	Hedonic	Extra 2	.35	-.58*	2.68
	Recognition	8	Gustatory	Extra 2	.75*	-.09	2.80
	WM	1	Gustatory	Lager 2	-.77*	.19	-3.15
	WM	7	Gustatory	Lager 2	-.67*	.31	-2.94
	WM	7	Hedonic	Lager 2	-.75*	.24	-3.17
G-C	Hedonic	12	Gustatory	Lager 1	-.84*	.08	-2.78

Note. E = Experts, G = General, C = Consumers, * = significant *p*-value ($p < .01$)

<u>Radar charts. Mean intensity for each sensory attribute by group and beverage. A = aroma (olfactory phase); G = retronasal aroma (gustatory phase).</u>

Figure C.1.1

Water. Mean Intensity Judgement of each Sensory Attribute by Group

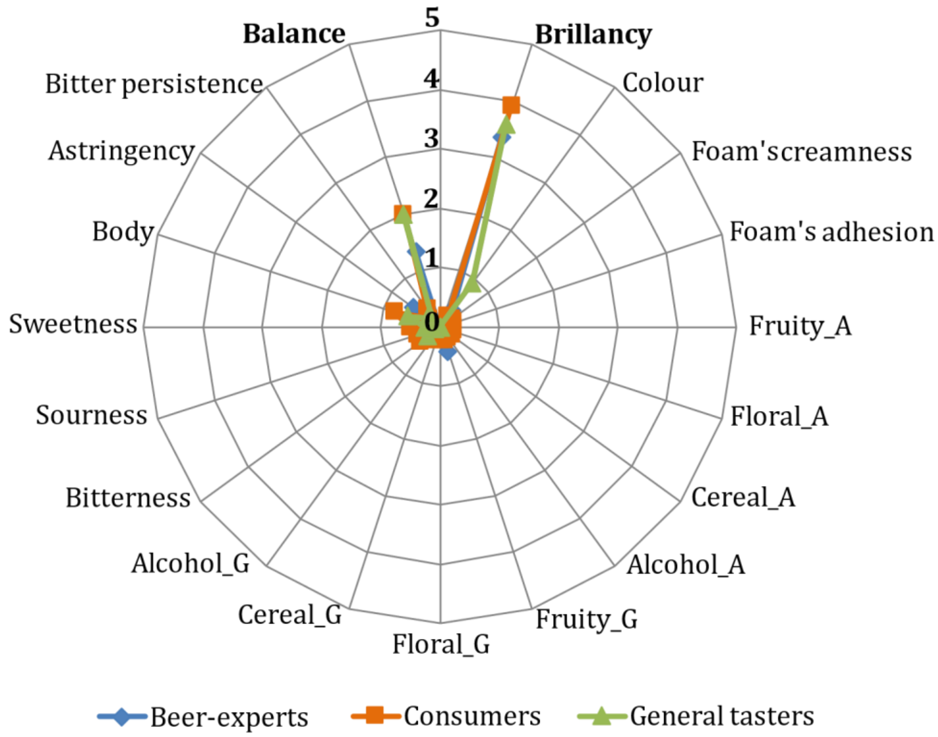


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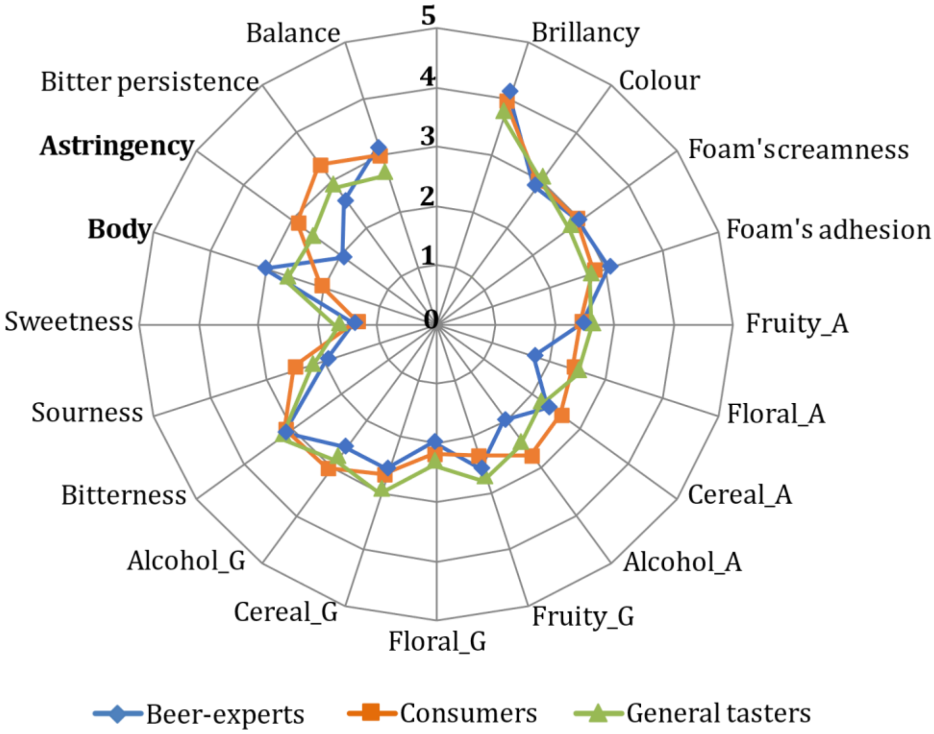
Figure C.1.2

Lager 1. Mean Intensity Judgement of each Sensory Attribute by Group



|Appendix C

Figure C.1.3

Lager 2. Mean Intensity Judgement of each Sensory Attribute by Group

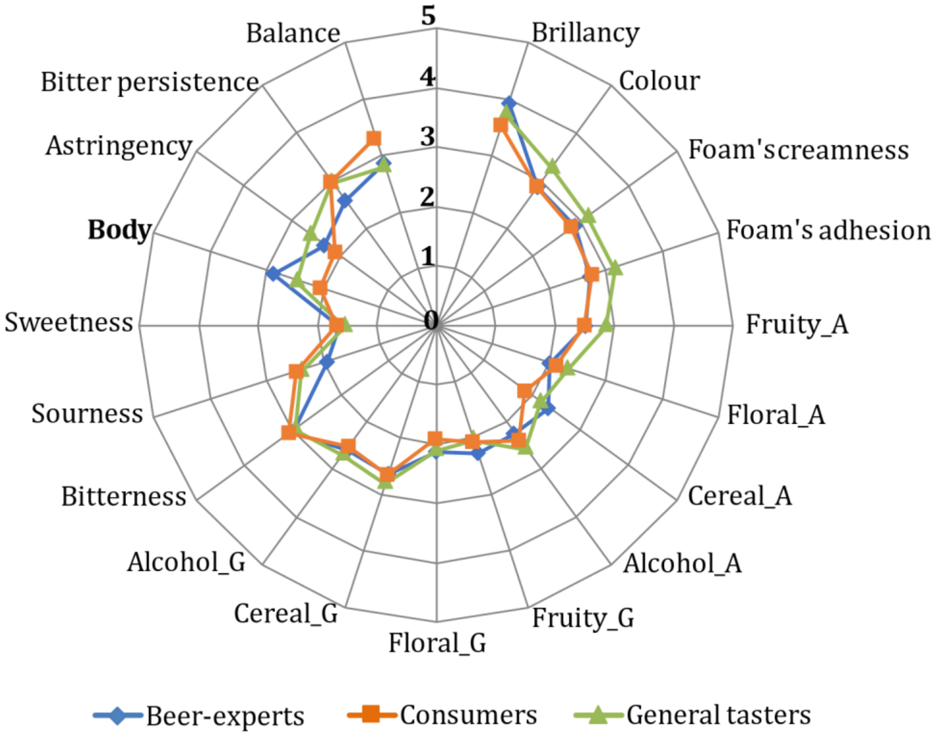


Figure C.1.4

Extra 1. Mean Intensity Judgement of each Sensory Attribute by Group

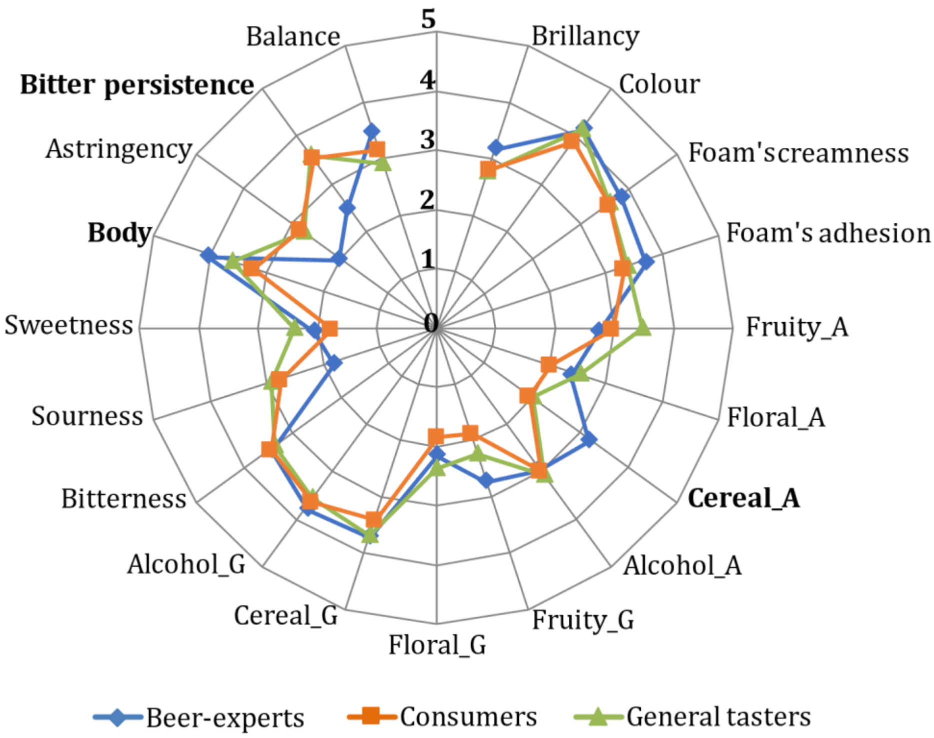
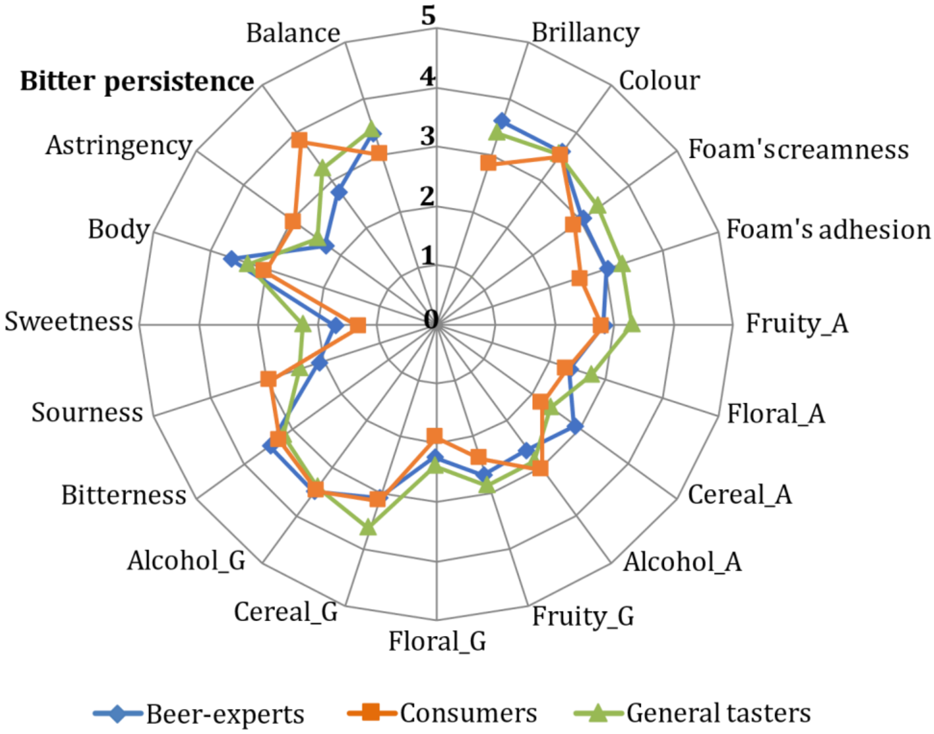


Figure C.1.5

Extra 2. Mean Intensity Judgement of each Sensory Attribute by Group



Appendix C.2: EEG: Reliable Component Analysis

Figure C.2.1

Reliable Component Analysis. Source of Correlated Neural Activity for the 15 Most-Reliable Components in Six Orthogonal Brain Views, for the Whole Sample (Beer-Experts, General Tasters, and Consumers

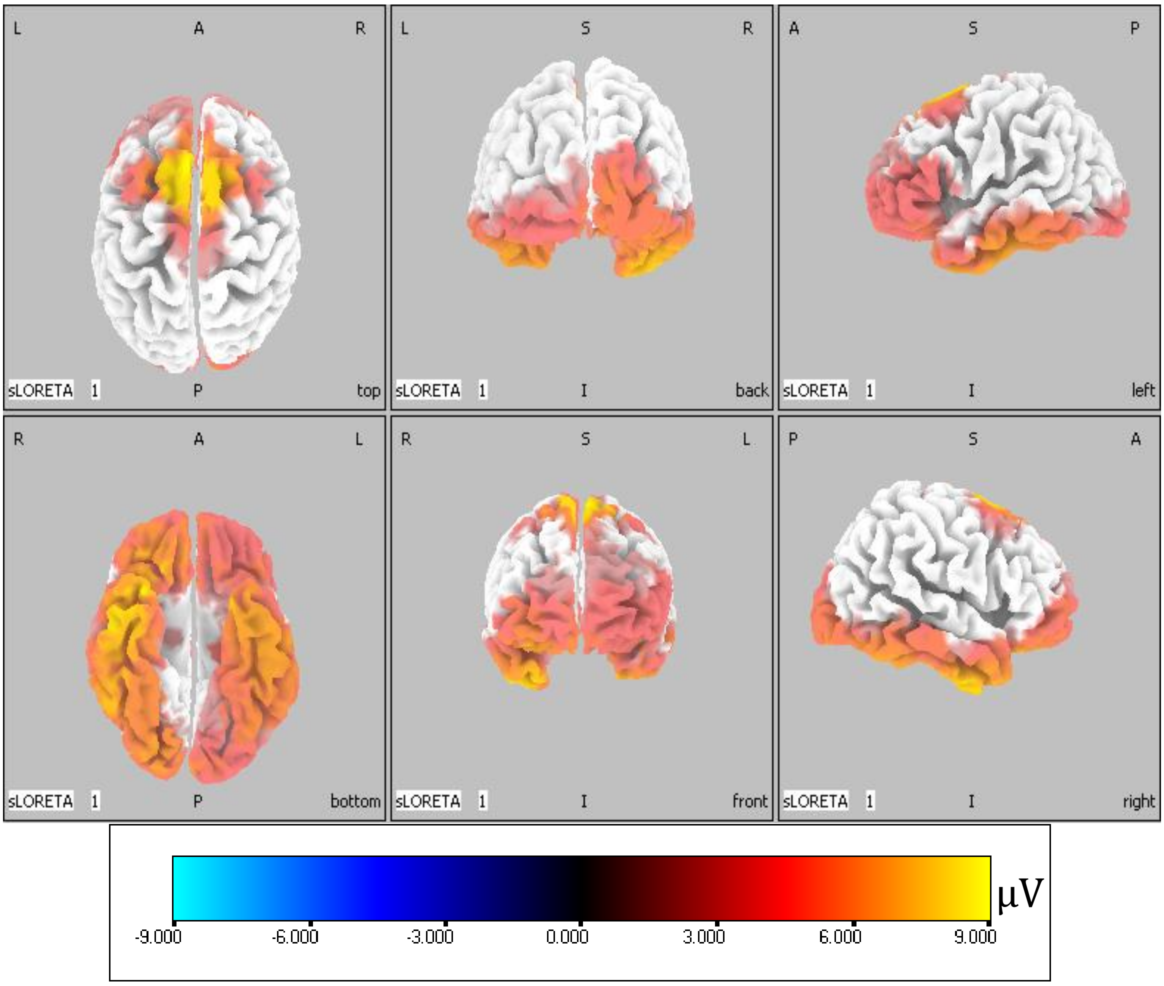


Figure C.2.2

Axial Brain Sections of the Reliable Component Analysis Results for the whole Sample

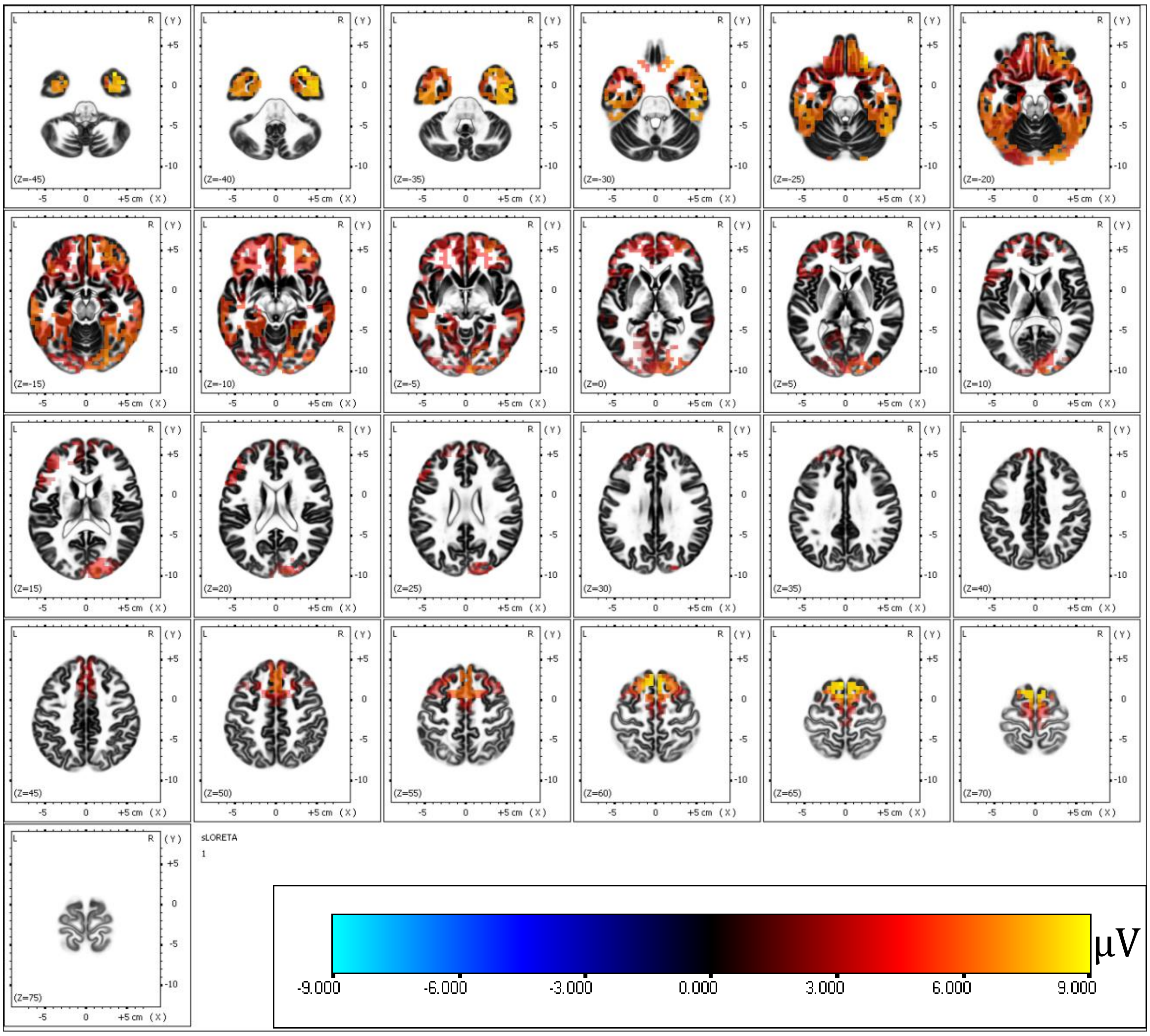


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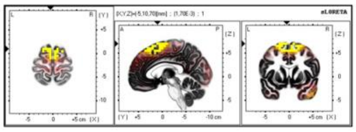
Figure C.2.3

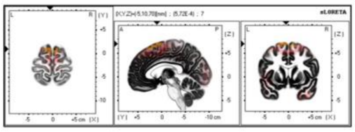
Brain Sections showing the Estimated Localization (Brodmann Areas inside Brackets) and Functional Group for each Reliable Component for the Whole Sample

1. **Working memory**

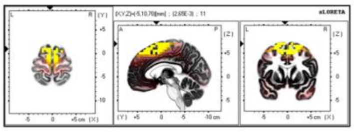
RC 1. Bilateral superior frontal gyrus (BA 6)



RC 7. Bilateral superior frontal gyrus (BA 6)

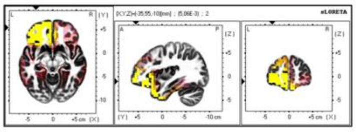


RC 11. Bilateral superior frontal gyrus (BA 6)

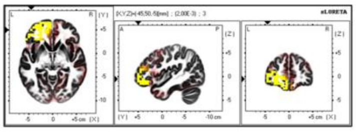


2. **Hedonic**

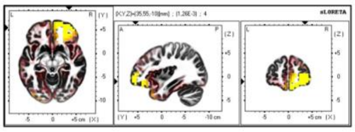
RC 2. Left medial prefrontal cortex (BAs 10, 11)



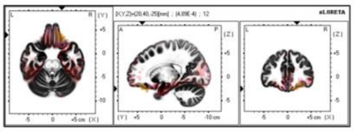
RC 3. Left medial prefrontal cortex (BAs 10, 11, 47)



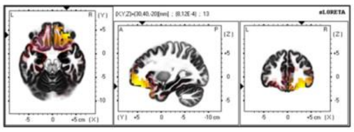
RC 4. Right medial prefrontal cortex (BAs 10, 11, 47)



RC 12. Right orbitofrontal cortex (BAs 11, 47)

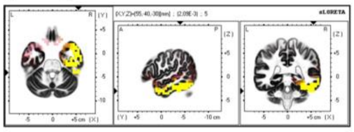


RC 13. Right orbitofrontal cortex/ Medial prefrontal cortex (BAs 10, 11)

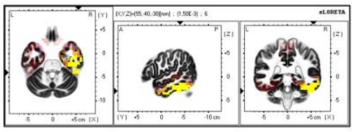


3. **Recognition memory**

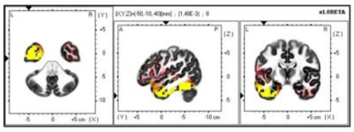
RC 5. Right fusiform gyrus (BA 20)



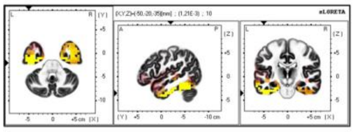
RC 6. Right fusiform gyrus (BA 20)



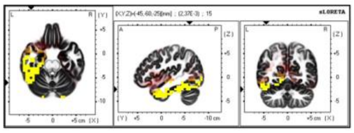
RC 8. Left fusiform gyrus (BA 20)



RC 10. Left fusiform gyrus (BA 20)

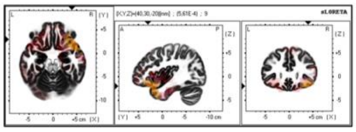


RC 15. Left fusiform gyrus (BA 37)



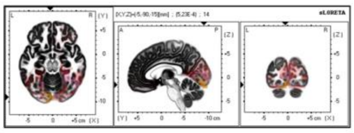
4. **Retrieval memory**

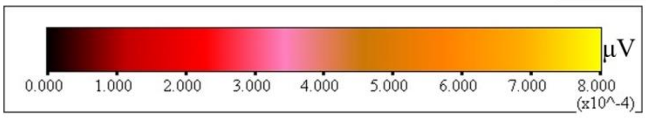
RC 9. Right inferior frontal/superior temporal gyrus (BAs 38, 47)



5. **Visual Processing**

RC 14. Left lingual gyrus (BAs 17, 18)





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