Cognitive Processes in Acquiring Food Preferences:

Evaluative Conditioning Studies with Food-Related Stimuli

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Abstract

In this thesis, [1]we explored the potential of EC interventions with food-related stimuli to form and modify food preferences. The main research questions within this dissertation revolve around the role of memory in EC, the potential preparedness effect for smell-taste combinations and the hypothesized differential learning patterns between normal weight and obese participants in processing high-calorie palatable foods.

In Chapter 2, we present evidence for the relevance of memory and the preparedness of smell-taste pairings in EC. In Experiment 1, we tested the role of memory in smell-taste EC. In Experiment 2, we investigated the role of memory more conclusively and tested for the presence of the preparedness of smell-taste combinations. The results show that both in Experiment 1 and in Experiment 2 we found EC effects only in the presence of memory. Furthermore, the results of Experiment 2 support the preparedness hypothesis for smell-taste pairings in EC.

In Chapter 3, we tested the role of memory for food CS-US pairings and looked at the preparedness hypothesis for smell-taste combinations in an EC study with real foods as CSs. We measured EC effects in the explicit evaluative ratings and in food consumption of food CSs. The results showed no overall EC effects neither in the explicit evaluative ratings, nor in food consumption. Nonetheless, we found that participants consumed more of food CSs that had previously been paired with pleasant USs, but only when participants remembered CS-US pairings. Interestingly, for non-remembered pairings the pattern of the results was reversed.

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[1] In this thesis, I chose to use the personal pronoun "we" instead of "I" to acknowledge the involvement of my co-workers. The presented research findings are a result of team effort. However, by using the pronoun “we” – by no means - I mean to deny full responsibility for my dissertation. Credit to Anne Gast for her contribution in all the three lines of studies described within this thesis, and, to Simone Dohle for co-operation within the project presented in Chapter 3.

In Chapter 4, we investigated the hypothesized differences in learning effects between normal weight and obese participants in a computerized EC procedure with high-calorie and tasty-looking foods as CSs. We compared the magnitude of EC effects measured in the explicit evaluative ratings (Experiment 4, 5) and in the intention to consume food CSs (Experiment 4) between the two groups. We also looked at group differences in the accuracy at the guessing trials within the implemented EC paradigm. The results showed overall EC effects measured both in the explicit evaluative ratings and in the intention to consume foods. These learning effects were moderated by valence memory. We did not, however, find any evidence to support the hypothesized differences in the magnitude of learning effects between normal weight and obese individuals.

Together, the research findings described in this dissertation make significant contribution to the existing body of knowledge on the role of memory in EC, especially in EC studies with food-related stimuli. We also provide first evidence for the preparedness of smells and tastes which has a yet to-be-explored applied value in the domain of forming food preferences.

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CHAPTER 1: General Introduction – The Origins of Food Preferences

"To eat is a necessity, but to eat intelligently is an art."
François de la Rochefoucauld (1613-1680)

Food is one of the basic needs that humans require to survive. What we eat significantly contributes to our mental and physical well-being, and we spend a substantial amount of time and resources on food-related tasks (Rozin, Fischler, Imada, Sarubin, & Wrzesniewski, 1999). One could say, from a biological perspective, eating is simply a way of providing our bodies with necessary nutrients; yet, research shows it is much more than that. Food is in fact rated as one of the main sources of pleasure in people's everyday life (Rozin, 1990). Thus, the rewarding value of eating could be one of the driving mechanisms of food choices, especially since liking of foods may be one of the main factors contributing to food consumption behaviors (Martins & Pliner, 2005). Yet, when one eats beyond nutritional motives, and seeks food for pleasure even when satiated, it could lead to the development of serious health problems. One of many potential consequences of such non-homeostatic eating behaviors (e.g., overeating) is obesity.

Obesity, with its prevalence systematically rising worldwide (Ng et al., 2014), is an urgent issue yet to be tackled. Associated with serious health consequences and manifesting in the quality of life as well as the life expectancy itself, obesity has been a subject of thorough investigation in the last decades. However, despite extensive research, we are still unsure about the reasons why people develop preferences for objectively unhealthy choices and researchers did not find a successful way to help people lose (and maintain) body weight, and, develop healthier eating patterns. Specifically, studies show that dieting programs are often unsuccessful and that almost half of the people who sought help losing weight within professional weight loss programs, report to have gained even more weight than when they had started the program (baseline) a few years following the interventions (Mann et al., 2007).

In this dissertation, we focus on learning mechanisms contributing to, and, potentially forming healthier food preferences, suggesting evaluative conditioning (EC) interventions as a way to change attitudes towards foods.

1.1 The Twofold Nature of Food Preferences

Needless to say, whether we like or dislike a food product vastly determines whether or not we will want to consume it or not. But what really determines whether a food is to our liking or not? Taste is reported to have the most substantial impact on our food choices, with sociocultural and economic factors being rated as less influential (Drewnowski, 1997). The forthcoming section will summarize the state of the literature on mechanisms underlying food preferences.

1.1.1 Innate food (dis)likes.

Despite individual differences in liking of tastes, sugary foods are consistently reported to be the most liked (e.g., McCaughey, 2008; Mennella, Bobowski, & Reed, 2016), and bitter foods as universally disliked (e.g., Mennella, Bobowski, & Reed, 2016; Mennella & Bobowski, 2015). Humans have an ability to distinguish between five major taste types: sweet, sour, bitter, salty and umami. Based on chemicals present in food, humans can identify and categorize nutrients and toxins with their sense of taste (Breslin & Spector, 2008). For example, it is assumed that foods rich in fats and carbohydrates are perceived as sweet in taste, and foods containing toxic chemical compounds are bitter in taste (Breslin, 2013). Hence, the ability to identify sweet and bitter tastes has an important evolutionary aspect as it helps people choose energy-dense foods and avoid consuming foods that are potentially harmful.

The reasons why sugars are liked could be related to particular biochemical properties of sugars, which have been associated with pain relief and improved mood (Blass & Shah, 1995). When sugar is consumed, endogenous opiates – known to reduce pain – are released, blocking pain afferents (e.g., Fernandez et al., 2003; Lindqvist, Bealemans, & Erlanson-Albertsson, 2008). As a result, consuming sweets could improve mood or relieve stress via opioidergic neural routes. Greenberg (2002) studied these calming properties of sugars in the context of painful medical examinations on children and infants, showing that administering of sugar-coated pacifiers significantly reduced pain in infants. Recent studies done in the context of needle-related pain confirm the notion of pain-relieving properties of sugar. Simultaneously administering sucrose-based solutions during needle-related procedures significantly reduced pain, and it made the examination more bearable for patients (Kassab, Foster, Foureur, & Fowler, 2012).

Early studies on food preferences in human infants suggested that innate preferences for sweet and dislikes for bitter are present at very early age (Birch, 1999). Desor, Maller and Turner (1973) suggest that the preference for liking sweet taste - typically associated with foods rich in sugars and carbohydrates - is present among human neonates already in the first hours after birth. The authors reported a strong preference for a glucose-based solution over a pure water solution, as the neonates consumed significantly more of the glucose-based solution. Interestingly, a similar pattern of results was found in animal studies on non-verbal facial expressions in response to sugary and bitter water solutions (Steiner, 1997). Non-human primates exhibited non-verbal facial movements categorized as “acceptance” when consuming sweetened drinks and “rejection” facial movements when consuming drinks combined with bitter substances (Steiner & Glaser, 1984; Steiner & Glaser, 1995).

1.1.2 Learnt food (dis)likes.

Despite some findings suggesting that we are born with tendencies to favor (e.g., preference for sweet taste) and avoid (e.g., dislike of bitter taste) particular tastes, our food preferences are not set in stone. A growing body of research suggests that people's preferences do change across their lifespan and that food (dis)likes can be modified through experience (Birch, 1999). Importantly, however, whether these early taste preferences are actually indicative of the actual innate preferences is unclear as some authors suggest that human food preferences might be formed as early as in mother's womb (Mela, 1999).

In line with this idea, research shows that the first evidence for experience-based learning can be found as early as in prenatal and postnatal periods of humans' life (Mennella, Coren, Jagnow, & Beauchamp, 2001). Mennella and colleagues (2001) investigated how mothers' diets during pregnancy influenced early food preferences of their newborns. Pregnant women were assigned to one of three food conditions in which they would be asked to either (1) consume carrot juice during pregnancy, (2) consume carrot juice during lactation, or (3) consume only water during both periods. The results of the study showed that the infants who had previously been exposed to carrot juice, either in their mother's womb or during the lactation period, manifested more positive responses when consuming carrot juice-based foods compared to newborns that were not exposed to carrot juice at all. These findings suggest that food preferences can be subject to modifications through experience and learning already at very early age. In an attempt to understand potential underlying mechanisms of changes in food preferences, the following learning phenomena are discussed: mere exposure, flavor-consequence learning, and evaluative conditioning.

1.2 The Mechanisms Underlying the Formation of Food Preferences

1.2.1 Mere exposure.

Previous research suggests that the change in attitudes could be attributed to one of the learning phenomena, called the mere exposure effect (Zajonc, 1968). The mere exposure effect implies that stimuli that humans are repeatedly exposed to, could become more liked as a result of simple mere exposure. This effect was found across different types of stimuli, and, importantly for the formation of food preferences, on foods, too (Pliner, 1982).

In line with the findings of Pliner (1982), studies on food (dis)likes in the context of children's food neophobia (fear of new foods) found that repeated exposures to novel foods increased children's acceptance to consume these foods (Birch & Marlin, 1982). The mere exposure effect in studies with foods was found independently of participants' age (e.g., Pliner, 1982; Sullivan & Birch, 1994) and independently of whether the stimuli were novel or well-known (Birch, 1998). This increase in liking was furthermore suggested to have the potential to generalize to similar food categories, and it was recommended as an early intervention among children to promote healthier eating habits and consumption of vegetables (Dovey, Staples, Gibson, & Halford, 2008).

We argue, however, that on a conceptual level it is difficult to determine whether the increase in liking towards foods can be really attributed to the mere exposure effect in these cases or whether there are other learning phenomena that can better explain these attitude changes. We suggest flavor-consequence learning as an alternative explanation.

1.2.2 Flavor-consequence conditioning.

Every time we eat something, we not only experience foods, but at the same time consume foods that have a range of post-ingestive consequences. Depending on whether these post-ingestive consequence are pleasant (e.g., feeling satiated) or unpleasant (e.g., feeling nauseous) the liking of the food or flavor associated with the consequence would either increase (for positive consequences) or decrease (for negative consequences). Consequently, when we consume something that leads to having an upset stomach, it will most likely make us avoid consuming this food in the future. On the other hand, foods that improved our moods or provided us with an energy boost would be the ones that we would most likely consume more of. Thus, according to flavor-consequence learning, we tend to dislike foods that co-occurred with negative post-ingestive consequences and like foods that co-occurred with pleasant post-ingestive consequences (e.g., Mela, 2000).

In this type of learning, a novel food, or flavor, acts as a conditioned stimulus (CS) and the consequences of ingesting it serves as unconditioned stimuli (USs). These conditioning effects have been consistently found in animal studies, where rats were found to systematically prefer to consume foods (or flavors) previously paired with sugars or nutrients (e.g., Rusiniak, Hankins, Garcia, & Brett, 1979; Sclafani & Ackroff, 1994). Similar findings were reported for flavor-consequence learning in humans by Havermans and Jansen (2007), who found that children evaluated vegetables (that had previously been paired with sugar) as tastier, even in the absence of sugar after vegetable-sugar pairings. This result suggests that children's early attitude towards vegetables can be modified as a result of pairing vegetables with sugar.

However, depending on how attitude change towards food is operationalized, flavor-consequence learning can be explained by three different types of conditioning. If participant's attitudes towards foods are measured in salivation or glucose levels as a response to consuming foods, flavor-consequence learning could be seen as an instance of classical conditioning (Pavlov, 2010). If participants' liking for foods is measured by observing whether participants consume more / less of foods after the conditioning procedure, flavor-consequence learning could be seen as an instance of operant learning (Catania, 1984). Then, if participants' attitudes towards foods are measured in explicit evaluative ratings, flavor-consequence learning could be seen as a type of evaluative conditioning.

In this thesis, we focus on attitude change towards foods measured by explicit ratings. We will thus investigate evaluative conditioning as a learning process underlying the acquisition and change of food preferences.

1.2.3 Evaluative conditioning as a way of forming food preferences.

Evaluative conditioning (EC) is a change in evaluation of a conditioned stimulus (CS) after it was paired with a - typically valent - unconditioned stimulus (US; De Houwer, 2007). Typically, EC is studied with novel and neutral stimuli as conditioned stimuli and stimuli that are rather known and have the ability to evoke either negative or positive feelings are used as unconditioned stimuli.

In the last decades, EC has been investigated in different fields of psychology. Typical EC studies are conducted in a picture-picture paradigm where neutral images are paired with positive or negative images, however, EC effects have been found across different stimulus modalities (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). Particularly interesting in the context of the formation of food preferences, is smell-taste EC (e.g., Baeyens, Eelen, Van den Bergh, & Crombez, 1990; Dickinson & Brown, 2007; Wardle, Mitchell, & Lovibond, 2007). In this type of EC procedure, smells and tastes are used as stimuli. Given that when consuming food we usually experience both its smell and taste, this type of EC seems to be ecologically relevant to investigate food preferences. In smell-taste EC, the liking of a smell (the CS) would change according to the valence of a pleasant or an unpleasant taste (the US) that the smell had been paired with.

1.3 Research Aims and Focus

The main research aims of this dissertation revolve around the formation of food preferences through EC interventions, and possibly their practical implications in a broader health psychology perspective. In this thesis, the main focus is on the role of memory and preparedness in EC studies with food-related stimuli. Also, group differences in the size of EC effects between normal weight and obese individuals are investigated.

1.3.1 The role of contingency awareness in EC (Chapter 2 & 3).

Whether EC effects can be found without memory for CS-US contingencies has been the most investigated question in EC research (for a meta-analysis, see: Hofmann et al., 2010). In this meta-analysis, contingency memory was found to be a significant moderator of EC effects with EC effects being stronger for remembered CS-US pairings than for non-remembered ones. Yet, there are studies reporting EC effects in the absence of contingency memory (e.g., Baeyens, Eelen, Van den Bergh, & Crombez, 1990; De Houwer, Baeyens, & Eelen, 1994; Dickinson & Brown, 2007; Hütter, Sweldens, Stahl, Unkelbach, & Klauer, 2012). The majority of studies that support memory-dependent EC, however, used visual or auditory stimuli. For other modalities (e.g. smell, taste) there is less consistent evidence for a relationship between memory and EC (e.g. Hammerl & Grabitz, 1996; Zellner, Rozin, Aron, & Kulish, 1983). In particular, for smell-taste EC there is a study reporting only memory-dependent EC effects (Wardle, Mitchell, & Lovibond, 2007) while other studies suggest that EC effects for smell-taste combinations can be found in the absence of contingency awareness (Baeyens, Eelen, Van den Bergh, & Crombez, 1990; Dickinson & Brown, 2007). Thus, the following question arises: Is memory for pairings always needed for EC effects in food-related stimuli? To answer this question, we investigated the role of explicit memory for CS-US pairings in EC with food-related stimuli across three experiments presented in Chapters 2 and 3.

In Chapter 2, we tested whether EC effects for non-remembered smell-taste pairings would be found, and whether the magnitude of EC effects for these pairings would be larger than for other stimulus modality pairings. In Chapter 3, we investigated the role of explicit memory for CS-US pairings in an experiment with foods and non-foods to test whether food-smell EC effects would be less dependent on memory for pairings than other stimulus modality combinations.

1.3.2 The role of preparedness in EC (Chapter 2 & 3).

The idea of some associations between the stimuli being created more easily than others has been suggested by Seligman in his concept of preparedness (1970). Seligman and Hager (1972) describe prepared associations as associations that lead to faster and stronger learning effects, and that are more resistant to extinction than non-prepared associations. Öhman and Mineka (2001) further underline that to find a prepared association it is necessary to observe a superior conditioning for some specific stimulus combinations which could not be otherwise attributed to the salience of the stimuli. Examples of prepared associations are well described in animal studies (e.g. Garcia, Kovner, & Green, 1970; Green, Bouzas, & Rachlin, 1972). A study on rats conducted by Green, Bouzas and Rachlin (1972) investigated the phenomenon of preparedness in three experimental conditions where a gustatory cue (saccharin) was paired with, and predicted, either an illness (induced by lithium chloride), a constant continuous electric shock or a short electric shock. The investigators found that the animals avoided drinking from a bottle containing saccharine in the illness condition, but did not avoid the liquid in the electroshock conditions. From an evolutionary perspective it seems valid to assume there is biological preparedness of foods and stomach illness which could at least partially explain these results. Another example of preparedness in the context of learning contingencies could be fear conditioning where stimuli that are relevant to the survival of an organism (such as snakes or spiders) have higher potential to condition fear responses due to their evolutionary relevance than other, survival-irrelevant ones (Seligman, 1970). Finally, based on findings from studies investigating interactions between olfactory and gustatory stimuli and their processing in flavor literature (e.g. Dalton, Doolittle, Nagata, & Breslin, 2000; Yeomans, Mobini, Elliman, Walker, & Stevenson, 2006), we argue that another likely prepared association could be between smells and tastes. Research on the concept of flavor shows that smell-taste combinations are processed in a special way and sum up to a unimodal sensory experience called flavor (Auvray & Spence, 2008). Given their special status and way of processing, we argue that smell-taste combination could be an example of such prepared associations in EC. This phenomenon of potential stronger EC effects for smells and tastes is particularly interesting in the context of forming food preferences since a better understanding of the relation between smell and taste is vital for addressing rising health eating-induced problems in society today (Shepherd, 2006). Thus, in Chapters 2 and 3, we investigated whether there is a preparedness effect for smell-taste combinations observable in significantly larger size of EC effects for smell-taste pairings compared to other stimulus modality combinations.

In Chapter 2, we tested whether EC effects from smell-taste pairings would be easier to establish than from image-taste pairings (Experiment 1), and whether tastes (compared to sounds) have a stronger impact on the size of EC effects for smells than for images (Experiment 2). In Chapter 3, we tested whether food-smell stimulus modality combinations would lead to stronger EC effects compared to non-food-smell stimulus modality pairings (Experiment 3).

1.3.3 Differential learning patterns between normal weight and obese individuals (Chapter 4).

The idea that normal weight and obese individuals differ in terms of learning patterns follows up on several findings in the obesity literature. A recent meta-analysis by Yang, Shields, Guo and Liu (2018) shows that obesity is associated with a range of cognitive impairments such as poorer working memory and learning compared to lean individuals. Coppin, Nolan-Poupart, Jones-Gotman and Small (2014) showed that obese individuals, relative to normal weight participants, failed to learn to prefer more advantageous over less advantageous outcomes in a preference conditioning learning task. Independently of deficits in executive functions, obese individuals were furthermore found to manifest attentional biases towards food-related stimuli and an increased level of food-related impulsivity (Maayan, Hoogendoorn, Sweat, & Convit, 2011; Mobbs, Crépin, Thiéry, Golay, & Van der Linden, 2010; Schag, Schönleber, Teufel, Zipfel, & Giel, 2013) which could be additional moderators of learning effects in the context of forming food preferences.

Thus, in Chapter 4, we tested whether normal weight and obese participants would differ in learning effects measured in EC effects and in the accuracy at a learning task with food stimuli (Experiment 4 and 5) and non-food stimuli (Experiment 5).

1.4 Thesis Format

In the next three chapters of this dissertation the experimental findings from the three above-mentioned lines of studies are presented. Chapter 2 is an empirical investigation of the role of memory and potential preparedness effects in smell-taste EC studies. Chapter 2 was submitted for publication as a Registered Report in Cognition and Emotion prior to collecting the data and received in principle acceptance. Thus, Chapter 2 appears in this thesis in the format as the Registered Report that will be submitted in the journal in the current form (or with editorial changes). Chapter 3 focuses on behavioral measures of EC effects and potential preparedness effects in EC with food-related stimuli. Chapter 4 ends the empirical section with investigating differential learning patterns in processing of palatable foods in the sample of obese and normal weight individuals in two online studies. The structure in which each of the three empirical chapters are built, enables readers to read each of them as an independent piece of work. Finally, the empirical part of this thesis is followed by the general discussion and an overview of thesis' findings in the broader context of literature.

CHAPTER 2: Memory and Preparedness in Smell-Taste EC

2.1 Abstract

We investigated two questions, (1) the relevance of memory for evaluative conditioning (EC) effects after smell-taste pairings, and (2) the potential preparedness of smell-taste combinations for yielding EC effects. The relevance of memory for EC effects is a subject of intense research. The majority of studies that investigate the memory-EC relation use visual stimuli and typically show no or relatively small EC effects without memory. For smell-taste combinations, only few studies exist, with mixed results regarding the role of memory in EC. The idea that there might be a preparedness of smell and taste pairings comes from classical conditioning studies showing preparedness in food aversion and from research on joint processing of smells and tastes. In Experiment 1, we report a conceptual replication of previous studies with smell-taste pairings in which we found no evidence for memory independent EC overall. In a pre-registered Experiment 2, we tested the role of memory more conclusively and tested the preparedness hypothesis for smell-taste pairings. The results support the preparedness hypothesis for smell-taste pairings in EC. Furthermore, as in Experiment 1, we did not find evidence for memory independent EC in Experiment 2.

2.2 Introduction

2.2.1 Contingency awareness in evaluative conditioning.

Evaluative conditioning (EC) is an evaluative change of a typically neutral conditioned stimulus (CS) as the result of being paired with a typically valent unconditioned stimulus (US; De Houwer, 2007). EC has been investigated in numerous areas of research, and it is believed to play a crucial role in shaping attitudes in people's everyday lives (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010).

The most investigated question in this area is whether the attitude change can occur without participants' explicit memory for the co-occurrences between neutral and valent stimuli (see Sweldens, Corneille, & Yzerbyt, 2014, for a review). Many studies investigating this question claim that EC effects depend on explicit memory for CS-US pairings (Bar-Anan, De Houwer, & Nosek, 2010; Gast, De Houwer, & De Schryver, 2012; Gast & Kattner, 2016; Pleyers, Corneille, Luminet, & Yzebryt, 2007). Others also find that memory is necessary, but that remembering the US valence (without necessarily remembering the identity of US) is sufficient for EC effects to occur (Stahl & Unkelbach, 2009). Finally, there are findings supporting EC effects without explicit memory (Baeyens, Eelen, Van den Bergh, & Crombez, 1990; De Houwer, Baeyens, & Eelen, 1994; Dickinson & Brown, 2007; Hütter, Sweldens, Stahl, Unkelbach, & Klauer, 2012). Most studies on the relation of EC and memory used visual or auditory stimuli. For other modalities (e.g. olfactory, gustatory, haptic stimuli) there is less evidence of a relationship between memory and EC (e.g. Zellner, Rozin, Aron, & Kulish, 1983). For the combination of olfactory (smell) and gustatory (taste) stimuli EC effects were reported without memory for the co-occurrences, yet, the evidence in the literature is so far scarce and inconclusive (Baeyens et al., 1990; Dickinson & Brown, 2007; Wardle, Mitchell, & Lovibond, 2007).

In the studies described in the three papers that have been published on EC with smell-taste combinations, participants were asked to smell and drink scented and colored water solutions which contained either unpleasant or pleasant tastants. The main research questions were whether conditioning with tastes could lead to changes in liking of smells and colors and whether these effects occurred without explicit memory. All three papers reported EC effects only for smell-taste, and not for color-taste combinations, yet, the evidence on whether participants had to recall smell-taste pairings is mixed. While two of the papers report such effects without contingency awareness (Baeyens et al., 1990; Dickinson & Brown, 2007), the third paper reports no smell-taste EC effect without contingency awareness (Wardle et al., 2007). With regard to the color-taste pairings, participants in all three studies were aware of the contingencies; EC effects for these pairings, however, were not found in any of them.

In one of the studies that found a smell-taste EC effect without awareness (Baeyens et al., 1990), these effects could have resulted from the smell-taste memory task being relatively difficult. Participants were presented with a taste and had to choose the correct CS from a list of all colors and smells that were present in the learning phase and it is unclear whether they were allowed to taste the stimuli, and, if so, whether it was time-limited. It is possible that this description-based memory task is particularly difficult and therefore not very sensitive for detecting awareness of smell-taste combinations.

Dickinson and Brown (2007) reported similar results on the role of contingency awareness as they found EC effects for smell-taste pairings among participants who were not aware of which smell was paired with which taste. The measurement procedure was designed to be a more sensitive measure of contingency awareness based on notions of Shanks and John (1994). For this, the authors implemented the same continuous rating scales to collect participants' memory judgements as they used for the evaluative ratings. Furthermore, the measurement phase was timed in the same way as was the learning phase. Their conclusion that smell-taste EC was unaware was based on the finding that in aggregated analyses participants showed no reliable knowledge of the smell-taste contingencies. In a reanalysis of this data after a categorization of participants as aware vs. unaware (participants recalled at least three vs. less than three out of four pairings), however, Wardle and colleagues (2007) found smell-taste EC effects only in the group of participants who were aware of pairings. On the other hand, this categorization of Wardle and colleagues, could also be argued to be arbitrary. A general point is that all previous studies used memory measures that are aggregated across items. Because memory is not a property of the person, but of the combination of item and person, however, this does not make full use of the information and potentially leads to biased conclusions (Pleyers et al., 2007). Therefore item-based analyses of memory are recommended for EC paradigms (e.g., Gast, De Houwer, & De Schryver, 2012; Pleyers et al., 2007).

Taken together, even though there is some evidence for the moderating role of memory in smell-taste EC, it is important to further investigate and establish whether participants have to be able to consciously recall the CS-US pairings for EC effects to occur. It remains particularly relevant for the ongoing debate on dual-process and single-process theories in EC literature to better understand the role of memory in EC (Gawronski & Walther, 2012; Sweldens et al., 2014).

2.2.2 Preparedness in the context of associative learning.

Evidence from the literature on classical conditioning shows that some contingencies are easier to learn than others (Krane & Wagner, 1975). The idea of some links between the stimuli being created more easily than others has been proposed by Seligman (1970, 1971) in his concept of preparedness. Prepared associations can be characterized by three aspects: faster learning, acquisition of a larger response, and enhanced resistance to extinction. It is also claimed that such associations are less cognitive and mediated by evolutionary old brain structures (Seligman & Hager, 1972). Importantly, to call an association prepared, we should be able to observe superior conditioning with certain stimulus combinations that cannot be explained purely by the salience of the stimuli (Öhman & Mineka, 2001). Implications of prepared associations were widely studied in animal studies (e.g. Garcia, Kovner, & Green, 1970; Green, Bouzas, & Rachlin, 1972). For instance, a study on rats conducted by Green and colleagues (1972) investigated the phenomenon of preparedness in three experimental conditions where a gustatory cue (saccharin) predicted either nausea (induced by lithium chloride), a constant continuous electroshock, or a short electroshock. The researchers found that the animals avoided drinking a liquid containing saccharine in the illness condition, but not in the electroshock conditions. Biological preparedness of foods and stomach illness seems to be a valid potential explanation of these results.

Another potential prepared association is between olfactory and gustatory stimuli. Smell and taste interactions were investigated in numerous studies on the concept of flavor (e.g. Dalton, Doolittle, Nagata, & Breslin, 2000; Small et al., 2004; Yeomans, Mobini, Elliman, Walker, & Stevenson, 2006). Often, smells and tastes are confused with each other; aroma presence and intensity may alter perceived sweetness, sourness, and saltiness of foods – characteristics which refer to taste, not smell (e.g. Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009; Stevenson, Prescott, & Boakes, 1999). It has been argued, that sensory characteristics of foods such as taste and smell sum up to an oral unified sensation which is often described as flavor (Auvray & Spence, 2008). Research into the multisensory perception of flavor shows that individual components of flavor are rarely perceived and processed independently (Auvray & Spence, 2008; Veldhuizen, Shepard, Wang, & Marks, 2010). Neuroimaging studies identified the anterior cingulate cortex (ACC), the caudal orbitofrontal cortex (OFC), and the insula (Small et al., 2004) as key regions involved in flavor perception and integration of smell-taste combinations. In line with the findings on the confusion of smells and tastes and their unified perception are results from functional magnetic resonance imaging studies that showed greater activation in these brain areas when smells and tastes are presented together compared to any activation caused by smells or tastes presented independently (de Araujo, Rolls, Kringelbach, McGlone, & Phillips, 2003; Small & Prescott, 2005).

Based on these findings on unified perception and confusion of smell and taste, at least two accounts of EC might likely predict that smell-taste combinations show a preparedness effect in EC. One of these accounts is the Implicit Misattribution account that postulates that

EC effects are due to misattributing the affective properties of USs to CSs. Therefore, it could be argued that EC effects should be stronger the more likely CS and US are to be confused with each other (Jones, Fazio, & Olson, 2009) and that this is particularly likely if CS and US are olfactory and gustatory stimuli. The other account is the Holistic Account of EC (Martin & Levey, 1994) that postulates that the transfer of valence from USs to CSs occurs through forming a holistic representation of the CS, the US and the affective evaluation of the US. Therefore, EC effects should be stronger if CS and US are more likely to be holistically processed, which is arguably the case if CS and US are smells and tastes.

In the above-mentioned three papers that investigate smell-taste EC, an EC effect due to pairings with gustatory USs occurred only on smell CSs and not on visual CSs (Baeyens et al., 1990; Dickinson & Brown, 2007; Wardle et al., 2007). These results are thus in line with the prediction that EC effects are stronger for smell-taste than for other stimulus combinations. There is, however, at least one reason why this larger effect in the smell condition cannot with certainty be attributed to a preparedness of smell-taste associations: Olfactory CSs might be easier to condition than visual CSs, irrespective of the use of a gustatory US. This could be a general difference between olfactory and visual stimuli, or – maybe more plausible – it is possible that the specific type of visual stimulus chosen (color) is more difficult to condition than the specific type of olfactory stimulus chosen (smell). It is possible that colors are difficult to condition because they are ubiquitous stimulus features that participants have strong preexisting attitudes about.

To conclude, while there are theoretical reasons to assume a preparedness for smell-taste combinations that leads to larger EC effects and while such a preparedness could explain the stronger conditioning effects of gustatory USs on smell than on color (Baeyens et al., 1990; Dickinson & Brown, 2007; Wardle et al., 2007), clear evidence for smell-taste preparedness in EC is still lacking. Such preparedness in EC might be of particular importance as better understanding of the acquisition of food preferences could be highly relevant in addressing eating induced health problems (Shepherd, 2006).

To summarize, we investigate two questions in this paper. The first one is whether *EC effects for non-remembered smell-taste pairings can be found and if they are larger than non-remembered pairings of other stimulus combinations.* The second research question is whether *EC from smell-taste combinations is easier to establish than from other modality-combinations (i.e., are smell-taste combinations prepared in the context of EC).*

2.3 Experiment 1

In Experiment 1, we used positive (sugar syrup) and negative (polysorbate 20) tastants as USs and combined them with two types of CSs: Food smells as olfactory stimuli and bottle labels as visual stimuli. The study had thus two within-participants factors: CS type (olfactory, visual) and US valence (positive, negative). In a conceptual replication of the study by Baeyens and colleagues (1990), we tested whether (1) EC effects occur for smell-taste combinations, (2) whether EC effects are stronger for smell-taste combinations than for visual-taste combinations and (3) whether memory for the pairings and its interaction with CS type is related to the size of the EC effect, and (4) whether there are EC effects of non-remembered CS-US combinations. The study was approved by the ethical committee of Deutsche Gesellschaft für Psychologie.

Compared to the study by Baeyens and colleagues (1990), we made several changes. First, we replaced colors with novel bottle labels as colors are well-known stimuli and we did not consider them a fair comparison category to smells. Second, to ensure equal conditions for olfactory and visual CSs, we presented both types of CSs in parallel during the conditioning phase. Third, we used a computerized and paced procedure to improve precision of the timing. Finally, participants were not time-constrained in the measurement phase and could look at the bottle designs, respectively smell the drinks, while giving their evaluative ratings at their own pace. Furthermore, they were allowed to smell and look at CSs and taste USs while giving their memory judgments.

2.3.1 Method.

2.3.1.1 Participants.

Fourty-eight students (31 female, 17 male) between the ages of 18 and 50 years (M = 24.5; SD = 5.4) were tested at a campus of the University of Cologne. Each participant received either 5 euros or course credit for their participation. Every participant gave an informed consent and none of them reported diabetes or allergies when prescreened orally. Additionally, we asked participants to privately create a personal letter code according to a set of rules they received on a sheet of paper in order to match the data sets from this study with the ones from the study we pre-registered to avoid double participation.

2.3.1.2 Stimulus material.

Participants consumed water-based solutions presented as 5-ml servings in 30-ml plastic cups containing one of four smells (grapes, mango, cacao, or blackberry) as olfactory stimuli ($CS_{olfactory}$) and one of two tastes (sugar syrup, polysorbate 20) as gustatory stimuli ($US_{gustatory}$). Visual stimuli (CS_{visual}) were four different bottle labels appearing simultaneously to the drink consumption on the computer screen (see Appendix 1 for detailed description of the stimuli). In every trial a combination of one $CS_{olfactory}$, one CS_{visual}, and one $US_{gustatory}$ was present; these combinations were fixed across the trials of one participant, but varied between participants. For each participant, two of the selected smells and two of the selected bottle labels were always combined with polysorbate 20 ($US_{gustatory\_negative}$) and two of the selected smells and two of the selected bottle labels were always combined with sugar syrup ($US_{gustatory\_positive}$). These combinations were assigned across participants in a way that each

$CS_{olfactory}$ appeared an equal number of times with each CS_{visual} and each US was paired with each CS equally often. Between trials, participants ate household type bread sticks and were allowed to drink water.

2.3.1.3 Procedure.

Participants worked at laptops that ran the experimental procedure and saw the CS_{visual} on the screens. On the same desk, we placed the water solutions (drinks) that contained the $CS_{olfactory}$ and $US_{gustatory}$, as well as bread sticks and water to neutralize taste between trials. During all phases, participants followed the instructions presented on the computer screen. The experiment consisted of three main phases.

2.3.1.3.1 Conditioning phase.

In the conditioning phase, participants were presented with a set of 18 (2+16) plastic cups containing drinks placed in the moulds of a muffin tray with numbers on it. Sixteen of the solutions contained the $CS_{olfactory}$-$US_{gustatory}$ combinations for the conditioning phase. Eight of these 16 drinks contained polysorbate 20 ($US_{gustatory\_negative}$) and the remaining eight drinks contained sugar syrup ($US_{gustatory\_positive}$). Each of the smells was contained in four of the drinks. Two additional cups containing only water were used for practice trials.

At the beginning of the conditioning phase, participants were instructed about the course of the procedure. To ensure attention to visual, olfactory, and gustatory stimuli, participants were throughout each conditioning trial exactly informed what to do in a paced procedure (see Table 1 for timing and exact instructions). To further ensure precision, the conditioning phase started with two practice trials.

The procedure was timed in a way that participants were smelling at the drinks and looking at the stimuli presented on the screen simultaneously and drinking the content of the cups afterwards. There were thus equal timing conditions for both types of CSs. The order of the 16 conditioning trials was randomized.

Table 1. Exact instructions and timing of conditioning trials of Experiment 1.

Instructions	Duration
[Blank screen]	0.1 sec
- Take the cup No. [] - Hold it above the tray, without smelling it.	5.0 sec
[Blank screen]	0.1 sec
- After this statement disappears: - Move the cup to your nose and smell it. - At the same time, look at the bottle on the screen.	7.0 sec
- Now look and smell at the same time.	5.0 sec
- Pour the liquid of the cup into your mouth. - Move the liquid in your mouth until the instruction telling you to swallow appears.	8.0 sec
- Swallow now. - Place the cup in its place on the tray. - Eat a piece of bread. (When you are ready for the next trial, press ENTER) [last line added after 2.0 sec]	until keypress, min. 2.0 sec
[Blank screen]	0.5 sec

2.3.1.3.2 Evaluation phase.

In the evaluation phase, participants were asked to evaluate all $\mathrm{CS}_{\mathrm{olfactory}}$ (smells) and $\mathrm{CS}_{\mathrm{visual}}$ (bottle labels) with rating scales on the computer screen ranging from 1 (very unpleasant) to 9 (very pleasant) by pressing a number on the keyboard. For the rating of the smells, participants were presented with four numbered cups containing the four smells and asked to smell each and indicate its pleasantness one after the other. For the rating of the bottle labels, the four bottle labels appeared on the screen one after the other and participants were asked to indicate their pleasantness in the same way as for smells. Smells and bottle labels were rated in a counterbalanced order across participants. One order of presentation within the stimulus modality was fixed. This was done in order to avoid mistakes when placing drinks into the tray in the correct order, which could have resulted in mistakes in assigning responses to conditions. Please note that due to the counterbalanced CS-US assignment, stimulus order is not confounded with conditions.

2.3.1.3.3 Memory phase.

To increase sensitivity of the memory measure, we decided to implement a recognition memory task, where participants experience the stimuli again in the memory phase, rather than a recall task (which was implemented in the previous studies on smell-taste EC).

For assessing memory for the smell-taste combinations, participants were presented with the four numbered cups containing the four smells. Participants were asked to indicate for one smell after the other with which taste it had been combined. During this procedure, participants had two cups containing the two tastes and they were instructed to take a sip from each of them while giving their memory judgements for smell-taste combinations. The task to assess memory for the visual-taste link, was identical except the four bottle labels were presented on the screen. Memory for smell-taste and visual-taste combinations was assessed in a counterbalanced order across participants and an order of presentation within the CS modality was fixed.

2.3.2 Results.

2.3.2.1 Evaluative conditioning and preparedness.

To investigate whether neutral smells can be evaluatively conditioned by pairing them with positive and negative taste and whether the conditioning effect with tastes has a stronger effect on olfactory than on visual stimuli, we conducted a repeated measures ANOVA with the factors US valence and CS type on evaluative ratings. The main effect of US valence was significant, $F(1, 47) = 4.091$, $p = .049$, partial eta$^2 = .080$ indicating an overall EC effect. The main effect of CS type was not significant, $F(1, 47) = 2.679$, $p = .108$, partial eta$^2 = .054$. The interaction of US valence and CS type was not significant, $F(1, 47) = 0.309$, $p = .581$, partial eta$^2 = .007$, which means that we did not find evidence for a difference in the size of the EC effect between olfactory and visual stimuli (see Fig. 1 for descriptive statistics).

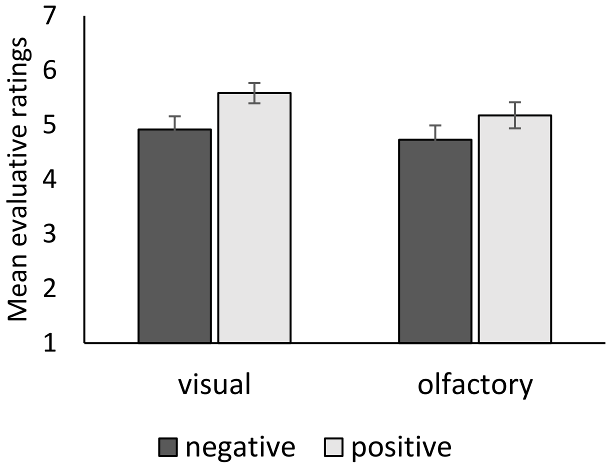

Fig.1 Evaluative ratings in Experiment 1 for conditions of US valence and CS type with error bars depicting standard errors.

2.3.2.2 Evaluative conditioning and memory.

To explore the relationship between EC effects, memory and the type of CS, we tested the effects of US valence, CS type, and memory for pairings on evaluative ratings (see Fig. 2 for descriptive statistics) with a linear mixed model analysis with crossed random effects for participants and CSs. Such models are an extension of common ANOVA designs and can be interpreted similarly (i.e., we interpret the specified interactions), but additionally take variability at the level of participants and at the level of stimuli into account separately. It has particular advantage with memory data where it can be conducted even on relatively few data points (Krueger & Tian, 2004). Within-participants ANOVAs, on the other hand, when analyzing memory data from EC experiments, typically suffer from substantial power loss due to listwise participant-exclusion because of empty cells.

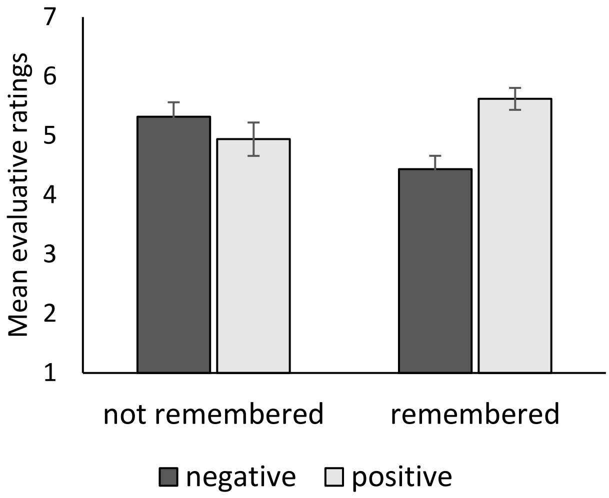

Fig. 2 Evaluative ratings in Experiment 1 for conditions of US valence and memory for pairing with error bars depicting standard errors (based on aggregated data)

We built and tested the model including US valence (negative = -1, positive = 1), CS type (visual = -1, olfactory = 1), and memory for pairings (not remembered = -1, remembered = 1) as fixed factors, random intercepts for participants and CSs, and by-participant random slopes for main effects of the three fixed factors and by-CS random slopes for US valence and memory for pairings (results of the final model are listed in Table 2).

As shown in Table 2, the only significant effect in this model was the interaction of US valence and memory for pairings (t = 2.86, p = .005). To explore this interaction effect, we calculated simple effects for non-remembered and remembered pairings by recoding US valence (0 = negative, 1 = positive), memory for pairings (0 = not-remembered, 1 = remembered) and kept CS type contrast coded. Other than that, we kept the model structure the same as before. For remembered pairings across levels of CS type, CSs were rated significantly more positive when paired with a positive US compared to a negative US (i.e., EC effect; t =

3.25, *p* = .004). For non-remembered pairings (coded respectively as 0 = remembered, 1 = not-remembered), the EC effect was not significant (*t* = -0.458, *p* = .649) and descriptively in the opposite direction. EC effects were thus obtained only for remembered and not for non-remembered pairings. The effect size for the found interaction of memory for pairings and US valence for the described model equals standardized Cohen's *d* of 0.375 (Judd, Westfall, & Kenny, 2017).

Table 2. The components of the final model for predicting evaluative ratings based on US valence, CS type, and memory for pairings.

	B	***SE* (*B*)**	***t***	***p***
Intercept	5.057	0.194	25.992	< .001
US valence	0.229	0.151	1.519	.153
Memory for pairings	0.001	0.126	0.008	.993
CS type	-0.171	0.174	-0.984	.356
US valence*Memory for pairings	0.324	0.113	2.856	< .01
US valence*CS type	-0.045	0.122	-0.370	.722
Memory for pairings*CS type	0.038	0.109	0.349	.727
US valence*Memory for pairings*CS type	0.055	0.110	0.506	.613

2.3.3 Discussion.

In Experiment 1, we tested whether gustatory USs could lead to changes in liking of olfactory CSs they were paired with and whether this effect on olfactory CSs differed in size from the effect on visual CSs. We found an overall EC effect that was not significantly moderated by CS type.

The experiment thus tentatively supports the evidence for the effectiveness of gustatory USs to condition olfactory CSs (Baeyens et al., 1990; Dickinson & Brown, 2007; Wardle et al., 2007). In addition, we found tentative first support for the possibility to evaluatively condition visual CSs by tastes. The results suggest that in our study, visual stimuli were successfully conditioned with tastes. In previous studies, visual stimuli were not successfully conditioned by tastes. This discrepancy might be explained by the use of different types of stimuli. While we used unknown and novel bottle labels as visual CSs, colors were used as visual stimuli in the previous studies. Colors are well-known stimuli that participants are likely to have relatively fixed attitudes about, which might make them less susceptible to EC procedures.

The non-significant difference between visual and olfactory CSs might seem as an argument against the preparedness of smell-taste combinations in yielding EC effects. Yet, we conducted a post hoc power analysis for the interaction of US valence and CS type which showed that assuming a potentially medium effect size of Cohen's *d* of 0.5 for this interaction, the power to detect it would be .748. In addition to this potential power issue, the current design does not allow such a conclusion because it does not distinguish between main effects of CS type and the interaction of CS type and US type. It is one interpretation of the data that smells and bottle labels simply do not differ in their effectiveness as CSs. Another possible interpretation, however, is that bottle labels are generally more effective CSs than smells, but that smells have a prepared relation with tastes, which bottle labels do not have. These effects could cancel each other out and result in similar EC effects on smells and bottle labels.

An analysis that included memory showed a moderation of the EC effect by memory for the pairings. EC effects were – independent of CS type – found only for remembered and not for non-remembered pairings. A caveat to this conclusion is that this analysis by memory might be biased towards yielding larger EC effects for remembered pairs because participants might base their memory judgments on their evaluation of the CS (Hütter et al., 2012). This bias, however, should occur both with visual and with olfactory stimuli. It is therefore important to note that we also did not find a three-way interaction, which tentatively suggests that if there was an unaware EC effect for smell-taste combinations it is at least not much larger than the unaware EC effect for visual-taste combinations.

2.4 Experiment 2 (Registered Experiment)

In order to investigate our research questions more conclusively, we planned a pre-registered experiment. In Experiment 1, we did not find a difference in the magnitude of EC effects for smell-taste and visual-taste pairings. This result could be attributed to (1) a lack of test power, (2) the absence of prepared associations of smell and taste, or (3) a difference in the general susceptibility of smells and bottle labels to be conditioned, a preparedness effect of smell-taste combinations, and both effects cancelling each other out. To disentangle these explanations, we added auditory USs to our design as comparison condition with gustatory USs. To increase reliability, we collected evaluative ratings prior to the conditioning procedure and looked at the change in evaluative ratings (pretest to posttest). We examined the ability of USs of different modalities to condition olfactory and visual CSs in an experiment with the three within-participants factors: US valence (positive, negative), CS type (olfactory, visual), and US type (gustatory, auditory). Change in evaluative ratings was the main dependent variable. Specifically, we tested whether there was a three-way interaction between CS type, US type, and US valence. If there was preparedness for the smell-taste combination, there should be a three-way interaction with the following pattern: Gustatory USs (compared to auditory USs) should have a more positive/less negative impact on the size of the EC effect (difference in ratings of $CS_{positive} - CS_{negative}$) for olfactory CSs than for visual CSs. As explained in the Discussion of Experiment 1, the intuitively relevant simple main effects (e.g., the effectiveness of olfactory vs. visual CSs when combined with gustatory USs or the effectiveness of gustatory vs. auditory USs when combined with olfactory CSs) are less informative because potential stimulus main effects can increase or diminish these effects. Finally, we planned to test whether EC effects could be found for smell-taste stimulus combinations that were not remembered and whether non-remembered EC effects from these stimulus combinations were larger than EC effects from non-remembered pairings of other stimulus modality combinations.

2.4.1 Method.

2.4.1.1 Participants.

Because standard power analysis tools as GPower are not suited for designs with more than one within-participants factor, we used PANGEA power calculator (Westfall, 2015) based on the hierarchical ordering principle assumption for our design for a three-way within-subjects ANOVA. We assumed an effect size of standardized Cohen's $d = 0.3$ for the three-way interaction as the smallest effect size that was of sufficient theoretical interest to justify the costs due to the complex experimental procedure. For an effect of this size, PANGEA suggested that with a sample of $N = 120$ we have a power of $1\text{-}\beta = .91$.

We recruited 120 participants from University of Cologne who were rewarded with course credit or financial compensation of 7 euros, and who were prescreened as described for Experiment 1. We followed our preregistered plan to exclude participants who previously participated in Experiment 1 and participants who clearly did not follow the experimental procedure accurately (e.g., we planned to exclude participants who did not consume all the drinks, did not pay attention to the computer screen during the conditioning procedure, behaved as if they were under influence of psychoactive substances or did not complete all the parts of the experiment) according to the experimenter's judgment. This led to the exclusion of two participants who did not understand and did not follow the instructions. The final sample consisted of 118 persons (96 female, 22 male).

2.4.1.2 Stimulus material.

In total, twelve stimuli (four olfactory CSs, four visual CSs, two auditory USs and two gustatory USs) were used across the procedure. Smells, tastants, bottle labels, as well as the additional material (water, bread sticks, trays, cups) were the same as used for Experiment 1. As auditory stimuli, we used a harp sound (Nr. 809) from IADS (The International Affective Digitized Sounds; Bradley & Lang, 1999) with high valence ratings (*M* = 7.44, *SD* = 1.41 on a scale of 1 to 9) and a metal scratch sound from previous conditioning studies (Neumann & Waters, 2006) with low valence ratings (*M* = 1.46, *SD* = 1.43 on a scale of 0 to 8). Both stimuli were pretested in our lab (*N* = 36) on the valence dimension and were distinctively negative (*M* = 1.53, *SD* = 0.91), respectively positive (*M* = 6,92, *SD* = 1.90) on a scale from 1 to 9 and were successfully used as auditory USs in a recent study conducted in our lab (Benedict & Gast, in review). For detailed descriptions of the stimulus material used in both experiments see Appendix 1.

2.4.1.3 Procedure.

All factors of this design were manipulated within participants. Different to Experiment 1, there was in each trial always only one CS paired with one US. This means that each participant received one pair of each of the following eight combinations: $CS_{olfactory}$-$US_{gustatory\_positive}$, $CS_{olfactory}$-$US_{gustatory\_negative}$, CS_{visual}-$US_{gustatory\_positive}$, CS_{visual}-$US_{gustatory\_negative}$, $CS_{olfactory}$-$US_{auditory\_positive}$, $CS_{olfactory}$-$US_{auditory\_negative}$, CS_{visual}-$US_{auditory\_positive}$, CS_{visual}-$US_{auditory\_negative}$.

The procedure for $CS_{olfactory}$-$US_{gustatory}$ (smell-taste) and CS_{visual}-$US_{gustatory}$ (visual-taste) pairings was similar to the procedure described for Experiment 1 with the difference that in each trial only one CS was present. The procedures for $CS_{olfactory}$-$US_{auditory}$ (smell-sound) and

CS_{visual}-$US_{auditory}$ (visual-sound) pairings were similar with the differences that the USs were sounds administered through headphones ($US_{auditory}$) and that the drinks did not contain tastes.

The eight different pairs each participant received were repeated in four learning cycles (32 learning trials in total). Two of the four $CS_{olfactory}$ and two of the four CS_{visual} were always combined with negative USs (one each with $US_{gustatory\_negative}$ and $US_{auditory\_negative}$, respectively) and the other half of the four $CS_{olfactory}$ and CS_{visual} were always combined with positive USs (one each with $US_{gustatory\_positive}$ and $US_{auditory\_positive}$, respectively). Tastes were thus present only in half of the trials and sounds in the other half of trials. Similarly smells and visual stimuli were only present in half of the trials each. To avoid interruptions and keep the procedure consistent across trials, however, participants were always asked to smell the drinks, look at the screen, pour the drinks into their mouth and listen to the sounds through the headphones.

2.4.1.3.1 Pre-evaluation phase.

At the start of the pre-rating phase, each participant pre-rated all olfactory and visual CSs with the procedure described for the evaluation phase of Experiment 1. Each participant gave one evaluative rating per CS. Whether participants started with pre-rating of smells or bottle labels was counterbalanced.

2.4.1.3.2 Conditioning phase.

At the beginning of the conditioning phase, each participant received two metal trays with 34 (32+2) plastic cups. Two of the cups (containing only water) were used for practice trials. Thirty-two plastic cups (16 in each the metal tray) were used in the conditioning phase. Participants were instructed to follow the computerized procedure step by step and instructed to smell the drinks, watch the visual stimuli, taste the content of the cups, and listen to the sounds. Participants were also given the information that in some trials there was nothing to look at, listen to, smell, or taste (e.g. in smell-sound trials there were no visual stimuli to look at and no taste in the drinks). In a precisely paced trial-by-trial procedure, participants were also in each trial again asked to smell, look at, taste, and listen to the stimuli (for exact instructions and timing see Table 3).

Table 3. Exact instructions and timing during the conditioning trials of Experiment 2.

Instructions	Duration
[Blank screen]	0.1 sec
- Take the cup No. [] - Hold it above the tray, without smelling it.	5.0 sec
[Blank screen]	0.1 sec
- Smell the drink and look at the screen.	5.0 sec
- Pour the liquid into your mouth and listen to the sound. [The sound starts playing 1.0 sec into this slide]	4.0 sec
- Move the liquid in your mouth and listen to the sound.	3.0 sec
- Swallow now. - Place the cup back. - Eat a piece of bread. (When you are ready for the next trial, press ENTER)	Until the keypress
[Blank screen]	0.1 sec

2.4.1.3.3 Evaluation phase.

Participants rated olfactory and visual CSs with the procedure described for Experiment 1. Each participant gave one evaluative rating per each CS.

2.4.1.3.4 Memory phase.

The memory for CS-US pairings was assessed separately for olfactory and visual CSs in counterbalanced order with a fixed presentation order within the CS modality. For assessing memory for the smell-sound and smell-taste links, participants were asked to indicate for each smell one-by-one with which sound or taste it had been previously paired with. To do so, participants had a metal tray containing cups with olfactory CSs (to smell on) which they were asked to work through one-by-one. They were also provided with both gustatory USs to taste and two buttons to play the two auditory USs on the computer screen. Once participants smelled on the CS, tasted both gustatory USs and played both auditory USs, they were asked to mouse-click a button on the computer screen corresponding to the US they thought the given CS had been paired with. To reduce the potential influence of inferring the correct US based on the (conditioned) liking of the CS (Hütter et al., 2012), we added the option to respond with an "*I don't know button*". The memory assessment for the visual-sound and visual-taste links was the same, except that participants did not have cups with olfactory CSs, but bottle labels appeared on the computer screen one-by-one.

2.4.1.4 Analysis plan.

We planned to test the effects of experimental factors on the change in evaluative ratings (calculated by subtracting pretest ratings from posttest ratings). To evaluate the research question regarding preparedness, we planned to examine the three-way-interaction of US type (gustatory, auditory), CS type (olfactory, visual) and US valence (positive, negative) on change in evaluative ratings in SPSS with a within-participants ANOVA. We were to conclude that our results were in line with the above described preparedness hypothesis if this three-way-interaction was significant and showed the above described pattern (gustatory USs (compared to auditory USs) should have a more positive/less negative impact on the size of the EC effect (difference in ratings of $CS_{positive} – CS_{negative}$) for olfactory CSs than for visual CSs).

The question regarding the role of memory for pairings was planned to be analyzed in R (package "*lmer*") with item-based linear mixed models. On a subset of non-remembered pairs, we planned to test a model including: US valence, CS type, and US type. Based on these factors (along with crossed random effects for subjects) we planned to predict change in evaluative ratings. First, in this model we planned to test whether there were EC effects for non-remembered smell-taste combinations. Second, we planned to test whether the magnitude of EC effects for non-remembered smell-taste combinations was bigger than EC effects from other non-remembered stimulus combinations. In case of convergence problems, we planned to fit the most complex model supported by the data and exclude random effects based on their explained variance, starting with random slopes.

2.4.2 Results.

2.4.2.1 Evaluative conditioning and preparedness.

To investigate the preparedness hypothesis, and to compare the ability of gustatory and auditory USs to condition olfactory and visual CS, we conducted a three-way within-participants ANOVA with the following factors: US valence (negative, positive), CS type (olfactory, visual) and US type (gustatory, auditory) to test the effects of these factors on the change in evaluative ratings.

The main effect of US valence was significant, $F(1,117) = 15.091$; $p < .001$; partial eta^2 = .114 indicating an overall EC effect. The main effect of CS type was significant, too, $F(1, 117) = 51.211$, $p < .001$, partial eta^2 = .304, indicating higher evaluative ratings for visual CSs compared to olfactory CSs. The interaction of US valence and CS type was significant, $F(1,117) = 7.986$; $p = .006$, partial eta^2 = .064, indicating that EC effects were stronger for visual than olfactory CSs. Follow-up test showed a significant EC effect for visual CSs ($F(1,117) = 24.741$; $p < .001$, partial eta^2 = .175), but not for olfactory CSs ($F(1,117) = 0.491$; $p = .485$, partial eta^2 = .004). The main effect of US type ($F < 1$), the interaction of CS type with US type ($F < 1$), and the interaction of US valence and US type ($F < 1$) were not significant. Central to our hypothesis, the three-way interaction of US valence, CS type, and US type was significant, $F(1, 117) = 6.380$, $p = .013$, partial eta^2 = .052. To understand whether the pattern of this three-way interaction was in line with our prediction, we calculated differences scores (difference in ratings of $CS_{positive} - CS_{negative}$). These are depicted in Fig. 3. As can be seen, gustatory USs (compared to auditory USs) had a more positive/less negative impact on smells than on bottle labels. This pattern is in line with our hypothesis. Specifically, for olfactory CSs gustatory USs led to a stronger EC effect than auditory USs ($F(1,117) = 4.588$; $p = .034$; partial eta$^2 = .038$). For visual CSs, on the other hand, EC effects where descriptively, but not significantly, larger when USs are sounds rather than tastes, ($F(1,117) = 1.570$; $p = .213$; partial eta$^2 = .013$).

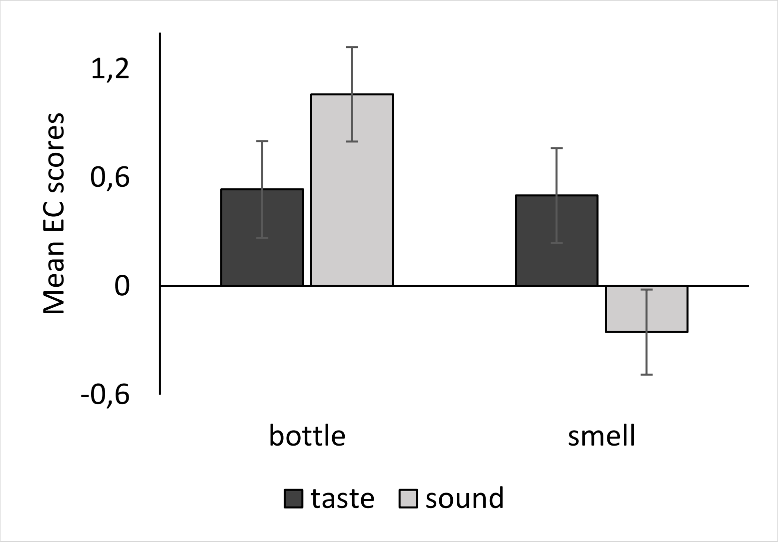

Fig. 3 Mean EC scores on a change in liking pretest to posttest for conditions of CS type and US type with error bars depicting standard errors.

2.4.2.2 Evaluative conditioning and memory.

To investigate whether EC effects can be found for non-remembered CS-US pairings, and in particular for non-remembered smell-taste pairings, we tested the relationship between EC effects, CS type and US type on the change in evaluative ratings on a subset of *only non-remembered pairs* with a pre-registered linear mixed-effects model analysis with crossed random effects for participants (results of the final model are listed in Table 4).

Table 4. The components of the model for predicting the change in evaluative ratings for not remembered pairings based on US valence, CS type and US type.

	B	*SE* (*B*)	*T*	*p*
Intercept	-0.874	0.107	-8.131	< .001
US valence	0.117	0.082	1.421	0.156
CS type	-0.525	0.097	-5.392	< .001
US type	-0.072	0.082	-0.873	0.383
US valence*CS type	-0.049	0.082	-0.599	0.549
US valence*US type	0.092	0.082	1.117	0.265
CS type*US type	0.016	0.082	0.194	0.846
US valence*CS type*US type	-0.092	0.082	-1.120	0.263

As depicted in the Table 4, no effect involving US valence is significant. On this subset of non-remembered pairs there is thus no EC effect (main effect of US valence) and also no two-way or three-way interaction involving this factor with CS type or US type. The only significant effect is the main effect of CS type (t = - 5.392; p < .001) which shows that the liking for olfactory CSs significantly decreased from pretest to posttest compared to visual CSs. The effect size for this effect equals standardized Cohen's *d* of - 0.485 (Judd, Westfall, & Kenny, 2017).

2.4.2.3 Exploratory analyses.

In order to explore a potential explanation for the preparedness effect, we conducted a not preregistered two-way repeated-measures ANOVA with the factors: CS type (olfactory, visual) and US type (gustatory, auditory) and memory for CS-US pairings (percentage of correct CS-US identification) as DV. The main effect of CS type was significant, $F(1,117)$ = 4.929; p = .028; partial eta^2 = .040, indicating that the overall percentage of correct memory identifications was significantly higher when the CS was a bottle label (*M* = 39.8%, *SD* = 35.9%) than when it was a smell (*M* = 32.0 %, *SD* = 33.8%). The main effect of US type was significant, too, $F(1,117)$ = 13.034; p < .001, partial eta^2 = .100, indicating that auditory USs

(*M* = 41.1%, *SD* = 34.9%) were significantly better remembered than gustatory USs (*M* = 30.7%, *SD* = 34.8%). The interaction of CS type and US type was not significant (*F* < 1).

2.4.3 Discussion.

In Experiment 2, we found an overall EC effect and, most importantly, a three-way interaction of US valence, CS type, and US type that is in line with our prediction about a preparedness effect for smell-taste pairings: When smells were the CSs, gustatory USs led to stronger EC effects than auditory USs, but for visual CSs, this difference was not only weaker but descriptively reversed.

Analyses with the subset of non-remembered pairs showed no EC effect and also no moderation of the EC effect by the factors US type and CS type. We therefore found neither evidence for the idea that EC effects with smell-taste combinations might occur without memory for the pairings, nor for the idea that such unaware effects might be stronger for this stimulus combination than for others.

Exploratory analyses on memory for CS-US pairings showed that participants recalled significantly more CS-US pairings with visual CSs (compared to olfactory CSs) and were significantly better at recalling auditory USs (compared to gustatory USs). The first finding is in line with literature on processing of smells, which suggests that humans are particularly bad at identifying and naming smells (Yeshurun & Sobel, 2010), especially relative to easy to verbalize bottle labels with distinct names. Importantly for our current research question, we did not find an interaction of CS type and US type, which suggests that the advantage of smell-taste pairings in yielding EC effects is not observable in memory, partially restricting the interpretation of the preparedness effect for smell-taste combinations.

2.5 General Discussion

In two studies, we tested whether there is evidence that smells and tastes are a prepared association in producing EC effects, and, whether EC effects – in particular for smell-taste pairings – could be found in the absence of memory for CS-US pairings.

The idea that there are prepared stimulus combinations that lead to larger EC effects is quite intuitive and it probably influenced previous studies on EC with smell-taste combinations. Nevertheless, the current Experiment 2 is the first to test a preparedness hypothesis in a straightforward manner. We found that for olfactory CSs, conditioning with tastes resulted in stronger EC effects than conditioning with sounds, with a descriptively reversed pattern for visual CSs. Previous studies did compare EC effects after smell-taste pairings with EC effects after color-taste combinations and found larger effects in the smell-taste combination. This finding, however, is difficult to interpret because it could either be due to a preparedness of the smell-taste combination or an advantage of the smell over the visual CS that is independent of the taste US. Interestingly, in Experiment 1 we did not find differences in the magnitude of EC effects for smell-taste compared to visual-taste CS-US pairings, we did find significant differences in the magnitude of EC effects in the three-way interaction of Experiment 2. We claim that the study design of Experiment 1 did not allow us to distinguish between main effects of CS type and interactions of CS type and US type. We addressed this limitation by adding sound USs to the study design of Experiment 2 to have a comparison condition with taste USs.

Our findings speak clearly for the preparedness for smell-taste combinations and fit well with neuroimaging findings on the concept of flavor, that suggest a special way of processing olfactory and gustatory information in the brain (de Araujo, Rolls, Kringelbach, McGlone, & Phillips, 2003). For taste and smell, all information is assumed to be processed together forming a unimodal sensation called flavor (Small et al., 2004).

In the Introduction we mentioned two accounts of EC that we think are likely to predict the preparedness effect of smell-taste pairings: The Implicit Misattribution account and the Holistic Account of EC. The Implicit Misattribution account (Jones, Fazio, & Olsen, 2009) postulates that EC effects should be stronger when CSs and USs are more likely to be confused with one another, as EC effects result from misattributing the affective properties of USs to CSs. The Holistic Account of EC (Martin & Levy, 1994) postulates that the transfer of valence from USs to CSs occurs through forming a holistic representation of the CS, the US and the affective evaluation of the US. We think that our findings from Experiment 2 with regard to preparedness can be explained by the Holistic Account of EC (Martin & Levy, 1994) as according to this model, EC effects are formed through the transfer of valence from USs to CSs which would be facilitated by smells and tastes being processed as a unified sensation (e.g., Auvray & Spence, 2008). It is, thus, in line with this account that smell-taste combinations would lead to stronger EC effects. In principle, the Implicit Misattribution account of EC can also explain preparedness of smell-taste combinations. Given its assumption that the misattribution of the valence of the US to the CS happens implicitly (Jones, Fazio, & Olson, 2009), however, we would argue that it explains our findings less well as analyses conducted on a subset of only non-remembered CS-US pairings showed no EC effect, and no interaction with the stimulus modalities whatsoever.

The results of Experiment 2 showed also a significant interaction of CS type and US valence on valence ratings, which manifested in stronger EC effects for bottle labels than smells (overall). Accordingly, across the four stimulus combinations visual-sound pairings, and not smell-taste pairings lead to the strongest EC effects. This result pattern renders the evidence for the preparedness effect on first sight less apparent but it is important to keep in mind that the preparedness effect is interpreted solely based on the three-way interaction. Therefore, this result pattern does not make our conclusion that we found evidence for preparedness less valid whatsoever.

In both experiments EC effects were found only for CS-US pairings which were remembered; we thus found no evidence for memory-independent EC. In line with the majority of memory research in EC this suggests that memory for CS-US pairings might under most conditions be necessary for EC effects to occur (for a meta-analysis see: Hofmann et al., 2010). Most studies pointing to the relevance of memory, however, were conducted with visual stimuli. Given previous reports of EC without memory after smell-taste pairings (Baeyens et al., 1990; Dickinson & Brown, 2007; but see Wardle et al., 2007), we thought there could be EC effects for smell-taste pairs - even for non-remembered CS-US pairings. Nonetheless, our findings suggest that even smell-taste pairings are directly linked to explicit memory, which is in line with the general claim that memory for pairings is necessary for EC effects to occur (Hofmann et al., 2010). However, it should be mentioned that in both experiments we conducted, in the memory measure for the CS-US pairings participants had to choose one – either a positive or a negative – US for each CS. It is possible that participants based their memory judgments on how they felt about the CS. This could lead to a stronger EC effect for remembered than for non-remembered CS-US pairs that is not due to a causal influence of memory on EC (Hütter et al., 2012). While this is a possible confounding factor in Experiment 1, we modified the memory measure in Experiment 2 to minimize the potential influence of inferring the correct US based on the liking of the CS by introducing an “I don’t know” option. In addition, it is important to note that while the mentioned process might artificially increase EC effects with remembered compared to non-remembered pairs, this should be the same across stimulus modalities. In case there was an advantage for not-remembered smell-taste pairs, this should then still show in a relative comparison with the other stimulus modalities. We thus should have found a three-way interaction of US valence (EC effect), CS type and US type on the non-remembered pairs – which we did not. We therefore believe that our current results suggest no evidence that smell-taste pairings are a boundary condition for memory-independent EC.

The results fit with a Declarative Memory Model (DMM) of EC (Gast, 2018). This model proposes four conditions that should be fulfilled for EC effects to occur: forming of a memory trace, surviving and then retrieving the memory trace, and, finally using the evaluative information from the retrieved memory trace during the evaluation of the CS. We have to concede that we did not specifically design the current experiments to test which of these four conditions are met. However, we found EC effects only for CS-US pairings that were correctly remembered at the end of the experiments. This, we believe, suggests that the claim that storage, retention, and explicit retrieval are necessary for EC effects to be found, can for now be upheld for all four stimulus combinations that we tested in Experiment 2.

Apart from its hypothesis on the relevance of explicit memory, the stages proposed in the model can be used as a framework for distinguishing processes relevant for the occurrence of EC effects. One might thus ask at which stage the prepared relation of CS and US is a relevant factor. So far, we can tentatively exclude two groups of possible explanations: First, the current results suggest that the ability to recall CS-US pairs is necessary even when CS and US are smell and taste, respectively. The preparedness effect is thus not due to certain stimulus combinations leading to EC effects without explicit knowledge. Second, the memory results for the four stimulus modality pairings did not show the same preparedness pattern as the EC effect. This is a problem for all explanations based on the assumption that smell-taste pairings are encoded, stored, or retrieved easier. One explanation for the preparedness effect would thus be that even when participants did not recall smell-taste pairings better, once they were able to recall them, they made different use of this encoded information. This might suggest that most relevant for the prepared relation of CS and US is in fact the moment at which participants retrieve memory traces during the evaluation of the CS, thus at the fourth stage of the DMM. An alternative explanation would be that smell-taste pairings lead to the perception and encoding of unified flavor sensations and that this unified encoding occurs only when the pairings are also encoded explicitly. While this explanation is somewhat less parsimonious, it fits very well with research on unified smell-taste perception (Small et al., 2004).

In addition to its theoretical relevance, the reported preparedness for smells and tastes are of applied importance, in particular to health psychology. Prepared associations of smell-taste combinations could contribute to the rising problem of obesity. Potentially this preparedness effect for smell-taste combinations could be explored in the domain of consumer research and food preferences acquisition as a means to develop new - healthier - food products contributing to healthier eating habits (Shepherd, 2006).

CHAPTER 3: Evaluative Conditioning of Foods and Actual Food Consumption

3.1 Abstract

In Experiment 3, we investigated the potential of an evaluative conditioning (EC) intervention to successfully modify existing attitudes towards high-calorie snacks. We investigated the following three research questions, (1) the presence of EC effects both in the explicit evaluative ratings (of food and non-food CSs) and in food consumption (of food CSs), (2) the potential preparedness effect for smell-taste combinations present in food-smell CS-US pairings, and (3) the relevance of memory in food-smell EC effects. We did not find overall EC effects neither in the explicit evaluative ratings, nor in food consumption of food CSs. We did find significant memory-moderated differences in food consumption of food CSs. For remembered CS-US pairings, participants consumed more of food CSs that had been previously paired with positive USs. For non-remembered pairings this pattern of the results was reversed.

3.2 Introduction

The escalating prevalence of obesity and type 2 diabetes has been associated with an increase in energy intake due to snacking on high-calorie foods (Bertéus Forslund, Torgerson, Sjöström, & Lindroos, 2005) and a rise in consumption of sweetened drinks (Montonen, Järvinen, Knekt, Heliövaara, & Reunanen, 2007). Alarmingly, roughly one-fourth of daily-calorie intake comes from sweetened beverages and snacks among children (Piernas & Popkin, 2010). With a high prevalence of obesity, along with its accompanying social ostracization and health risks, we observe a tendency of people engaging in actions focused on losing weight through dieting (Kruger, Galuska, Serdula, & Jones, 2004). However, even though dieters often manage to successfully lose their body fat and reach their desired weight, they are rarely capable of maintaining it, despite their efforts (Mann et al., 2007). One factor that might contribute to these difficulties is the habit of snacking (Swinburn, Caterson, Seidell, & James, 2004). Snacking *per se* would not be considered a serious health risk if it was not predominantly associated with indulging in foods high in sugar and fat (Hampl, Heaton, & Taylor, 2003). These kinds of foods seem to induce positive affect and stimulate reward circuits in the brain which may lead people to consume high-calorie foods despite being aware of the health risks associated with them (e.g., Boyland & Halford, 2013; Ziauddeen, Alonso-Alonso, Hill, Kelley, & Khan, 2015). In fact, it has been shown that such positively-associated food cues can trigger food seeking and the desire to consume high-calorie foods even in the absence of hunger (e.g., Colagiuri & Lovibond, 2015; Watson, Wiers, Hommel, & de Wit, 2014). Thus, to observe a reduction in food consumption of high-calorie foods, we argue it is vital to change people's attitudes towards these foods.

Evaluative conditioning (EC), defined as a change in evaluation of a conditioned stimulus (CS) due to this stimulus having been paired with a - typically valent - unconditioned stimulus (US; De Houwer, 2007), has been successfully used as a way of changing people's attitudes towards people and every-day objects (Hofmann et al., 2010). Thus, we argue that EC interventions could be implemented in the context of food preferences and used as ways to modify existing positive associations with high-calorie foods. Existing in health psychology studies on EC with food-related stimuli typically focus on creating positive associations with healthy (or novel) foods rather than changing existing positive associations with unhealthy foods (Walsh & Kiviniemi, 2013). Given how problematic the habit of snacking on high-calorie foods is, we argue that changing the attitude towards high-calorie foods that people tend to overeat at is a more ecologically valid approach.

So far, studies on EC in the context of changing attitudes towards unhealthy snacks suggest that EC interventions have a potential to modify attitudes towards, and consumption of, high-calorie snacks (Hollands & Marteau, 2016; Hollands, Prestwich, & Marteau, 2011; Lebens et al., 2011; Shaw et al., 2016). However, due to their designs and methodological set ups which we describe below, these studies did not test the effects of EC interventions on explicit attitudes towards foods nor the act of food consumption in an optimal way.

In two computer-based studies (Hollands & Marteau, 2016; Hollands et al., 2011), the authors found that after pairings of high-calorie foods with aversive stimuli, participants were more likely to choose a healthy (relative to an unhealthy) food product in a subsequent food choice task. The authors did not find, however, any EC effects neither on implicit nor on explicit attitudes towards snacks. The only participants who did manifest significant implicit devaluations of snacks after the EC intervention were those who exhibited more positive attitudes towards snacks at baseline.

Lebens and colleagues (2011) investigated the potential of a picture-picture EC intervention to change attitudes towards snacks. In the conditioning phase, female participants were presented with healthy foods together with positive images and unhealthy foods together with negative images. Partially in line with the findings of Hollands and Marteau (2016), Lebens and colleagues (2011) reported a more negative associations with high-calorie snacks after an EC intervention and an increase in liking of healthy foods. Moreover, after the conditioning phase, participants' task was to shop for groceries in a virtual supermarket. Once they completed this task, the calories coming from snacks and the calories coming from healthy foods were calculated as dependent variables. Even though the implicit attitudes changed due to an EC intervention, the authors did not find the same effects on the behavioral measure, as participants did not differ in the amount of calories coming from healthy (versus unhealthy) foods.

As much as the above results suggest that EC has a potential to modify implicit attitudes towards foods, in all of these studies participants were merely looking at the stimuli presented on a computer screen and were never exposed to real foods in the conditioning phase, making study procedures not particularly ecologically valid. In order to see the actual potential for the ability of EC to successfully condition food preferences, we argue that participants should experience real (actual) food products both in the conditioning phase and in the measurement phase during their evaluation. Another methodological issue present in the studies described above is the fact that in the behavioral measure of liking (food choice tasks) participants were asked to select a given food from food products which had not been used in previous phases of experiments. Because of this, the actual EC effects were not measured, but, instead, the potential of EC effects to generalize to different categories of foods.

A recent study conducted by Shaw and colleagues (2016) seems to address most of these limitations. The authors investigated the potential of EC interventions in the actual consumption of sweetened soft drinks. Both in the conditioning phase and in the measurement phase participants were presented with the actual drinks, which were paired with either negative (disgust-evoking) or positive images, and were consuming them. Similar to previous findings, the implicit attitudes towards sweetened beverages were reported; yet, there were no differences in soft drinks consumption in the taste test that followed the conditioning procedure. Importantly, however, the used brands of beverages were well-known brands and their logos were visible to participants across the conditioning phase. Thus, the absence of EC effects in the behavioral measure might have resulted from the stimuli being not novel (or not neutral) enough.

Taken together, even though there is some evidence supporting EC procedures being successful in modifying attitudes towards foods, it remains unclear to which extent EC is effective. Furthermore, the lack of conclusive findings in regards to the impact of EC on explicit evaluative ratings and on behavioral measures of liking shall be explored more thoroughly.

In an attempt to address all the methodological issues highlighted above and in order to fill the gap in the literature, we designed an EC study with real-life foods[2] to test the effectiveness that EC interventions have on modifying attitudes towards and the actual consumption of high-calorie foods. Similar to experiments reported in Chapter 2, in this chapter we additionally tested the preparedness hypothesis for smells and tastes as a potential moderator of EC effects. As suggested in Chapter 2, the preparedness effect for smell-taste combinations might lead to stronger EC effects with food stimuli, thus, in the current study we used foods and non-foods as CSs to test whether conditioning effects would differ depending on whether smells or images were USs. We furthermore investigated the role of explicit memory in EC to test whether we could replicate memory-dependent EC effects for food-related stimuli reported in Chapter 2.

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[2] The study was approved by the ethical committee of Deutsche Gesellschaft für Psychologie.

3.3 Method

3.3.1 Participants.

Eighty-three (relative to pre-registered eighty[3]) participants recruited at a campus of the University of Cologne volunteered to participate in this study. Each participant received 7 euros or course credit for their participation. Every participant consented to participate in the study and none of the participants reported diabetes or food allergies when prescreened orally prior to the start of the experimental procedure. Additionally, participants were asked to privately create a personal word code according to a set of rules they received on a sheet of paper, so that their data sets could be stored anonymously.

3.3.2 Research questions.

The following hypotheses were pre-registered prior to launching the study (http://aspredicted.org/blind.php?x=3bp5ex): Firstly, we hypothesized that EC effects would be observable in the explicit evaluative ratings (both for foods and non-foods) and in the behavioral measure of liking (the amount of food consumed in the taste test) for foods. Secondly, we expected to find significant differences in the magnitude of EC effects (both in the explicit evaluative ratings and in food consumption) between different stimulus modality combinations[4]. Third, we planned to investigate (without a specific hypothesis) the role of explicit memory in food-smell EC effects compared to other CS-US pairings to examine whether food-smell EC effects on explicit ratings were less dependent on explicit memory than

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[3] We planned to test 80 participants, yet, we collected three additional participants in case there was missing data for planned comparisons.

[4] Specifically, we hypothesized that the EC effects on food stimuli would be stronger for food-smell pairings compared to food-image pairings both in evaluative ratings and in food consumption. Furthermore, we hypothesized that this difference between smell-USs and image-USs would be larger for pairings with food CSs than for non-food CSs.

other stimulus combinations. We planned to conduct exploratory analyses including hunger and BMI scores in the context of learning effects.

We planned to investigate the role of explicit memory for CS-US pairings in the behavioral measure of liking (the amount of food consumed in the taste test) for foods, however, this analysis was by omission not pre-registered prior to conducting the study and is thus described in this thesis as exploratory.

3.3.3 Design.

The experiment had three fully-crossed within-participant factors: US valence (positive, negative), US type (smell, image), and CS type (food, non-food). Every participant was presented with all the eight CS-US pairings: CS_{food}-$US_{olfactory\ negative}$, CS_{food}-$US_{olfactory\ positive}$, $CS_{non\text{-}food}$-$US_{olfactory\ negative}$, $CS_{non\text{-}food}$-$US_{olfactory\ positive}$, CS_{food}-$US_{visual\ negative}$, CS_{food}-$US_{visual\ positive}$, $CS_{non\text{-}food}$-$US_{visual\ negative}$ and $CS_{non\text{-}food}$-$US_{visual\ positive}$. Each of the eight (four food and four non-food) CSs was paired with either a positive or a negative US which could have been, respectively, either a smell or an image.

3.3.4 Stimulus material.

The food CSs were four high-calorie snacks by widely available brands in Germany. The non-food CSs were four stationary objects. Food (CSs_{food}) and non-food ($CSs_{non\text{-}food}$) stimuli were presented on the bottom of paper food containers and accompanied by smells ($USs_{olfactory}$) or images (USs_{visual}) stimuli.

3.3.4.1 Food products.

The four chosen food CSs were pre-tested ($N = 30$) on the pleasantness dimension prior to conducting this study: sesame fish-shaped crackers by “funny-frisch” company, butter biscuits by “Bahlsen” company, chocolate-covered raisins by “K-Classic” company, and, caramel candies by “Werther’s Original” company. The foods were on average rated as *M* = 5.34 (*SD* = 1.51) on a 8-point liking Likert scale ranging from 0 (very unpleasant) 8 (very pleasant). The list of ingredients of the four chosen food products can be found in Appendix 2.

3.3.4.2 Non-food products.

The four chosen non-food CSs were commonly used no-name stationary items: paperclips, pencil sharpeners, erasers, binder clips. The items were pre-tested (*N* = 30) on the pleasantness dimension prior to conducting this study and were on average rated as *M* = 5.22 (*SD* = 1.36) on a 8-point liking Likert scale ranging from 0 (very unpleasant) 8 (very pleasant), matching the evaluative ratings of food stimuli in the pretest.

3.3.4.3 Smells.

The following four smells were chosen as olfactory USs in the study: vanilla aroma, gingerbread aroma, onion aroma, and vinegar. The three aromas (vanilla, gingerbread and onion) were food aromas obtained from TH. Geyer company (“Premium Flavor Selection”, TH. Geyer, Germany, DIN ISO 9001:2008). The fourth stimulus was vinegar of 5% sourness, a house brand product purchased from K-Classic.

All the smell USs were pre-tested (*N* = 30) on the pleasantness dimension prior to conducting this study, on a 9-point liking from 1 (very unpleasant) to 9 (very pleasant). For the positive olfactory USs, we chose vanilla (*M* = 6.10, *SD* = 2.62) and gingerbread (*M* = 7.27, *SD* = 1.57) aromas. For the negative olfactory USs, we chose onion aroma (*M* = 3.93, *SD* = 1.39) and vinegar aroma (*M* = 3.03, *SD* = 1.19) The four smell CSs were presented on cotton pads wetted with water-based aroma solutions dispersed at different quantities: 2 ml of 3% vanilla aroma water solution, 1 ml of 3% gingerbread aroma water solution, 5ml of 20% vinegar water solution and 2 ml of 0.5% onion aroma water solution.

3.3.4.4 Images.

As image USs, we used four affective images taken from the International Affective Picture System (IAPS) and other sources. All the images were pre-rated in our lab prior to the experimental procedure on the valence dimension on a 9-point liking Likert scale from 1 (very unpleasant) to 9 (very pleasant) and all the visual stimuli had been previously used in our lab in EC paradigms. For negative visual USs we used images of a shark (*M* = 1.72, *SD* = 1.83) and a wound (*M* = 1.84, *SD* = 1.99). For positive visual USs we used images of milky way (*M* = 8.56, *SD* = 1.84) and blossoms (*M* = 7.75, *SD* = 1.68). All the images were glued to the bottom of the lid of paper containers in a form of printed in color stickers.

3.3.5 Procedure.

The study took place in a room with an access to a fridge (in which all the edible stimuli were stored) and big windows to air out the room in breaks between testing participants. Participants were seated at one of the two working spaces, and, at the start of the experiment, received printed sheets with information about the study and the consent they had to sign if they wanted to participate in the study. The experimenter was present in the room to answer possible questions. When participants signed the consent, they moved on to the first experimental phase.

The experimental procedure consisted of the three main phases: conditioning phase, evaluation phase, and memory phase, which was followed by the collection of body measures. In each of the phases of the study, participants were asked to follow instructions printed on the sheets of papers in front of them.

3.3.5.1 Conditioning phase.

The conditioning phase started with a detailed and printed instruction that informed participants exactly what to do in each trial, a set of 8 paper food containers that carried the

CS-US combinations (see Stimulus material section above) and one additional practice container containing a neutral printed image on the bottom of the lid with nothing inside the container. In the instruction participants were asked in each trial to take the container, remove the lid and look at it, look at and smell the content of the container. Participants were informed that the procedure was self-paced, but that they should not take too long. At the start of the conditioning phase, an experimenter demonstrated in a practice trial what participants had to do. Afterwards, participants independently did six cycles of the eight CS-US combinations with a short break in between (after the first three cycles). In each cycle, every container contained one of the two types of CSs (either a food CS or a non-food CS) and one of the two types of USs (either a smell or an image). The assignment of CSs and USs was counterbalanced across participants. The order of presentation of the CS-US combinations was pre-randomized for each participant and presented in a fixed order across all six learning blocks. After each trial, participants were asked to smell a bowl containing coffee beans in order to neutralize previous smells lingering in their nostrils.

3.3.5.2 Evaluation phase.

Evaluation phase consisted of two sub-phases: evaluation of food CSs and evaluation of non-food CSs with the use of printed questionnaires containing questions per each of the CSs[5]. Food and non-food CSs were rated in a counterbalanced order across participants.

3.3.5.2.1 Evaluation of food CSs.

In the evaluation phase of food CSs, participants were presented with the four food products that were used in the conditioning phase at the pre-randomized per participant order. All the food products were served to participants in glass bowls, one-by-one.

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[5] The original versions of the questionnaires that were used in the evaluation phase are attached as Appendix 3.

Each participant received a booklet consisting of a set of questions regarding different aspects of the evaluated foods. Among the questions, there was a measure of explicit evaluative ratings for which participants had to indicate on a scale ranging from 1 (very unpleasant) to 9 (very pleasant) how much they liked each CS. In line with consumption tests reported in the literature (e.g., Nijs, Murius, Euser, & Franken, 2010), these evaluative ratings were collected in a set of questions regarding different properties of the foods (with a question measuring explicit evaluative ratings on the first position of the questionnaire). For each of the food products, participants were asked to taste it in order to judge its taste qualities. Participants were furthermore informed that they could eat as much as they wanted of each of the food products while answering the questions. The amount of foods in grams per each of the evaluated foods had been weighed prior to the evaluation phase, and, weighed once more after participants were finished.

3.3.5.2.2 Evaluation of non-food CSs.

In the evaluation phase of non-food CSs, participants followed a similar procedure to the described above procedure for evaluating food CSs, except that they were not asked to consume any of the stationary objects. At the start of this sub-phase, each participant received the four non-food CSs one-by-one at the pre-randomized order. Participants were then asked analogous questions regarding liking and physical properties of the stimuli and indicated their answers in a similar booklet that was used for food stimuli.

3.3.5.3 Memory phase.

Memory for CS-US pairings was assessed separately for CSs that were previously paired with olfactory USs, and separately for CSs that were paired with visual USs. The memory phase was, thus, divided into two counterbalanced across participants sub-phases: memory for pairings with olfactory USs, and, memory for pairings with visual USs.

3.3.5.3.1 Memory for pairings with olfactory USs.

In the memory measure for CS_{food}-$US_{olfactory}$ and $CS_{non\text{-}food}$-$US_{olfactory}$ pairings, participants' task was to recall for each of the food and non-food CSs with which of the four aromas it had been previously paired with. Participants were provided with a printed booklet containing instructions to follow, a set of four paper containers (labeled with letters from A to D) with the four aromas used in the conditioning phase before. The experimenter was presenting the CSs one-by-one in a pre-randomized per participant order.

At the start, participants read that their task was to try to recall which aroma a given food product or stationary item had been previously paired with. When participants indicated they were ready to start, the experimenter would bring CSs one-by-one for participants to give their memory judgments. Each of the CSs was presented in one of the four paper containers with lids number from 1 to 4. Participants read that they should remove the lid and look at the content of the cup. Then, they would be instructed to take each of the containers containing aromas which had been placed in front of them at the desk, remove the lids, and breathe in the smell from each of them. They would read that it was important they smelled all of them to be sure of which aroma had been paired with the CS they were giving their memory judgments for. Once participants made up their minds, they would read that they should write down the letter assigned to the container with the aroma they thought the CS had been paired with.

3.3.5.3.2 Memory for pairings with visual USs.

In the memory measure for CS_{food}-US_{visual} and $CS_{non\text{-}food}$-US_{visual} pairings, the procedure was the same as for the assessment of memory for CS-US pairings with olfactory stimuli, except that participants' task was to recall for each of the food and non-food CSs with which of the four images it had been previously paired with. Participants used the same printed booklet containing the exact instructions to follow, a set of four paper containers (labeled with letters from E to H) with the four images used in the conditioning phase before. Each of the CSs was presented to the participants individually by an experimenter in pre-randomized per participant orders.

Participants read that their task was to try to recall which image a given food product or stationary item had been previously paired with. The experimenter brought CSs one-by-one for participants to give their memory judgments. In this sub-phase, visual USs were presented as printed in color images which were glued on the bottom of container lids. The containers with visual USs were numbered from 5 to 8. Participants started by removing the lid and looking at the content of the presented CS. Then, they would open each of the containers containing images which had been placed in front of them at the desk. They would look at each of the lids and read that it was important they looked at all of them to make sure they could decide which image had been previously paired with the CS they were giving their memory judgments for. Participants would read that they should write down the letter assigned to the container with the images they thought the CS had been paired with.

3.3.5.4 Additional measures.

Participants were asked to indicate how hungry they were on a scale ranging from 1 (not hungry at all) to 9 (very hungry), to give an estimate of the time (in minutes) that passed since the last meal they had prior to the study, and, to indicate the extent to which they had problems with smelling (e.g., allergies or runny nose) on a scale ranging from 1 (no difficulties smelling) to 9 (very difficult to smell). Body measurement – height and weight – were collected at the end of the experimental procedure by measuring each participant and writing down their height (in centimeters) and weight (in kilograms), so that BMI scores could be calculated.

3.3.6 Data analysis.

We tested the effects of experimental factors on the explicit evaluative ratings and on food consumption as pre-registered. Exploratorily, we tested the effects of explicit memory for CS-US pairings, hunger and BMI on food consumption. All the models were tested with item-based linear mixed model analyses in R.

3.4 Results

3.4.1 The effects of US valence, CS type and US type on evaluative ratings.

To test the effects of experimental factors on evaluative ratings, we aimed to fit a model with main effects of US valence (negative = -1, positive = 1), CS type (food = -1, non-food = 1) and US type (smell = -1, image = 1) and their interactions on evaluative ratings along with crossed random effects for participants, CSs, USs (as intercepts) and random slopes for all fixed factors with linear mixed model analyses. The model converged with only one significant effect, for CS type (t = -6.026; p < .001) with participants on average rating food CSs as more pleasant than non-food CSs (independently of the US valence and US type). None of the hypotheses-relevant effects were significant (see Table 5).

Table 5. The effects of factors US valence, CS type and US type on evaluative ratings.

	B	***SE* (*B*)**	***t***	***p***
Intercept	5.750	0.085	67.490	< .001
US valence	0.041	0.076	0.542	.588
US type	0.028	0.076	0.369	.713
CS type	-0.530	0.088	-6.026	< .001
US valence*US type	-0.063	0.077	-0.830	.407
US valence*CS type	-0.013	0.076	-0.166	.868
US type*CS type	-0.143	0.076	-1.873	.062
US valence*US type*CS type	-0.045	0.077	-0.594	.553

3.4.2 The effects of US valence, CS type, US type and memory for pairings on evaluative ratings.

In the next step we added memory for pairings as another factor into the model to test the effects of the four experimental factors on evaluative ratings together: US valence (negative = -1, positive = 1), CS type (food = -1, non-food = 1), US type (smell = -1, image = 1) and memory for pairings (not remembered = -1, remembered = 1) with their interactions on evaluative ratings along with crossed random effects for participants, CSs, USs (as intercepts) and random slopes for all fixed factors with linear mixed model analyses. The model converged, but none of the effects were significant (see Table 6).

Table 6. The effects of factors US valence, CS type, US type and memory for pairings on evaluative ratings.

	B	*SE* (*B*)	*t*	*P*
Intercept	5.519	0.245	22.512	< .001
US valence	-0.002	0.113	-0.017	.987
US type	-0.188	0.111	-1.692	.106
CS type	-0.486	0.295	-1.647	.130
Memory for pairings	0.289	0.152	1.902	.088
US valence*US type	-0.083	0.109	-0.762	.447
US valence*CS type	0.075	0.194	0.389	.712
US valence*Memory for pairings	0.017	0.131	0.130	.899
US type*CS type	-0.087	0.196	-0.446	.673
US type*Memory for pairings	0.228	0.131	1.742	.110
CS type*Memory for pairings	-0.080	0.137	-0.581	.573
US valence*US type*CS type	0.039	0.194	0.199	.850
US valence*US type*Memory for pairings	0.047	0.130	0.365	.722
US valence*CS type*Memory for pairings	-0.056	0.110	-0.513	.608
US type*CS type*Memory for pairings	0.010	0.112	0.087	.931
US valence*US type*CS type*Memory for pairings	-0.131	0.109	-1.195	.233

In addition to this model, we tested a model trimmed of random intercepts and slopes for CSs and USs as we had only eight stimuli per each of the two factors (eight CSs and eight USs in total) and modelling random parts for them is considered to contribute to loss in power (Judd, Westfall, & Kenny, 2017). We thus tested a model with the same main effects of US valence, CS type, US type and memory for pairings, their interactions, and crossed random effects only for participants, on evaluative ratings. Similar to the previous model, none of the hypotheses-relevant effects were significant.

3.4.3 The effects of US valence and US type on food consumption.

To test the effects of experimental factors on food consumption, we aimed to fit a pre-registered model with main effects of US valence (negative = -1, positive = 1) and US type (smell = -1, image = 1) and their interactions on food consumption along with crossed random effects for participants, CSs, USs (as intercepts) and random slopes for all fixed factors with linear mixed model analyses. The model converged, but none of the hypotheses-relevant effects were significant (see Table 7).

Table 7. The effects of factors US valence and US type on food consumption.

	B	*SE (B)*	*T*	*p*
Intercept	48.201	11.285	4.271	< .05
US valence	1.263	1.885	0.670	.576
US type	1.597	1.558	1.025	.306
US valence*US type	0.762	1.557	0.489	.625

To increase power for our comparisons, we additionally tested a model trimmed of random intercepts and slopes for CSs and USs. We thus tested a model with the same main effects of US valence and US type, its interaction, and crossed random effects only for participants, on food consumption. Like for the original model, none of the hypotheses-relevant effects were significant.

3.4.4 The effects of US valence, US type and memory for pairings on food consumption.

In the next step, we added memory for pairings as another factor into the previous model to investigate the role of US valence, US type and memory for pairings on EC effects measured in food consumption of food CSs. We thus built and aimed to fit the model with main effects of US valence (negative = -1, positive = 1), US type (smell = -1, image = 1), memory for pairings (not remembered = -1, remembered = 1) and their interactions on food consumption along with crossed random effects for participants and random slopes for all fixed factors with linear mixed model analyses. The model converged and the results of it are presented in Table 8.

Table 8. The effects of factors US valence, US type and memory for pairings on food consumption.

	B	*SE* (*B*)	*t*	*p*
Intercept	46.261	4.249	10.888	< .001
US valence	-0.250	3.063	-0.082	.935
US type	2.458	3.127	0.786	.433
Memory for pairings	1.824	3.536	0.516	.606
US valence*US type	1.776	2.909	0.610	.542
US valence*Memory for pairings	6.220	3.038	2.047	.042
US type*Memory for pairings	-0.263	3.262	-0.081	.936
US valence*US type*Memory for pairings	-3.778	2.983	-1.267	.207

As presented in Table 8, the only significant effect in this model was the interaction of factors US valence and memory for pairings ($t = 2.047$, $p = .042$). To understand the direction of this effect, we re-tested the model separately on subsets of non-remembered and remembered pairings. The analyses showed that when participants remembered food CS-US pairings (independently of US type) they consumed more of the foods that had been previously paired with positive USs ($t = 2.404$, $p = .019$). For non-remembered pairings this pattern reversed, with participants consuming significantly less of positively-paired foods in the absence of memory for contingencies ($t = -2.453$, $p = .022$).

3.4.5 Hunger, BMI and learning effects.

For exploratory purposes we investigated the role of US valence, hunger and BMI in EC effects - both in evaluative ratings and food consumption. We thus built and tested two models: on the explicit evaluative ratings of food CSs and on food consumption of food CSs. In both models we tested main effects of the following factors: US valence (negative = -1, positive = 1), hunger, BMI and the interactions of all fixed factors with linear mixed model analyses. There were no significant effects neither in the model for the explicit evaluative ratings, nor in the model for food consumption.

3.5 Discussion

In the present study we investigated EC effects with real-life stimuli: food and non-food CSs that were paired with either smells or images. First, we tested whether EC effects would be present in explicit evaluative ratings for food and non-food CSs. We furthermore tested whether these learning effects would also be observable in actual consumption of food CSs. Second, we tested whether certain stimulus modality combinations yielded stronger EC effects compared to other stimulus modality pairings. Based on the findings supporting preparedness effect for smell-taste combinations reported in Chapter 2, we hypothesized that conditioning effects for food stimuli would be stronger after being paired with smells than with images. We furthermore expected the difference between olfactory and visual USs to be larger for food CS-US pairings relative to non-food CS-US pairings. Third, we investigated the role of explicit memory for pairings in food-smell EC effects observable in the explicit evaluative ratings and exploratorily in actual food consumption. Finally, we explored the role of hunger and BMI as potential moderators of learning effects.

No EC effects on the explicit evaluative ratings were found across all the stimulus modality combinations and this lack of effect was independent of whether participants could recall CS-US pairings or not. The same pattern of results appeared for the behavioral measure of learning effects as we did not find any differences in the amount of food consumed, either. We also did not find effects of hunger, nor BMI, on the explicit evaluative ratings and on food consumption of food CSs. We did, however, find a significant interaction of US valence and Memory for pairings in an exploratory analysis which showed that participants who could recall CS-US pairings consumed more of the foods that had previously been paired with pleasant USs (compared to the ones paired with negative USs). Interestingly, for participants who did not remember CS-US pairings this relationship was reversed. Whether the interaction of US valence and Memory for pairings in the actual food consumption could be interpreted as EC effects is arguable as we did not observe EC effects on the explicit evaluative rating whatsoever, nor did we find overall EC effects in the behavioral measure (food consumption). Finally, it could as well be that participants inferred the memory based on arbitrary differences in valence for the CSs.

Overall, not being able to find EC effects on the explicit evaluative ratings, nor on the actual food consumption in our study raises a question on the boundary conditions for EC effects to occur for real-life and tangible stimuli. As a very robust phenomenon, EC effects were successfully reported across various stimuli in standard EC procedures (Hofmann et al., 2010); yet, little is known about EC effects occurring in a more applied and ecologically valid context with the actual objects. In fact, previous studies (conducted within our research group) with real-life stimuli aiming at detecting EC effects failed to observe it, too.

We argue, that the absence of EC effects in the present study could be attributed to deviations in the experimental design relative to typical EC procedures. First, in the present study, participants were interacting with real-life and tangible objects rather than images appearing for a brief moment on the computer screen as it is typically done in EC studies (Hofmann et al., 2010). Both in the conditioning phase and in the measurement phase of our experiment, participants actively interacted with the stimuli. Second, in all the phases of the experiment, participants were given unlimited time to take each of the CSs in their hands, look at it and explore by touching, tasting (for food CSs) or to think of how one could use the items and list their purposes (for non-food CSs) in the measurement phase. Through such a procedure the attention towards and focus on the stimuli were enhanced and participants had time to weigh in many sensory inputs before they gave their evaluation judgments. Importantly, both types of CSs which were used in this study were well-known snacks and sweets (food CSs) or every day stationary items (non-food CSs). It is thus likely, that participants had multiple experiences and valent memories of foods or stationary items prior to experiencing them being paired with valent USs later on. Even though all the CSs had been pre-tested on the pleasantness dimension and were rated as neutral on average, they might have been rated as neutral on the aggregated level, but in fact participants could have had multiple positive and negative associations with each of the stimuli. This, combined with not being time-constraint and encouraged to actively engage with the CSs, might have led participants to base their evaluation judgments on all the valence-related inputs summed up together rather than on the valence based on recent CS-US pairings. This would explain why there were no differences in the explicit evaluative ratings of the CSs based on the valence of the USs they had been paired with.

Another point to consider is the specificity of the measurement phase in the current study, which makes it possible to attribute lack of EC effects to the phenomenon of extinction in conditioning literature (Baeyens, Eelen, & Crombez, 1995). In the measurement phase, participants were presented with each of the CSs one-by-one and asked to take each of the stimuli in their hands, to taste (food CSs) and to explore their physical characteristics (non-food CSs) before they gave their evaluative judgments. Participants had an unlimited time to interact with the CSs before they evaluated them. It could be thus argued that what participants experienced prior to the actual evaluation of the CSs were CS-only trials which followed after the conditioning phase. These trials would be then considered extinction trials which were found to reduce EC effects in some of the studies (for more details, see a meta-analysis: Hofmann et al., 2010). However, whether EC effects are sensitive to extinction procedures are still debatable (e.g., De Houwer, 2011; Gast & De Houwer, 2013; Gawronski, Gast, & De Houwer, 2014) suggesting that the extinction phenomenon as a potential explanation of not detecting EC effects in the current study is rather unlikely. Finally, another potential factor that might have contributed to not detecting any EC effects in the present study would be related to the concept of causality. In the conditioning phase of the present study, participants could easily tell that images and smells did not belong to the CSs. Images were glued on the bottom of the lid of containers in which CSs were presented and smells were administered in a form of soaked in aromas cotton pads placed next to foods or stationary items inside the containers. Participants could have then perceived CS-US pairings as separate and not related to each other items. This explanation is less likely though as CS-US pairings were still presented in close proximity and participants should have been able to process them together. Finally, there is a possibility that the used USs were not strong enough to lead to an evaluative change of the CSs, but it is rather unlikely as all the USs had been pre-rated prior to the study and we selected stimuli with distinctively positive and negative ratings.

CHAPTER 4: Differential Learning Patterns Between Normal Weight and Obese Individuals

4.1 Abstract

Previous research findings on learning effects in obesity suggest that obese individuals might learn worse compared to lean individuals. It was furthermore suggested that in obesity one may observe a pattern of poorer cognitive performance relative to normal weight individuals. To test whether obese individuals indeed exhibit differential learning patterns, we investigated group differences in learning effects in an online EC study with high-calorie foods as CSs.

We investigated three main questions, (1) the presence of EC effects both in the explicit evaluative ratings and in the intention to consume food CSs, (2) the hypothesized group differences in the magnitude of EC effects and in the accuracy of valence guessing trials between normal weight and obese participants, and (3) the role of memory in EC with high-calorie food CSs. We found overall EC effects measured both in the explicit evaluative ratings (Experiment 4 and 5) and in the intention to consume foods (Experiment 4) which were moderated by valence memory. We found no evidence in favor of the hypothesized differences between normal weight and obese individuals in the magnitude of EC effects nor in the accuracy of valence predictions.

4.2 Introduction

Nowadays, obesity has become an urgent problem worldwide, both on an individual and on a societal level, that remains to be successfully tackled. Within last decades, the global prevalence of obesity was rising (e.g., Stevens et al., 2012; Rennie & Jebb, 2005). Furthermore, with no country so far reporting a single success in addressing this urgent issue within their national health policies (Ng et al., 2014), we observe a growing epidemic of obesity already among children and adolescents (e.g., Dutton, Martin, Nackers, & Pan, 2015; Hruby & Hu, 2015). Some of the researchers raised unsettling concerns about the fall in life expectancy in next decades due to obesity-related health risks, yet, despite its high importance, current interventions aiming at losing weight are far from being effective and satisfactory (Campos, Saguy, Ernsberger, Oliver, & Gaesser, 2005). Furthermore, studies show that existing interventions oriented on losing weight are often ineffective and roughly half of the people who try losing weight within professional weight loss programs, report to have gained even more weight than when they had started the programs a few years later (Mann et al., 2007). Thus, interventions focused on reducing obesity and programs oriented at losing weight should have the highest priority in planning health policy strategies worldwide. Especially, since research findings suggest that even small changes in body weight due to weight loss are visible in health improvement (Knowler et al., 2002).

Importantly, the last few decades of intense research show that among the obese – independently from numerous somatic and health problems – another potential consequence may be observed: a characteristic profile of poor cognitive performance. Numerous studies on obesity across different age groups, provide consistent findings on obesity being linked to cognitive impairments independently of medical conditions and mental disorders, even when controlled for socioeconomic factors (Smith, Hay, Campbell, & Trollor, 2011). Previously, it was suggested that the link between poor cognitive performance and obesity could be bidirectional (for a review of the associations between obesity and cognitive functions, see: Smith, Hay, Campbell, & Trollor, 2011), yet, a meta-analysis of studies investigating cognitive performance after significant weight loss reports that obese individuals who became considerably thinner improved on various measures of executive functions, suggesting a rather causal relationship of adiposity (excess of fat) on cognitive impairments (Siervo et al., 2011).

Yang and colleagues (2018) in a recent meta-analysis of cognitive performance in obese further confirms that obesity is not only associated with poor mental and physical health, but also with broad impairments on a range of executive functions, including inhibition, decision-making and planning. These deficits can manifest in children with obesity and be present across the lifespan in the adulthood (Liang, Matheson, Kaye, & Boutelle, 2014). Yet, still little is known about specific impairments in learning and memory processes. Coppin and colleagues (2014) across two experiments explored group differences between obese and normal weight individuals in the Conditioned Cue Preference Test (CCPT) which measures preference conditioning for initially neutral stimuli (Johnsrude, Owen, Zhao, & White, 1999) with working memory and stimulus reward association learning effects assessed within this test.

The results of both experiments showed that obese individuals exhibited deficits in preference conditioning as they formed stronger preference for stimuli associated with negative outcomes (yielding smaller rewards) and scored lower on a working memory task compared to normal weight individuals. Interestingly, this pattern of results was found for both – food and monetary rewards, with obese individuals selecting patterns associated with smaller food and smaller monetary rewards. The results suggest that preference conditioning might be impaired in obesity and that obese individuals fail to learn about consequences and negative outcomes which might consequently lead to overeating or compulsive way of eating in the absence of hunger.

Neuroscientific findings show similar patterns of obesity being associated with a range of phenomena visible in human brain activity and structure. For instance, a negative relationship between BMI and grey matter volume was systematically identified in brain regions involved in executive functions (Walther, Birdsill, Glisky, & Ryan, 2010). Other studies reported similarities between obesity and addictions in terms of aberrant dopaminergic circuits with obese individuals found to exhibit decreased levels in dopamine D2 receptors characteristic also for drug-addicted subjects (Volkow et al., 2008). The dopaminergic system is believed to be of great importance in the context of learning and adaptive behavior (Bayer & Glimcher, 2005) as dopamine is thought to mediate learning from positive and negative outcomes (e.g., Van der Schaaf et al., 2014). Consequently, alterations in dopamine circuits have been further associated with difficulties in learning, especially in unknown and uncertain situations (Mathar, Neumann, Villringer, & Horstmann, 2017). Difficulties in learning from reward prediction errors have been reported not only among obese, but also in clinical samples of psychoactive substances-addicts (e.g., Chiu, Lohrenz, & Montague, 2008; Park et al., 2010). Patients addicted to alcohol were reported to have significantly impaired abilities to flexibly adapt their behavior to changes in reinforcement-learning tasks (Park et al., 2010). If that is the case, both obese, and addicted individuals, might manifest similar difficulties in learning from reinforcements which might contribute to having difficulties in adjusting dysfunctional behavior. These difficulties in learning might as a result furthermore contribute to maintaining dysfunctional eating behaviors (or in the case of drug addicts continuing to substance abuse).

Following up on the above-described findings, in two experiments we investigated whether obese individuals indeed differ in terms of learning effects. Given that obese individuals were found to have poorer working memory and learned worse compared to lean individuals, we designed a novel custom-tailored EC procedure with valence guessing trials. As argued in previous chapters, EC effects are typically moderated by memory (e.g., Gast, De

Houwer, & De Schryver, 2012; Hofmann et al., 2010), and EC paradigms can be used as a tool to measure learning effects. In this task, participants not only had to correctly identify the valence, but also to store this information in the working memory across the procedure. If obese (compared to lean) individuals do differ in terms of learning effects and working memory capacity, this EC task might be able to capture this difference.

4.3 Experiment 4

In Experiment 4, we selected high-calorie and tasty-looking foods to serve as CSs, as sweet and fatty foods are main food categories associated with snacking, and which, through increased energy intake greatly contribute to weight gain (Bertéus Forslund, Torgerson, Sjöström, & Lindroos, 2005). Given that, we investigated whether pairing unhealthy food products with either negative or positive images could change participants' attitudes towards these foods. Should an EC procedure lead to group differences in the change of existing attitudes towards unhealthy foods between normal weight and obese individuals, this finding would be of high relevance and importance.

4.3.1 Method.

4.3.1.1 Participants.

Our sample size was set for 58 participants, as according to G*Power 3.1.9.2, with power of .95 we would be able to detect a small to medium effect size of f = .18 for the two-way interaction on this number of participants. However, expecting a fair number of participants being excluded from the analyses (due to the complexity of the valence guessing task) we collected the data from 70 participants in total recruited via the online experimental platform Prolific Academic (PA) who volunteered to participate in this study. There were two groups of participants: normal weight (*N* = 35) and obese (*N* = 35) for whom the following inclusion criteria were the same: English language as a mother tongue, no literacy difficulties, no chronic diseases (e.g. diabetes), not following any special diet, no cognitive impairment (nor dementia) and not reporting to suffer daily due to any mental illness. Furthermore, an additional inclusion criterion for normal weight participants were BMI scores ranging from 20 to 24.9, and, for the obese group BMI scores ranging from 30 to 39.9. The study took on average about 16 minutes and participants received 1.50£ for compensation.

4.3.1.2 Research questions.

The following hypotheses were pre-registered prior to the data collection (http://aspredicted.org/blind.php?x=fr3w6c): Firstly, we hypothesized that EC effects would be observable in the explicit evaluative ratings and in the intention to consume foods across weight conditions. Secondly, we expected that EC effects would be stronger for normal weight participants compared to obese participants in the explicit evaluative ratings and in the intention to consume foods. Furthermore, we planned to conduct a complementary regression analysis with BMI (calculated based on weight and height responses collected at the end of the procedure) and try to predict EC effects for each participant based on individual BMI scores. Third, we hypothesized that normal weight participants would predict the valence of the upcoming US more correctly than obese participants. Additionally, we planned to perform exploratory analyses including the role of explicit valence memory and hunger in EC effects.

4.3.1.3 Design.

The experiment had three main factors: two within-subjects, US valence (negative, positive), which was the valence of the US the CSs were presented with during the learning phase, and time of measurement of the explicit evaluative ratings and intention to consume foods (pretest in the pre-rating phase, posttest in the rating phase). Weight category was a between-subjects factor (normal weight, obese). The change in the explicit evaluative ratings, the intention to consume and the accuracy of predictions of the valence of the US the CS had been shown with were the three main dependent variables.

4.3.1.4 Stimulus material.

12 high-calorie food images selected from an online database were used as CSs. As for the USs, we used 12 images taken from IAPS database and other sources which were pretested (*N* = 100) in our lab in terms of pleasantness on a 9-point rating scale (1 standing for very unpleasant and 9 standing for very pleasant). Six of the stimuli selected as USs have negative ratings of pleasantness (*M* =1.59; ranging from 1.01 to 1.84) and six have positive ratings of pleasantness (*M* = 8.13; ranging from 7.64 to 8.73). To every CS, all the negative USs (negative condition) or all the positive USs (positive condition) were assigned randomly in a way that one CS was paired once with each US of a given valence condition.

4.3.1.5 Procedure.

The procedure consisted of four main phases: pre-rating phase, conditioning phase, rating phase, memory phase, and hunger and body measurements phase.

4.3.1.5.1 Pre-rating phase.

In the pre-rating phase, participants were presented with 12 food images in a random order and asked to indicate how much they liked each of them and how much they wanted to consume each of them. To indicate how much they liked a given food, they were asked to indicate on a scale ranging from -4 (very unappealing) to 4 (very appealing) how (un)appealing they found each of the food images. To indicate how much they wanted to consume a given food, they were asked to indicate how eager they were to consume each of the food products on a scale ranging from -4 (not at all) to 4 (very much). Participants were able to mouse-click a number between -4 and 4 on a rating scale appearing on the screen. The order of pre-ratings was counterbalanced in a way that half of the sample gave their evaluative ratings first and then indicated their intention to consume foods, and, the other half of the sample did it in the reverse order.

4.3.1.5.2 Conditioning phase.

The conditioning phase consisted of six blocks with 12 trials each, in which every CS was presented once with one of the randomly selected USs of the given valence it was assigned to (six food-negative CS-US pairings and six food-positive CS-US pairings). The order of CS-US pairings was randomized within each of the six blocks separately. At the beginning of the conditioning phase participants saw a screen with all the USs in two separate columns grouped by valence, so that they would know which image belonged to which valence category.

A single trial started with a white blank screen appearing for 1.0 sec which was followed by the presentation of the CS for 1.0 sec on the top of the screen. Then, participants received the instructions in which they were informed that their task was to try to predict what the valence of the US which appeared on the screen afterwards would be. Participants had 2.0 sec to guess the valence of the US by pressing one of the two letters on the keyboard: A (negative) or L (positive). Participants were asked to place fingers on the two relevant for the task letter keys to easily press them when needed. Participants were furthermore informed that they would not receive any feedback on whether they predicted the US correctly or not, but they would know whether their estimate is correct or incorrect by seeing the US which appeared on the screen after 2.0 sec were over independently of whether participants had pressed any button or not.

4.3.1.5.3 Rating phase.

In the rating phase, participants were again presented with the same 12 food images in a random order and asked to follow the identical procedure as for the pre-rating phase. The order of ratings was counterbalanced in the same way as for pre-ratings (half of the sample gave their evaluative ratings first and then indicated their intention to consume foods, and, the other half of the sample did it in the reverse order).

4.3.1.5.4 Memory phase.

In the memory phase, participants worked on a memory test in which memory for the CS-US pairings was assessed in a valence identity task. All 12 food images appeared in smaller versions on the screen individually and participants' task was to recall for each food image whether it was mainly paired with negative or positive images. To do so, they had to mouse-click on the box "negative" or on the box "positive". If participants could not recall the valence of the US, there was an "I don't know" button which they could mouse-click in this case. There was no time restriction for this task.

4.3.1.5.5 Hunger and body measurement.

In the last phase of the experiment participants were asked to indicate their current at that time level of hunger on a scale from -4 (not hungry at all) to 4 (very hungry). Participants were also asked to input their weight (measured either in kilograms or pounds) and their height (measured in either feet or centimeters). We collected hunger ratings to control for a potential moderating role of hunger in processing of food images.

4.3.1.6 Data analysis.

We tested the influence of experimental factors on the change in the explicit evaluative ratings and on the change in the intention to consume foods between normal weight and obese participants, as pre-registered. Exploratorily, we conducted an analysis on the accuracy at valence guessing trials across all the learning blocks between normal weight and obese participants. The analyses were conducted on aggregated data in SPSS 23.0.

4.3.2 Results.

4.3.2.1 Evaluative ratings and intention to consume.

To test whether food images can be evaluatively conditioned by presenting them together with either unpleasant or pleasant images, and, whether the conditioning effects are stronger among normal weight compared to obese participants, we conducted pre-registered two 2x2 ANOVAs with a between participants factor weight category (normal weight, obese) and a within participants factor US valence (negative, positive) separately on the change in the explicit evaluative ratings, and, on the change in the intention to consume (both calculated by subtracting pretest ratings from posttest ratings).

4.3.2.1.1 Weight category and evaluative ratings.

First, we tested the effects of experimental factors on the change in the explicit evaluative ratings. The main effect of US valence was significant, *F*(1, 68) = 7.121; *p* = .010; partial eta^2 = .095 indicating an increase in liking previously positively-paired foods compared to negatively-paired ones. Neither the main effect of weight category, *F*(1, 68) = 3.114; *p* = .082; partial eta^2 = .044, nor the interaction of US valence and weight category were significant, *F*(1, 68) = 0.001; *p* = .972, partial eta^2 = 0.

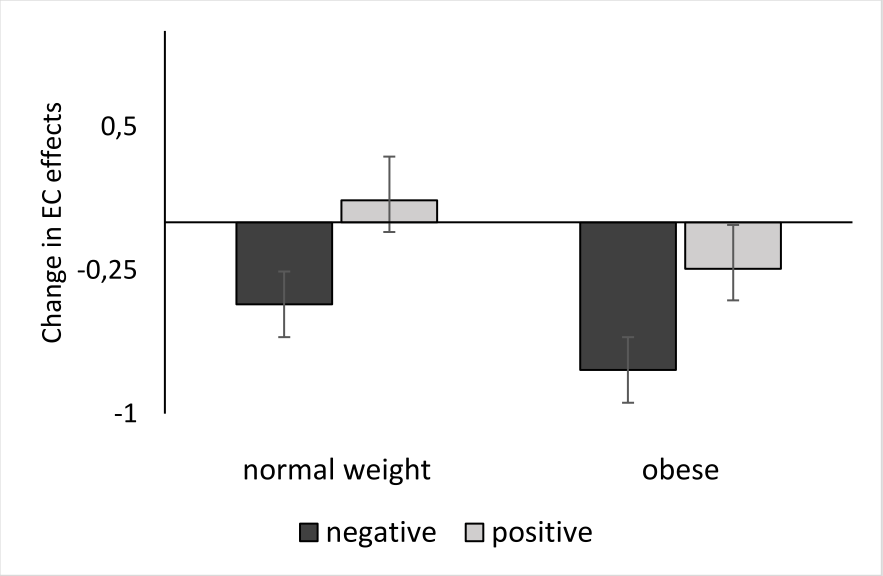

Fig. 4 Change in EC effects pretest to posttest between normal weight and obese participants with error bars depicting standard errors.

4.3.2.1.2 Valence memory, hunger and evaluative ratings.

With a linear regression analysis, we tested the model in which we aimed to predict the change in EC effects (calculated as the difference of positively-paired to negatively-paired) from pretest to posttest based on valence memory and hunger. Valence memory was a percentage of correct valence categorizations across all the CSs and hunger was hunger ratings given by each participant at the end of the experiment. The tested model fit the data, $F(2,67) = 8.981$ $p < .001$ and explained 18.8% variance of the change in EC effects (pretest to posttest). Both valence memory and hunger were significant predictors, with beta of .353 for valence memory ($t = 3.252$; $p = .002$) and beta of -.304 for hunger ($t = -2.802$; $p = .007$), indicating that the better valence memory the stronger the change in EC effects and the higher hunger ratings the weaker the change in EC scores.

4.3.2.1.3 Weight category and intention to consume.

Second, we explored the effects of experimental factors on the change in the intention to consume. The main effect of US valence was significant, with $F(1, 68) = 17.789$; $p < .001$; partial eta^2 = .207 indicating a significant increase in the change in the intention to consume foods that had been previously paired with pleasant images and a significant decrease in the change in the intention to consume foods that had been paired with unpleasant images. Neither the main effect of weight category ($F(1, 68) = 1.927$; $p = .170$; partial eta^2 = .028) nor the interaction of US valence and weight category were significant ($F(1, 68) = 0$; $p = .989$, partial eta^2 = 0).

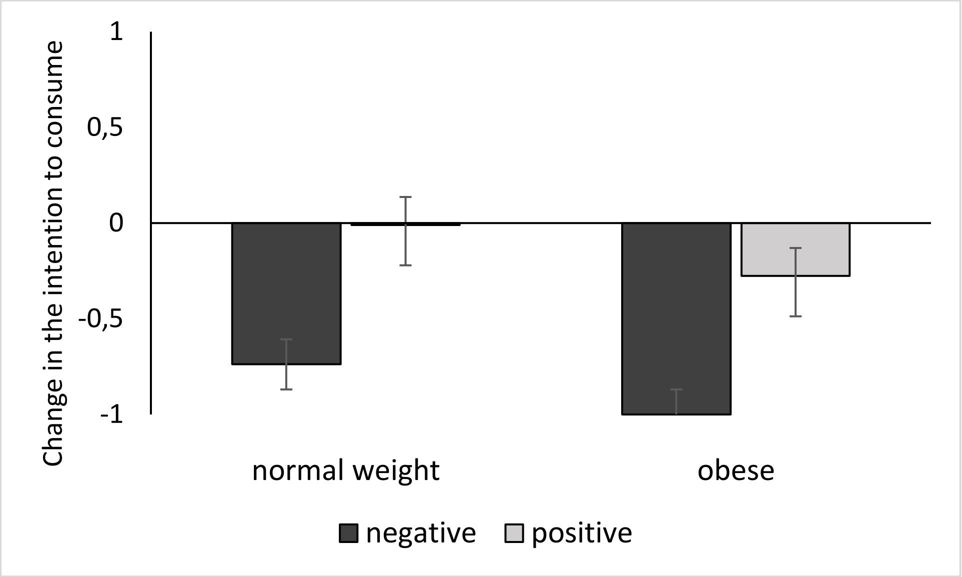

Fig. 5 Change in the intention to consume pretest to posttest for normal weight and obese participants with error bars depicting standard errors.

4.3.2.1.4 Valence memory, hunger and intention to consume.

We furthermore tested the model in which we aimed to predict the change in intention to consume (calculated as the difference of positively-paired to negatively-paired) pretest to posttest based on valence memory and hunger. Valence memory was operationalized as a percentage of correct valence categorizations across all the CSs and hunger was hunger ratings given by each participant at the end of the experiment. The tested model fit the data, $F(2,67) = 3.245$ $p = .045$ and explained 8.8% variance of the change in the intention to consume (pretest to posttest). Valence memory was a significant predictor with beta of .292 ($t = 2.505$; $p = .015$), indicating that the better valence memory the stronger change in the intention to consume. Hunger was not a significant predictor.

4.3.2.2 Accuracy.

4.3.2.2.1 Weight category and accuracy.

To explore differences in the accuracy at valence guessing trials in the learning phase we conducted an independent t-test. The between participants factor was weight category (normal weight, obese) and the average accuracy of valence guessing trials was the dependent variable. As pre-registered prior to collecting the data, we excluded the first learning block and analyzed subsequent five learning blocks for accuracy of predictions. We furthermore excluded participants who had less than 50% (chance level) of correct valence categorizations. The sample for the described below analysis consisted of 63 participants in total (33 in the normal weight and 30 in the obese group).

The independent t-test analysis for the factor weight category on accuracy of valence guessing trials did not show any significant differences in the average accuracy of learning between normal weight (M = 80%; SD = 13.9%) and obese (M = 78%; SD = 13.4%) participants, with $t(61) = 0.796$; $p = .429$.

4.3.2.2.2 Weight category and accuracy across learning blocks.

Exploratorily, without any exclusions, we conducted a 2x2 ANOVA with weight category (normal weight, obese) as a between-participants factor and learning block (five blocks) as a within participants factor on the accuracy of predictions in the valence guessing trials. The main effect of learning block was significant, $F(4,64) = 14.634$; $p < .001$; partial eta^2 = .478, showing that accuracy was significantly improving across the learning blocks. Post-hoc pair-wise comparisons with Sidak test showed that accuracy at valence guessing trials was significantly increasing from one block to another until participants reached the third block. The accuracy of predictions did not significantly improve from the third blocks onwards. Neither the main effect of weight category ($F(1,67) = 1.438$; $p = .235$; partial eta^2 = .021) nor the interaction effect of learning block and weight category (*F*(4,67) = 0.184; *p* = .947; partial eta^2 = .003) were significant (for descriptive statistics, see Fig.6).

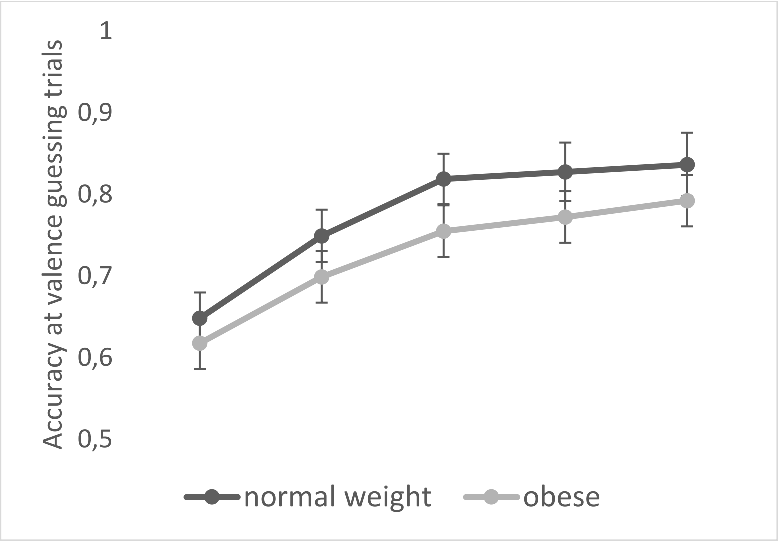

Fig 6. Accuracy at valence guessing trials across learning blocks for normal weight and obese participants with error bars depicting standard errors.

4.3.3 Discussion.

In Experiment 4, we investigated potential group differences between obese and normal weight participants in learning effects in a novel custom-designed EC task with food stimuli. We tested whether by pairing tasty-looking and high-calorie food images with valent images, one could modify liking of and intention to consume of foods. Exploratorily, based on valence memory and hunger ratings we aimed to predict learning effects measured in the change in EC effects and in the change in the intention to consume.

As expected, we found an overall EC effect measured in the change in the explicit evaluative ratings of negatively- and positively-paired foods from pretest to posttest. We observed the same pattern of results in the change in the intention to consume conditioned foods, as participants reported higher desire to consume foods that had been previously paired with pleasant images compared to foods paired with unpleasant images. This result may imply that EC effects can generalize beyond evaluative ratings of the stimuli, perhaps onto more behavioral and “real life” dimensions, e.g., intention to eat something. The exploratory regression analyses showed that both types of learning effects (measured in the change in EC effects and in the change in the intention to consume) could be predicted based on valence memory. Across all the participants, the better valence memory the higher change in EC effects, and the higher valence memory the stronger intention to consume foods. For the analyses on the change in EC effects hunger ratings furthermore predicted the size of the change in EC effects. The higher hunger ratings, the smaller magnitude of EC effects. This result was not present for the change in the intention to consume. Together, these results suggest that both types of learning effects were stronger for participants whose valence memory was better, and, that the change in EC effects was stronger for participants who were not hungry. High hunger ratings leading to smaller learning effects could thus be considered as a potential moderator interfering with participants’ performance in the task. This finding is in line with the existing literature on attention-grabbing properties of food images in the state of hunger where high hunger ratings were found to be associated with a heightened focus on food stimuli (e.g., Stockburger, Schmälzle, Flaisch, Bublatzky, & Schupp, 2009) which could interfere with the cognitive performance in the task. In the present study attentional shifts towards food stimuli could have led to less resources having been allocated to USs, hence, resulting in smaller magnitudes of EC effects. It is possible that EC effects could potentially increase due to directing attention to the USs if the USs were foods, however, the food stimuli which were used in the present study were CSs and not USs, which makes this possibility unlikely.

We furthermore tested whether the size of changes in EC effects and the learning effects in terms of accuracy at valence guessing trials in the learning phase would differ between the two groups selected based on BMI scores. The non-significant difference in the magnitude of the change in EC effects between obese and normal weight participants might suggest that obese and normal weight participants do not differ in terms of processing palatable foods in an EC procedure. We find this finding surprising, though, as there is a solid evidence in the literature suggesting that obese individuals perform significantly poorer compared to lean individuals on a range of cognitive tasks (for a recent meta-analysis, see: Yang et al., 2018). Exploratorily, we investigated group differences in the accuracy at valence guessing trials across all learning blocks. The results showed that the accuracy at valence guessing trials was significantly increasing from one block to another until the third block, with no further increase onwards. We did not, however, see group differences in the accuracy in the first three learning blocks as this pattern of results was the same for both weight category groups suggesting that perhaps the task was not complex enough for participants to manifest group differences.

Importantly, the lack of significant group differences in learning effects in this study could potentially be attributed to inaccurate BMI estimates of the participants resulting in substantial loss of power for planned comparisons. In Experiment 4, we recruited participants through an online platform based on a range of criteria. One of them were already existing on the website weight categories calculated based on BMI values provided by participants. It is not possible, however, to find out when these BMI scores were collected and whether participants' weight did not fluctuate since. In an attempt to control for that, in Experiment 4 we additionally collected self-reported measures of weight and height at the end of the experimental procedure. We used these values to calculate BMI scores per each participant, so that we could use it to re-categorize participants in the two weight categories of interest. We used the same inclusion criteria as earlier; including only participants who fell in the weight category with BMI scores ranging from 20 to 24.9 in the group of normal weight and only participants with BMI scores ranging from 30 to 39.9 in the group of obese. Strikingly, after this re-categorization we ended up with 20 participants not fitting into any of the two weight categories, which suggests that in the original analysis participants might have been miscategorized due to mentioned above weight fluctuations. Thus, our final sample consisted of 21 individuals in the normal weight group and 29 individuals in the group of obese, relative to having 35 participants in each weight category at the baseline. Despite re-analyzing the data with this new weight category variable we found the same pattern of results with no significant differences in learning effects between normal weight and obese, thus, we did not report it within the Results section. However, given this significant loss of participants relative to the pre-registered sample size, we calculated a post hoc power analysis to see how likely it was to detect potential group differences with fewer participants than planned. The results showed that even if we assumed a potentially medium effect size of Cohen's *d* of 0.5 for the independent t-test on accuracy at the valence guessing trials, the power to detect group differences between normal weight and obese participants would be .53. The power to detect the hypothesized group differences for planned comparisons was thus very low.

Power issues aside, another potential explanation for the null finding in this study could be a particular way in which food stimuli are processed by the obese. In a recent review on the role of attentional biases in different weight groups, systematic attentional biases towards food-related stimuli among the obese were reported (for the review, see: Hendrikse et al., 2015). In line with these findings, neuroimaging studies provide further evidence for differential activation patterns in brain regions involved in reward processing, suggesting heightened vigilance towards food-related stimuli at the neural level among obese individuals (e.g., Stice, Figlewicz, Gosnell, Levine, & Pratt, 2013; Volkow & Wise, 2005; Yokum, Ng, & Stice, 2011). If these findings were to be taken into account, one might speculate that potential differences in learning effects between normal weight and obese participants could have been masked due to obese individuals allocating more attention to food images compared to lean individuals, processing food CS-US pairings more thoroughly. This could thus have led to obese participants scoring similarly to normal weight participants in this task.

To address the above-mentioned limitations of Experiment 4 and disentangle potential explanations for the obtained results, we decided to conduct a follow up Experiment 5.

4.4 Experiment 5

In Experiment 4, we did not find differences in learning effects between obese and normal weight participants. The null findings could be attributed to inaccurate body measurements and substantial loss of power resulting from excluding participants who did not meet inclusion criteria for investigated weight categories, or, to attentional biases towards food stimuli among obese, making it unlikely to detect differential learning patterns in the tested sample.

In Experiment 5, we added one between-participants factor: CS type, into the EC task used in Experiment 4, as having only food CSs (as in Experiment 4) could have led to the hypothesized group differences being masked by attentional biases towards food among the obese. By having two types of CSs in the present study, we were able to compare learning effects both on non-food and food CSs to conclusively test whether obese and normal weight individuals indeed differ in terms of learning effects. Additionally, to assure that the body measurements were recent, we included in the sample only participants who did not report fluctuations in body weight within 6 months prior to the study.

4.4.1 Method.

4.4.1.1 Participants.

Our sample was set for 140 participants, as according to G*Power 3.1.9.2, with power of .95 we would be able to detect a small to medium effect size of $f = .18$ hypothesized group differences in the planned three-way analysis. However, similar to Experiment 4, we expected a fair number of participants being excluded from the analyses. We thus collected the data from 156 participants in total who were recruited via an online experimental platform Prolific

Academic (PA) and who volunteered to participate in the study. Same as in Experiment 4, we applied the same inclusion criteria for the two groups of participants: normal weight (N=78) and obese (N=78).

To avoid participants being potentially miscategorized (as in Experiment 4), we pre-registered that we would additionally re-categorize participants into the two weight category variables based on provided by the participants body measurements and use the new re-categorized grouping variable in the planned analyses. For better estimates, in both groups, we included only participants who reported not having lost (or gain) a significant amount of weight within 6 months prior to the study.

Despite controlling for weight fluctuations and re-categorizing participants, due to missing data and participants not fitting into either of the weight categories, our final sample for comparisons of EC effects between the two groups consisted of *N* = 100 (with 59 participants in normal weight group and 41 participants in obese group). For the analysis on the accuracy at valence guessing trials the sample size further decreased to *N* = 91 due to excluding participants who scored below the chance level.

4.4.1.2 Research questions.

The following three hypotheses were pre-registered prior to collecting the data (http://aspredicted.org/blind.php?x=k2xg2k): Firstly, we hypothesized that overall EC effects would be observable in the explicit evaluative ratings of both food and non-food CSs across weight conditions. Secondly, we expected that EC effects for non-food CS-US pairings will be stronger for normal weight participants compared to obese participants, but there would be no significant group differences for food CS-US pairings. Third, we hypothesized that normal weight participants would predict the valence of the upcoming US more correctly than obese participants for non-food CSs, but there would be no group differences in the accuracy of predictions of the valence of the upcoming US for food CSs.

4.4.1.3 Design.

Experiment 5 had the same three main factors as in Experiment 4: two within-subjects, US valence (negative, positive), time of measurement of the explicit evaluative ratings (pretest, posttest) and one between-subjects, weight category (normal weight, obese). Additionally, there was another between-subjects factor: CS type (food, non-food). As in Experiment 4, the main dependent variables were the change in the explicit evaluative ratings and the accuracy of predictions in valence guessing trials. Different to Experiment 4, we did not measure the intention to consume as this measure would not be applicable to non-food CSs.

4.4.1.4 Stimulus material.

The selection of the USs in Experiment 5 was exactly the same as in Experiment 4. As for the CSs, in Experiment 5 we used 12 high-calorie food images[6]. Additionally, we used 12 images of landscapes matching food CSs in terms of valence. Each participant saw only one type of CSs across the experiment (either food or non-food stimuli). To every CS, all the negative USs (negative condition) or all the positive USs (positive condition) were assigned randomly the same way as in Experiment 4.

4.4.1.5 Procedure.

The procedure in Experiment 5 was the same as in Experiment 4 and consisted of four main phases: pre-rating phase, conditioning phase, rating phase and memory phase, followed by hunger and body measurement.

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[6] We used 9 out of 12 food images from Experiment 1 and 3 new ones as we replaced food images which were rated as much more pleasant at the pre-rating phase relative to the rest of food images in Experiment 1.

4.4.1.6 Data preparation and data analysis.

Prior to conducting the study, we pre-registered the way in which we would prepare the data and the way we would examine main hypotheses. In the first step, we excluded participants who did not press any button on more than 20 valence guessing trials. In the second step, we calculated BMI scores based on participants' self-reported weight and height estimates which we subsequently used to categorize participants into one of the two weight categories (normal weight, obese). Finally, for the analyses with accuracy we excluded participants who scored below 50% of correct valence categorizations. Data was analyzed on aggregated data in SPSS 23.0.

4.4.2 Results.

4.4.2.1 Evaluative ratings.

To test whether EC effects would be observable in the explicit evaluative ratings across both types of CSs and weight categories, and whether the magnitude of these effects would differ between the groups, we conducted a pre-registered three-way ANOVA for CS type (food, non-food), weight category (normal weight, obese) and US valence on the change in the explicit evaluative ratings (calculated by subtracting pretest ratings from posttest ratings). Additionally, in an exploratory analysis we aimed to predict the change in EC effects for food CSs (measured as the change in the explicit evaluative ratings pretest to posttest) based on explicit memory and hunger ratings.

4.4.2.1.1 Weight category, CS type and evaluative ratings.

The conducted three-way ANOVA showed the following pattern of results: The only significant main effect was for US valence, $F(1,96) = 29.811$; $p < .001$; partial eta^2 = .237, indicating an overall EC effect on a change in evaluative ratings (pretest to posttest) with a more positive change in EC effects for the CSs that had been previously paired with positive

USs (*M* = 0.092; *SD* = 0.793) and a more negative change in EC effects for the CSs that had been paired with negative USs (*M* = -0.695; *SD* = 1.160).

Neither the main effect of CS type (*F*(1,96) = 0.003; *p* = .957; partial eta^2 = 0), nor the main effect of Weight category (*F*(1,96) = 0.513; *p* = .476; partial eta^2 = .005) were significant. None of the interactions were significant either, with: US valence and CS type (*F*(1,96) = 0.418; *p* = .519; partial eta^2 = .004), US valence and Weight category (*F*(1,96) = 1.004; *p* = .319; partial eta^2 = .010), CS type and Weight category (*F*(1,96) = 2.607; *p* = .110; partial eta^2 = .026s and US valence, CS type and Weight category (*F*(1,96) = 0.285; *p* = .595; partial eta^2 = .003). For descriptive statistics, see Fig.7.

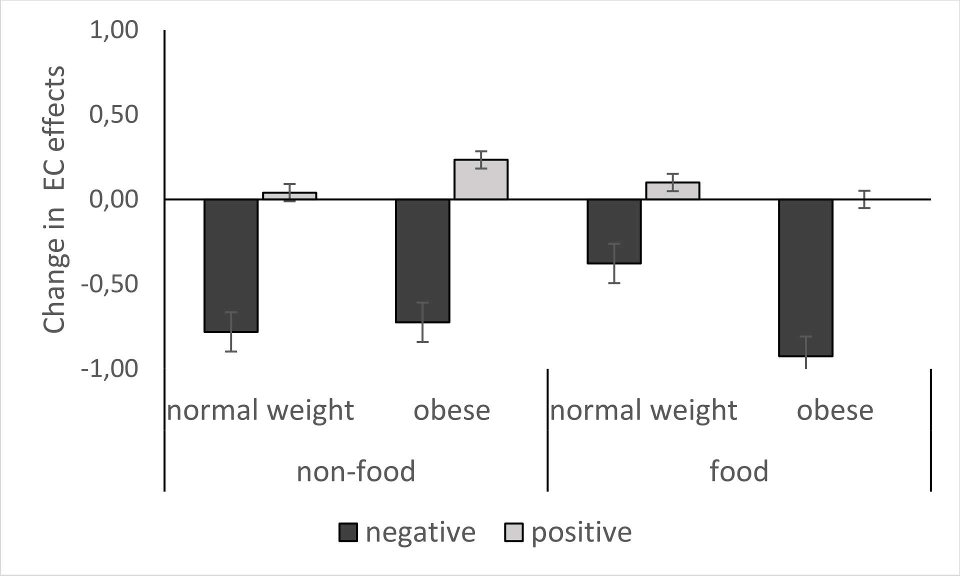

Fig. 7 Change in the explicit evaluative ratings pretest to posttest for non-food and food CSs between normal weight and obese participants with error bars depicting standard errors.

4.4.2.1.2 Valence memory, hunger and evaluative ratings.

To test whether EC effects for food CSs can be predicted based on valence memory and hunger we conducted a linear regression analysis. We tested the model in which we aimed to predict the change in EC effects (pretest to posttest) for food CSs based on valence memory (percentage of correct valence categorization across all the food CSs) and hunger (hunger ratings given by each participant). The model we tested fit the data, $F(2,70) = 6.597$. $p = .002$ and explained 13.5% variance of EC effects on change scores. Valence memory was a significant predictor with standardized beta of .352 ($t = 3.210$; $p = .002$) whereas hunger did not significantly predict the dependent variable ($t = 1.703$; $p = .093$).

4.4.2.2 Accuracy.

To test the effects of weight category and CS type on the accuracy at valence guessing trials we conducted a pre-registered two-way ANOVA for weight category and two types of CSs on the accuracy of predictions. We also conducted an exploratory analysis for the relationship between BMI, hunger and the accuracy at valence guessing trials.

4.4.2.2.1 Weight category, CS type and accuracy.

The results of the two-way ANOVA showed that neither the main effect of weight category ($F(1,87) = 0.85$; $p = .772$; partial eta^2 = .001), nor the main effect of CS type ($F(1,87) = 0.027$; $p = .869$; partial eta^2 = 0) were significant. The interaction of weight category and CS type was not significant either ($F(1,87) = 0.474$; $p = .493$; partial eta^2 = .005). For descriptive statistics, see Fig 8.

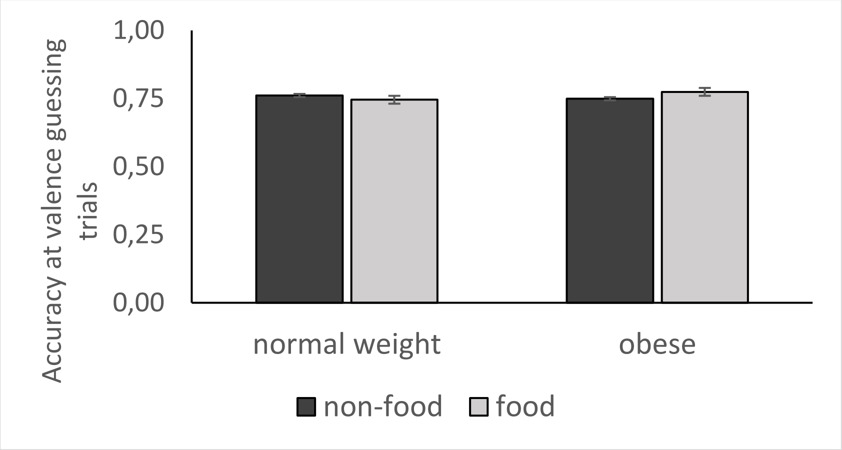

Fig. 8 The accuracy at valence guessing trials for non-food and food CSs between normal weight and obese participants with error bars depicting standard errors.

4.4.2.2.2 Hunger, BMI and accuracy.

With linear regression analysis, we tested the model in which we aimed to predict accuracy at valence guessing trials based on BMI and hunger. The predictor BMI was a BMI score calculated based on self-reported weight and height of participants and the predictor Hunger was hunger ratings given by each participant. The tested model did not fit the data, $F(2,106) = 0.972$. $p = .381$ and neither BMI ($t = -0.475$; $p = .635$), nor Hunger ($t = 1.221$; $p = .225$), predicted the accuracy at valence guessing trials.

4.4.3 Discussion.

In Experiment 5, we aimed to further investigate the potential of an EC task with valence guessing trials to successfully change attitudes towards food and non-food CSs. We compared the size of EC effects and the accuracy of valence predictions between normal weight and obese participants to examine if the two groups differ in terms of learning effects. In addition, we exploratorily tested the explicit valence memory and hunger as potential moderators of learning effects.

As expected, in Experiment 5 we not only found EC effects for food CSs (hence, replicating the results of Experiment 4), but we also found EC effects for non-food CSs. Importantly for our research questions, however, we did not find differences in the magnitude of EC effects between normal weight and obese participants neither for non-food nor food CSs. Similar, the analyses for the accuracy at valence guessing trials yielded no significant group differences for food CSs (replicating null findings from Experiment 4) neither for non-food CSs. We therefore have no evidence supporting the idea of differential learning patterns between obese and normal weight individuals, neither in learning effects measured by EC effects, nor in the accuracy of US valence predictions in the EC task.

Further exploratory analyses for the effects of explicit valence memory and hunger on EC effects for food CSs showed that memory was a significant predictor of the magnitude of EC effects. The more correct valence identifications for CS-US pairings, the higher EC effects. Hunger, however, did not predict EC effects. This result suggests that EC effects are moderated by explicit valence memory, which is in line with the majority of studies reporting stronger EC effects when participants can recall CS-US pairings (for a meta-analysis, see: Hofmann et al., 2010).

Despite some researchers reporting group differences in learning effects between obese and normal weight participants (e.g., Coppin et al., 2014; Mathar, Neumann, Villringer, & Horstmann, 2017), we failed to find a similar pattern of results in our sample. This finding is even more surprising given that a recent meta-analysis on executive function performance in obesity provides robust findings of obese participants scoring significantly poorer on a range of cognitive tasks relative to normal weight individuals (Yang et al., 2018). We argue that similar to Experiment 4, in the present study there are several occurrences that could have contributed to detecting no group differences in learning effects.

In Experiment 5, we recruited participants through the same online platform based on BMI score ranges. In an attempt to control for recent weight fluctuations, we additionally collected self-reported weight and height estimates from participants within the study to re-categorize them into the two weight groups of interest. After calculating BMI scores for each participant, based on the pre-registered BMI inclusion criteria, we categorized them into either normal weight participants or obese participants group. Participants who did not provide estimates of their body measurements and those who did not fit either of the weight categories were excluded. Prior to collecting the data, we set our planned sample size for $N = 140$ (respectively 70 participants in each of the weight categories) to reach power of .95 to detect a small to medium effect size for planned comparisons. However, as described in the Method section above, due to missing data and participants not fitting into either of the weight categories our final sample for comparisons of EC effects and the accuracy of predictions dropped significantly. Thus, we calculated post hoc power analyses for the most theoretically important planned comparisons: (1) potential group differences between obese and normal weight participants in EC effects for non-food CSs, (2) potential group differences in the accuracy at valence guessing trials for non-food CSs. The results of the analyses showed that even assuming a medium effect size of Cohen's *d* of 0.5, the power to detect the hypothesized group differences would be 0.787 for the analyses on EC effects and 0.748 for the analyses on the accuracy of valence predictions. This significant loss of power could have partially contributed to the analyses not being powerful enough to detect the hypothesized group differences.

However, given a significant loss of the data relative to the planned sample size for this analysis, we conducted a follow up analysis calculating Bayes Factor (BF) for group comparisons in the accuracy at valence guessing trials for non-food CSs to determine whether the obtained results could still be conclusive. We thus used the parameters from the conducted two-way ANOVA for the hypothesized difference between obese and normal weight participants in the accuracy at valence guessing trials for non-food CSs. The analysis yielded $BF = 3.331$, providing evidence in favor of the null hypothesis. This result suggests that even with significantly fewer than planned participants in each of the groups the no significant group difference in learning effects in our sample seems to be a reliable finding.

4.5 General Discussion

In this chapter, we investigated whether obese individuals differ in terms of learning effects in a custom-designed EC procedure. We aimed to capture the hypothesized differential learning patterns between normal weight and obese individuals, and, to investigate if these differences in learning effects could be observed both in the magnitude of EC effects and in the accuracy of valence predictions. In exploratory analyses we also tested the possible moderating role of explicit valence memory and hunger ratings on EC effects. In Experiment 4, we used high-calorie food CSs and in Experiment 5 we had both food and non-food CSs to control for potential attentional biases towards foods in obesity which could have masked the expected group differences.

Previous studies have investigated the effectiveness of an EC intervention to condition high-calorie snacks. Yet, despite reporting changes in implicit attitudes towards snacks, they did not provide sufficient evidence that an EC intervention can lead to changes in the explicit evaluative ratings of conditioned foods (e.g., Hollands & Marteau, 2016; Hollands et al., 2011). Thus, unlike previous research, our findings provide the first evidence that EC interventions can alter explicit attitudes towards high-calorie foods. Furthermore, the results of Experiment 4 showed that the intention to consume foods was affected by the EC procedure in the same way as the explicit evaluative ratings of foods. This novel result suggests that EC effects can be generalized to more behavioral measures of food preferences, such as the intention to consume. Participants in Experiment 4 indicated a higher desire to consume foods that had been previously paired with positive images and a lower desire to consume food that had been paired with negative images.

In both experiments, we found that explicit valence memory successfully predicted EC effects. The results show that higher memory for CS-US pairings led to larger EC effects. This pattern of results is in line with many studies in EC claiming memory for CS-US combinations as (potentially) necessary for EC effects to be present (for a meta-analysis, see: Hofmann et al., 2010). Regarding the moderating role of hunger, participants in Experiment 4 exhibited smaller EC effects the hungrier they were. This result suggests that participants who were hungrier at the start of the study, were perhaps more distracted by high-calorie food images and thus performed worse than participants with lower hunger ratings. However, this finding was not replicated in Experiment 5 as hunger was not a significant predictor of EC effects neither for food nor non-food CSs.

The idea that obese (compared to lean) individuals learn differently is supported by recent findings from a meta-analysis on cognitive functioning in obesity and overweight, which links poorer cognitive performance with obesity and reported that obese individuals score lower on a range of cognitive tasks (Yang et al., 2018). Specifically, in the Introduction of this chapter, we mentioned two studies that successfully reported differential learning patterns between obese and normal weight participants (Coppin et al., 2014; Mathar et al., 2017). Based on previous findings, we tested whether we could replicate group differences in learning effects in two experiments. Opposite to our hypotheses, in both studies we observed a pattern of results suggesting no differences between the weight groups in learning effects. Importantly, we did not find group differences neither in the magnitude of EC effects, nor in the accuracy in valence guessing trials. We discuss below possible characteristics of our study that could have contributed to the discrepancy between our results and the results reported by Coppin and colleagues (2014) and Mathar and colleagues (2017).

Previously in this chapter we mentioned potential difficulties in categorizing participants into two weight groups based on information provided by participants on self-reported body measurements. Systematic reviews comparing self-reported versus experimenter's measures of weight and height show significant discrepancies reaching roughly a 20% difference between the actual and reported body measurements (e.g., Gorber, Tremblay, Moher, & Gorber, 2007; Spencer, Appleby, Davey, & Key, 2002). On average, people tend to overestimate their height (the tendency which gets even stronger among shorter men) and underestimate their weight (which becomes even more visible among overweight and obese individuals overall). Considering that we did not collect body measurements ourselves in the study and only relied on participants' self-reported height and weight, we might have relied on inaccurate estimates. These potential differences in reporting one's body measures might have led to having under- (or over-) estimated values, which may have made it more difficult for our statistical tests to capture potential differences in learning effects between lean and obese participants.

Another potential reason why we did not observe group differences in learning effects could be due to the complexity of the task or the type of learning effects we in fact measured in our procedure. The majority of studies that report group differences in cognitive performance and executive function implemented more complex tasks that tapped into a range of different executive functions (for a meta-analysis, see: Yang et al., 2018). For example, in studies by Coppin and colleagues (2014) participants' task was to learn about positive and negative outcomes and subsequently apply this knowledge to complex decision making tasks. Similarly, in a study by Mathar and colleagues (2017), participants' ability to learn from reinforcements was subsequently measured in implicit learning performance. In our experiments, learning effects were measured in a relatively simple EC procedure containing only 12 CS-US pairings making valence guessing trials a relatively simple task. Thus, our task might not have been complex enough to capture group differences neither in EC effects, nor in the accuracy at valence guessing trials. This is supported by an exploratory finding in Experiment 4[7]:

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[7] We performed an analogical exploratory analysis in Experiment 5 which showed the same main effect of learning block. Participants overall improved their accuracy until they reached block 4 and from then onwards the accuracy

Independent of weight condition, participants significantly improved in the accuracy at valence guessing trials in the first three learning blocks. Following block three, the accuracy of valence predictions did not improve, suggesting that the task was relatively simple, leading to a ceiling effect in performance. Perhaps if we added more CS-US pairings in the EC task or if participants had to perform a more cognitively-loaded task in the conditioning phase, we could capture significant group differences in learning effects.

Thus, we believe because of the reasons discussed above, we were unable to detect differences in learning effects between normal weight and obese individuals in our experiments. It might be also the case that the published studies overestimated the effects. Importantly, future lab studies with collected-in-person body measurements are a necessary step to investigate these hypothesized group differences together with more complex EC paradigms.

CHAPTER 5: General discussion

Using EC interventions with food-related stimuli across five experiments, we tested whether EC procedures can be used as a way to form and modify food preferences. In this thesis, we focused on the role of memory, and we tested for the presence of the preparedness effect for smell-taste combinations in EC. We furthermore investigated the hypothesized differences in learning effects between normal weight and obese participants. In this final chapter, the main empirical findings of this thesis are briefly brought together and put in the context of the wider EC literature.

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of predictions did not improve. As in Experiment 4, this effect was independent of weight category and normal weight vs obese individuals did not differ in the learning curve across the five learning blocks.

5.1 Overview of Thesis Findings

In Chapter 2, in a smell-taste EC paradigm we report EC effects only for remembered and not for non-remembered pairings (Experiment 1 and 2). In Experiment 2, we also provide first evidence for the presence of the preparedness effect for smell-taste combinations in EC.

In Chapter 3, in a study with food and non-food CSs we did not find overall EC effects measured with the explicit evaluative ratings (of food and non-food CSs), nor did we find EC effects measured in the proposed behavioral measure of EC: food intake (of food CSs). We did not find any hypotheses-relevant interactions with US valence on the explicit evaluative ratings, either. We did, however, report the memory-moderated differences in food consumption of food CSs. For remembered food CS-US pairings participants consumed more of food CSs that had been previously paired with positive USs. This pattern was reversed for non-remembered food CS-US pairings. Given the absence of overall EC effects measured in the explicit evaluative ratings, this finding is somewhat problematic. Yet, one could cautiously interpret this memory-moderated effect of US valence on food intake as a potential EC effect operationalized as food consumption.

In Chapter 4, we found overall EC effects in the explicit evaluative ratings (Experiment 4 and 5) and in the intention to consume foods (Experiment 4). These learning effects were moderated by valence memory, with larger EC effects among participants with better memory. Contrary to the hypothesized group differences between normal weight and obese individuals, these results were independent of weight category, as there were no differences in learning effects between the two groups. We did not find any group differences in the accuracy at valence guessing trials, either. As discussed in Chapter 4, due to potential theoretical and methodological difficulties accompanied by significant loss of power for planned group comparisons, we cannot conclude whether normal weight and obese participants differ in terms of learning effects. Thus, we do not discuss these null findings anymore in this section and focus on findings that are more relevant to the formation of food preferences.

5.2 Theoretical Implications

The role of memory in yielding EC effects was tested in Chapters 2, 3 and 4. In Chapter 2, the explicit memory for CS-US pairings was explored in a smell-taste EC paradigm across two experiments. We tested if EC effects for non-remembered smell-taste pairings were present, and whether the magnitude of EC effects for these pairings would be larger than for other stimulus modality pairings. In Chapter 3, we investigated the role of explicit memory for CS-US pairings in an experiment with foods and non-foods to test whether food-smell EC effects would be less dependent on memory for pairings than other stimulus modality combinations. In Chapter 4, we looked at the relationship between the size of EC effects and the valence memory for USs the food CSs had been paired with.

Questions of whether EC effects depend on memory and whether participants must be aware of the CS-US pairings have been a subject of debate within the last decades. Despite many researchers reporting that EC effects depend on explicit memory (e.g., Bar-Anan, De Houwer, & Nosek, 2010; Gast, De Houwer, & De Schryver, 2012; Gast & Kattner, 2016; Pleyers, Corneille, Luminet, & Yzebryt, 2007), these memory-dependent EC effects are typically found for stimuli such as images or sounds (Hofmann et al., 2010). However, the role of memory in EC with food-related stimuli is less clear as some researchers report EC effects in the absence of memory in smell-taste EC paradigms (Baeyens et al., 1990; Dickinson & Brown, 2007) whereas other researchers found only memory-dependent EC effects for smell-taste pairings (Wardle et al., 2007). Smell-taste EC paradigms are ecologically relevant to the formation of food preferences as in this paradigm smells are typically used as CSs and tastes as USs. Given that EC effects for food-related stimuli have been suggested to be less dependent on memory, it is of high relevance to investigate the relationship between the role of memory and EC effects for food-related stimuli to understand its underlying processes.

In two experiments presented in Chapter 2, we tested whether memory-independent EC effects could indeed be found for smells and tastes. Despite previous findings suggesting that smell-taste EC effects may not depend on the explicit memory of pairings, in both experiments we found EC effects only for remembered and not for non-remembered pairings. In Chapter 3, we investigated the role of explicit memory in an EC procedure with real-life foods used as CSs with two measures of the change in liking: the explicit evaluative ratings and food consumption of food CSs. Although we did not find overall EC effects in the explicit evaluative ratings, nor in food consumption, we did find differences in the amount of food consumed in the behavioral measure of liking of food CSs, which was moderated by memory. For CS-US pairings that were remembered participants consumed significantly more of the foods that had previously been paired with pleasant USs (relative to the foods paired with negative USs) and this relationship was reversed for non-remembered CS-US pairings. In Chapter 4, we found overall EC effects in the explicit evaluative ratings (Experiment 4 and 5) and in the intention to consume foods (Experiment 4). Similar to the findings from Chapter 2 and 3, these results were moderated by valence memory, in which participants with better valence memory demonstrated stronger learning effects. These effects were independent of whether participants were obese or not.

Altogether, the results presented above are in line with the majority of studies in EC research suggesting that EC effects are moderated by memory and potentially may be a precondition for EC effects to occur (for a meta-analysis, see: Hofmann et al., 2010). Gast's (2018) DMM model of EC proposes that the majority of EC effects found with typical EC paradigms could be explained by the rationale behind this model. The model assumes that memory traces are formed in the learning phase and that these memory traces are necessary to be stored and afterwards retrieved, so that the CS can be evaluated according to valence of the paired US. The memory-moderated EC effects presented in this thesis are thus in line with the assumptions of this model as participants had to encode, store and use the retrieved information about the pairings during the CS evaluation.

Given previously suggested EC effects for smell-taste combinations even in the absence of memory (Baeyens et al., 1990; Dickinson & Brown, 2007), we thought that perhaps smells and tastes are processed differently together compared to other stimulus modality combinations. We thus tested for the presence of preparedness for smell-taste combinations in EC in Chapter 2. We found the preparedness effect for smell-taste combinations in a way that for smells as CSs, taste as USs led to stronger EC effects than when USs were sound. Interestingly, this difference was not only weaker, but also descriptively reversed when CSs were images. We furthermore tested whether this preparedness effect for smell-taste combinations would be present without the memory for pairings. We did not, however, find any EC effects or hypotheses-relevant interactions with the valence of the USs. We thus claim, that even in the area in which a less conscious pathway of forming preferences was suggested, memory is still necessary for EC effects to occur. Interestingly, although we found the preparedness for smells and tastes only in the presence of memory, the follow up memory analysis showed that participants did not in fact recall more of the smell-taste pairings compared to other stimulus modality combinations. The preparedness effect cannot be thus attributed to participants remembering smell-taste combinations better. One possible explanation for this preparedness effect for smell-taste combinations could be related to the relevance and belonginess of CSs and USs to each other (Lovibond, Siddle, & Bond, 1993). We suggest that due to the belonginess of smells and tastes, people might find taste US more relevant when evaluating CSs, even if the memory for smell-taste CS-US pairings is not objectively better compared to other stimulus modality pairings. This explanation for the preparedness effect for smell-taste combinations would be somewhat in line with the multisensory integration showed in neuroimaging studies on processing smells and tastes (e.g., Small et al., 2004). In previous chapters, we argued that smells and tastes are considered to be processed together as a unimodal sensory sensation called flavor. Neuroimaging studies suggest that the presentation of smell-taste combinations leads to greater activation in key brain regions responsible for processing olfactory and gustatory information, and, that this activation is greater compared to the activation in these regions elicited by presenting smells and tastes alone (de Araujo et al., 2003; Small & Prescott, 2005). We speculate that this super-additive activation and processing resulting from both types of stimuli experienced together might have led participants to make a better use of the evaluative information about the taste US while evaluating the smell CS as according to the literature of flavor smells and tastes are processed holistically. This idea of preparedness for smell-taste combinations also fits the Holistic Account of EC (Martin & Levy, 1994) which assumes that EC effects are formed through the transfer of valence from USs to CSs. According to this model, if CSs and USs are processed as a whole, the EC effects for such CS-US pairings should be stronger, thus, this appears to fit our preparedness results (e.g., Auvray & Spence, 2008).

5.3 Practical Implications.

Relevant to health psychology and food scientists, we showed that smells and tastes have a special relation with each other. In Chapter 2, we found first evidence for this somewhat intuitively prepared relation of smells and tastes observable in stronger EC effects for smell-taste combinations relative to other CS-US pairings. This preparedness effect for smell-taste combinations could be looked at from two perspectives. On one hand, it is possible that due to these prepared associations, certain objectively unhealthy food preferences are easily learned (e.g., strong preference for fatty and sugary foods), which could partially contribute to the pandemic of obesity. On the other hand, however, food scientists could apply the same rationale behind the preparedness effect to their advantage by promoting healthier food choices.

In Chapter 3, we furthermore tried to speak to very practical implications of preparedness for smell-taste pairings by investigating EC effects in a study with real foods. We did not, however, find the preparedness effect for smells and tastes as we did not find any EC effects at all – neither in the explicit evaluative ratings of food CSs nor in food consumption of food CSs. In the Discussion section of Chapter 3, we discussed potential boundary conditions for EC effects to occur with real-life stimuli. We argued that the absence of EC effects in this study could be attributed to deviations in the experimental design relative to typical EC interventions. In our study, participants interacted with real foods rather than looked at the images appearing on the computer screen as it is typically done in EC studies (Hofmann et al., 2010). The majority of studies reporting attitude changes due to EC interventions with food-related stimuli also used computer-based picture-picture paradigms in which participants do not interact with real food stimuli, but merely look at pairings on the screen (e.g., Hollands & Marteau, 2016; Hollands, Prestwich, & Marteau, 2011; Lebens et al., 2011). Different to these studies, across all the experimental phases of Experiment 3, participants interacted with real foods. Furthermore, in the measurement phase, participants were given an unlimited time to actively explore foods by smelling, touching and consuming them. Importantly, all the foods which were used as CSs were well-known snacks and sweets that participants most likely had relatively fixed attitudes about. We thus speculate that having unlimited time to evaluate CSs in the measurement phase, participants' existing attitudes towards foods were activated, and, as a result, participants might have based their food CSs evaluations on existing attitudes towards foods rather than on recently formed through CS-US pairings conditioned valence associations. Somewhat related and plausible explanation could be that participants' attitudes towards foods did in fact change after the conditioning procedure. However, once participants consumed foods in the absence of USs in the measurement phase, these learning effects were overwritten by the pleasantness and the tastiness of high-calorie foods on their own. Nevertheless, even though we did not find straightforward overall EC effects in the explicit evaluative ratings, nor in food consumption of foods in this study, we did find significant memory-dependent differences in food consumption, which could potentially be interpreted as EC effects in a behavioral measure. Overall, these mixed findings suggest that in future research the potential methodological and theoretical constraints described above should be taken into account while designing studies to conclusively test whether real foods (and potentially their consumption) could be conditioned through EC interventions.

Finally, in two experiments presented in Chapter 4, we tested whether participants' existing positive attitudes towards high-calorie foods could be subject to evaluative changes due to an EC procedure in a computerized picture-picture paradigm. We found attitude changes measured in EC effects not only on the explicit evaluative ratings of foods, but also on another proposed measure of liking: intention to consume foods. These findings on EC effects present both in the explicit evaluative ratings and in the intention to consume are promising. One could cautiously conclude that EC has a potential to successfully modify food preferences, even if we attempt to modify already established positive associations with high-calorie foods.

Coming back to the quote by François de la Rochefoucauld - *"To eat is a necessity, but to eat intelligently is an art."* which this thesis was opened with, perhaps one day there will be tools that will help us all to master the art of eating intelligently and EC interventions seem to be a good candidate to contribute to it.

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Appendix 1

Stimulus material

Experiment 1

We selected four concentrated food aromas (CSs$_{\text{olfactory}}$) “Premium Flavor Selection”, TH. Geyer, Germany. The selected aromas were: grapes (product number 651493), mango (product number 221109), cacao (product number 259532) and blackberry (product number 648673). We used aroma concentrations of 1,5% (blackberry, cocoa and mango) and 2% (grapes) in water solutions. According to the technical reports of these aromas provided by Th. Geyer (“Premium Flavor Selection”, TH. Geyer, Germany, DIN ISO 9001:2008 zertifiziert), the selected aromas do not contain any of the tested common allergens. The exact concentrations and the aromas we used for the study were determined in a previously conducted pretest. In the first phase of this pretest, participants (*N*=30) were given a selection of seven aromas each at two different concentrations and evaluated them on two dimensions: pleasantness and intensity. In the next phase, participants were asked to match the seven aromas of concentrations ranging from 1% to 2,5% presented on a metal tray with the same selection of aromas on another metal tray to measure how distinctive the aromas were. Final selection of the aromas used in the main study depended on (1) relatively neutral evaluations and (2) distinctiveness of the aroma. In the main study (Experiment 1) participants were asked to drink only a relatively small amount of the solutions (less than 150 ml in total).

As visual stimuli (CSs$_{\text{visual}}$), we used custom-designed visual labels of made-up beverages with unknown names generated by a random words generator, which we pretested in a previous pretest. In the pretest, participants (*N*=20) evaluated 15 custom-made beverages brands appearing on the computer screen one-by-one on the pleasantness dimension and the four which were evaluated as most neutral and had distinctive names were chosen for the main study. The selected bottle labels had the following names: mitosh, bintes, flersa and vasclo.

Appendix 1

We selected polysorbate 20 as $\mathrm{US}_{\mathrm{gustatory\ negative}}$ which is used for example as a wetting agent in food products (Wikipedia) and has been previously used in psychological studies on EC with food stimuli (e.g., Baeyens, Eelen, Van den Bergh, & Crombez, 1990; Gast & De Houwer, 2012; Kerkhof, Vansteenwegen, Baeyens, & Hermans, 2009). Polysorbate 20 was added to scented water at the concentration of 1.2 ml/liter. As $\mathrm{US}_{\mathrm{gustatory\ positive}}$ we used household type sugar syrup, which was added to scented water at the concentration of 60 ml/liter. Both tastants ($\mathrm{USs}_{\mathrm{gustatory}}$) are odor and color free at the given concentrations.

Experiment 2

The selection of olfactory stimuli ($\mathrm{CSs}_{\mathrm{olfactory}}$), visual stimuli ($\mathrm{CSs}_{\mathrm{visual}}$) and gustatory stimuli ($\mathrm{USs}_{\mathrm{gustatory}}$) was the same as in Experiment 1. As auditory stimuli ($\mathrm{USs}_{\mathrm{auditory}}$) we used two sounds which were pretested in our lab (N=36): a pleasant one (harp) and an unpleasant one (metal scratch). The main difference in administering $\mathrm{USs}_{\mathrm{gustatory}}$ (tastants) was that in some trials $\mathrm{US}_{\mathrm{gustatory}}$ was dissolved in scented water and in other trials pure water in Experiment 2 whereas it was always dissolved in scented water in Experiment 1.

Appendix 2

The list of the four food CSs along with their ingredients used in Experiment 3.

Schoko Rosinen der Firma „K-Classic“: Rosinen (44 %), Zucker, Vollmilchpulver, Kakaobutter, Kakaomasse, Süßmolkenpulver (enthält Milch), Emulgator: Sojalecithine, modifizierte Kartoffelstärke, Glukosesirup, Überzugsmittel: Gummi Arabicum, Vanilleextrakt.

Caramelts Karamell-Konfekt der Firma „Werther's Original“: Zucker, pflanzliche Fette (Palm, Shea), Sahnepulver (14,4 %), Molkenerzeugnis, Butterreinfett, Maltodextrin, Magermilchpulver, magerer Kakao, Emulgator Lecithine (Soja), Karamellzuckersirup, natürliche Aromen, Salz.

Knabbergebäck goldfischli Sesam der Firma „funny-frisch“: Weizenmehl, Palmöl, Sesamsaat (8%), Mohnsaat, Zucker, Speisesalz, Glukosesirup, Molkenerzeugnis, Buttermilchpulver, Milcheiweiß, Magermilchjoghurt, modifizierte Wachsmaisstärke, Vollmilchpulver.

Butterblätter der Firma „Bahlsen“: Weizenmehl, Butter 25%, Zucker, Mandeln 4,3%, Glukosesirup, Süßmolkenpulver, Salz, Backtriebmittel: Natriumhydrogencarbonat und Dinatriumdiphosphat, Buttermilchpulver, flüssiges Vollei, Haselnüsse, Weizenstärke.

Appendix 3

The questionnaire measuring attitudes towards food CSs in Experiment 3.

1. Bitte geben Sie an, wie sehr Sie den Geschmack dieses Lebensmittels mögen. Geben Sie Ihre Antwort, indem Sie die entsprechende Zahl einkreisen.

1 2 3 4 5 6 7 8 9

Überhaupt nicht Sehr

2. Bitte beschreiben Sie, wie es sich in Ihrem Mund anfühlt, dieses Lebensmittel zu essen:

. . . .

3. Welche Farbe würden Sie für die Verpackung des Lebensmittels wählen?

. . . .

4. Was für Personen würden Ihrer Meinung nach dieses Produkt kaufen?

. . . .

5. Was wäre eine typische Situation, in der Personen dieses Lebensmittel konsumieren würden?

. . . .

6. Woran erinnert dieses Lebensmittel Sie?

. . . .

7. Wie knusprig würden Sie das Essen einordnen?

1 2 3 4 5 6 7 8 9

Überhaupt nicht knusprig Sehr knusprig

8. Wenn Sie das Essen im Mund haben, was schmecken Sie?

. . . .

9. Wie würden Sie die Struktur des Essens in 1-2 Worten beschreiben?

. . . .

Appendix 3

The questionnaire measuring attitudes towards non-food CSs in Experiment 3.

1. Bitte geben Sie an, wie visuell ansprechend Sie diesen Gegenstand finden. Bitte geben Sie Ihre Antwort, indem Sie die entsprechende Zahl einkreisen.

1 2 3 4 5 6 7 8 9

sehr unangenehm sehr angenehm

2. Bitte beschreiben Sie, wie sich der Gegenstand in Ihrer Hand anfühlt:

. . . .

3. Welche Farbe würden Sie für die Verpackung des Gegenstands wählen?

. . . .

4. Was für Personen würden Ihrer Meinung nach dieses Produkt kaufen?

. . . .

5. Was wäre eine typische Situation, in der Personen diesen Gegenstand benutzen würden?

. . . .

6. Woran erinnert Sie der Gegenstand?

. . . .

7. Wie sehr würden Sie gerne den Gegenstand haben wollen?

1 2 3 4 5 6 7 8 9

Überhaupt nicht Sehr gerne

8. Nennen Sie 1-2 Adjektive um die Optik des Gegenstandes zu beschreiben:

. . . .