Flavours of desire: Cognitive representations of appetitive stimuli and their motivational implications

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Abstract

How do people cognitively represent appetitive stimuli? Do interactions with appetitive stimuli shape how we think about them, and do such representations affect motivation to consume? Although much is known about how people respond to appetitive stimuli, little is known about how they are represented. We examine this in the domain of sugar-sweetened drinks, which constitute a significant self-control problem for many people. Given people's rich and diverse learning histories of consuming them, we propose that representations of these stimuli will show high variability, and that they will reflect idiosyncratic simulations, or re-enactments, of previous consumption experiences. Representing drinks in terms of consuming and enjoying them may predict the motivation to consume. In three experiments (total $N = 457$), participants described non-alcoholic drinks in a "feature listing task", a free production task to assess cognitive representations of concepts through natural language. We also measured consumption frequency, desire to drink, and intake (Exp. 3), and we measured (Exp. 1 and 2) or manipulated (Exp. 3) thirst. Illustrating the variability of participants' representations of drinks, participants reported a large number of different features (210-331 unique features per drink). Drinks were described heavily with words related to consumption and reward experiences, especially sugary drinks, and especially when consumed frequently. Consumption and reward features predicted desire and intake, more strongly than thirst. These findings suggest that simulations of previous rewarding interactions play a key role in representations of appetitive stimuli, and that understanding these representations may be useful across domains of appetitive behaviour.

Keywords: grounded cognition, cognitive representation, mental simulation, motivation, health behaviour, consumer behaviour

Introduction

How do people cognitively represent appetitive stimuli? Which features come to mind when people encounter different foods or drinks, or other motivational stimuli, for example related to tobacco, sex, or media? Are these features modulated by an individual's current states and past experiences, and do they affect motivation and behaviour? Previous research suggests that people differ in the degree to which they process foods in terms of their tastiness vs. their healthiness, and that these differences predict choices (Sullivan et al., 2015). Similarly, some people respond to appetitive and addictive stimuli with increased attention, and this predicts their cravings (e.g., Field et al., 2009, 2016). Activations in brain areas associated with reward or with self-control in response to pictures of foods are associated with indulgent and healthy patterns of choices, respectively (e.g., Batterink et al., 2010; DelParigi et al., 2006; Lawrence et al., 2012; Petit, Merunka, et al., 2016). Indeed, when instructed to imagine consuming a food, or even simply smelling a food, people can easily do so in vivid sensory detail, which again affects neural, physiological, and behavioural responses (Cornil & Chandon, 2016; Keesman et al., 2016; Krishna et al., 2014; Larson et al., 2014; Morewedge et al., 2010; Muñoz-Vilches et al., 2019; Petit et al., 2017). What is the representational content, however, that is activated when we observe these variations in blood-flow in the brain, visual attention, imagery, and behaviour? In other words, while much research has established how people *respond* to appetitive stimuli, very little is known about how people cognitively *represent* such stimuli, and how this relates to motivation and behaviour.

Based on people's rich, highly variable individual experiences with appetitive stimuli, there may be a diversity of representations of such stimuli. This could be meaningfully related to differences in cognitive, affective, neural, and behavioural responses to them. To name but two examples, whether somebody represents a food in terms of its taste and texture, or in terms of its ingredients and production process, will likely affect their desire for it.

Similarly, whether somebody represents a cigarette in terms of holding it in the same hand as a glass of wine on a warm summer evening, or in terms of the toxins it contains and the lung damage it can cause, likely affects their attentional biases and cravings. Such representations of appetitive stimuli, however, have so far not been established systematically. In this paper, we propose a theoretical framework and a first empirical investigation to systematically establish the content of these representations using natural language, and their links with motivation and behaviour.

Given people's learning histories of consuming appetitive stimuli, like food or drink, we propose that people cognitively represent these stimuli by simulating, or re-enacting, previous, potentially rewarding consumption experiences. Thus, we predict that when thinking about or encountering appetitive stimuli, people activate aspects of previous consumption experiences, such as specific sensory experiences, context features, or other idiosyncratic information encoded in previous encounters, such that their representations are experience-based and highly variable. We further argue that the content of these representations may shape future behaviour toward these stimuli, such that representations that include simulations of physical pleasure and reward are more likely to motivate subsequent consumption than those that do not. In the current paper, we examine this issue in the domain of sugar-sweetened beverages, which constitute a significant self-control and public health problem.

The consumption of sugar-sweetened beverages is very common, with at least 50% of Americans having consumed a sugary drink on a given day (Bleich et al., 2018). However, the consumption of sugary drinks is associated with a number of negative health consequences, such as weight gain, obesity, metabolic syndrome, and diabetes (e.g., Bentley et al., 2020; Deshpande et al., 2017; Pan et al., 2013). It is therefore surprising that very little is known about the motivation to consume sugary drinks, and the psychological processes underlying it. Sugary drinks thus seem a particularly useful domain to study representations of appetitive stimuli, and whether they contribute to the motivation to consume.

What is known so far about why people consume sugar-sweetened beverages? Some research has focused on behaviours associated with their consumption. Among adolescents, for example, those who drink more sugar-sweetened beverages also have unhealthy eating behaviours (Kremers et al., 2007; Scully et al., 2017). Surveys and qualitative research show that availability, habits, and taste expectations also play an important role in sugary drink intake (Tak et al., 2011; Zoellner et al., 2012). Further, viewing advertisements for sugar-sweetened beverages increases consumption (Koordeman et al., 2010). This research suggests that contextual factors, such as being exposed to sugary drinks or reminders of them, as well as taste expectations, may play a key role in the desire and consumption of sugary drinks. Similarly, these factors may also be part of people's cognitive representations of these stimuli, such that people think about consumption situations or about the taste of a drink when they are exposed to beverage cues, for example the name or package of a drink. However, the actual, potentially very rich and detailed content of these representations has not been studied, although it may provide important insights into the self-control dilemmas that people face in this domain, as well as in other domains where cravings and desire affect behaviour (e.g., food, alcohol, sex, tobacco, media; see Hofmann et al., 2012).

Mental representations of appetitive stimuli

What is known so far about how people cognitively represent appetitive stimuli? In research asking participants to list their thoughts about specific foods while eating, participants listed many sensory and reward-related thoughts, especially when the foods had been described with reference to multiple, compared to a single sense (Elder & Krishna, 2010). This suggests that taste, smell, texture and enjoyment of the foods were highly salient when freely describing eating a food. In line with this, neuroimaging research shows that when people process food or drink cues, such as words or images, this triggers activation in areas of the brain involved in, among others, sensory and reward processing (Chen et al., 2016; e.g., González et al., 2006; Piqueras-Fiszman & Spence, 2015; Simmons et al., 2005; van der Laan et al., 2011). These activations are stronger for sweeter and generally more attractive foods, and their strength can meaningfully predict outcomes such as intake or weight gain (Lawrence et al., 2012; Stice et al., 2013, 2015). These findings may reflect that appetitive stimuli are represented in terms of what they taste and smell like and the reward they can provide. A recent study combining fMRI with natural language food descriptions went further to show that tastier foods have more refined neural representations as well as more elaborate, ingestion-related cognitive representations than less tasty foods (Londerée & Wagner, 2020). The precise content of such representations, and how they differ across types of stimuli, however, remains unclear from these studies.

Research with reaction-time based attitude measures shows that participants often associate specific food and drink objects with words reflecting positive valence. The strength of these associations is meaningfully related to their consumption habits and to observable behaviours, and likely results from associative learning and conditioning processes (e.g., Baeyens et al., 1996; Brunstrom, 2007; Hollands et al., 2011). Using reaction-time measures, De Houwer and De Bruycker, for example, found that vegetarians had more positive attitudes towards vegetables over meat, compared to meat eaters (De Houwer & De Bruycker, 2007). Hollands and colleagues (2011) found that learning to associate high-calorie foods with vivid, negative health outcomes weakened associations of these foods with positively valenced constructs. Indeed, the strength of associations between food-words and positively valenced constructs can predict food choice and intake (e.g., Friese et al., 2008; Richetin et al., 2007).

In the domain of alcohol, researchers have examined associations with outcome expectancies of drinking (Brown et al., 1987; Jajodia & Earleywine, 2003; Jones et al., 2001).

Here, it has been shown that many people represent alcohol in terms of positive physical and social effects such as feeling more romantic, powerful, happy, and confident, and as a pleasurable marker of special occasions, especially if they consume alcohol more frequently (e.g., Brown et al., 1987; Jajodia & Earleywine, 2003; Thush & Wiers, 2007). Indeed, when asked to list behaviours that lead to certain outcomes (e.g., relaxation), the likelihood of participants listing "drinking alcohol" was associated with the frequency of their drinking alcohol (Stacy et al., 1994), and with prospective alcohol use, controlling for previous use (Stacy, 1997). Even among children, responding "good" to the question "How do people feel when they drink alcohol?" was associated with higher drinking behaviour (Dunn & Goldman, 2000). Thus, alcohol drinkers represent alcoholic drinks at least partially in terms of the social and physical experience of consuming them.

Importantly, however, all of these studies only examined associations with pre-selected constructs, typically chosen for their high positive or negative valence; or they assessed the strength of participants' specific outcome expectancies from drinking alcohol. As a result, they do not provide an unconstrained, comprehensive assessment of the content of people's cognitive representation.

Free production tasks, as used in cognitive science, can provide access to cognitive representations in a less constrained manner. The so-called Associative Group Analysis Method (Kelly, 1985) is a tool to elicit verbal responses to study in detail the shared belief systems of a group of participants and compare this with other groups. It has been used, for example, to examine differences between pre-treatment and post-treatment drug users and non-users in their self-image (Szalay et al., 1992), or belief structures about smoking and tobacco among smokers, ex-smokers and non-smokers (Peterson & Martin, 2003). However, this measure focuses on representations shared by groups of similar individuals, rather than on individual, idiosyncratic representations, and their links with motivation and behaviour.

In contrast, feature listing is a free production task which focuses on individuals rather than group-level representations. Using this task, McRae and colleagues, for example, asked participants to list features that are "typically true" of a large number of concepts, including a number of food words (McRae et al., 2005). Here, participants spontaneously listed features that reflect experiences of eating the foods, such as "eaten with ice-cream" for cake, or "is juicy" for nectarine. In another study using a free production task, more ingestion-related words were listed for tastier compared to less tasty foods when participants were asked to describe foods to a hypothetical person who has never consumed them (Londerée & Wagner, 2020).

Similar findings emerge when participants are asked to freely provide meaningful category names for different foods. In such tasks, the categories participants list often refer to aspects of personal eating experiences, and to eating contexts (Blake et al., 2007; Ross & Murphy, 1999). Finally, research on thematic relations with food and drink concepts also shows that people think about these in terms of interacting with them in specific situations (Jouravlev & McRae, 2016). Here, participants were instructed to list names of other living or non-living things that might interact with or be related to the target concepts, which included some foods and drinks. For the concept "beer", for example, participants responded most often with "alcohol", "cup/glass", "bar/pub", and "party", and for "ice-cream", they responded most often with "cone", "cold", "chocolate", and "summer". These responses suggest that participants imagined the concepts in a specific context, and then listed features of this context. Similarly, when providing free first associations in the domain of alcohol, participants frequently mentioned alcohol-related words in response to alcohol homographs (e.g., pitcher), and this was associated with the frequency of drinking alcohol (Stacy et al., 1997). Together, these findings on features, categories, and thematic relations all suggest that people represent foods and drinks in terms of consuming them in specific situations and with specific outcomes (see also Wu & Barsalou, 2009).

A grounded cognition perspective on food and drink representations

These findings are consistent with predictions derived from the grounded cognition theory of desire (Papies et al., 2017; Papies & Barsalou, 2015). Specifically, this theory suggests that appetitive stimuli are represented through idiosyncratic re-enactments, or simulations, of varying aspects of consumption that have been encoded in previous consumption experiences. Every time a person interacts with an appetitive stimulus, for example by consuming a food or drink, they form or update a comprehensive memory representation of this experience that is referred to as a "situated conceptualisation" (Barsalou, 2009; Papies et al., 2017; Papies, Barsalou, et al., 2020; Papies & Barsalou, 2015). Such a situated conceptualisation can contain and integrate information of various kinds, for example information on the visual appearance of a food or drink (e.g., shape, colour, package), information on the sensory experience of consuming it (e.g., taste, texture), information on the physical and social context of consumption (e.g., location, sounds, other people present), as well as information on one's visceral states and experiences (e.g., hunger, pleasure), motor behaviours (e.g., grabbing, holding, chewing) and active long-term goals (e.g., health, social connectedness). These representations are not assumed to be accurate reflections of reality, but may be shaped by what is salient and relevant to the perceiver in the situation, given their motivational states and traits (Papies et al., 2015).

Later, when one part of such a situated conceptualisation is encountered again, its other, non-present elements can be activated via pattern completion inferences and implemented as simulations (Barsalou, 2009; Papies & Barsalou, 2015). In other words, being exposed to one part of a situated conceptualisation of a consumption experience (e.g., the word "crisps", or seeing a bag of crisps in a shop) can trigger simulations of other elements of the situated conceptualisation (e.g., the taste and mouthfeel of eating crisps, the taste of an accompanying cold drink, the pleasure of relaxing with friends). These processes are not unique to appetitive objects. Indeed, research on grounded processes in cognition more generally suggests that our knowledge about the world is represented by simulations, or re-enactments, of perceptual experiences in the relevant sensory modalities, which have been stored in previous experiences (Barsalou, 2008, 2009). Thinking about an object such as a cup or a hammer, for example, leads to activations of brain areas that are also involved when processing the stimulus perceptually or when actually picking it up and using it (e.g., Martin et al., 1996; Pulvermüller & Fadiga, 2010; Tucker & Ellis, 2001). These simulations help to predict the experience of interacting with the world around us (e.g., knowing how a hammer feels in your hand), and prepare for effective goal-directed action, based on previous experiences.

As a result, simulations of the sensory and rewarding aspects of consumption can easily be activated by a variety of cues, such as eating situations, food or drink names, or food or drink images. This is consistent with findings on memory associations and outcome expectancies in the domain of alcohol, such that alcohol-related cues trigger simulations of drinking and of feeling relaxed, especially among heavier drinkers. This can also explain why researchers often observe strong associations of appetitive objects with affective and reward-related words, such as in the IAT or affective priming measures. However, this theory also implies that the variability in their previously learned consumption experiences will lead to tremendous variability in people's representations of appetitive objects. This may not always be captured in traditional rating or response time tasks with pre-selected stimuli, but could possibly be captured in less constrained production tasks (e.g., Jouravlev & McRae, 2016; Londerée & Wagner, 2020; Wu & Barsalou, 2009).

Simulations and motivation

We suggest that people not only represent appetitive stimuli by simulating previous consumption experiences, but that these simulations can affect motivation and behaviour (see also Cornil & Chandon, 2016; Elder & Krishna, 2012; Larson et al., 2014; Muñoz-Vilches et al., 2019). This applies the general idea that simulations support goal-directed action (Barsalou, 2009; Pulvermüller & Fadiga, 2010; Tucker & Ellis, 2001) to the domain of appetitive behaviour. Thus, we specifically propose here that when encountering an appetitive stimulus, people are most likely to simulate those features that they have experienced and encoded frequently in previous, similar situations, and which may therefore seem useful for the current situation (i.e., be action-relevant). This may mean that for attractive foods and drinks, sensory and rewarding aspects may be particularly salient and therefore likely to be simulated (Londerée & Wagner, 2020; McCrickerd & Forde, 2016; Spence, 2016). Indeed, when evaluating a food, people spontaneously simulate its taste, a key component of food reward (e.g., Larson et al., 2014; van der Laan et al., 2011). Such simulations may increase the motivation to consume and experience the reward again, especially among people who often consume the food or drink. Similarly, this may mean that simulations of consumption and reward may be particularly pronounced in hungry or thirsty states, because this would increase the chances of motivated behaviour to reduce the deprivation (see Siep et al., 2009; Spence et al., 2016). This would also be consistent with research showing that perceptual processes are modulated by goal states in ways that make goal-directed behaviour more likely (Alter & Balcetis, 2011; Balcetis & Dunning, 2006; Spence, 2011; Veltkamp et al., 2008).

Previous research in the domain of food and eating behaviour provides support for this link between simulations and motivation, showing for example that attractive foods are particularly likely to be represented through eating simulations. In a small-scale feature listing study (McRae et al., 2005; Wu & Barsalou, 2009), participants freely produced features that are "typically true of" four attractive foods (e.g., crisps, cookies) and four neutral foods (e.g., rice, cucumber; Papies, 2013). Participants listed a wide variety of features, ranging from visual and sensory characteristics to eating context, reward experiences, health implications, production, preparation, category information, and others. These features were then coded as eating simulation features if they referred to the eating experience and its immediate consequences (e.g., words describing taste, texture, pleasure, or eating context), or as other features (e.g., visual, health, food production, food preparation, linguistic and category information). Results showed that overall, participants listed twice as many eating simulation features for the attractive than for the neutral foods (53% vs. 26%). More specifically, attractive foods were more likely to be described in terms of taste, texture, and temperature, compared to neutral foods, which in turn were heavily described in terms of visual features. For attractive foods, there was also a small correlation of eating simulation features with rated food attractiveness. These findings are consistent with the idea that the sensory and rewarding aspects of eating are preferentially encoded for attractive foods, and therefore dominate their cognitive representations (see also Londerée & Wagner, 2020).

Two studies to assess representations of alcoholic drinks show a similar pattern of findings (Keesman et al., 2018). Here, participants in a laboratory and a field setting listed features of alcoholic drinks that they consume often, alcoholic drinks that they don't typically consume, sugary drinks, and water. The alcoholic and sugary drinks were more described in terms of sensory experiences and consumption context than water. The social consumption context was especially salient for frequently consumed alcohol. Social context features, but not sensory or hedonic features, showed small correlations with daily life alcohol cravings and intrusive alcohol thoughts, but only in a lab setting with student participants, and not in a bar setting with members of the general population. These findings are generally consistent with the idea that those features that are especially salient and rewarding during consumption heavily shape people's cognitive representations, and that they may reflect increased desire for the appetitive stimuli. However, the predictive value of these features for understanding motivation and actual behaviour in real-life settings is as yet unclear.

Related but separate work shows that simulations of interacting with foods can increase the motivation to eat them. Using salivation as an indirect measure of desire, Keesman and colleagues showed that actively imagining eating a food, compared to simply viewing it, increased salivation, especially if the food was attractive (Keesman et al., 2016). Similarly, actively imagining the process of eating a food, compared to imagining the outcomes of eating, increased the preferences for attractive yet unhealthy over healthy foods (Muñoz-Vilches et al., 2019, 2020; Xie et al., 2016). Vividly imagining the taste, smell, and texture of a food increases expectations of pleasure (Cornil & Chandon, 2016; see also Larson et al., 2014). Spontaneous mental simulation, too, has been shown to increase the motivation to consume a food, for example through advertising slogans inducing sensory simulations (Elder & Krishna, 2010), through images that induce simulations of the motor behaviours involved in eating (Elder & Krishna, 2012), or through multisensory imagery of eating in response to olfactory and visual food cues (Krishna et al., 2014). These findings quite clearly suggest that consumption and reward simulations contribute to desire. Thus, if appetitive stimuli are represented through such simulations, these representations could contribute to desire and actual consumption.

In sum, various lines of previous research suggest that people may spontaneously simulate eating or drinking food and drink stimuli that they are exposed to, and that such simulations contribute to desire. No previous work, however, has established the content and the potential richness of these simulations, how they differ between more and less attractive stimuli, how they are related to previous experiences and current states (e.g., hunger, thirst), and how they contribute to motivation and consumption. The feature listing task may be useful for capturing such rich and varied representations of appetitive stimuli, but the relations of listed features with measures of motivation and behaviour need to be established. The present research was designed to address these issues in the domain of drinks, to start systematically establishing the nature of representations of appetitive stimuli and their relationship with motivational states (e.g., thirst) and role in motivated behaviour, and to further validate the feature listing task as a useful tool for this research area.

Overview

We present three experiments. Each experiment includes a feature listing task that allows us to assess the content of participants' representations of drinks of varying attractiveness, and relate these to the frequency of consumption and to current desire. Based on previous work in the domain of food (Papies, 2013), we expect consumption and reward features to be especially dominant in descriptions of attractive compared to neutral drinks. Therefore, we included at least two popular sugar-sweetened beverages (Coca-Cola and Fanta) as attractive drinks in each experiment, contrasting them with bottled water and tap water as neutral drinks. We also included other non-alcoholic drinks as fillers. Participants completed the feature listing task with stimuli presented as words (Exp. 1), pictures (Exp. 2), or actual objects (Exp. 3). They were instructed to "list features that are typically true" of each drink (Exp. 1), or to "describe this drink right now", providing a stronger momentary focus (Exp. 2 and 3). In addition to measuring how often participants consume each drink, we assessed their current desire for each drink after (Exp. 1 and 2) or before (Exp. 3) the feature listing task. In the laboratory, we also measured actual intake of the four key drinks (Exp. 3). Finally, we measured (Exp. 1 and 2) or manipulated (Exp. 3) participants' thirst to assess the effect of deprivation on representations and their role in motivated behaviour.

In Experiment 1, we also aimed to better understand whether participants indeed experience the domain of sugar-sweetened beverages as a domain of self-control conflict, as we assume. Specifically, we reasoned that in addition to consuming and enjoying them, participants would be aware of the negative health consequences of consuming sugary drinks. As a result, we expected that they would hold both negative and positive evaluations of these drinks simultaneously (i.e., ambivalence; Conner & Sparks, 2002; Giner Sorolla, 2001), as has been shown for alcohol (Houben & Wiers, 2006). To assess the feelings of conflict that may arise from this, we included a direct measure of ambivalence, assessing to what degree participants had mixed feelings about drinking sugary drinks and water. We predicted that participants would experience more mixed feelings about sugary drinks compared to water.

Experiments 1 and 3 were pre-registered on the Open Science Framework, where all materials, data, and analysis scripts can be accessed (https://osf.io/4s6qa/?view_only=6bfb8601d6c24c86953df47fc4f81ccb). Experiment 2 was a replication of Experiment 1 that served as a test of the adapted feature listing instructions for Experiment 3, so was not pre-registered separately. We report all manipulations, measures and exclusions.

Experiment 1

In this first experiment, we asked participants to list features that are typically true of each of a number of non-alcoholic drinks. We then assessed how much they desired each drink in the moment, how often they consume it, and how thirsty they felt. We hypothesised that participants would list a greater proportion of consumption and reward features for sugary drinks than for water (Hypothesis 1). We further predicted that the proportion of consumption and reward features for sugary drinks would be especially high among participants who often consume sugary drinks (Hyp. 2a), and among those who are thirsty

(Hyp. 2b). We further predicted that the proportion of consumption and reward simulation features listed for sugary drinks would predict participants' desire to consume them (Hyp. 3).

Finally, we predicted that participants would have more 'mixed feelings' about consuming sugary drinks than about consuming bottled water and tap water (Hyp. 4), and that stronger 'mixed feelings' towards sugary drinks would be associated with a higher frequency of drinking them (Hyp. 5). Finally, we predicted that participants would list a greater proportion of long-term positive health features for both bottled and tap water than for sugary drinks (Hyp. 6).

Method

The Supplemental Online Materials for this study provide details on additional exploratory questions, measures, and analyses, and on the power analyses conducted. These may be of interest to some readers, but do not bear on the main findings of the paper. The experiment was approved by the College of Science and Engineering Ethics Committee at the University of Glasgow, and all participants provided informed consent before participating.

Participants

We collected data from 218 adults currently living in the UK via the online platform Prolific (www.prolific.co). The sample size was selected to match an earlier pilot study (N = 200), but we also conducted a series of power calculations using the 'pwr' package in *R*. These calculations were based on effect sizes from three main results of a pilot study that we test again in the current experiment.

We concluded that a sample of 200 participants would provide sufficient power to detect the key effects of interest observed in our pilot study. Our a-priori inclusion criteria were: participants are between 18-70 years, live in the UK, have normal or corrected to normal vision, have no current eating disorders, diabetes, or allergies to any drink products, learning disabilities, and are not pregnant. Furthermore, we preregistered to exclude participants who experience technical issues and participate on a mobile phone or tablet. Based on these preregistered criteria, we excluded 14 participants (*n* = 7 participated on a mobile phone or tablet, *n* = 2 provided illegible answers on the feature listing task, *n* = 4 had not consumed some of the sugary drink products, and *n* = 1 experienced technical issues).

The final sample consisted of 204 adults (201 women, 1 male, 1 non-binary, and 1 missing) with a mean age of 36.8 years (*SD* = 12.2) and an average BMI of 27.9 (*SD* = 8.26).

Experimental design

A within-participant design was used in which participants were presented with words for 3 sugary drinks (regular Coca-Cola, orange soda, squash (*a mix of fruit syrup with water*)), 2 types of water (bottled water, tap water), and 4 filler drinks (Diet Coke, orange juice, tea, coffee). The dependent variables were (1) the proportion of consumption and reward features generated for each drink during completion of the feature-listing task, (2) the desire to consume the drinks, (3) mixed feelings experienced in regard to the drinks, and (4) the proportion of long-term positive health consequences features generated for each drink during completion of the feature-listing task. Thirst and consumption frequency were additional predictors and measured as continuous variables.

Procedure and measures

Data was collected online between 2 pm and 5 pm. The study took on average 20 minutes to complete. Participants were instructed to participate on a desktop or laptop and not to consume any drink or food during the session. Then, they were presented with the inclusion criteria and the consent form. Unless otherwise indicated, all measures were assessed on a 100-point visual analogue scale (VAS).

After indicating informed consent, participants reported how thirsty they felt in the moment (0 – "not at all", to 100 – "very much"; *M* = 41.8, *SD* = 25.8). The thirst item was presented amongst other mood items (happy, calm, hungry, excited). Then, participants indicated the time of their last drink.

Next, participants performed the feature listing task: they were asked to list features that are "typically true" of the nine drinks (presented as words, i.e., "Regular Coca-Cola", "Regular orange soda (e.g. Fanta)", "Diet Coke", "Regular squash (e.g. Ribena)", "bottled water (e.g. Volvic)", "tap water", "orange juice (e.g. Tropicana)", "tea", "coffee". Participants were instructed to describe properties that are "typically true of the object" (McRae et al., 2005; Wu & Barsalou, 2009). Each drink was presented on screen individually and participants typed their answers into an empty box beneath the drink name, with features separated by a comma. The order of the drinks was randomized for each participant. Prior to commencement of the feature-listing task, example features were provided to participants for the concept "television" ("black, square, entertainment, watch with friends, evening"). There was no time limit during the feature listing task. Participants were instructed to respond spontaneously, and to write down the typical features that come to mind first. They were instructed to enter at least five features, but there was unrestricted space to enter more than five.

Next, we measured desire to consume for each drink separately with the following question: "Right now, in this moment, how much would you like to consume [drink item]?" (0 – "not at all" to 100 – "very much".) Then we measured consumption frequency for each drink by asking how often participants consume them (0 – "never" to 100 – "very often"), and whether they had tried each drink before (No/Yes).

Participants filled out the self-report habit index (Verplanken & Orbell, 2003) adapted for sugary drinks, bottled water and tap water, assessing to what degree they disagree or agree with statements on a 7-point scale (e.g., "Drinking sugary drinks is something I do without thinking"). We then measured mixed feelings about consuming sugary drinks, bottled water, and tap water. For these three drink types, a statement was displayed, e.g., "I have mixed feelings about drinking sugary drinks" (0 – "strongly disagree", 50 – "neither agree nor disagree", 100 – "strongly agree"). Then, we assessed the short-term reward of consuming each drink ("How often do you consume this drink as a reward?"; 0 – "Never", 50 – "Sometimes", 100 – "Very often"). Seven items assessed intentions to change consumption (0 – "Strongly disagree" to 100 – "Strongly agree"), for example "I would like to decrease my sugary drink consumption". Next, we measured perceived healthiness of each drink by asking participants "How healthy do you think this drink is?" (0 – "not at all" to 100 – "very healthy").

Then, four open questions (not analysed here) prompted participants to describe a) three situations in which they typically drink a sugary drink, b) three reasons that they typically have for drinking sugary drinks, describe c) three situations in which they typically drink bottled water, d) three reasons that they typically have for drinking bottled water. Then, one item assessed weight loss intentions: "To what extent are you currently trying to lose weight?" on a 0-100 scale with the anchors "Not at all", "Somewhat", and "Very much".

At the end of the experiment, we assessed general demographics (age, gender, current country of residence, body weight and height). For exploratory reasons, we also assessed socioeconomic status by asking about participant's highest educational qualification and perceived wealth (see SOM). We assessed any medical reason or otherwise why the participant could not consume any of the drinks included in the study. Finally, we assessed whether participants experienced any technical difficulties during completion of the study, and what they thought we expected to find. Lastly, we obtained meta-data on the screen size and device on which participants completed the experiment.

Coding of feature listing entries

Two coders individually coded the features that participants entered during the feature listing task using a feature listing app (https://niklasjohannes.shinyapps.io/feature_coding/). The agreement between coders was high (all Cohen's k > .8). The disagreements in features were discussed and the two coders came to a mutual agreement. Based on Papies et al., (2020), features were coded as **'consumption situation'** if they referred to the sensory experience (e.g., "sweet", "cold", "fizzy") or action (e.g. "drinking"), the context (e.g., "with salty food", "with friends"), the immediate positive consequences (e.g. "tasty", "thirst quenching"), or the immediate negative consequences (e.g. "disgusting", "bloating"). Features were coded as **'non- consumption situation'** if they refer to how the product was produced (e.g. "from mountains"), packaged (e.g. "in bottles"), purchased/accessed (e.g. "expensive"), prepared/stored (e.g. "in the fridge"), or its cultural embeddedness (e.g., "popular", "kids drink it"). Features were coded as **'situation independent'** if they refer to the long-term positive health consequences of consumption (e.g. "good for you", "healthy"), the long-term negative health consequences of consumption (e.g. "bad for you", "rots teeth"), overall positive evaluations (e.g. "good"), overall negative evaluations (e.g. "bad"), ingredients/content (e.g. "low calories", "sweeteners"), visual properties (e.g. "brown", "clear"), category words (e.g. "beverage"), linguistic information (e.g., mentioning the name of the drink), factual information unrelated to consumption ("70% of the body is water"), or other uses of the product (e.g. "for cleaning"). Any feature that could be equally plausibly coded in two or more superordinate categories (e.g. "consumption situation", "non-consumption situation", "situation independent") was coded as "ambiguous".

Our main dependent variable was the proportion of consumption and reward features, which we calculated by adding the proportions of sensory and action features, contextual features, and immediate positive consequences, and dividing this sum by the total number of features generated for each drink, per participant. We similarly calculated the proportion of long-term positive health features for each drink by dividing the number of positive long-term health consequence features by the total number of features that the participant generated for that drink.

Data analysis plan

All analyses were conducted in R (R Core Team, 2020). Data processing and visualization was done with 'tidyverse' (Wickham et al., 2019). Before carrying out the analyses, we explored our data with density plots (see OSF). These indicated that some of our variables were not normally distributed, and we thus had to amend part of our pre-registered analysis plan. The changes that we implemented were the following: 1) Because the main dependent variables are based on proportions, we could not rely on linear models assuming a Gaussian distribution. Therefore, when comparing proportion means, we relied on binomial mixed effects models using *glmer* from the 'lme4' package (Bates et al., 2015). When comparing several means we used pairwise comparisons using the *emmeans* function from the 'emmeans' package (Lenth, 2020) which applies adjusted alpha levels for multiple comparisons (Tukey correction). 2) For our correlation analyses, we relied on the Kendall method which is the preferred choice for data that is not normally distributed. 3) For comparing between dependent group means from continuous variables with a non-Gaussian distribution, we relied on a Wilcoxon signed-rank test as an alternative to a paired *t*-test.

Thus, in all analyses of feature listing proportions, we used binomial mixed effects models, and when predicting desire, we used linear mixed effects models. We employed a maximal random effects structure (Barr et al., 2013), such that we included random intercepts for participants, and random slopes for drink type to vary across participants if multiple drinks were included. For more detailed information about model fitting and model diagnostics see our data and data analysis files on the OSF. Lastly, we standardized all predictors in our linear models.

Results

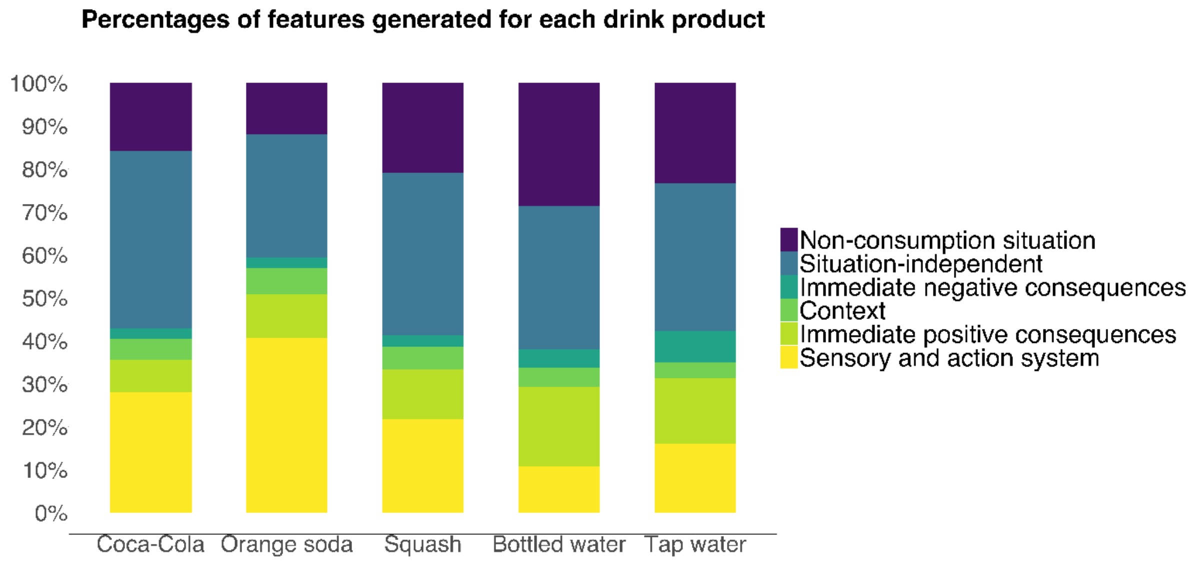
Participants reported on average *M* = 4.74 (*SD* = 0.90) features per drink, taking on average *M* = 36.4 (*SD* = 26.7) seconds for this task (numbers and response latencies were similar across drinks). Illustrating the variability of participants' representations of drinks, they reported 281 unique features for Coca-Cola, 267 for orange soda, 331 for squash, 305 for bottled water, and 291 for tap water. To provide a sense of the variety of features listed, examples of sensory features (referring to taste/flavour, temperature, or texture) are "sweet", "strong flavour", "bitter", "sour", "tangy", "cold", "bubbly", "fizzy", "sticky"; examples of context features are "summer", "ice", "on a hot day", "thirsty", "at work", "good alcohol mixer", "meal", "sports", "at the gym", "on-the-go"; examples of immediate consequence features are "nice", "hydrated", "refreshing", "alert", "satisfying", "awake", "guilt", "energy", "sickening", "burps". Situation-independent features included visual features like "dark", "brown", "amber", "black colour", "orange", "bright", "yellow", "clear", "colourless", as well as long-term health consequences like "good for you", "nutritious", "survival", "unhealthy", "tooth rotting", "diabetes", "cavities", "headache", and ingredients like "chlorine", "sugar", "colourants", "additives", "non-alcoholic", "with pulp". Participants also listed a large number of non-consumption situation features include features related to packaging such as "bottle", "can", "plastic", "bright packaging", "recyclable", "reusable", "with lid", "portable", or features related to production such as "filtered", "mountain", "purified", "tested", "from the source", "manufactured". A list of all features for each category can be found on the OSF, and their distribution across categories can be seen in Figure 1.

The results of our confirmatory tests are reported in the order of our pre-registered hypotheses. For all analysis scripts and further exploratory analyses, see the SOM.

Consumption and reward features for sugary drinks vs. water (Hyp. 1)

In line with our hypothesis, a higher proportion of consumption and reward features was reported for sugary drinks (*M* = 45%, *SD* = 26%) than for water (*M* = 34%, *SD* = 24%). The effect of drink type was significant in a binomial mixed effects model comparing all three sugary drinks (Coca-Cola, orange soda, squash) with both types of water (bottled and tap), $b = 0.32$, $SE = .07$, $p < .001$. Pairwise comparisons revealed that participants listed a higher proportion of consumption and reward features for orange soda (*M* = 57%, *SD* = 27%) than for bottled water (*M* = 34%, *SD* = 25%), $b = 0.95$, $SE = 0.21$, $p < .001$, and tap water (*M* = 35%, *SD* = 23%), $b = 0.90$, $SE = 0.20$, $p < .001$. However, there was no difference in the proportion of consumption and reward features between Coca-Cola (*M* = 41%, *SD* = 23%) and bottled water or tap water (*p*'s > .626), nor between squash (*M* = 39%, *SD* = 25%) and bottled water or tap water (*p*'s > .859; see Figure 1).

Figure 1. Percentage of features for the drinks of interest for the categories consumption situation, non-consumption situation, and situation-independent in Experiment 1.



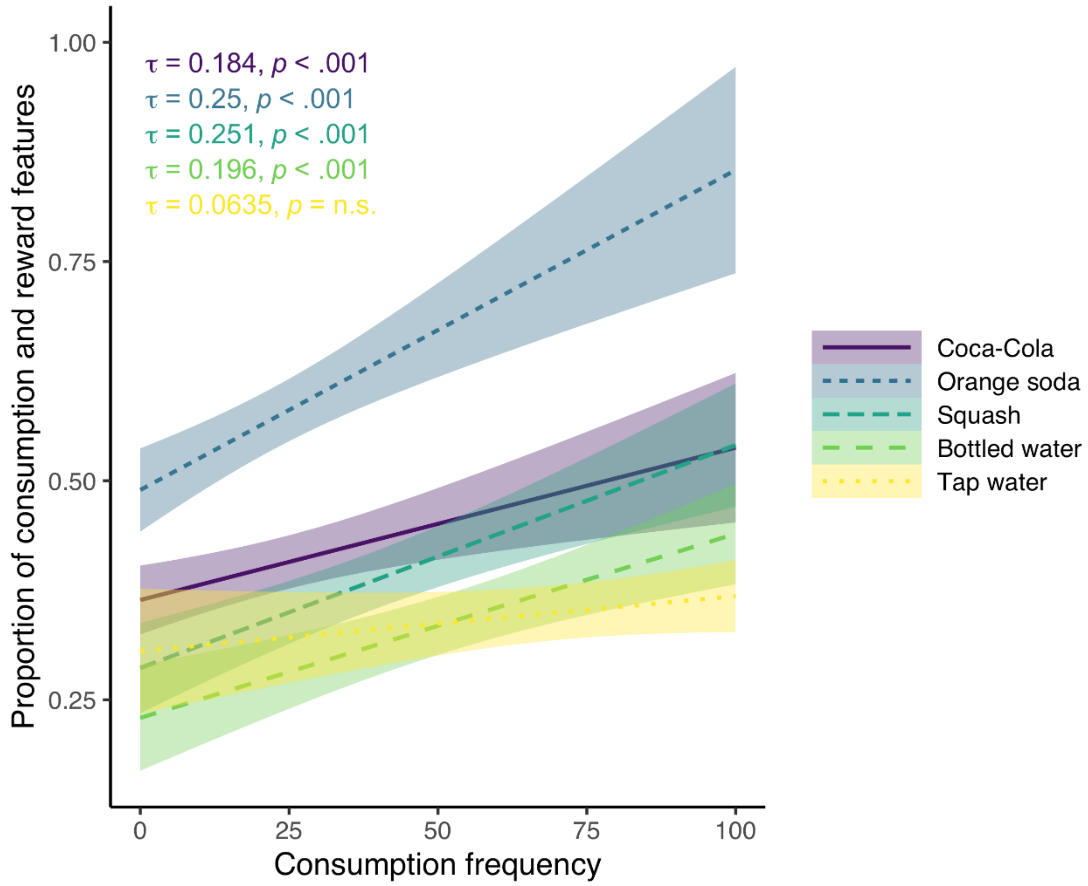
Note. Consumption and reward features include features related to context, immediate positive consequences, and sensory and action system.

Consumption frequency predicting consumption and reward features (Hyp. 2a)

As predicted, more consumption and reward features were listed for drinks that participants reported consuming more frequently, $b = 0.38$, $SE = .08$, $p < .001$, as was shown by a binomial mixed effects model predicting the proportion of consumption and reward features, with drink type (sugary drinks vs. water) and frequency of their consumption as fixed-effects predictors. While there were strong main effects of frequency and of drink type ($b = 0.50$, $SE = .09$, $p < .001$), there was no interaction between frequency and drink type, $b = 0.09$, $SE = .08$, $p = .310$. Thus, across drinks, consuming a drink more often was associated with listing more consumption and reward features (see Figure 2).

To examine effects specifically for Coca-Cola vs. bottled water, as pre-registered, we tested a binomial mixed effects models with the proportion of consumption and reward features as the outcome variable, and drink product (Coca-Cola vs. bottled water) and frequency of their consumption as fixed-effects predictors. This revealed a main effect of frequency, $b = 0.49$, $SE = .14$, $p < .001$. There was also a main effect of drink product in this model, showing that more consumption and reward features were reported for Coca-Cola than for bottled water, $b = 0.61$, $SE = .26$, $p = .020$, when consumption frequency was controlled for (in contrast to the specific comparison reported above, see Hyp. 1). However, the predicted interaction between drink and frequency of consumption was not significant, $b = -0.04$, $SE = .27$, $p = .894$.

Figure 2. Regression lines (with 95% CI) and correlation coefficients (Kendall) between frequency and proportion of consumption and reward features across drinks in Experiment 1.



Note. Consumption frequency was measured on a visual analogue scale from 0 – "never" to 100 – "very often".

Effect of thirst on consumption and reward features (Hyp. 2b)

In contrast to our hypothesis, thirst did not predict the proportion of consumption and reward features. This was shown in binomial mixed effects models, which indicated a main effect of drink type, $b = 0.32$, $SE = .07$, $p < .001$, but not thirst ($b = 0.08$, $p = 0.27$) and no interaction ($b = 0.04$, $p = .610$).

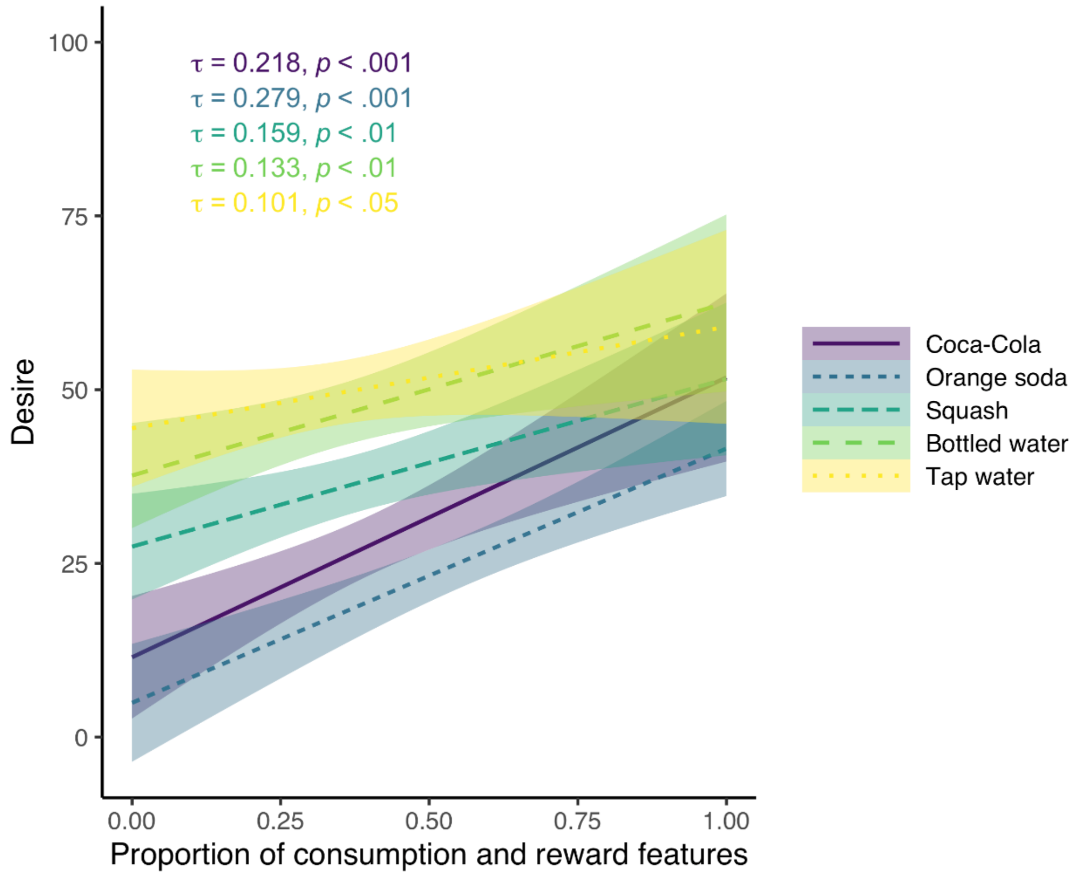
To examine the effect of thirst specifically for Coca-Cola, as pre-registered, we constructed a binomial regression model with the proportion of consumption and reward features generated for Coca-Cola as the outcome variable, and frequency of Coca-Cola consumption, current thirst, and their interaction as predictors. This allowed us to see whether thirst would increase consumption and reward features particularly among frequent consumers of Coca-Cola. Again, there was no effect of thirst (b = -.01, p = .930), no interaction with frequency, (b = .07, p = .670), and also no main effect of frequency (b = .26, p = .140). To see the analyses for the other drinks, which also did not show effects of thirst, see the SOM. Overall, thirst did not influence the production of consumption and reward features.

Consumption and reward features predicting desire (Hyp. 3)

Participants who listed more consumption and reward features for the drinks reported a stronger desire to consume them. This was shown by a linear mixed effects model predicting desire for sugary drinks and water from consumption and reward features and drink type (comparing the three sugary drinks with both waters), which revealed a significant main effect of proportion of consumption and reward features, b = 6.91, SE = 1.03, p < .001 (see Figure 3). In addition, an effect of drink type showed that overall, participants reported higher desire for water than for sugary drinks, b = -10.24, SE = 1.18, p < .001. There was no interaction (b = 0.06, p = .960). In addition, consumption and reward features predicted desire even when controlling for thirst (see SOM).

Kendall correlations between the proportion of consumption and reward features and desire show that while this relationship held across drinks, it was descriptively stronger for the sugary drinks than for water (see Figure 3). In sum, consumption and reward features predicted desire, more so than thirst.

Figure 3. Regression lines (with 95% CI) and correlation coefficients (Kendall) between desire to consume and percentage of consumption and reward features across drinks in Experiment 1.



Note. Desire was measured on a visual analogue scale from 0 – “not at all” to 100 – “very much”.

Ambivalence about sugary drinks (Hyp. 4 and 5)

In line with our hypothesis (Hyp. 4), participants’ experience of ‘mixed feelings’ was higher for sugary drinks (Mdn = 67.0) compared to bottled water (Mdn = 43.3), $p < .001$, and tap water (Mdn = 13.2), $p < .001$, as was shown by two paired Wilcoxon signed rank tests for non-Gaussian distributions.

In contrast to our hypothesis, ambivalence toward sugary drinks was not associated with consumption frequency (Hyp. 5). We computed three Kendall correlations between the ratings of experiencing mixed feelings about sugary drinks and the frequency of consuming Coca-Cola, orange soda, and squash. None of these correlations were significant, all τ's < .10.

Positive long-term health consequences (Hyp. 6)

We had pre-registered a test to examine whether participants listed more positive long-term health consequences for water than for sugary drinks. The proportion of positive long-term health features was very low for all drinks, particularly for sugary drinks (Coca-Cola: $M = 0$, $SD = 0$; orange soda: $M < 0.01$, $SD = 0.01$), but also for water (bottled water: $M = 0.07$, $SD = 0.12$; tap water: $M = 0.06$, $SD = 0.11$). We did not test for statistical significance.

For the sake of completeness, we also examined the proportion of negative long-term health features across drinks. Again, proportions were low overall, but more so for water (bottled water: $M < 0.01$, $SD = 0.02$; tap water: $M = < 0.01$, $SD = 0.02$) than for sugary drinks (Coca-Cola: $M = 0.08$, $SD = 0.13$; orange soda: $M = 0.05$, $SD = 0.10$).

These finding shows that neither sugary drinks nor water are strongly represented in terms of long-term positive or negative health consequences. We explored whether positive and negative health consequences affect the main finding of consumption and reward features on desire for, respectively, water and sugary drinks. Positive long-term health consequences positively predicted desire for water, and negative long-term health consequences negatively predicted desire for sugary drinks, although these findings should be interpreted with caution due to the very low proportion of health features. For both drink types, consumption and reward features remained a more important predictor of desire (see analysis details in the SOM).

Manipulation check

Pairwise comparisons showed that each sugary drink was perceived as less healthy than water, all $p < .001$ (see the SOM for details).

Summary and Discussion

This experiment was designed to provide an initial assessment of the role of consumption and reward features in representations of sugary drinks and water, and of their role in desire. Around 300 unique features were listed for each of our drinks of interest, attesting to the variability of participants' representations of these drinks. Participants listed more features related to consumption and reward for sugary drinks (esp. orange soda) than for water, for example describing their taste and mouthfeel. This suggests that they simulated drinking and enjoying them, when they were asked to list features that are "typically true" of these drinks.

Participants also listed more consumption and reward features if they consumed the drinks more often, and the proportion of consumption and reward features in a participant's description predicted desire. We had predicted these effects particularly for the sugary drinks, but they held equally for both sugary drinks and water. Since this is correlational evidence, we cannot draw conclusions about the direction of the effects. However, these findings are in line with the grounded cognition theory of desire, and specifically the idea that sensory, hedonic, and context information stored during previous consumption experiences plays an important role in cognitive representations of appetitive objects. Such information may be encoded preferentially during consumption, and motivate later desire to consume.

In line with our prediction, we also found that participants reported more mixed feelings about consuming sugary drinks than water, confirming that indeed, sugary drinks may constitute a self-control challenge for many people. It is possible that this results from the enjoyment of consuming them while being aware that they are unhealthy, but our measure of experienced ambivalence does not speak to the source of these "mixed feelings". In contrast to our hypothesis, mixed feelings were not more pronounced among those who consumed these drinks more often. Generally, long-term health consequences were also not very salient in participants' descriptions of drinks. Thus, it is also possible that the "mixed feelings" do not result from health considerations, but from other sources. This could be addressed in future research.

Contrary to our hypothesis, self-reported thirst was not associated with listing more consumption and reward features for any drink. This might be due to the feature listing task instructing participants to list features that are "typically true" of each drink, thus focusing them on stable representations that are less affected by momentary needs. Therefore, to provide a different and likely better test of the same hypothesis in Experiment 2, we changed the instructions and asked participants how they would describe each drink *right now*.

Experiment 2

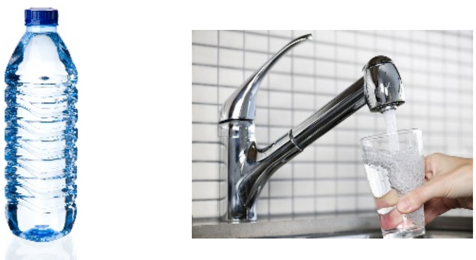
Experiment 2 was designed to replicate the key findings of Experiment 1, and again test the effect of thirst. Thus, we hypothesised that sugary drinks elicit more consumption and reward simulation features than water (Hyp. 1), that these features are associated with consumption frequency (Hyp. 2a) and with thirst (Hyp. 2b), and that they predict desire (Hyp. 3). We also again predicted that participants would report more long-term positive health consequences for water than for sugary drinks (Hyp. 4).

Method

Experiment 2 was a direct replication of Experiment 1 with four major differences. First, we changed the instructions of the feature listing task. Instead of instructing participants to list *typical* features of each drink, we asked them "How would you describe this drink right now?", to allow the task to capture variability in representations associated with momentary needs, such as thirst. Second, in the feature listing task, we presented pictures of the drinks (see Figure 4), instead of text labels, which more closely reflects the way drinks are encountered in daily life and may therefore activate slightly different representations than words (Glaser, 1992). Third, the feature listing task contained fewer drinks (i.e., only Coca-Cola, Fanta [orange soda], Diet Coke, bottled water, and tap water). Fourth and finally, we included fewer measures, that is, we included only the following measures from Exp. 1 (in this order): current thirst (*M* = 47.2, *SD* = 24.3), time of last drink, feature listing, desire, consumption history, consumption frequency, an assessment of one's usual drink when thirsty, and demographics (i.e., age, gender, current residency, height, weight).

Again, the Supplemental Online Materials provide details on additional exploratory questions, measures, and analyses, such as detailed comparisons between all drinks. These may be of interest to some readers, but do not bear on the main findings of the paper. The experiment was approved by the College of Science and Engineering Ethics Committee at the University of Glasgow, and all participants provided informed consent before participating.

Figure 4. Examples of the stimuli used in Experiment 2



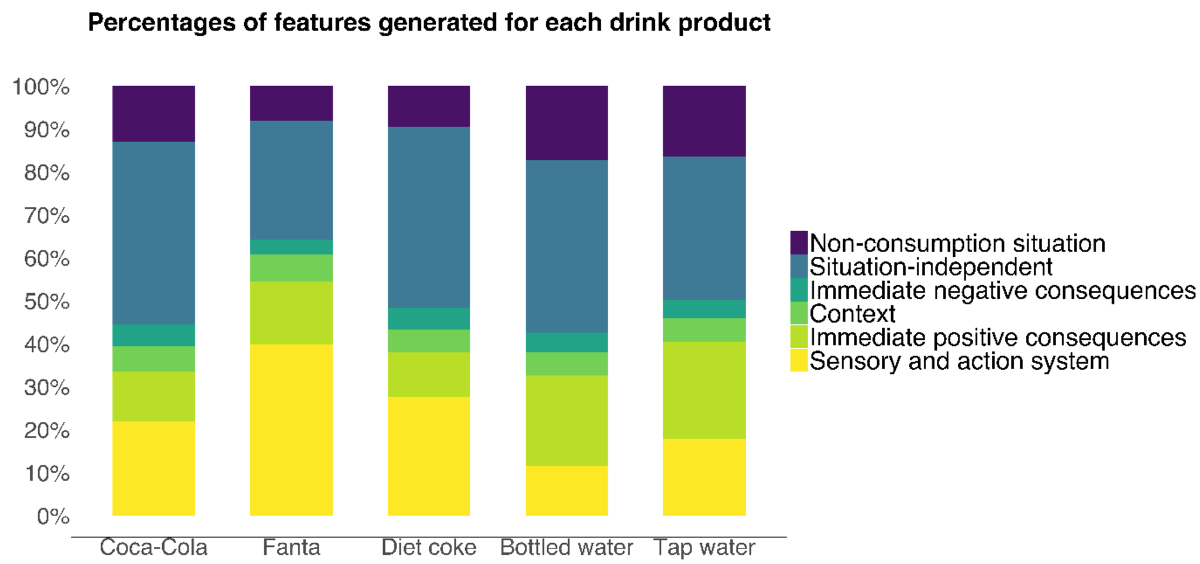
Participants

We collected data from 169 adults living in the UK via the platform Prolific. We identified the sample size with the pwr package in *R*: we powered for a multiple regression (the impact of frequency and thirst on the proportion of consumption and reward features), with 95% power and small to moderate effect size. The analysis yielded 50 participants. Since we wanted to conduct more analyses on this sample, we recruited 169 participants in total (between 18-70 years, living in the UK, normal or corrected to normal vision, no current eating disorders, diabetes, or allergies to any drink products, learning disabilities, not pregnant). Furthermore, as in Experiment 1, we excluded those who experienced technical issues and participated on a mobile phone or tablet. Based on these criteria, we excluded 12 participants (*n* = 10 participated on a mobile phone or tablet, *n* = 2 had allergies to one of the drink products). The final sample consisted of *N* = 157 adults (91 females, 66 males) with mean age 35.9 years (*SD* = 12.7) and mean BMI 25.5 (*SD* = 6.2).

Results

Participants reported on average 4.63 (*SD* = 0.78) features per drink, taking on average *M* = 36.7 (*SD* = 26.8) seconds for this task (numbers and response latencies were similar across drinks). Illustrating the variability of participants' representations of drinks, there were 262 unique features for Coca-Cola, 213 for Fanta, 312 for Diet Coke, 212 for bottled water, and 210 for tap water.

Figure 5. Percentage of features for each drink for the categories consumption situation, non-consumption situation, and situation-independent in Experiment 2.



Note. Consumption and reward features include features related to context, immediate positive consequences and sensory and action system.

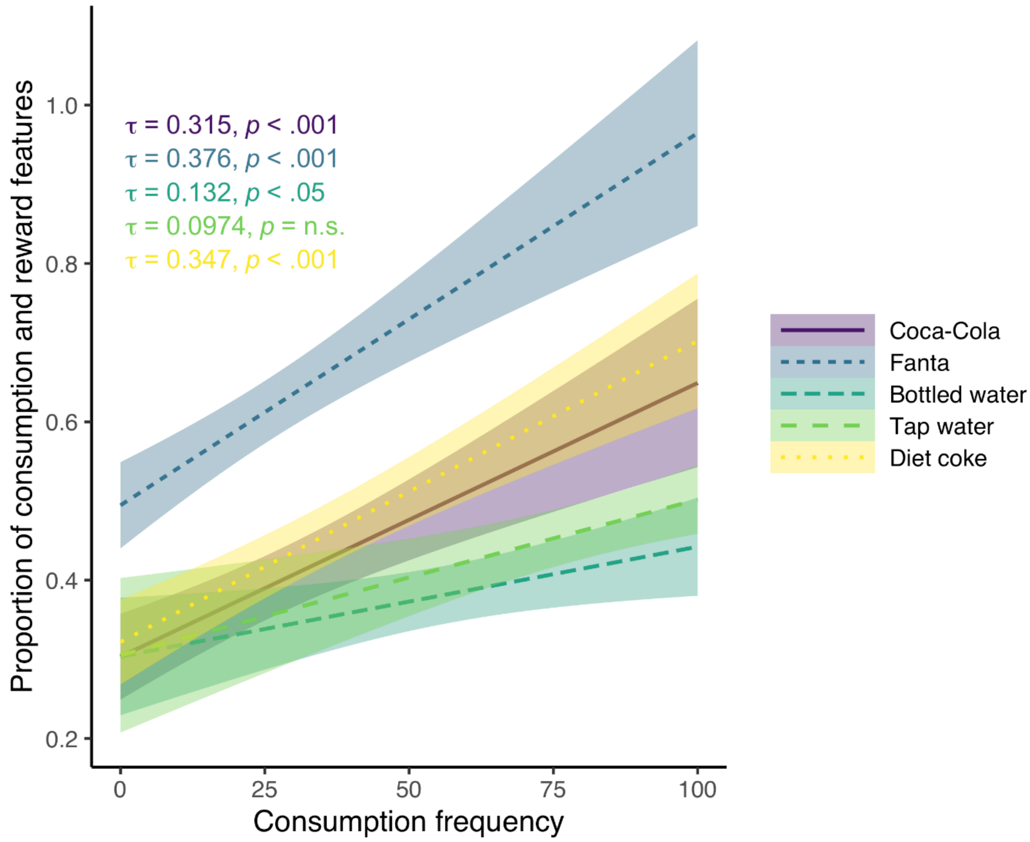
Consumption and reward features for sugary drinks versus water (Hyp. 1)

A binomial mixed effects model comparing both sugary drinks (Coca-Cola, Fanta) with both types of water (bottled, tap) showed that there was no overall difference between consumption and reward features listed for sugary drinks (M = 50%, SD = 30%) and water (M = 42%, SD = 24%), b = 0.04, SE = .10, p = .726. Pairwise comparisons showed that, as in Experiment 1, participants described Fanta (M = 61%, SD = 28%) more in terms of consumption and reward features compared to bottled water (M = 38%, SD = 24%), b = 0.93, SE = 0.23, p < .001 but not tap water (M = 46%, SD = 24%), b = 0.60, SE = .23, p = .070. There was again no difference between Coca-Cola (M = 39%, SD = 28%) and bottled water or tap water p's > .753 (see Figure 5).

Consumption frequency predicting consumption and reward features (Hyp. 2a)

More consumption and reward features were listed by participants who frequently consume the drinks, which is in line with our hypothesis and the findings of Exp. 1 (see Figure 6). This was evident from a binomial mixed effects model, which included drink type (sugary drinks vs. water) and consumption frequency as fixed-effects predictors of consumption and reward features and showed a main effect of frequency, b = 0.78, SE = .12, p < .001. There was also a main effect of drink type, b = 0.78, SE = .12, p < .001, which shows that when controlling for consumption frequency, more consumption and reward features were listed for sugary drinks than for water overall (Hyp. 1). Finally, and unlike Experiment 1, there was also an interaction of drink type and consumption frequency, b = 0.30, SE = .12, p = .010, indicating that the association of consumption frequency and consumption and reward features was especially pronounced for sugary drinks.

Figure 6. Regression lines (with 95% CI) and correlation coefficients (Kendall) between consumption frequency and proportion of consumption and reward features across drink categories in Experiment 2.



Note. Consumption frequency was measured on a visual analogue scale from 0 – "never" to 100 – "very often".

Effect of thirst on consumption and reward features (Hyp. 2b)

Thirst was associated with listing more consumption and reward features. We fitted a binomial mixed effects model with the proportion of consumption and reward features generated for the drinks as the outcome variable and current thirst and drink type (sugary drinks vs. water) as predictors. This revealed a main effect of thirst, $b = 0.29$, $SE = .09$, $p < .001$, the main effect of drink type discussed above, $b = 0.29$, $SE = .08$, $p < .001$, and no interaction, $b = 0.01$, $p = .916$.

As in Exp. 1, we examined whether thirst would increase consumption and reward features particularly among frequent consumers of one specific sugary drink, Coca-Cola. However, again, the proportion of consumption and reward features for Coca-Cola was not predicted by thirst (b = .02, p = .916) or its interaction with consumption frequency (b = -.01, p = .956).

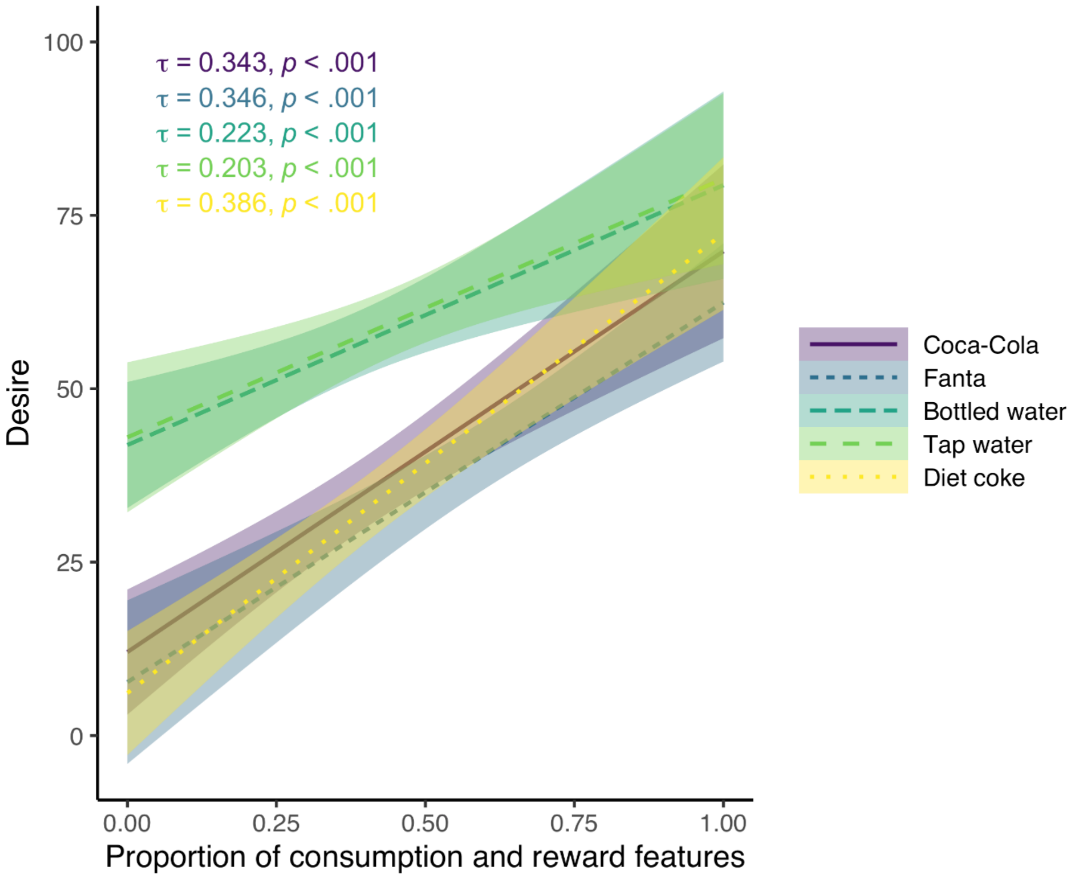
Thus, across all drinks together, feeling thirstier was associated with including a higher proportion of consumption and reward features when describing the drinks.

Consumption and reward features predicting desire (Hyp. 3)

Again, listing more consumption and reward features was associated with more desire (see Figure 7). We fitted linear mixed effects models predicting desire for sugary drinks and water from consumption and reward features and drink type. As in Experiment 1, there was a main effect of consumption and reward features, b = 11.7, SE = 1.35, p < .001, showing that a higher proportion of consumption and reward features listed was associated with higher desire. A main effect of drink type, b = -11.9, SE = 1.57, p < .001, indicated that, on average, participants desired water more than sugary drinks. There was no interaction, b =1.24, p = .341.

In addition, consumption and reward features predicted desire even when controlling for thirst b = 10.21, SE = 1.45, p < .001, and more strongly than thirst , b = 6.00, SE = 1.34, p < .001. Unlike Experiment 1, an interaction with thirst indicated that consumption and reward features tended to predict desire for drinks especially for thirstier participants, b = 2.90, SE = 1.43, p = .045, although this interaction would not survive correction for multiple testing.

Figure 7. Regression lines (with 95% CI) and correlation coefficients (Kendall) between desire to consume and proportion of consumption and reward features across drink categories in Experiment 2.



Note. Desire was measured on a visual analogue scale from 0 – "not at all" to 100 – "very much".

Long-term health consequences (Hyp. 4)

As in Experiment 1, proportions of positive health features listed by participants were very low across all drinks, so that a statistical test was not meaningful. Again, proportions were close to zero for sugary drinks (Coca-Cola: $M = 0$, $SD = 0$; Fanta: $M < 0.01$, $SD = 0.02$) and below 10% for water (bottled water: $M = 0.09$, $SD = 0.12$; tap water: $M = 0.06$, $SD = 0.10$).

Also as in Experiment 1, proportions of negative long-term health features were low overall, but more so for water (bottled water: $M = 0$, $SD = 0$; tap water: $M = 0.004$, $SD =$

0.03) than for sugary drinks (Coca-Cola: $M = 0.09$, $SD = 0.13$; Fanta: $M = 0.04$, $SD = 0.10$). Participants did not seem to represent these drinks very much in terms of long-term health consequences. Moreover, as in Experiment 1, positive long-term health consequences predicted desire for water, and negative long-term health consequences negatively predicted desire for sugary drinks. However, for both drink types, consumption and reward features were a stronger predictor of desire (see details in the SOM).

Summary and Discussion

Experiment 2 replicated the key findings of Experiment 1, using images rather than words. When controlling for consumption frequency or thirst, participants again described sugary drinks more in terms of consumption and reward features than bottled and tap water. Again, participants also listed more consumption and reward features if they consumed a drink more often. In contrast to Experiment 1, we also found support for our hypothesis that this effect is particularly pronounced for sugary drinks. Critically, we found again that listing a higher proportion of consumption and reward features was associated with a stronger desire to consume a drink, and here, this effect was somewhat enhanced by thirst. Together, these findings again suggest that consumption and reward experiences play a key role in cognitive representations of appetitive objects, and that their content is meaningfully related to participants' past experiences and current motivation.

In this experiment, we had changed the feature listing instructions to elicit participants' current, rather than "typical" representations, in order to assess the relationship with the state of thirst. In line with our prediction, we found that the thirstier participants had indicated to be at the start of the experiment, the more they described the drinks in terms of their consumption and reward features. This suggests that feeling thirsty may make both sugary drinks and water appear more attractive, as it activates memories of highly rewarding consumption experiences encoded when similarly thirsty (see Papies et al., 2015). In other words, thirst was associated with retrieving a more rewarding representation, possibly to motivate consumption to reduce thirst. In line with this reasoning, consumption and reward features also predicted desire more among thirstier participants. To provide another, stronger test of this idea, we next manipulated thirst in the laboratory.

Experiment 3

Experiment 3 had three major goals. First, it was designed as a stronger test of the hypothesis that thirst increases consumption and reward simulations, by manipulating thirst in laboratory setting rather than relying on self-report. Second, we wanted to test whether representations of drinks in terms of consumption and reward features predict not only desire, but also actual intake of sugary drinks. Finally, the study allowed us to replicate findings from Experiment 1 and Experiment 2 in a laboratory setting.

We administered the feature listing task with actual objects as stimuli, rather than words or images. However, it is possible that looking at the drinks and describing them increases desire, even more so than looking at images of drinks or reading the names of drinks. Any correlation with a measure of desire assessed after the feature listing task might therefore be somewhat inflated. Therefore, we assessed desire *before* the feature listing task in this experiment. This allows us to test whether desire and consumption and reward features are associated, even when desire is assessed before participants deeply process the drinks in order to describe them, which might trigger or increase desire.

Another change from Experiments 1 and 2 is that now, we focused our comparison between sugary drinks and water specifically on sensory features, rather than on consumption and reward features (i.e., sensory, context, and immediate positive consequence features). Studying the category means in Experiment 1 and 2 (see Figures 1 and 4) suggests that the main difference between sugary drinks and water is in sensory features. The immediate positive consequences, on the other hand, are at least as salient for water as for sugary drinks.

Therefore, for the hypothesis concerning the differences between drink types, we now focused on sensory features alone. However, we also explored the effect on consumption and reward features as a whole, as in Exp. 1 and 2.

Since we had not previously studied the representations of drinks among clearly thirsty participants, we decided to test our replication hypotheses in the non-thirsty condition. Therefore, the hypotheses for Experiment 3 are as follows. We predicted that in the non-thirsty condition, participants would list more sensory features for Coca-Cola (Hyp. 1a) and for Fanta (Hyp. 1b) compared to bottled and tap water. We further predicted that in the non-thirsty condition, the proportion of consumption and reward features (i.e., sensory system, contextual features, immediate positive consequences) would predict intake from each drink (Hyp. 2). Finally, with regard to the effect of thirst, we hypothesised that thirsty participants would generate more consumption and reward features across all drinks than non-thirsty participants (Hyp. 3). Additionally, we planned to explore Hypotheses 1 and 2 also among thirsty participants.

Method

The Supplemental Online Materials provide the Bayesian analyses pertaining to our stopping rule, as well as details on additional exploratory questions and analyses, such as comparisons between all drinks, and details on long-term health features. These may be of interest to some readers, but do not bear on the main findings of the paper. The experiment was approved by the College of Science and Engineering Ethics Committee at the University of Glasgow, and all participants provided informed consent before participating.

Participants and design

We determined our sample size with a Bayesian Sequential Sampling method (Schönbrodt et al., 2017). We first identified a minimum sample size of $N = 100$, which was calculated based on the lowest number of participants that we need for detecting a medium effect size for our between-subject prediction, i.e., Hypothesis 3, because this would require the highest number of participants. We determined our maximum sample size of $N = 148$ based on budget. We determined that if after having collected the minimum sample size the data is at least 6 times (BF = 6) more likely under the alternative than under the null hypothesis, or vice versa at least 6 times more likely under the null than under the alternative hypothesis (BF = 1/6), we would stop data collection. If this was not the case, we would continue data collection (in N = 4 intervals) until we reach a BF = 6 or BF = 1/6, or until we reach our maximum sample size. After collecting the minimum sample size (N = 100), the Bayes Factor was BF_{01} 0.17, thus we stopped data collection.

We recruited participants from the university subject pool who were 18-40 years old, did not have diabetes or allergies for drink products, were not on a restrictive diet, consumed sugary drinks at least once a week, and had not drunk or eaten anything two hours before the start of the experiment. The study took approximately 15 minutes and participants earned £3.

We manipulated thirst between participants (thirsty vs. non-thirsty). All participants were asked not to consume any beverages or foods two hours before the experiment. Then, participants who were randomly assigned to the non-thirsty (vs. thirsty; $n = 50$ per condition) condition received a drink (500 ml of a cold, fruit-flavoured tea without sugar) to quench their thirst at the beginning of the experiment.

The final sample consisted of 100 participants of which 68 females, 31 males, and 1 who identified differently. They had a mean age of 24.3 ($SD = 4.38$) and a mean BMI of 22.6 ($SD = 3.24$).

Procedure and measures

Participants were informed of the 2-hour fasting requirement when they signed up for the study via the University of Glasgow subject pool. Upon arrival, participants confirmed the inclusion criteria, read the study information sheet, and signed the consent form. Self-report data were collected with paper and pencil. Participants rated their current thirst (1-10 scale, 1 = *not at all*, 10 = *very much;* Time 1 thirst rating). Participants in the non-thirsty condition then received a drink to quench their thirst, and participants in the thirsty condition answered a filler question (i.e., whether they tried a black current "Ribena" squash before, and how much they liked it), before they rated their current thirst again (Time 2 thirst rating).

Participants then rated their desire for each drink (Coca-Cola, Fanta, bottled water, tap water, and filler items) on a 1-10 scale ("How much would you like to drink [drink product] right now?"; 1 = *not at all*, 10 = *very much*). Next, the experimenter provided participants with the feature listing task. We used the same instructions as in Experiment 2, and we presented participants with the actual drinks in a plastic cup (0.5 pint). We used Coca-Cola, Fanta, Highland Spring (a common Scottish brand of still bottled water), and tap water. The experimenter presented each participant with each drink product (in a randomized order, counterbalanced) one by one and instructed them to describe the drinks with words and phrases that come to mind spontaneously. We calculated the proportion of sensory features, and the proportion of consumption and reward features for each drink product for each participant.

Then, participants were asked to sample the drinks. The experimenter placed all four drinks on the table in front of the participant in a square, so that there was no specific order implied. Participants were asked to rate each drink in terms of how social, refreshing, enjoyable, and fresh it is (1 = *not at all*, 10 = *very much*). We did not analyse these ratings but merely requested them as a pretext for consuming some of each drink, and participants were instructed to have at least one sip of each drink before rating it. They were also told that the drinks would not be used for other participants, so they could finish them if they wanted to. After giving the instructions and providing the final questionnaire (see below), the experimenter left the room.

Finally, participants were asked to indicate how often they consume the drink products on a 1-10 scale (1 = *never*, 10 = *very often*), and they reported their gender, age, height, and weight. They were also asked what they thought the study was about. This final questionnaire was provided together with the drinks ratings form. Participants were told that this questionnaire could be filled out right after they rated the drinks, and that while they filled it out, they could go on and finish the drinks if they liked. This was done to provide enough time to finish the drinks. Finally, participants were paid, debriefed, and dismissed.

Before the arrival of the participants, the experimenter poured and weighed the drinks in a 0.5-pint plastic cup. After the experiment, the experimenter weighed the cups again and subtracted the leftover from the original amount to determine intake.

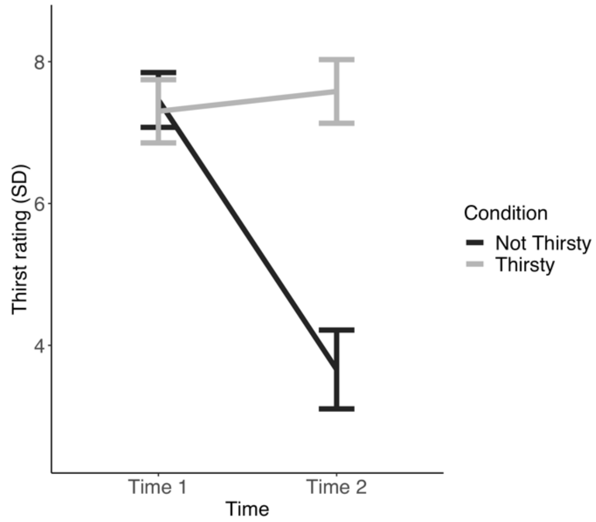
Results

Participants reported on average 5.00 (SD = 0.80) features per drink (similar across drinks). Illustrating the variability of participants' representations of drinks, 232 unique features were reported for Coca-Cola, 240 for Fanta, 222 for bottled water, and 248 for tap water.

Thirst manipulation check

We tested whether our manipulation of thirst was successful with a linear mixed effects model with condition (thirsty vs. non-thirsty) and time of the thirst rating (Time 1 vs. Time 2) as fixed effects, and participant as a random effect. As Figure 8 shows, the interaction between thirst and time was significant, $b = 4.08, SE = .30, p < .001$. Simple effects analysis confirmed that participants in the thirsty condition reported higher thirst at Time 2, compared to participants in the non-thirsty condition, $b = 3.92, SE = .36, p < .001$. Thus, the manipulation was successful.

Figure 8. Mean thirst ratings of participants in the thirsty and non-thirsty conditions at the beginning of the experiment (Time 1) and after participants in the non-thirsty condition had consumed a drink (Time 2), in Experiment 3. Thirst was rated on a 1-10 scale. Error bars represent 95% confidence intervals.



Sensory features for sugary drinks vs. water (Hyp. 1)

As predicted, more sensory features were listed for sugary drinks (*M* = 32%, *SD* = 20%) than for water (*M* = 19%, *SD* = 19%), among non-thirsty participants. This was confirmed in binomial mixed effects models comparing the two sugary drinks (Coca-Cola, Fanta) with both types of water (bottled, tap) which showed a main effect of drink type, *b* = 1.15, *SE* = .38, *p* = .002.

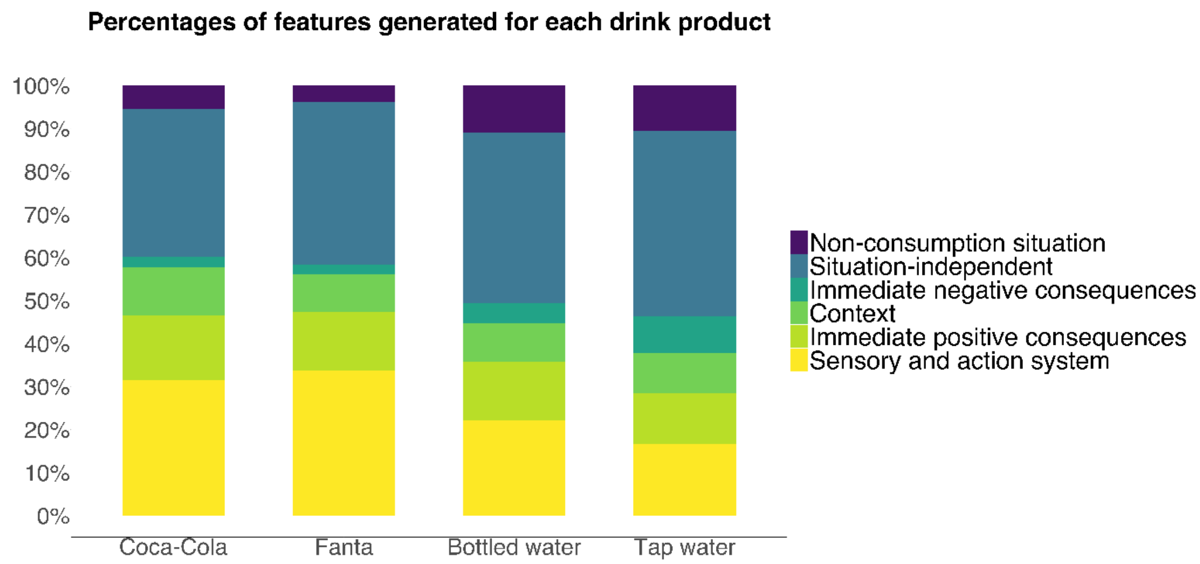
However, these differences were not significant at the level of individual drinks, as shown by binomial models comparing Coca-Cola (*M* = 32%, *SD* = 20%) with bottled water (*M* = 23%, *SD* = 21%), *p* = .304 (Hyp. 1a), and to tap water (*M* = 16%, *SD* = 17%), *p* = .068, and comparing Fanta (*M* = 32%, *SD* = 20%) to bottled water, *p* = .304 (Hyp. 1b), and to tap water, *p* = .068 (see Figure 9).

We also explored the use of sensory features to describe sugary drinks vs. water in thirsty participants and found that here too, when comparing the two sugary drinks (Coca-Cola, Fanta) with both types of water (bottled, tap), more sensory features were reported for sugary drinks (*M* = 33%, *SD* = 19%) than for water (*M* = 17%, *SD* = 16%), *b* = 0.95, *SE* =

0.39, p = .015. In sum, and consistent with the pattern of consumption and reward features in Exp. 1 and 2, sugary drinks were more described in terms of sensory features than water, although not in the pre-registered comparisons of specific drinks.

When we expanded this analysis to include comparisons between proportions of all consumption and reward features (i.e., now including the sum of sensory, context, and immediate positive consequence features), across non-thirsty and thirsty participants, we again saw that more consumption and reward features were listed for sugary drinks compared to water, b = 0.50, SE = .10, p < .001, replicating the key finding of Exp. 1 and 2 (see Figure 9 for percentages of features per drink).

Figure 9. Percentage of features for each drink for the categories consumption situation, non-consumption situation, and situation-independent in Experiment 3.



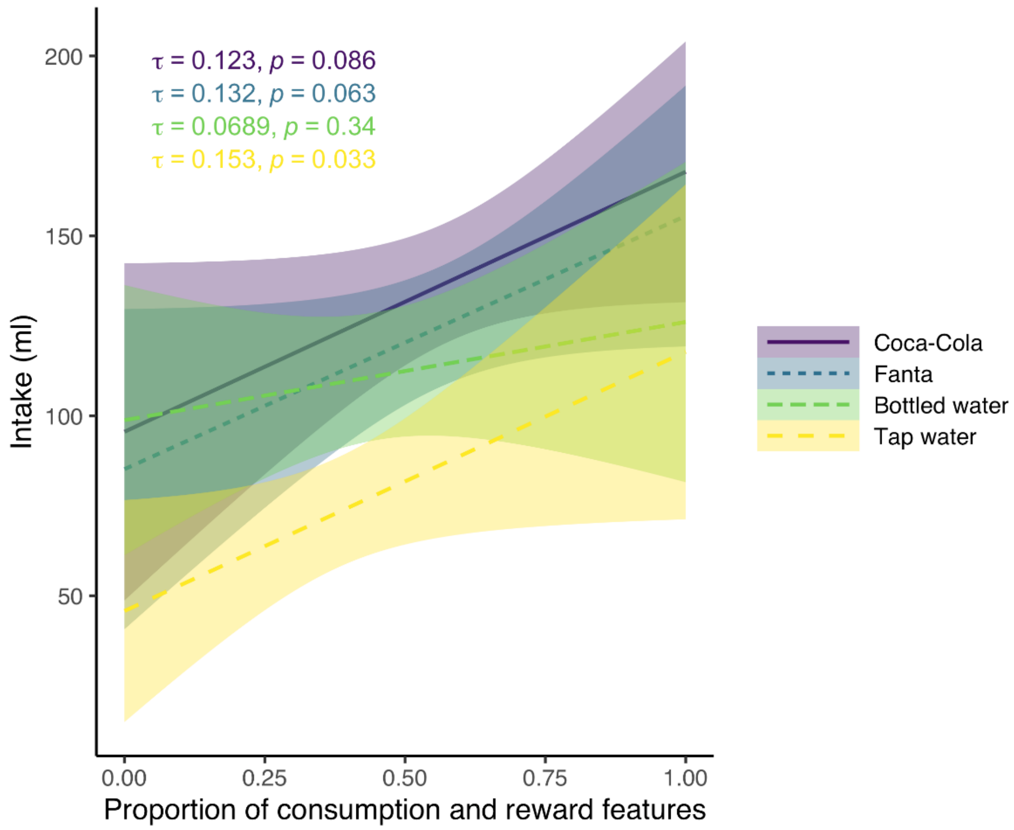
Note. Consumption and reward features include features related to sensory and action system, context, and immediate positive consequences of consumption.

Consumption and reward features predicting intake (Hyp. 2)

Consumption and reward features predicted intake (see Figure 10), as was shown in a linear mixed effects model predicting intake from consumption and reward features, b = 22.82, SE = 4.05, p < .001.

In line with our hypothesis, the proportion of consumption and reward features also predicted intake specifically among non-thirsty participants, b = 17.70, SE = 6.12, p = .005. There was no interaction with drink type (b = -1.39, p = .802). When drinks were analysed separately, the effects were not significant (Coca-Cola b = 8.88, p = .520; Fanta b = -.71, p = .960; bottled water b = 9.40, p = .427; tap water b = 10.7, p = .374).

Figure 10. Regression lines (with 95% CI) and correlation coefficients (Kendall) between proportion of consumption and reward features and intake (in ml) across drink categories in Experiment 3 (all participants).



We also explored this issue among thirsty participants. Again when all drinks were pooled, the proportion of consumption and reward features predicted intake, $b = 27.4$, $SE = 5.33$, $p < .001$, and the interaction with drink type was not significant, $b = 10.1$, $SE = 5.56$, $p = .071$. When analysed separately, consumption and reward features predicted intake of Coca-Cola, $b = 26.5$, $SE = 12.6$, $p = .041$, and Fanta, $b = 33.3$, $SE = 11.1$, $p = .004$, but not bottled water, $b = 5.66$, $p = .673$, or tap water, $b = 23.2$, $p = .068$.

Unexpectedly, thirsty participants did not drink significantly more on average ($M = 118$, $SD = 86.7$) than non-thirsty participants ($M = 105$, $SD = 88.3$), $F(1, 398) = 2.14$, $p = .144$. Thus, how much participants drank was not driven by thirst, but by thinking about the drinks in terms of consumption and reward features.

Finally, we explored whether consumption and reward features predicted intake over and above important determinants of consumption such as habits (i.e., consumption frequency) and desire. Indeed, consumption frequency was a significant predictor of intake in the complete sample, $b = 10.3$, $SE = 4.0$, $p = .011$, but consumption and reward features still predicted intake when frequency was controlled for in the complete sample, $b = 22.47$, $SE = 3.91$, $p <.001$, and also separately among non-thirsty participants, $b = 17.39$, $SE = 5.79$, $p = .003$, and among thirsty participants, $b = 26.58$, $SE = 5.17$, $p < .001$. Similarly, desire was a significant predictor of intake in the complete sample, $b = 34.92$, $SE = 3.93$, $p <.001$, and consumption and reward features predicted intake when desire was controlled for in the complete sample, $b = 15.74$, $SE = 3.78$, $p <.001$, and separately among thirsty participants, $b = 22.44$, $SE = 5.17$, $p <.001$. This effect was not significant among non-thirsty participants alone, but in the same direction, $b = 8.15$, $SE = 5.48$, $p = 0.14$. Thus, consumption and reward features predicted intake over and above consumption frequency, and over and above current desire, although not specifically for non-thirsty participants alone.

Effect of thirst on consumption and reward features (Hyp. 3)

Hypothesis 3 concerned all participants. In contrast to our hypothesis, there was no effect of thirst on consumption and reward features. A binomial regression model revealed no difference between the proportion of consumption and reward features listed on average by thirsty (M = 50%, SD = 25%) and non-thirsty (M = 48%, SD = 24%) participants, $b = 0.05$, $p = .642$. Specific comparisons showed that there was also no effect of thirst on consumption and reward features for each of the drinks individually (all $p > .596$), and no interaction with consumption frequency, $b = 0.06$, $SE = 0.10$, $p = .558$.

Consumption and reward features predicting desire

Replicating and extending the findings of Exp. 1 and 2, we found that consumption and reward features were associated with desire for the drinks, even if desire was measured before the feature listing task. Linear mixed effects models revealed a significant main effect of proportion of consumption and reward features on desire, $b = 0.49$, $SE = 0.12$, $p < .001$. There was no effect of drink type ($b = 0.19$, $p = .212$) and no interaction ($b = 0.13$, $p = .280$). The effect of consumption and reward features on desire remained when controlling for thirst, which also predicted desire, $b = 0.80$, $SE = 0.14$, $p < .001$, with no interaction, $p = .95$.

Thus, if participants desired a drink more, they listed a higher proportion of consumption and reward features for it. This held for both sugary drinks and water, and was independent of thirst.

Long-term health consequences

As in Experiment 1 and 2, proportions of *positive* health features listed by participants were very low for all drinks (Coca-Cola: $M = 0$, $SD = 0$; Fanta: $M < 0.01$, $SD = 0.04$; bottled water: $M = 0.06$, $SD = 0.11$; tap water: $M = 0.05$, $SD = 0.10$). Similarly, proportions of *negative* long-term health features were low (bottled water: $M = 0$, $SD = 0$; tap water: $M = 0.01$, $SD = 0.04$; Coca-Cola: $M = 0.04$, $SD = 0.09$; Fanta: $M = 0.01$, $SD = 0.04$). Participants did not describe the drinks very much in terms of long-term health consequences.

We did not find any significant effects of long-term health features on desire or intake (details provided in the SOM). In sum, long-term health consequences of the drinks were not salient to participants, and showed no association with motivation and behaviour.

Summary and Discussion

As in Experiment 1 and 2, participants listed more consumption and reward features for sugary drinks than for water. They specifically also listed more sensory features for sugary drinks than for water overall, although not when comparing specific drinks only. Consumption and reward features again predicted desire, and they predicted intake across drinks. However, as in Experiment 1, but in contrast to the correlational data from Experiment 2, there was no evidence that consumption and reward features were more salient when participants were thirsty compared to not thirsty.

The absence of an effect of thirst on the production of consumption and reward features might be related to the fact that a higher proportion of such features was listed in both groups, compared to the Exp. 1 and 2 (49% on average, compared to 46% in Exp. 1 and 45% in Exp. 2). It is possible that completing a feature listing task with live appetitive objects within easy reach, and with the expectation of consuming them later, activated stronger simulations of interacting with them than words or pictures, especially among this sample of participants who consumed sugary drinks at least once per week. This could lead to a higher proportion of consumption and reward features being listed overall (i.e., a ceiling effect), and would be in line with the grounded cognition perspective that such simulations prepare for situated action, i.e., for actual intake. Future research should test this possibility.

Surprisingly, thirst also did not have a pronounced effect on intake. However, both desire and intake were clearly associated with consumption and reward features. Thus, thinking about the drinks in terms of consuming and enjoying them was more strongly associated with motivated behaviour than physiological needs.

General discussion

Summary

In three experiments, we used natural language to examine how people cognitively represent sugary drinks and water, and how these representations relate to their consumption habits and current motivation to consume. In line with the assumption that people's representations should reflect their highly variable, idiosyncratic consumption experiences, we found high variability in the features that participants used to describe the drinks, with more than 300 unique features per drink in some cases. Despite this high number of unique features, however, we also found systematic patterns, which were in line with the grounded cognition perspective that stimuli that provide stronger sensory and rewarding experiences during consumption are more strongly represented through re-enacting or simulating these experiences. Specifically, we found that across experiments, participants described sugary drinks more in terms of features reflecting consumption and reward experiences than water. These consumption and reward features were consistently associated with consumption frequency across experiments, especially for sugary drinks (Exp. 2). These consumption and reward features also consistently predicted desire, and predicted consumption of the drinks in Experiment 3 among both thirsty and non-thirsty participants, more so than thirst itself. Crucially, consumption and reward features predicted intake even when controlling for frequency of consumption or desire.

Surprisingly, thirst was only weakly related to listing consumption and reward features. We found correlational evidence for this hypothesized relationship only in Experiment 2, but not in Experiment 1, and also not in Experiment 3, where thirst was manipulated. The absence of a thirst effect in Experiment 3 could be due to the nature of the stimuli, with the actual drinks in front of participants triggering strong simulations in all participants. Still, overall, we did not find consistent evidence that a heightened motivational state to drink, or higher need to drink, increases the degree to which people think about drinks in terms of consuming and enjoying them – or indeed their intake. We had reasoned that specifically among frequent consumers of sugary drinks, feeling thirsty could trigger simulations of the strong reward previously experienced from consuming the sugary drinks when thirsty. This could motivate increased consumption in line with one's physiological need. However, although our experiments might be underpowered to detect such interaction effects, we found no indications for this pattern in any of our experiments, nor did we find evidence that participants consumed more in response to thirst in Experiment 3.

Theoretical implications and future research

Our findings have implications for our understanding of cognitive representations of appetitive stimuli more generally. First of all, our work suggests that it is possible to establish at least parts of these representations, for example using feature listing. Although, as we expected, there was high variability and diversity in the drink features that participants reported, there were meaningful patterns in the different types of features listed. Our findings clearly showed that features that are salient during consumption, such as sensory and reward features (see Elder & Krishna, 2010), are dominant in the cognitive representation of appetitive objects. This is consistent with neuro-imaging research on responses to food cues (e.g., Chen et al., 2016; Petit, Merunka, et al., 2016; Spence et al., 2016; van der Laan et al., 2011). It is also consistent with natural language descriptions of more attractive foods being more focused on eating experiences, while also being encoded with more refined neural representations (Londerée & Wagner, 2020).

In addition, the degree to which consumption and reward features dominated representations correlated meaningfully with participants' states and traits. Specifically, current desire and consumption frequency were both positively associated with listing consumption and reward features, such that participants who desired a drink more or consumed a drink more often described it more in terms of sensory, context and rewarding features experienced during consumption. Thus, our work also suggests that participants' consumption behaviour shapes their representations of appetitive objects. Indeed, these feature listing protocols analysed here can be seen as reflections of participants' situated memories of consuming the drinks. In addition to superficial or stereotypical features listed to describe the drinks, and in addition to valenced features reflecting evaluative conditioning, participants produced a large number of unique features most likely drawn from situated representations of their own experiences. Crucially, however, consumption and reward features predicted actual consumption even when controlling for consumption frequency. Thus, although these cognitive representations are shaped by experience, they are not merely a byproduct, but have a unique and independent role in driving motivated behaviour.

The large number of unique features produced suggests that the features listed by participants are not merely superficial word associations, but result from participants' retrieval of idiosyncratic consumption memories while completing the feature listing task, and may therefore reflect situated simulations (Santos et al., 2011). These simulations seem to involve several modalities and reflect visual information about colour and packaging, sensory information about taste and texture, information about consumption contexts, and information about the immediate bodily and affective effects of consumption (Larson et al., 2014; McCrickerd & Forde, 2016; Piqueras-Fiszman & Jaeger, 2015; Simmons et al., 2005). This is also consistent with the idea in grounded cognition approaches more generally that situated simulations prepare for effective goal-directed behaviour (Barsalou, 2009; Elder & Krishna, 2012; Pulvermüller & Fadiga, 2010; Tucker & Ellis, 2001), which here was reflected in increased intake. Future research could use fMRI to assess whether participants indeed simulate consuming and enjoying appetitive objects while listing consumption and reward features for them, for example by assessing the concurrent activation of gustatory and reward areas in the brain.

In addition, future research could assess whether feature listing protocols strongly rely on episodic consumption memories, or whether explicitly asking participants to list features based on a specific personal memory might lead to even richer protocols than instructions to list “typical features” or simply describe a product. Indeed, previous research has shown that participants recalling a personal memory of eating a food (e.g., carrots) later chose more of that food from a buffet compared to participants who instead imagined somebody else eating that food (Robinson et al., 2011). This might suggest that instructions focusing attention on experiences of past consumption episodes might further strengthen the link between features listed and motivated behaviour, which warrants further research.

Importantly, we do not claim that our findings suggest that participants’ representations of appetitive stimuli are learned or accessed unconsciously, or that they influence behaviour in a purely automatic manner (Corneille & Mertens, 2020; Hofmann et al., 2008). Indeed, since we asked participants to write down features of objects, our findings show that participants have conscious access to at least parts of their cognitive representations of appetitive objects. Similarly, it is likely that these representations affect behaviour with varying degrees or features of automaticity. Thus, to the degree that participants are aware of their spontaneous thoughts about a food or drink, are aware of how these might affect their desires and behaviour, and are motivated to regulate their behaviour, they likely have some control over how these representations affect actions (De Houwer et al., 2009; Hofmann et al., 2008). Our results also showed, however, that consumption and reward features predicted beverage consumption independent of self-reported desire (although not when tested separately among non-thirsty participants). This suggests that feature listing captured an aspect of motivation that was not reflected in self-report ratings of the motivation to consume. Possibly, consumption and reward features capture a different content dimension, or are a more implicit measure, than the desire ratings, thus explaining additional variance in behaviour (see also Wiers et al., 2002). Future research should study these questions specifically. However, regardless of the degree of automaticity, our findings suggest that it is informative to study these representations, since they can provide novel insights that can potentially have important implications for understanding cognitive, affective, neural, and behavioural responses to appetitive stimuli.

These findings extend research on drinks-related associations and expectancies in the domain of alcohol. While research on alcohol associations typically uses more structured tasks, for example assessing the likelihood that participants provide alcohol-related responses to specific alcohol-related prompts, participants in our studies were asked to freely describe various drinks. Similarly, given that the role of outcome expectancies in consuming sugary drinks is not well understood, we did not focus participants on outcomes of consumption, as is typically done in free association tasks in the domain of alcohol (e.g., Dunn & Goldman, 2000). Participants in our feature listing tasks generated a large number of idiosyncratic drink-related cues, including sensory, context, outcome, and other features, reflecting their rich learning histories of consuming the drinks. Crucially, this approach also allowed us to systematically establish and assess differences in representational content between different drink categories, in this case sugary drinks and water. Our findings suggest that feature listing can be a useful, unconstrained but manageable tool for establishing the content of individual cognitive representations across domains, and for establishing links with motivation and behaviour. The grounded cognition theory of desire offers a natural way to integrate these findings on the role of memory associations (e.g., contextual cues triggering thoughts about consumption) and the role of outcome expectancies (e.g., anticipating rewarding experiences when thinking about consumption) into one theoretical framework.

Specifically, the theory suggests that they both form part of the situated conceptualisation of an appetitive stimulus, and that consumption and reward simulations in response to contextual cues or in response to thoughts of potential outcomes may lead to motivated behaviour (Papies, Barsalou, et al., 2020; Papies & Barsalou, 2015).

The findings on the effects of thirst on feature listing, desire, and intake, have potential implications for our understanding of the role of thirst in drinking behaviour, and of physiological needs in appetitive behaviour more generally. If our grounded cognition theory of desire is correct, the finding that thirst did not affect the listing of consumption and reward features might indicate that people's learning histories with regard to (sugary) drinks do not include increased reward from consumption when thirsty, because these drinks are not typically consumed in response to thirst. In other words, such drinks might be consumed for their sensory features, rather than their thirst-quenching features, which might also motivate consumption despite the adverse health consequences of sugar-sweetened beverages. This would also be consistent with the almost completely absent effect of thirst on consumption in this research (see also Krishna & Eder, 2018). Notably, participants in Experiment 3 who had not consumed any liquids for more than 2 hours only drank slightly more on average (13 ml) than those participants who had received a large beverage at the beginning of the experiment. This suggests that drinking behaviour is more guided by the expectation of pleasure than by physiological needs, at least within the degrees of thirst experienced by participants in the current experiment. This is also in line with findings that thirst cues can be easily ignored or suppressed, which may be associated with underhydration (Rodger et al., 2021). Future research could assess whether more extreme levels of thirst shape representations of drinks to be more attractive, whether tasks other than feature listing are more sensitive to need-related variability in cognitive representations, or whether cognitive representations of appetitive objects are relatively unaffected by physiological needs.

A theoretically important possibility with regard to the inconclusive findings on the relation between thirst and consumption and reward features is that these findings provide evidence against the grounded cognition theory of desire. In other words, these findings could simply suggest that the theory is incorrect, because a motivational state that should clearly drive behaviour towards relevant appetitive stimuli has not been found to affect the degree to which their consumption is simulated. As we discussed above, however, the relationship of thirst with behaviour was even weaker than its relationship with consumption and reward features, suggesting that thirst may not be a suitable variable for a rigorous test of the theory. A stronger manipulation of motivational relevance that has more consistent effects on behaviour may be more suitable, for example situational congruence, such as completing a feature listing and a consumption task for strong alcoholic drinks in the morning vs. in the evening. According to the grounded cognition theory of desire, such a manipulation should affect both consumption and reward simulations, as well as desire and consumption. If only desire or intake is affected by such a manipulation (e.g., participants consume more alcohol in the evening than the early morning), but consumption and reward simulations are not (e.g., consumption and reward simulations are the same in both settings), and if consumption and reward simulations are no longer predictive of desire or intake, this would provide strong evidence against the core assumption of the grounded cognition theory that consumption and reward simulations play a key role in desire. Testing the grounded cognition theory of desire in this or similar ways seems a fruitful avenue for future research.

Applied relevance

Our findings on the rich content and predictive value of cognitive representations for desire and intake may also have applied implications for understanding and improving the regulation of appetitive behaviour. Specifically, we suggest that understanding representations of appetitive objects held by individuals or groups of consumers may be useful, for example for supporting the transition to healthier or more sustainable consumption patterns.

It was striking, for example, how few health consequences were mentioned for the drinks. Even in Experiment 1, where the instruction was to list features that are "typically true" of each drink, being unhealthy was not very salient for most participants when describing sugar-sweetened beverages. In addition, when desire was assessed before the feature listing task, and so without deep processing of the stimulus before indicating desire, there was no association between health features listed and desire. Health features also did not predict intake. This suggests, in line with other work, that health considerations are not a strong driver of appetitive behaviour in this domain, so that reminding people of them may not be the best target for an intervention (e.g., Cadario & Chandon, 2020; Papies, 2017; Turnwald et al., 2019).

In contrast, consumption and reward features in participants' descriptions consistently predicted motivation across experiments. Such rewarding simulations in response to sugary drinks may explain people's difficulty in reducing their consumption, despite their adverse health consequences. While consumption and reward features predicted motivation descriptively more strongly for sugary drinks, this effect also occurred for water. This suggests that expectations of sensory pleasure and enjoyment are an important driver of appetitive behaviour also in this domain, and may be a better target for interventions than health considerations. In other words, making the sensory and rewarding features of healthy drinks, such as water, more salient may boost the motivation to consume it (see also Papies, 2020). More generally, though, knowing which of the many idiosyncratic features that we found predict desire for different stimuli on an individual level, will help us understand not only which aspects lead to self-control challenges, but also which aspects can be targeted to resolve them, for example through more tailored interventions or marketing efforts. While the effectiveness of increasing consumption and reward simulations to increase the appeal of healthy foods has been demonstrated in recent studies (Papies, Johannes, et al., 2020; Turnwald et al., 2019; Turnwald & Crum, 2019), the efficacy of this approach in the domain of drinks and other behaviours remains to be established (see Claassen et al., in press).

Strengths and Limitations

Our work has a number of methodological strengths, such as that our hypotheses are strongly grounded in theory, high statistical power based on power analyses with well-powered pilot data and on mixed effects models, the clear distinction between confirmatory (and pre-registered) vs. exploratory analyses, and the internal replication of key findings.

A clear limitation of this work is that we were only able to infer simulations from our feature listing measure of consumption and reward features, relying on natural language. While previous work has provided evidence indicating that feature listing relies on perceptual simulations (Wu & Barsalou, 2009), and while this measure here offers clear insights into the rich and varied content of participants' representations, it does not provide direct evidence that participants are actually simulating, or re-enacting, modality-specific consumption experiences, nor does it provide causal evidence for the role of simulations in representations and motivation (in contrast to Elder & Krishna, 2012). Before one is able to experimentally manipulate these simulations, however, one needs to know their nature and modality. If we take the features listed by our participants as an indicator, it is clear that consumption and reward simulations are a complex, multi-modal phenomenon that may be difficult to experimentally manipulate other than through explicit instructions. Instructional manipulations, however, would bring their own set of problems in terms of ecological validity and demand effects. Further development of experimental manipulations in this domain will be required. In addition, neuroimaging techniques could be used to assess whether simulation features indicate the activation of simulations in related brain areas.

An additional limitation is that we only studied a predominantly Western sample, with a particular food and drink culture, and which is exposed to extensive food marketing and food and drink images on social and other media (Petit, Cheok, et al., 2016; Spence et al., 2016). Therefore, we cannot easily generalise to different cultures with other habits and therefore, potentially different representations of appetitive stimuli. When replicating this work in other cultures, researchers would need to ensure that the categories of beverages chosen for the study match the consumption patterns of the target population.

Conclusion

This research demonstrated the rich, experience-based and highly variable nature of cognitive representations of appetitive objects, and their implications for motivated behaviour. Three experiments showed that participants' representations of drinks were dominated by sensory and rewarding features reflecting previous consumption experiences, especially for tasty, sugar-sweetened drinks. Thinking about drinks in terms of such consumption and reward features was more likely among participants who consumed them more often, and it predicted increased desire and intake. Together, these findings suggest that participants spontaneously simulate consuming and enjoying the drinks, and that such simulations motivate behaviour. Given the ubiquity of appetitive stimuli in daily life, understanding the content and nature of their cognitive representations can be useful for unravelling their often powerful effects on behaviour.

Context of the Research

This research results from the authors' shared interest in facilitating healthy eating and drinking, and hence in the underlying cognitive processes that create desire. Since very little is known about the motivation to consume sugary drinks, and possible strategies to shift consumption to healthier alternatives, we set out to examine cognitive representations of appetitive stimuli in this domain. Although this research directly examined natural language descriptions only of drinks, the findings potentially also speak to motivational processes in the domains of food, alcohol, and tobacco, among others. Thus, we believe that this work can contribute to our understanding of cognitive processes underlying desires more generally, as well as inform strategies to shift desires to healthy and sustainable behaviours.

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