Bidirectional Contrast Effects between Taste Perception and Simulation:

A Simulation-Induced Adaptation Mechanism

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Abstract

Four experiments reveal that actual taste perception and mental simulation of taste can exert a bidirectional contrast effect on each other. Experiment 1 shows that similar to actual taste experience, simulated taste experience is influenced by a prior actual taste in a contrastive manner. Experiment 2 shows that this contrast effect of actual taste on taste simulation occurs only when people adopt an imagery-based rather than an analytical processing mode. Experiment 3 demonstrates the bidirectional nature of the current effect and again shows that it depends on people's use of mental simulation. Lastly, experiment 4 replicates the observed effect in a realistic marketing environment. These findings support the proposition of a simulation-induced adaptation mechanism. Theoretical and practical implications of this research are discussed.

Keywords: contrast effect, taste perception, mental simulation, mental imagery.

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Imagine that you have just enjoyed a slice of pizza and are now looking at pictures of brownies and contemplating whether you should order one. Although actual perceptions of taste influence each other (Lawless, 1983), will the consumption of pizza influence the imagined taste of the brownie, making it seem sweeter than it actually is? In such a situation, the taste of the brownie has to be simulated, and the subsequent purchase decision must be based on this pre-consumption mental simulation of taste (MacInnis & Price, 1987). Given the ubiquitous use of taste simulations in our daily lives, it is somewhat surprising that so little research has addressed this topic, especially the ways in which taste simulation is influenced by actual taste experience. In the present research, we explore the idea that actual taste perception could exert a contrast effect on subsequent mental simulation of taste (and vice versa), and we demonstrate that taste simulation closely resembles actual taste in these bidirectional effects.

CONTRAST EFFECT IN TASTE PERCEPTION

Taste perceptions are susceptible to context effects and biases (e.g., Lawless, 1983, 1994; Lawless, Glatter, & Hohn, 1991; Lawless & Heymann, 2010; Mattes & Lawless, 1985). Research has shown that human taste perceptions are in no way accurate or consistent, and they can be largely influenced by contextual factors in a bottom-up manner. More specifically, judgments of actual taste are often made in contrast to contextual taste stimuli (i.e., prior tastes). For example, it has been shown that sodium soups with the same level of salt concentration often taste saltier when sampled after a low salt-concentration soup than after a high salt-concentration soup (Lawless, 1983). Mattes and Lawless (1985) asked participants to optimize the level of sweetness/saltiness of a beverage by diluting or concentrating the original high- or low-concentration fluid and found that levels of sucrose and salt of the optimized beverage were significantly higher when the original beverage featured a high versus low concentration of the substance. Examples of contrast effects in taste experience are ubiquitous in our daily lives. For instance, we might find a serving of dessert to be sweeter when eaten after a salty dish and perceive the same dessert to be less sweet after intakes of other sugary foods (cf. Guinard & Brun, 1998; Rolls, Rolls, Rowe, & Sweeney, 1981; Yee, Sukumaran, Kotha, Gilbertson, & Margolskee, 2011).

Contrast effects in taste perception can be explained by Helson's (1964) adaptation-level theory. This theory proposes that judgments of a stimulus in a context follow a linear function of the stimulus' deviation from the adaptation level, which is a type of running average of the context stimuli. For actual taste perceptions, contrast effects occur because the neural circuits responsible for taste processing are adapted to a certain level of activation during the processing of the contextual (i.e., prior) food stimulus. Later taste perception is judged in relation to this adapted level of activation (Helson, 1964). However, what happens when a simulated taste follows the contextual (and actual) stimulus? In the current research, we propose and show that taste simulations are isomorphic to actual tastes in terms of perceptual properties in that contrast effects occur bidirectionally between taste perceptions and simulations.

SIMULATION-INDUCED ADAPTATION

Although early conceptualizations suggested that sensory perception and simulation are dissociated from each other (cf. Fodor, 1975; Pylyshyn, 1984), recent research provides considerable evidence that common neural substrates underlie both actual and simulated sensorimotor experience (e.g., Chao & Martin, 2000; Djordjevic, Zatorre, Petrides, Boyle, & Jones-Gotman, 2005; O'Craven & Kanwisher, 2000), including taste (Simmons, Martin, & Barsalou, 2005). Simmons et al. (2005), for example, have shown that viewing pictures of appetizing foods activates neural circuits in the gustatory processing areas that are also active during the processing of actual tastes. These neural reenactments in the modality-specific regions constitute our conceptual knowledge and inference of taste. This is consistent with theories of grounded cognition (Barsalou, 1999, 2008), which hold that multi-modal mental simulation of sensorimotor experience is an integral part of our knowledge representation.

According to Simmons et al. (2005), for example, eating a slice of pizza activates neural circuits that are responsible for the processing of a later simulated taste of brownie. At the neural level, activations in the brain are very much alike for both a perception-simulation and a perception-perception sequence of tastes. Thus, similar to the contrast effects between actual taste experiences, a contrast effect of actual taste perception on subsequent taste simulation is likely to occur. By the same token, mental simulation of a salty food item would activate the same neural regions governing the processing of actual taste perception, and therefore would increase the perceived sweetness of a different sweet food item that is tasted later. Under the framework of adaptation-level theory (Helson, 1964), neural reenactments in modality-specific regions make actual (simulated) tastes constituents of the adaptation level for subsequent simulated (actual) tastes. We term this process *simulation-induced adaptation* and propose that it underlies our hypothesized bidirectional contrast effects between taste perception and simulation.

Helson (1964) made no predictions regarding whether people's mode or goal of processing would affect the adaptation level. The current conceptualization, however, posits that adaptation level is contingent on people's processing mode or goal. Though modality-specific mental simulation is proposed as an integral component of knowledge representation in theories of grounded cognition, the degree of simulation and consequently the influence of such simulations on judgments are nevertheless not invariant (e.g., Ackerman, Goldstein, Shapiro, & Bargh, 2009; Coventry, Christophel, Fehr, Valdés-Conroy, & Herrmann, 2013; Eelen, Dewitte, & Warlop, 2013; Solomon & Barsalou, 2004). Past research has shown that the extent to which individuals utilize mental imagery in information processing and decision making can be modulated by their processing mode or goal (Jiang, Adaval, Steinhart, & Wyer, 2014; Keller & McGill, 1994; Petrova & Cialdini, 2005; Shiv & Huber, 2000; Thompson & Hamilton, 2006). Since mental imagery corresponds to the deliberate activation of multi-modal mental simulation (Barsalou, 2008; Elder & Krishna, 2012), we expect that taste perception and simulation would be more likely to influence each other when people adopt an imagery-based processing mode.

THE CURRENT RESEARCH

Our research studies the bidirectional contrast effects between actual and simulated tastes and examines the moderating role of processing mode. Specifically, we propose that eating (imagining eating) a salty food item will lead people to judge a subsequently imagined (eaten) sweet food item to be sweeter, compared to conditions in which no such prior experience (imagery) exists. Moreover, in line with the simulation-induced adaptation mechanism, such contrast effects should be stronger when people adopt an imagery-based processing mode when evaluating the food item(s).

We test these hypotheses in four experiments. In experiment 1, we show that a prior actual salty taste increases judged sweetness for a subsequent sweet stimulus. Importantly, this effect occurred when the sweet stimulus was actually tasted as well as mentally imagined, supporting the proposed isomorphism between actual and simulated tastes. In experiment 2, we manipulate our participants' processing mode and show that the contrast effect of actual taste on simulated taste occurs only when participants adopt an imagery-based rather than an analytical processing mode. In experiment 3 we demonstrate a contrast effect from the opposite direction (the effect of simulated taste on actual taste) and show that it is also contingent on processing mode. In experiment 4 we replicate the observed effect in a realistic marketing environment to show its practical relevance.

In all the current experiments, sample sizes were determined prior to conducting the experiments and were affected by factors such as the experiments' sign-up rates and attendance rates. In addition to the key variables of interest, participants in most of our experiments were asked to answer some evaluative questions regarding the stimuli (see Methodological Details Appendix). These measures were added for the sake of the cover story and were not related to our hypothesis, nor did they influence our results significantly. We therefore do not discuss them further.

EXPERIMENT 1

In experiment 1 we aim to demonstrate the proposed isomorphic nature of actual and simulated tastes by showing a similar contrast effect of prior taste on taste judgment for both actual and simulated food stimuli. Participants first actually tasted a salty snack or nothing, then evaluated a target sweet food stimulus using either actual taste or mental simulation. Next they "recreated" the sweetness of the target food stimulus by making a cup of sugar water (adapted from Mattes & Lawless, 1985). We predicted that the taste-contrast effect would result in the recreated sweetness being higher after a taste of a salty snack than after eating nothing, and this effect should occur regardless of whether the target food stimulus is actually tasted or mentally simulated.

Research has shown that people do not necessarily experience a contrast effect during concurrent consumptions (Novemsky & Ratner, 2003; Schreiber & Kahneman, 2000) but nevertheless would predict such effects to occur as guided by their lay beliefs (Novemsky & Ratner, 2003). In the current design, the actual taste of the target food stimulus and the taste recreation task would greatly alleviate the concern that our effect is explained by a lay-belief account. In addition, we measure participants' lay belief about taste contrast to directly examine its role in the current effect (cf. Novemsky & Ratner, 2003).

Method

Participants. One hundred ninety-six undergraduate students from a university in Hong Kong participated for a monetary reward. Two participants failed to follow the experimental instructions (e.g., did not use all the sugar), so their data were excluded from the analyses. The final sample size was 194 (38% male; M_{age} = 20.36 years).

Design and procedures. Experiment 1 employed a 2 (prior actual taste: salty vs. none) × 2 (target stimulus mode: actual vs. simulated) between-participants design. Participants were told that this study was about food evaluation. Those in the salty-prior-taste conditions first evaluated a dried salty fish (a common local snack, see Appendix A) by actually eating a small piece of it. Participants in the no-prior-taste conditions skipped this part.

In the second task, participants were told to evaluate a brand of grape juice (see Appendix A) and do a taste recreation task. Participants in the actual-target conditions tasted a cup of the grape juice, while participants in the simulated-target conditions were instructed to rely on their imagination and to mentally simulate the experience of drinking the grape juice (adopted from Keller & McGill, 1994). Next, each participant was given two standard bags of sugar (total weight 15g) and a bottle of distilled water (430ml) and told that their goal was to make a cup of sugar water that would taste just as sweet as the grape juice they consumed (imagined). Participants were instructed to put all the sugar into a cup and then to add water until the beverage tasted right. We recorded the volume of water each participant used in making the sugar water by later weighing the water left in the bottle, which served as the dependent variable of this study. As an indication of their lay belief about taste contrast, all participants reported how they would expect their consumption experience of the juice to be if they had eaten something salty first (1 = not at all sweet, 9 = very sweet). At the end of the study, as in all other current experiments, participants reported their personal information and were debriefed, thanked, and dismissed.

Results

We predicted that participants who taste the salty fish first would judge the grape juice to be sweeter (and therefore add less water in the taste recreation task) compared to those who do not taste the fish, and this effect would occur regardless of whether the grape juice is actually tasted or simulated. We entered the amount of water that participants used in the taste recreation task in a 2 (prior actual taste: salty vs. none) × 2 (target stimulus mode: actual vs. simulated) between-participants ANOVA. Consistent with our prediction, the results revealed only a main effect of prior actual taste (see fig. 1). Participants who had eaten the salty fish first added significantly less water (*M* = 82.85ml, *SD* = 37.80) than participants in the no-prior-taste conditions (*M* = 99.23ml, *SD* = 36.10; $F(1, 190) = 9.60$, $p = .002$, $d = .44$). Importantly, there was no interaction effect between prior actual taste and target stimulus mode ($F < 1$, NS), nor was there a main effect of target stimulus mode ($F < 1$, NS).

Consistent with past literature on hedonic contrast (e.g., Novemsky & Ratner, 2003), participants believed that having eaten something salty first would make the juice appear quite sweet (*M* = 5.93, which is significantly higher than the midpoint of the scale, $p < .001$). Participants' lay belief about taste contrast, however, was not correlated with the amount of water they used in the taste recreation task ($r = .03$, NS). To further examine the role of this lay belief in the current effect, we ran a multiple regression analysis with the amount of water used as the dependent variable, and prior actual taste, target stimulus mode, and lay belief about taste contrast as the independent variables. We also included in the independent variables the three-way interaction term and the respective two-way interaction terms among the latter three variables. The results revealed no significant two-way interaction between prior actual taste and lay belief ($t(181) = -.03$, $p = .978$; the reduced degree of freedom was due to missing data on the lay-belief measure), nor was the three-way interaction significant ($t(181) = .25$, $p = .804$). This indicates that participants' lay belief about taste contrast did not moderate the effect of prior actual taste on the amount of water they used, and this was so regardless of whether the grape juice was actually tasted or mentally simulated.

Discussion

Results of experiment 1 indicate that people perceive a sweet drink to be sweeter when they have eaten something salty first, compared to when no prior salty taste precedes. Importantly, this is the case both when the sweet drink is actually tasted and when it is mentally simulated. The current findings therefore support the hypothesized isomorphism between actual and simulated tastes by showing that they are similarly affected by prior taste experience. In addition, results from the actual-target conditions and the analysis of the contrast lay-belief measure both suggest that a mere lay-belief account for the current effect is unlikely to hold.

EXPERIMENT 2

We have hypothesized that simulation-induced adaptation underlies the proposed isomorphism between the two types of taste (actual and mentally simulated). In experiment 2 we test this mechanism using a moderation-of-process design (Spencer, Zanna, & Fong, 2005). We predicted that the contrast effect between actual and simulated tastes (i.e., the simulated-target conditions in experiment 1) is more likely to occur when people process the target stimulus by actively using their mental simulation, and the effect should be attenuated when the mental-simulation process is “turned off.”

Past research has shown that the extent to which people engage in mental simulation can be determined by their mode of information processing (analytical vs. imagery processing, Keller & McGill, 1994; Petrova & Cialdini, 2005; Shiv & Huber, 2000; Thompson & Hamilton, 2006). Therefore, in experiment 2 we manipulate the extent to which participants engage in mental simulation by instructing them to rely on either their mental imagery (high simulation) or analytical reasoning (low simulation) when evaluating the target stimulus. If simulation-induced adaptation underlies the current effect, we would expect the effect to occur only when mental imagery but not analytical reasoning is used to evaluate the target stimulus.

Method

Participants. One hundred thirty-eight Hong Kong undergraduate students participated for a monetary reward. Twelve participants failed to follow the experimental instructions (e.g., did not drink the water) and their data were excluded from the analyses. The final sample size was 126 (21% male; $M_{\text{age}} = 21.42$ years).

Design and procedures. Participants were randomly assigned to conditions of a 2 (prior actual taste: salty vs. sweet) × 2 (processing mode: imagery vs. analytical) between-participants design. Upon arriving at the lab, participants were told that they would be taking part in a test for a new food. Participants first drank a cup of either salty (0.55g salt dissolved in 50ml water) or sweet water (4.2g sugar dissolved in 50ml water) to ostensibly clean and refresh their mouth. Then participants were shown a picture of a sweet Napoleon cake (see Appendix A) on their computer screens. Participants in the imagery conditions were instructed to rely on their imagination and to mentally simulate the experience of eating the cake and then evaluate it; whereas participants in the analytical conditions were asked to be careful and well-reasoned in their thought process and to make logical judgments of the cake that seemed right to them (Keller & McGill, 1994).

After viewing the cake picture, participants answered two questions regarding their estimated sweetness of the cake. Specifically, they indicated how sweet they thought the cake was (1 = not at all sweet, 7 = very sweet) and estimated its sugar content (1 = very low, 7 = very high). These two measures were averaged ($r = .43$, $p < .001$) to create a single index of estimated sweetness. Next, all participants indicated the extent to which they utilized their mental simulation when evaluating the cake using three items (adapted from Bone & Ellen, 1992; see also Elder & Krishna, 2012): “As you viewed and evaluated the Napoleon cake, to what extent did any images of eating the Napoleon cake come to mind?” (1 = to a very small extent, 7 = to a very great extent); “While viewing and evaluating the Napoleon cake, I experienced…” (1 = few or no images of eating the Napoleon cake, 7 = lots of images of eating the Napoleon cake); “All sorts of pictures, tastes and/or smells came to my mind while I viewed and evaluated the Napoleon cake” (1 = strongly disagree, 7 = strongly agree). Participants’ answers to these items were averaged to index their level of mental simulation ($\alpha = .81$).

Results

Participants in the imagery conditions reported adopting mental simulation of the cake to a greater extent ($M = 4.59$, $SD = 1.10$) than those in the analytical conditions ($M = 4.07$, $SD = 1.08$; $F(1, 122) = 6.80$, $p = .010$, $d = .48$). There was no main effect of prior taste or interaction effect on mental simulation (*F*s < 1, NS).

A 2 (prior actual taste: salty vs. sweet) × 2 (processing mode: imagery vs. analytical) ANOVA on estimated sweetness showed no main effect of either prior actual taste or processing mode (*p*s > .28) but a marginally significant interaction effect ($F(1, 122) = 3.73$, $p = .056$, $\eta_p^2 = .03$; see fig. 2). Planned contrasts showed that in the imagery conditions, participants who drank the salty water estimated the cake to be sweeter (*M* = 5.25, *SD* = .73) than did participants who drank the sweet water (*M* = 4.87, *SD* = .78; $F(1, 122) = 3.70$, $p = .057$, $d = .50$). In the analytical conditions, however, prior tastes had no significant effect on estimated sweetness of the cake ($M_{salty} = 4.80$, *SD* = .68 versus $M_{sweet} = 5.00$, *SD* = 1.08; $F < 1$, NS).

Discussion

Results of experiment 2 provide evidence that the contrast effect between actual and simulated taste is contingent upon people's use of mental simulation. Specifically, we demonstrate that people who have drunk salty water first estimate a cake in the picture to be sweeter than people who have drunk sweet water first. Importantly, this contrast effect occurs only when people adopt a high rather than low level of mental simulation when evaluating the cake. Our results support the proposed simulation-induced adaptation mechanism. The current findings also provide additional insights for adaptation-level theory (Helson, 1964) by showing that people's goal or processing mode can modulate the adaptation level of certain stimuli.

EXPERIMENT 3

Experiments 1 and 2 provided convergent support for our hypothesis that actual taste experience can have a contrast effect on mental simulation of taste through a simulation-induced adaptation mechanism. As discussed earlier, we expect the contrast effect between actual and simulated taste to be bidirectional. That is, mental simulation of taste should have a contrast effect on actual taste perception, and this effect should also depend on the activation of people's mental simulation. Experiment 3 tests this hypothesis.

Method

Participants. Ninety-six Hong Kong undergraduate students participated for a monetary reward. Data from six participants were excluded from the analyses because the participants failed to follow the experimental instructions (e.g., did not use all the sugar). The final sample size was 90.

Design and procedures. Participants were randomly assigned to three conditions (imagery processing vs. analytical processing vs. control). Participants in the first two conditions evaluated the dried fish snack in experiment 1 by either using their mental simulation (imagery condition) or relying on their analytical reasoning (analytical condition); they then answered some evaluative questions regarding the fish. The manipulation of processing mode (imagery vs. analytical) was similar to that in experiment 2. Participants in the control condition skipped this part. All participants then actually drank a cup of grape juice and did the same taste recreation task as in experiment 1. Participants also completed the same lay-belief measure as in experiment 1.

Results and discussion

A one-way ANOVA revealed a main effect of experimental conditions on the amount of water used in the taste recreation task ($F(2, 87) = 4.23$, $p = .018$; see fig. 3). Planned contrasts showed that participants in the imagery-processing condition used significantly less water in the taste recreation task ($M = 80.38$ml, $SD = 45.38$) than participants in both the analytical processing condition ($M = 105.48$ml, $SD = 34.90$; $F(1, 87) = 6.46$, $p = .013$, $d = .62$) and the control condition ($M = 105.40$ml, $SD = 33.68$; $F(1, 87) = 6.32$, $p = .014$, $d = .63$). The average amounts of water used in the latter two conditions were almost identical ($F < 1$, NS). These results confirm that the contrast effect of prior taste simulation on subsequent actual taste occurs only when people adopt an imagery-based but not an analytical processing mode.

Once again, participants' lay belief was not correlated with the amount of water they used (r = .01, NS). We next pooled over data in the analytical and the control conditions and ran a multiple regression analysis with the amount of water used as the dependent variable, and the dummy variable representing the imagery condition versus the other two conditions, participants' lay belief about taste contrast, and these two variables' interaction term as the independent variables. The interaction was not significant ($t(86) = .74$, $p = .463$). Therefore, results in experiment 3 again suggest that our effect is not moderated or driven by people's lay belief about taste contrast.

EXPERIMENT 4

The previous experiments confirmed the validity of our hypothesis using different measures and stimuli. However, one potential drawback of these experiments is that they used manipulations and tasks that may seem unnatural and apply only in an experimental setting. To demonstrate the current effect's relevance to the field, in experiment 4 we replicated the contrast effect in experiment 3 in a more realistic marketing environment. Since experiment 3 showed that participants in the control condition behaved similarly to those in the analytical processing condition, we focused on the comparison between imagery-based and analytical processing conditions in the current study.

Method

Participants. Ninety-one (26% male; M_{age} = 21.00 years) Hong Kong undergraduate students participated for a monetary reward.

Design and procedures. Participants enrolled in a study about restaurant dining, presumably focusing on how people behave in a restaurant. Each participant was given a printed restaurant menu that closely mimicked those used in local Chinese restaurants. The menu featured six salty Chinese dishes. Non-Chinese participants were provided with an English translation of the menu (see Appendix B).

We manipulated participants' imagery-based versus analytical processing mode with a more natural method this time. Food tastes and prices are two major concerns of consumers when they visit a restaurant. Thus we randomly assigned participants to either a taste-imagery or a price-analytics condition. In the taste-imagery condition, participants were told that their goal in reading the menu was to select three dishes that they felt would be the tastiest. They were told to carefully imagine the tastes of the dishes, rate each dish on its tastiness, and briefly describe the taste of each dish. Participants in the price-analytics condition, however, were told that their goal was to select three dishes that they thought have the most reasonable prices. They were asked to look at the prices of the dishes, rate each dish on its price reasonableness, and provide the most reasonable price of each dish. It was expected that participants in the taste-imagery condition would mentally simulate the tastes of the dishes to a greater extent than participants in the price-analytics condition.

Next, as part of the same simulated dining experience, all participants actually ate and evaluated a serving of dessert (a small piece of chocolate cake; see Appendix A) that was ostensibly from the same restaurant. Participants rated the sweetness of the cake using the same two items in experiment 2, and their answers to these items were again averaged to create a single index of sweetness ($r = .53$, $p < .001$).

Results and discussion

Consistent with our expectation, participants in the taste-imagery condition rated the cake to be sweeter (*M* = 5.52, *SD* = .72) than did participants in the price-analytics condition (*M* = 5.15, *SD* = .90; $F(1, 89) = 4.84$, $p = .030$, $d = .45$; see fig. 4). Therefore, experiment 4 shows our effect's relevance to people's daily lives by replicating it in a realistic marketing environment and by using a manipulation of processing mode that is more pertinent to actual decision making.

GENERAL DISCUSSION

There has been considerable research recently that aims to better understand the nature of mental simulation and imagery (e.g., Jiang et al., 2014; Jiang & Wyer, 2009; Petrova & Cialdini, 2005; see Wyer, Hung, & Jiang, 2008, for a review). However, to the best of our knowledge, the current research is among the first to study context effects that occur across actual and simulated sensory experience. Across four experiments, we show that actual and simulated taste experiences are similarly affected by prior taste (experiment 1). This isomorphism between actual and simulated tastes is dependent on people's level of mental simulation such that it occurs only when a high rather than low level of taste simulation is activated (experiment 2). In addition, experiments 3 and 4 demonstrate the bidirectional nature of the current effect and its relevance in a more realistic marketing setting. These results support the claim that actual and simulated tastes are highly similar in perceptual properties, and our results are consistent with a simulation-induced adaptation mechanism.

The current research contributes to the extant literature in several ways. First, it supplements previous research on the effects of taste simulation on actual food consumption. This research has shown that people's mental simulations of taste experience could affect the habituation and satiation of subsequent actual food consumption (Larson, Redden, & Elder, 2013; Morewedge, Huh, & Vosgerau, 2010). For example, Morewedge et al. (2010) showed that repeatedly imagining eating a stimulus could lead to a habituation effect on the amount of subsequent actual consumption of the stimulus. Larson et al. (2013) demonstrated a similar habituation effect on the enjoyment of actual foods caused by prior repetitive taste simulation. However, an important theoretical question remains regarding whether these effects are driven by reductions in subsequent foods' hedonic and motivational impacts or by a habituation at the perceptual level (Morewedge, in press; Morewedge et al., 2010). Contributing to this research, the current paper demonstrates a contrast effect of taste simulation on actual taste perception, suggesting that the effects of taste simulation on actual food consumption may be perceptual rather than motivational.

Second, research on grounded cognition has mostly concentrated on the effects of incidental and unconscious influences of bodily states on higher-level conceptual processing, such as attitude formation and retrieval, judgment, and social perception (for reviews see Barsalou, 2008; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). The present research extends findings in this line of research and adds novel support to the body-mind link by showing that deliberative sensorimotor experience could influence mental simulation/imagery, and vice versa.

Lastly, our research contributes to the mental imagery literature by revealing important antecedents and consequences of taste imagery. Past research on mental imagery (especially in the marketing field) has focused almost exclusively on the visual modality (e.g., Jiang et al., 2014; Petrova & Cialdini, 2005; but see Krishna, Morrin, & Sayin, 2014). The current paper highlights the importance of investigating other dimensions of multisensory mental imagery in consumer research and will ideally stimulate further research in this area.

Alternative explanations

Previous research has suggested that contrast effects in perceptual domains may sometimes occur at the conceptual level (Novemsky & Ratner, 2003; Schreiber & Kahneman, 2000; see also Lawless & Heymann, 2010). Therefore, it is possible that the current effect is judgmental in nature and can be captured by various context-effect models in the conceptual domain (e.g., Mussweiler, 2003; Schwarz & Bless, 2007; Wedell, Hicklin, & Smarandescu, 2007). We believe that our findings are unlikely to be accounted for by these conceptual models for several reasons. First, experiment 1 provides evidence that the current contrast effect occurs in actual taste experience and is thus unlikely to be purely judgmental. Second, both experiments 1 and 3 show that the effect is not influenced by individuals' lay belief. More critically, in experiments 2 and 3 we demonstrate that the contrast effect occurs only when people adopt an imagery-based but not an analytical processing mode. It is unlikely that our processing-mode manipulation would systematically influence factors such as judgment standard, stimulus categorization, stimulus extremeness, or (dis)similarity testing—factors that are considered key determinants of assimilation versus contrast in those conceptual models (Mussweiler, 2003; Schwarz & Bless, 2007; Wedell et al., 2007).

Another alternative explanation of the current effect is that it may be driven merely by different anchoring of response scales. For example, in the current context, prior actual (imagined) taste could change the range of subjective values that participants perceive to be relevant in a rating scale when answering the questions. Therefore, the current effect may not reflect bottom-up perceptual changes but instead be caused by changes in how a response scale is subjectively positioned (Parducci, 1965). Such an alternative explanation may only be relevant for studies that used response scales (e.g., experiments 2 and 4). The behavioral measures in experiments 1 and 3, however, speak against this scale-anchoring explanation.

Limitations and future research

The present research has several limitations, and future studies are warranted. Due to methodological limitations, we only tested the proposed simulation-induced adaptation mechanism using a moderation approach (Spencer et al., 2005). Although our results support the proposed mechanism, future research should test the current effect's underlying process in a more direct manner. Another drawback of the present research is its inadequate ecological validity. Although experiment 4 was conducted in a more realistic setting, other experiments used tasks that were less natural for marketing activities. It would be ideal for future research to investigate this effect and its implications in field studies.

Our research has focused exclusively on taste perception. Future studies may address the interactive impacts between actual and simulated experience in other sensory modalities such as touch, smell, sound, and vision. For example, researchers may investigate whether touching a certain object with our hands could impact our mental simulation of the texture of some other material, and whether mentally simulating touching an object could influence our actual haptic perception of something else. In addition, recent research has revealed that senses in different modalities have interactive impacts upon the processing of each other (e.g., Spence, 2011, 2012). It will be fruitful for future research to explore the bidirectional influences between actual and simulated sensory experience across different modalities.

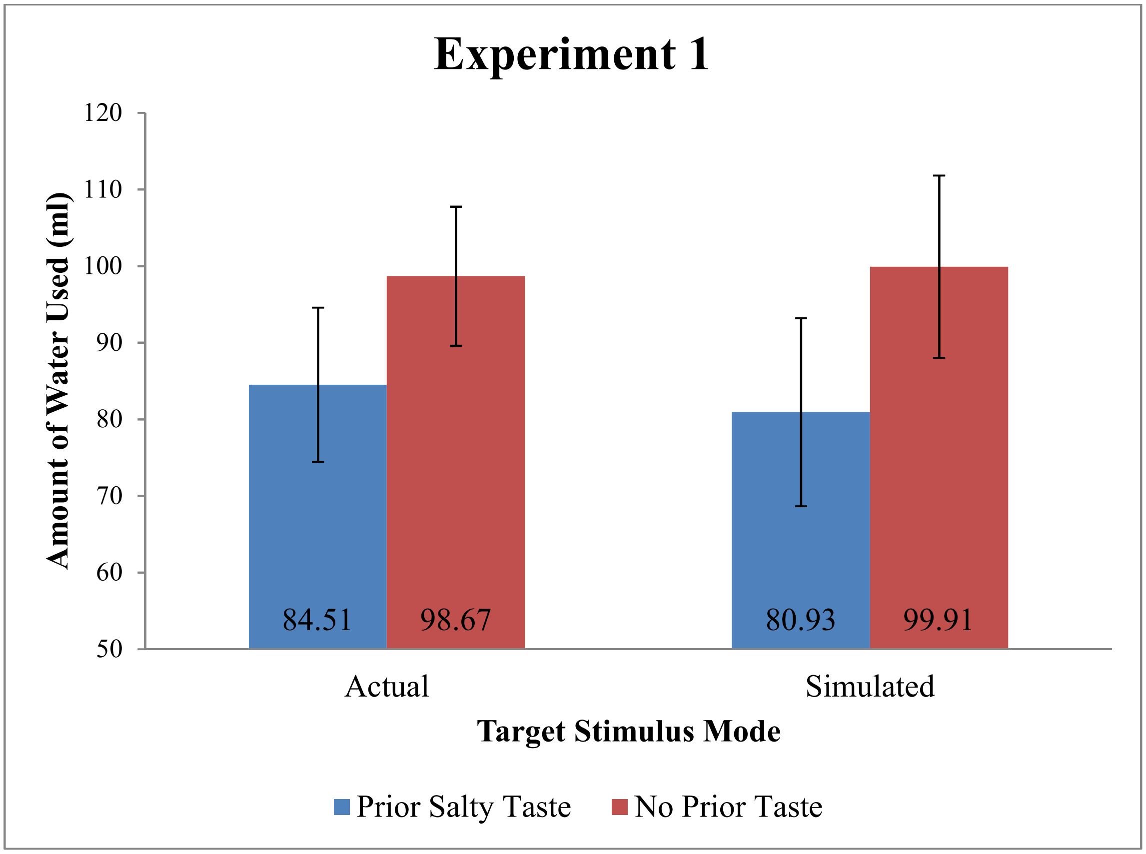
The current research does not test the impact of processing modes on the observed effect when both the prior and target food stimuli are actual. According to our proposed mechanism, the neural regions for taste processing must be activated when people actually eat something, and this activation cannot be prevented or revoked by adopting an analytical processing mode. Therefore, we believe that processing mode has an impact only on simulation, and it is unlikely that an analytical processing mode would reduce the contrast effect when both the prior and target stimuli are real. Future research is nevertheless called upon to validate this assumption.

Practical implications

Taste plays a central role in consumers' decision making related to dining and food purchases, and consumers' actual taste perception and mental simulation of taste are equally important in determining their taste evaluation. For marketing practitioners, the key takeaway from the current research is that they can influence consumers' decision making about foods in different situations by properly incorporating taste perception and simulation in their marketing practices. One example is to influence consumers' pre-consumption mental simulation of taste (MacInnis & Price, 1987) by strategically offering actual food samples. In supermarkets, for example, placing free samples of salty snacks in front of the shelves of sweet foods may effectively help promote sales of the latter products. Whereas taste simulation may have a greater influence on product sales in circumstances where actual taste is not convenient or possible, actual taste perception is certainly more important for product evaluation and customer loyalty in other situations. In order to enhance consumers' actual taste experience, proper taste simulation may be evoked. For example, the current findings imply that it might be a good idea for a dessert boutique to have a few posters on the wall featuring salty cuisines.

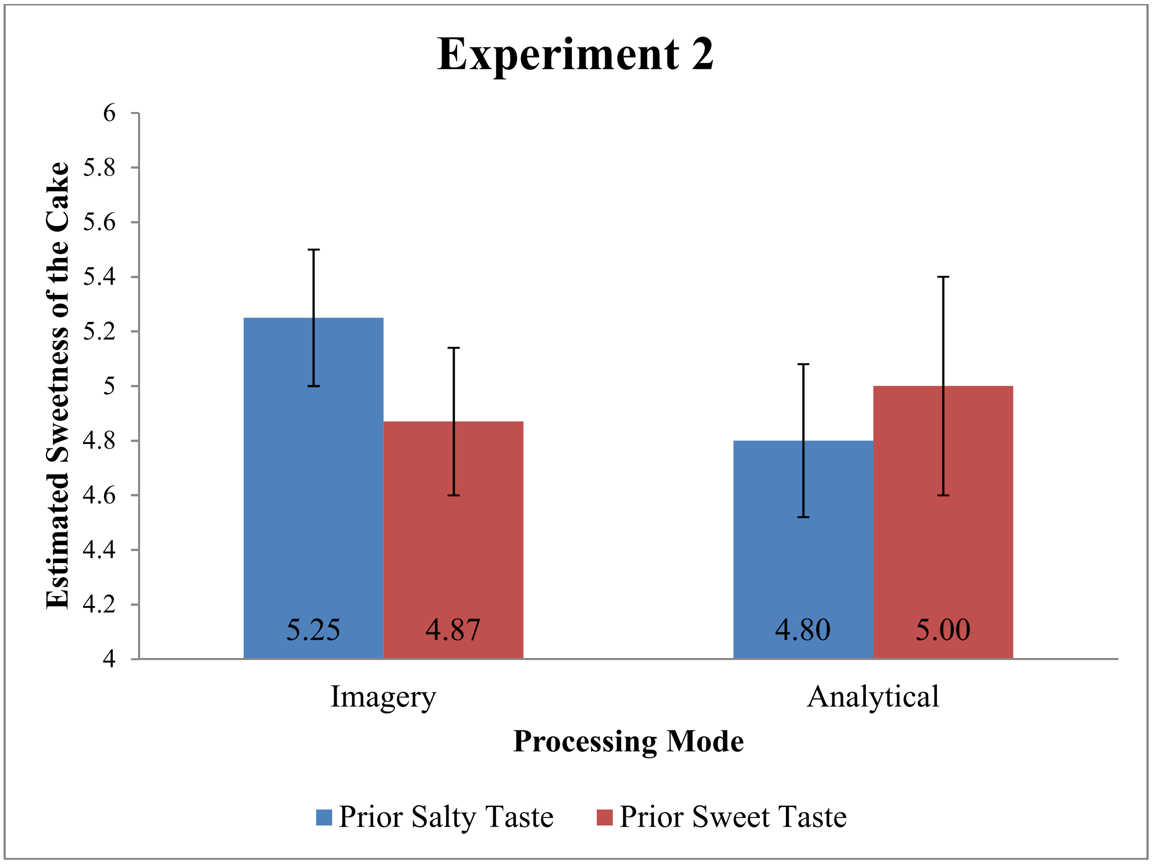
Our research also provides implications for consumer health and wellbeing. Worldwide obesity has more than doubled since 1980, and overweight plagued more than 1.9 billion adults in 2014 (World Health Organization, 2015). Excessive intake of sugar or salt is strongly linked to weight gain and illnesses such as diabetes and heart disease. Although consumers realize the hazard of eating too much sugar or salt, in many situations they do not have an accurate estimation of their sugar/salt intake due to various measurement and perceptual issues (e.g., Sigman-Grant & Morita, 2003). The taste-contrast effects found in the current research suggest that a prior intake of salty (sweet) food makes people judge a later food to be sweeter (saltier) when they adopt a high level of mental simulation. It is possible that this process will make consumers less likely to eat sweet (salty) food, because they feel that the food is "too sweet" ("too salty"), and therefore it is more of a threat to their health goals (Zhang, Huang, & Broniarczyk, 2010). The current research thus suggests an effective method to curb consumers' (over-)intake of sugar/salt through strategic arrangement of food sequence and proper induction of mental simulation.

Figure 1



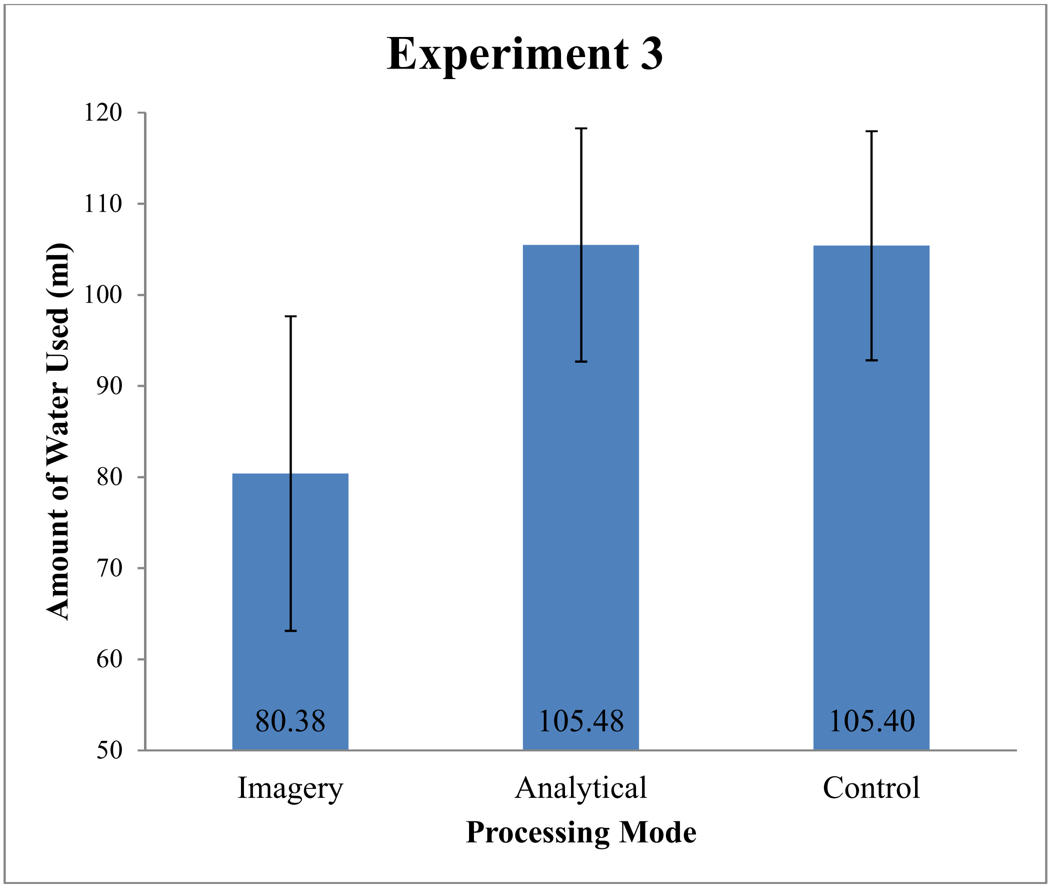
Note. The length of the error bars indicates the 95% confidence intervals of the respective means.

Figure 2



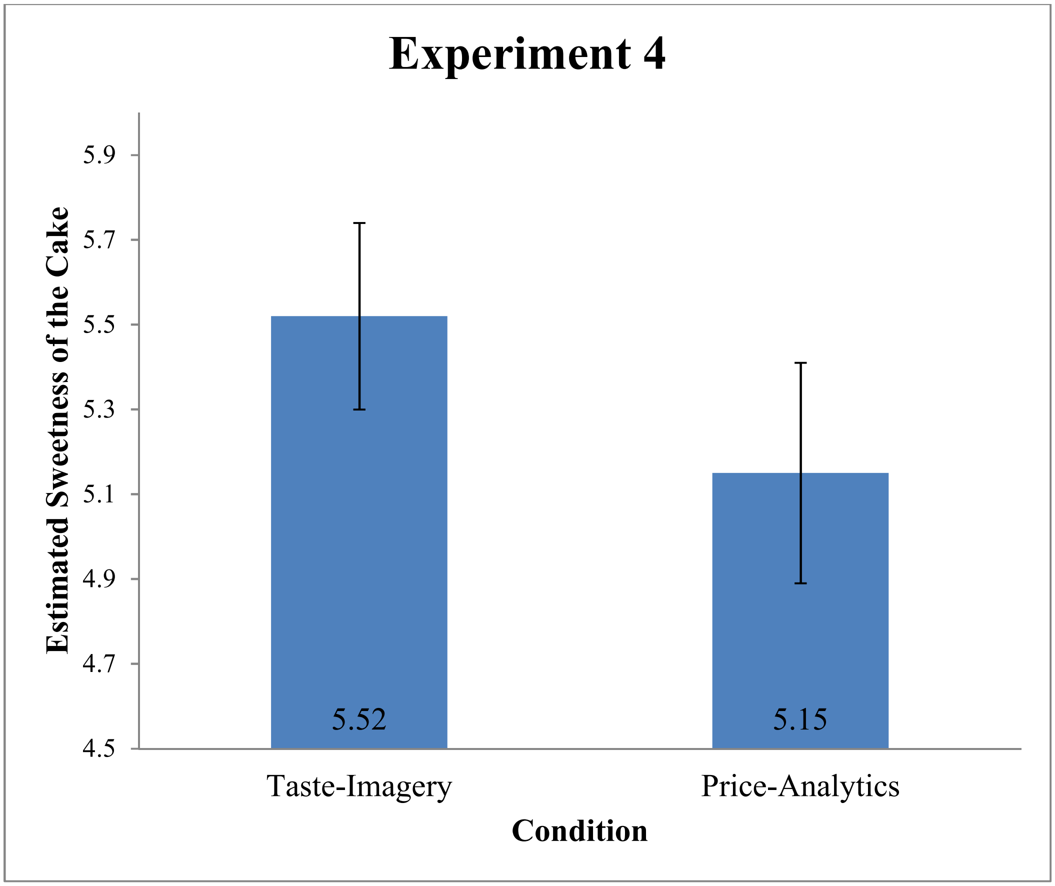
Note. The length of the error bars indicates the 95% confidence intervals of the respective means.

Figure 3



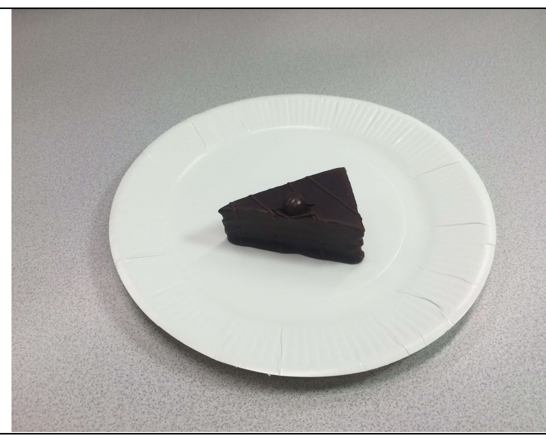
Note. The length of the error bars indicates the 95% confidence intervals of the respective means.

Figure 4



Note. The length of the error bars indicates the 95% confidence intervals of the respective means.

Appendix A - Experimental Stimuli

Dried fish snack used in experiments 1 and 3	Grape juice used in experiments 1 and 3
	
Picture of the Napoleon cake used in experiment 2	Chocolate cake used in experiment 4
	

Appendix B – Restaurant Menus Used in Experiment 4 (Chinese and English Versions)

Chinese version	English version
	

References

Ackerman, J. M., Goldstein, N. J., Shapiro, J. R., & Bargh, J. A. (2009). You wear me out: The vicarious depletion of self-control. *Psychological Science*, *20*(3), 326-332.

Barsalou, L. W. (1999). Perceptual symbol systems. *The Behavioral and Brain Sciences, 22*(4), 577-609.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617-645.

Bone, P. F., & Ellen, P. S. (1992). The generation and consequences of communication-evoked imagery. *Journal of Consumer Research*, *19*(1), 93-104.

Chao, L. L., & Martin, A. (2000). Representation of manipulable man-made objects in the dorsal stream. *NeuroImage, 12*(4), 478-484.

Coventry, K. R., Christophel, T. B., Fehr, T., Valdés-Conroy, B., & Herrmann, M. (2013). Multiple routes to mental animation: Language and functional relations drive motion processing for static images. *Psychological Science*, *24*(8), 1379-1388.

Djordjevic, J., Zatorre, R. J., Petrides, M., Boyle, J. A., & Jones-Gotman, M. (2005). Functional neuroimaging of odor imagery. *Neuroimage*, *24*(3), 791-801.

Eelen, J., Dewitte, S., & Warlop, L. (2013). Situated embodied cognition: Monitoring orientation cues affects product evaluation and choice. *Journal of Consumer Psychology*, *23*(4), 424-433.

Elder, R. S., & Krishna, A. (2012). The “Visual depiction effect” in advertising: Facilitating embodied mental simulation through product orientation. *Journal of Consumer Research, 38*(6), 988-1003.

Fodor, J. A. (1975). *The language of thought*. New York: Crowell.

Guinard, J. X., & Brun, P. (1998). Sensory-specific satiety: Comparison of taste and texture effects. *Appetite*, *31*(2), 141-157.

Helson, H. (1964). *Adaptation-level theory*. New York: Harper & Row.

Jiang, Y., Adaval, R., Steinhart, Y., & Wyer, Jr., R. S. (2014). Imagining yourself in the scene: The interactive effects of self-imagery goals and visual perspectives on consumer behavior. *Journal of Consumer Research*, *41*(2), 418-435.

Jiang, Y., & Wyer, Jr., R. S. (2009). The role of visual perspective in information processing. *Journal of Experimental Social Psychology*, *45*(3), 486-495.

Keller, P. A., & McGill, A. L. (1994). Differences in the relative influence of product attributes under alternative processing conditions: Attribute importance versus attribute ease of imagability. *Journal of Consumer Psychology*, *3*(1), 29-49.

Krishna, A., Morrin, M., & Sayin, E. (2014). Smellizing cookies and salivating: A focus on olfactory imagery. *Journal of Consumer Research*, *41*(1), 18-34.

Larson, J. S., Redden, J. & Elder, R. S. (2013). Satiation from sensory simulation: Evaluating foods decreases enjoyment of similar foods. *Journal of Consumer Psychology*, *24*(2), 188-194.

Lawless, H. T. (1983). Contextual effect in category ratings. *Journal of Testing and Evaluation, 11,* 346-349.

Lawless, H. T. (1994). *Contextual and Measurement Aspects of Acceptability*. Final Report #TCN 94178, US Army Research Office.

Lawless, H. T., Glatter, S., & Hohn, C. (1991). Context-dependent changes in the perception of odor quality. *Chemical Senses, 16*(4), 349-360.

Lawless, H. T., & Heymann, H. (2010). Context effects and biases in sensory judgment. In D. R. Heldman (Ed.), *Sensory evaluation of food* (pp. 203-225). Springer, New York.

MacInnis, D. J., & Price, L. L. (1987). The role of imagery in information processing: Review and extensions. *Journal of Consumer Research, 13*(4), 473-491.

Mattes, R. D., & Lawless, H. T. (1985). An adjustment error in optimization of taste intensity. *Appetite, 6*(2), 103-114.

Morewedge, C. K. (In press). Utility: Anticipated, experienced, and remembered. In G. Keren and G. Wu (Eds.), *Blackwell handbook of judgment and decision making, 2nd Edition.* Malden, MA: Blackwell Press.

Morewedge, C. K., Huh, Y. E., & Vosgerau, J. (2010). Thought for food: Imagined consumption reduces actual consumption. *Science*, *330*(6010), 1530-1533.

Mussweiler, T. (2003). Comparison processes in social judgment: Mechanisms and consequences. *Psychological Review*, *110*(3), 472-489.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review, 9,* 184-211.

Novemsky, N., & Ratner, R. K. (2003). The time course and impact of consumers' erroneous beliefs about hedonic contrast effects. *Journal of Consumer Research*, *29*(4), 507-516.

O'Craven, K. M., & Kanwisher, N. (2000). Mental imagery of faces and places activates corresponding stimulus-specific brain regions. *Journal of Cognitive Neuroscience, 12*(6), 1013-1023.

Parducci, A. (1965). Category judgment: A range-frequency model. *Psychological Review*, *72*(6), 407-418.

Petrova, P. K., & Cialdini, R. B. (2005). Fluency of consumption imagery and the backfire effects of imagery appeals. *Journal of Consumer Research*, *32*(3), 442-452.

Pylyshyn, Z. W. (1984). *Computation and cognition: Toward a foundation for cognitive science.* Cambridge, MA: MIT Press.

Rolls, B. J., Rolls, E. T., Rowe, E. A., & Sweeney, K. (1981). Sensory-specific satiety in man. *Physiology & Behavior*, *27*(1), 137-142.

Schreiber, C. A., & Kahneman, D. (2000). Determinants of the remembered utility of aversive sounds. *Journal of Experimental Psychology: General*, *129*(1), 27-42.

Schwarz, N., & Bless, H. (2007). Mental construal processes: The inclusion/exclusion model. In D. A. Stapel and J. Suls (Eds.), *Assimilation and contrast in social psychology* (pp. 119-141). New York: Psychology Press.

Shiv, B., & Huber, J. (2000). The impact of anticipating satisfaction on consumer choice. *Journal of Consumer Research*, *27*(2), 202-216.

Sigman-Grant, M., & Morita, J. (2003). Defining and interpreting intakes of sugars. *The American Journal of Clinical Nutrition*, *78*(4), 815S-826S.

Simmons, W. K., Martin, A., & Barsalou, L. W. (2005). Pictures of appetizing foods activate gustatory cortices for taste and reward. *Cerebral Cortex* (New York: 1991), *15*(10), 1602-1608.

Solomon, K. O., & Barsalou, L. W. (2004). Perceptual simulation in property verification. *Memory & Cognition, 32*(2), 244-259.

Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception & Psychophysics, 73*(4), 971-995.

Spence, C. (2012). Managing sensory expectations concerning products and brands: Capitalizing on the potential of sound and shape symbolism. *Journal of Consumer Psychology, 22*(1), 37-54.

Spencer, S. J., Zanna, M. P., & Fong, G. T. (2005). Establishing a causal chain: Why experiments are often more effective than mediational analyses in examining psychological processes. *Journal of Personality and Social Psychology*, *89*(6), 845-851.

Thompson, D. V., & Hamilton, R. W. (2006). The effects of information processing mode on consumers' responses to comparative advertising. *Journal of Consumer Research*, *32*(4), 530-540.

Wedell, D. H., Hicklin, S. M., & Smarandescu, L. O. (2007). Contrasting models of assimilation and contrast. In D. A. Stapel and J. Suls (Eds.), *Assimilation and contrast in social psychology* (pp. 45-74). New York: Psychology Press.

World Health Organization (2015, January). Obesity and overweight. Retrieved from http://www.who.int/mediacentre/factsheets/fs311/en/

Wyer Jr., R. S., Hung, I. W., & Jiang, Y. (2008). Visual and verbal processing strategies in comprehension and judgment. *Journal of Consumer Psychology*, *18*(4), 244-257.

Yee, K. K., Sukumaran, S. K., Kotha, R., Gilbertson, T. A., & Margolskee, R. F. (2011). Glucose transporters and ATP-gated K+ (KATP) metabolic sensors are present in type 1 taste receptor 3 (T1r3)-expressing taste cells. *Proceedings of the National Academy of Sciences*, *108*(13), 5431-5436.

Zhang, Y., Huang, S. C., & Broniarczyk, S. M. (2010). Counteractive construal in consumer goal pursuit. *Journal of Consumer Research*, *37*(1), 129-142.