Something to Chew on: The Effects of Oral Haptics on Mastication, Orosensory Perception, and Calorie Estimation

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ABSTRACT

This research examines how oral haptics (due to hardness/softness or roughness/smoothness) related to foods influence mastication (i.e., degree of chewing) and orosensory perception (i.e., orally perceived fattiness), which in turn influence calorie estimation, subsequent food choices, and overall consumption volume. The results of five experimental studies show that, consistent with theories related to mastication and orosensory perception, oral haptics related to soft (vs. hard) and smooth (vs. rough) foods lead to higher calorie estimations. This "oral haptics–calorie estimation" (OHCE) effect is driven by the lower mastication effort and the higher orosensory perception for soft (vs. hard) and smooth (vs. rough) foods. Further, the OHCE effect has downstream behavioral outcomes in terms of influencing subsequent food choices between healthy versus unhealthy options as well as overall consumption volume. Moreover, mindful calorie estimation moderates the effects of oral haptics on consumption volume.

Melanie looked at the wedge of chocolate torte (laced with fudge sauce) on the plate in front of her. She picked up her fork and knife and cut a small piece. Gently, she put a bite into her mouth and chewed slowly, noticing how rich and soft the cake felt in her mouth. As she swallowed, she wondered how many calories she had consumed.

Although this anecdote is fictitious, it highlights the fact that we often eat with a fork and a knife or with a spoon and may not touch the food with our hands. However, we touch and process food with our mouths and even one month old babies can orally discriminate between foods (Gibson and Walker 1984). Both the visual appearance of food and the oral haptics (i.e., "mouthfeel") associated with chewing a food affect our eating experience (Rosenthal 1999). Furthermore, even if we touch a food, the way the food is perceived by one's hand versus one's mouth may be quite different (Topolinski and Pereira 2012). The anecdote above also highlights the important role of oral haptics in evaluating the food that we consume. Would Melanie's calorie estimation for the torte be influenced by the perceived oral haptics (e.g., relative hardness/softness or roughness/smoothness) of the torte or how much she had to chew it or how smooth the torte felt in her mouth? Would the calorie estimation influence Melanie's subsequent food choices and overall consumption volume? These are the questions we address in this research. Specifically, we study the effects of perceived oral haptics on mastication (i.e., degree of chewing) and orosensory perception (i.e., orally perceived fattiness), which in turn influence calorie estimations. In addition, we examine the downstream behavioral outcomes of the oral haptics–calorie estimation (OHCE) effect on subsequent food choices and overall consumption volume.

Oral haptics, commonly known as mouthfeel, is the phenomenon of perceiving objects such as food in one's mouth by active oral touch, such as through chewing (Rieser and Pick 1976; Topolinski and Pereira 2012) and orosensory perception (Schiffman et al. 1998), and is done through receptors mainly present in the tongue and the palate (Grover and Craske 1992). It is not clear as to whether a food (e.g., cake) with harder versus softer haptic properties would be associated with higher calorie content. In fact, when we asked this question to the general population on Amazon MTurk ($n = 41$; average age 37 years, 58% female), the response we got was mixed; 46% of participants thought that a harder and a softer version of a chocolate cake would be perceived as having the same calorie level, 32% felt that the softer cake would be perceived as having a higher calorie content, and 22% felt that the harder cake would be perceived as having higher calories. In this paper, we demonstrate that perceived oral haptics related to food properties systematically and significantly impact calorie estimation and can also influence subsequent food choices and consumption volume. We also propose and find that mastication plays an important role in influencing calorie estimation by mediating the effects of oral haptics on calorie estimation. In addition, we show that orosensory perception mediates the effects of mastication on calorie estimations. It might be noted that given the role of orosensory perception in our research, we limit our focus to food items with some degree of perceived fattiness (e.g., chocolates, fudge, and brownies).

Haptics research within the consumer psychology literature has focused on haptic perception felt through the hands, often referred to as manual haptics (e.g., Krishna and Morrin 2008; Peck and Childers 2003; Peck and Shu 2009; Peck and Wiggins 2006) and there is also a rich research stream in the food perception and consumption domain focusing on various issues (e.g., Aydinoglu and Krishna 2011; Chandon and Wansink 2006b; Raghubir and Krishna 1999; Raghunathan, Naylor, and Hoyer 2006; Wansink and van Ittersum 2003). However, oral haptics have not been studied in the marketing literature. Additionally, the connection between oral haptics and calorie perception has not been made, nor has any study examined how oral haptics might influence overall consumption or subsequent food choices. Studying the effect of oral haptics on calorie estimation and the downstream influences on consumption volume and subsequent food choices is thus novel and has strong conceptual implications.

Along with the conceptual implications, this research also has important practical implications for consumers, managers, and regulators. For consumers, understanding how oral haptics related to food properties influence food perceptions and consumption decisions is important because our findings suggest that encouraging more mindful eating through priming consumers to estimate calorie content can lead to decreased consumption of foods with soft haptic properties, which are perceived as more calorific. From a managerial perspective, food manufacturers offer products with different haptic properties to appeal to divergent consumer preferences. For instance, Ore-Ida offers many variations of French fries, such as the classic smooth Golden Fries and Golden Crinkles, and Keebler has introduced Chips Deluxe Soft and Chewy cookies as an alternative to their traditionally harder chocolate chip cookies. As the results of our studies suggest, changing the haptic properties of foods affects consumer perceptions about these foods in terms of calorie estimates which in turn can influence consumption volume and subsequent food choices.

We focus on calorie estimation because of worldwide problems related to obesity as well as the role of mindless eating in contributing to the obesity epidemic (Wansink 2006), which necessitates an increased focus on calorie estimations and perceived healthfulness of food products (Chandon and Wansink 2011). We also examine downstream implications of calorie estimation on practically relevant behavioral outcome variables such as consumption volume and subsequent food choices. Finally, we explore how more mindful consumption practices, such as paying attention to chewing and encouraging consumers to estimate the calorie content of foods can moderate the effect of oral haptics on calorie estimation and consumption volume.

In summary, we propose and demonstrate that oral haptics related to hardness/softness and roughness/smoothness of food influences mastication and orosensory perception, which in turn impacts calorie estimation, subsequent food choices, and consumption volume. Our choice for this particular set of haptic properties (i.e., hardness/softness and roughness/smoothness) is influenced by both practical and theoretical considerations, as will be discussed in further details in later sections. We build our hypotheses based on research on mastication (Foster et al. 2006; Mioche and Martin 1998) and the related aspects of orosensory perception (de Wijk and Prinz 2005; Rolls 2010; Schiffman et al. 1998). We test our hypotheses with the help of five experimental studies.

Study 1 shows that foods with soft (vs. hard) haptics are perceived as higher in calories (study 1). Study 2 provides direct process evidence that mastication mediates the effect of oral haptics on perceived calories. Furthermore, orosensory perception mediates the effects of mastication on calorie estimation. Study 3 shows that the oral haptics–calorie estimation (OHCE) effect gets magnified when consumers focus on the mastication process. Study 4 indicates that calorie perception related to food texture (rough vs. smooth) have downstream effects in terms of affecting subsequent food choices between healthy and unhealthy options. Finally, study 5 demonstrates that oral haptics impact consumption volume and this effect is moderated by a focus on calorie estimation.

THEORETICAL BACKGROUND

Prior research (Klatzky and Lederman 2002; Lederman and Klatzky 1987) has identified four major haptic properties (hardness, texture, temperature, and weight) of objects. In other words, hardness and texture (along with temperature and weight) are part of the core construct of haptics (Klatzky and Lederman 2002). Our work on mastication and calorie estimation lends itself more readily to hardness (vs. softness) and texture (roughness vs. smoothness) since these two properties are more likely to impact mastication and orosensory perception than temperature and weight. Food hardness is defined “as the force needed to penetrate a food item,” and the roughness aspect of food surface texture is defined as the “degree of abrasiveness of the product’s surface” (Lawless and Heymann 2010, 272).

The oral haptic properties of food hardness and surface texture are primarily perceived through mastication (Bourne 2004; Lawless and Heymann 2010) and orosensory perception (Schiffman et al. 1998) and to a lesser extent through exploration with the tongue. Mastication or degree of chewing is the oral “sensory-motor activity aimed at the preparation of the food for swallowing” (Bosman et al. 2004, 202). The mastication process is influenced by both the hardness (vs. softness) of food items as well as the texture of foods (e.g., roughness vs. smoothness) (Foster, Woda, and Peyron 2006; Mioche, Bourdiol, and Monier 2003; Roininen et al. 2003). Note that the sensory feeling of oral haptics is independent of other senses, including the pure sensations of taste and smell (Duffy 2007; Hayes and Duffy 2007). Prior research has also shown differences in oral haptics versus manual haptics (Topolinski and Pereira 2012). While there can be individual differences in mastication patterns, haptic properties of foods (in terms of hardness/softness or roughness/smoothness) have an overall influence on general patterns of mastication (Lenfant et al. 2009). For instance, hard (vs. soft) foods and foods with rough (vs. smooth) textures tend to require greater degree of chewing and more oral muscle activity (Foster et al. 2006; Mioche and Martin 1998). In essence, foods with higher levels of hardness (vs. softness) and foods with rougher (vs. smoother) textures require a greater degree of mastication (Peyron, Lassauzay, and Woda 2002).

In addition to influencing mastication, oral haptics are also related to orosensory perception of food. Orosensory perception is the orally perceived feeling of fattiness, creaminess, and richness in food (de Araugo and Rolls 2004; de Wilk and Prinz 2005; Schiffman et al. 1998). Both mastication and orosensory perception of food are related aspects of oral haptics which are experienced when food is consumed. In fact, research suggests that mastication is likely to influence orosensory perception (Foster et al. 2011; Smeets and Westerterp-Plantenga 2006).

During the process of mastication, the haptic properties of food influence the oral friction generated by the food. Foods that are typically high in fat or calories, such as butter, cream, cheese, and ice cream, tend to generate lower friction during mastication and higher orosensory perceptions (de Wijk and Prinz 2005; Schiffman et al. 1998). In essence, these types of high calorie and high fat foods tend to be smoother, softer, and/or creamier. In contrast, foods that are rougher or harder, such as raw vegetables and cereals, tend to generate a higher level of friction during mastication and weaker orosensory perceptions. These foods also tend to be ones that have lower calories and are generally perceived to be healthier.

Research related to association theories would suggest that the co-occurrence of two stimuli can result in the formation of an associative link (Shimp, Stuart, and Engle 1991; Van Osselaer and Alba 2000). When the two stimuli are repeatedly juxtaposed, the link strengthens

(McSweeney and Bierly 1984), and over time can become a predictive rule that consumers apply to other stimuli or new contexts (Van Osselaer and Alba 2000). In the context of the present research, this would suggest that repeated exposure to this pattern of mastication and orosensory perception, whereby unhealthier (healthier) food items tend to be those that are smooth (rough) and/or soft (hard), will lead to the formation of a mental association between certain types of mastication and orosensory perception and perceived healthfulness levels of food. Specifically, consumers would learn to associate low levels of oral friction, more intense sensations of fattiness, richness, creaminess, lower mastication, and higher orosensory perception with soft or smooth textured foods which tend to be less healthy (i.e., higher calories). Conversely, consumers would learn to associate higher levels of oral friction, less intense sensations of fattiness, richness, creaminess, higher mastication and lower orosensory perception with hard or rough textured foods, which tend to be perceived as healthier (i.e., lower calories). Further, over time this link will strengthen so that eventually the oral experience and the related mastication and orosensory perception alone (without accompanying changes in the nutritional or health properties of foods) can drive the same associations. So in essence, higher (lower) degree of mastication would be associated with lower (higher) degree of orosensory (i.e., fattiness) perception and lower (higher) calorie estimation. In sum, oral haptics (related to hardness/softness and roughness/smoothness) influence mastication, which in turn influences orosensory perception and calorie estimations. Based on the above discussions, we propose:

H1: The oral haptics–calorie estimation (OHCE) effect, whereby consumers will perceive foods with soft (vs. hard) or smooth (vs. rough) textures as being higher in calories.

H2a: The effect of oral haptics on perceived calories will be mediated by mastication.

H2b: The effect of mastication on perceived calories will be mediated by orosensory perception.

Figure 1 shows the theorized conceptual model related to the relationship between oral haptics, mastication, orosensory perception and calorie estimation, along with downstream behavioral outcomes (related to subsequent food choice and consumption volume), which will be discussed in details in later sections.

Insert figure 1 about here

STUDY 1: FOOD HARDNESS AND CALORIE ESTIMATION

Design, Participants, and Procedure

Study 1 tested hypothesis 1. Chocolate was used as the product in this experiment. Hard versus soft versions of a chocolate were obtained through a customized order at a specialty confectionary store. The store owner prepared exactly the same chocolate but left half of it exposed to dry air for about 5 hours to prepare the harder versions of the chocolate.

Sixty-five university students (average age: 23 years, 52% female) participated in the experiment in exchange for course credit and complimentary chocolate. The key dependent variable of calorie estimation was measured by asking participants to estimate the number of calories in the sampled food item, similar to what has been done in prior studies (e.g., Chandon and Wansink 2007). Participants also provided self-reported measures of their height, weight and hunger levels and these were equivalent across the manipulated conditions and did not have any effects on calorie estimation.

Participants were given a chocolate (either hard or soft) on a toothpick and were asked to pick up the toothpick and eat the chocolate directly from the toothpick (without touching the chocolate). This was done so that any results could be attributed solely to oral haptics with no input from manual (i.e., hand) touch. Each chocolate was .1 ounces (2 grams) and contained approximately 11 calories (see figure 2).

Insert figure 2 about here

A pretest (n = 51) was conducted to ensure that the chocolates were equivalent in terms of taste and visual appearance. Two participants did not answer the question on taste and one participant did not answer the question on visual appearance. Both taste and visual appearance were measured on 1-7 scales adopting measures used in prior studies (Elder and Krishna 2010; Hetherington and Regan 2011). Taste was measured by asking participants to rate the taste of the chocolate (1 = extremely bad, 7 = extremely good), and visual appearance was measured by asking participants to rate the visual appearance of the chocolate (1 = very bad, 7 = very good). The results of the pretest confirmed that the two types of chocolates were equivalent in terms of taste ($M_{soft} = 5.15$ vs. $M_{hard} = 5.46$; $F(1, 47) = .54$, $p = .47$) and visual appearance ($M_{soft} = 4.30$ vs. $M_{hard} = 4.85$; $F(1, 48) = 1.69$, $p = .20$).

Results

Main Test. Consistent with hypothesis 1, participants had higher calorie estimations for the soft (vs. hard) chocolate ($M_{soft} = 100.90$ vs. $M_{hard} = 65.09$; $F(1, 63) = 4.93$, $p < .05$). Besides being significantly different, note that by merely changing the hardness of the chocolate, the calorie estimate changed from about 65 to about 101, a 55% increase. It should be noted that each piece of chocolate contained 11 calories, so participants overestimated the calorie content irrespective of whether they sampled the hard or soft version. This by itself is not surprising since prior research shows that for small serving sizes, consumers tend to overestimate the calorie content (Chandon and Wansink 2006a; Livingstone and Black 2003). However, while participants overestimated the calorie content for both types of chocolates, they overestimated the calorie content of the soft chocolate by a higher magnitude.

Ruling Out an Alternative Explanation. Since perceived taste can influence calorie and healthfulness perceptions (Raghunathan et al. 2006), and all five senses have been shown to affect perceived taste (Elder and Krishna 2010), we examined if perceived taste was influenced by the food haptic properties. Perceived taste was measured as in prior studies (e.g., Elder and Krishna 2010) by using three items, asking participants to rate the taste, deliciousness, and quality of the chocolate on 1-7 scales (where 1= bad/low and 7 = good/high). The results of an ANOVA showed that, similar to what we observed in our pretest, the haptic properties of the chocolates did not influence perceived taste ($M_{soft} = 5.09$ vs. $M_{hard} = 5.30$; $F(1, 63) = .61$, $p = .44$), ruling out the role of perceived taste as a potential underlying process for influencing calorie estimations.

Discussion

The results of study 1 showed that, consistent with theories related to mastication and orosensory perception, consumers have higher calorie estimations when consuming a food item with soft (vs. hard) haptics. It is interesting to note that a case can be made for an alternative account, for the effects of oral haptics, based on effortful consumption, which would make the opposite prediction as that made by hypothesis 1. Specifically, greater effort might be associated with higher levels of energy or calories. Since hard (vs. soft) and rough (vs. smooth) foods require greater chewing effort, they may be considered more calorific. However, the results of study 1 rules out this alternative account and hence we do not discuss it further. Study 2 focuses on the underlying process relating mastication and orosensory perception to calorie estimation.

STUDY 2: THE "ORAL HAPTICS–CALORIE ESTIMATION EFFECT" AND MEDIATING ROLES OF MASTICATION AND OROSENSORY PERCEPTION

There should be greater mastication (i.e., greater degree of chewing) for similar food items with hard (vs. soft) and rough (vs. smooth) haptic properties and the higher mastication would in turn lead to lower fattiness (i.e., orosensory) perception and lower calorie estimation. Hence, as discussed earlier, mastication should mediate the effects of oral haptics on calorie estimation (hypothesis 2a). In addition, orosensory perception, or orally perceived fattiness, is expected to mediate the effects of mastication on calorie estimation (hypothesis 2b). (See figure 1 for a visual representation of these mediating effects.)

Design, Participants, and Procedure

A one-way between subjects experiment was conducted with hard versus soft food. The same type of chocolate as used in study 1 was used in this study also. Thirty-five university students (average age 24 years, 60% female) participated in this study for extra credit and complimentary chocolate. Participants were brought in small batches into a laboratory and asked to eat a chocolate. Mastication was operationalized in terms of number of chews. Research assistants unobtrusively recorded the total number of chews for each participant. The research assistants were previously trained to identify the total number of chews based on jaw movements. Specifically, they were trained to count the number of times a participant's jaw moved up and down starting from the time the chocolate was placed in the mouth until the chocolate was swallowed. The total number of times the jaw is raised and lowered has been used to measure chewing cycles in prior research (e.g., Van Der Bilt, Pocztaruk, and Abbink 2010) and serves as an objective measure of mastication effort. Orosensory perception was operationalized by asking participants to rate the perceived fattiness of the chocolate on a 7-point scale (where 1 = very low and 7 = very high).

Results

Consistent with hypothesis 1, oral haptics influenced calorie estimation, with participants perceiving the soft (vs. hard) chocolate to be higher in calories (M_{soft} = 95.0 vs. M_{hard} = 57.94; $F(1, 33) = 5.21$, $p < .05$).

Mediation analysis using Preacher and Hayes's (2008) bootstrapped samples (5,000) procedure (Zhao, Lynch, and Chen 2010) showed that controlling for number of chews, oral haptics had a significant effect on calorie estimation ($\beta = 37.06$; $t(32) = 2.28$, $p < .05$). The effect of number of chews on calorie estimation was also significant ($\beta = 2.65$; $t(32) = 2.40$, $p < .05$). The indirect effects of oral haptics on calorie estimation through number of chews was also significant, with a 95% bootstrap confidence interval of -34.59 and -2.18, implying mediation effects (since the confidence interval excludes zero), supporting hypothesis 2a.

The results of study 2 also showed that orosensory perception (operationalized as perceived oral fattiness of the food) mediated the effects of mastication on calorie estimation. Specifically, controlling for perceived fattiness, the number of chews had a significant effect on calorie estimation ($\beta = 3.14$; $t(31) = 2.78$, $p < .01$). The effect of perceived fattiness on calorie estimation was also significant ($\beta = 11.39$; $t(31) = 2.14$, $p < .05$). The indirect effect of number of chews on calorie estimations through perceived fattiness was also significant, with a 95% bootstrap confidence interval of .04 and 3.49, implying mediation effects. These results support the mediating role of orosensory perception (hypothesis 2b). See figure 1 for a visual representation of these mediating effects.

Discussion

The results of study 2 provide evidence regarding the mediating roles of mastication and orosensory perception for the effects of oral haptics on calorie estimation. The results also show that, consistent with the findings of study 1, calorie estimations are higher for similar chocolates with soft (vs. hard) haptics. Also, as expected, the mastication effort (as reflected in the total number of chews) was lower for chocolates with soft (vs. hard) haptics. More importantly, consistent with our theorization, the mastication effort mediated the effects of oral haptics on calorie estimations. In addition, orosensory perception mediated the effects of mastication on calorie estimation. The next two studies provide further evidence regarding how mastication and orosensory perception influence calorie estimations.

STUDY 3: MODERATING EFFECT OF FOCUSING ON MASTICATION

If mastication mediates the OHCE effect, then this effect should be stronger when consumers mindfully focus on the mastication process versus when they do not. This theorizing is consistent with prior research which shows for example that increasing the salience of a sensory cue through directing an individual's attention to that cue increases the influence of the cue in product evaluations (e.g., Krishna 2006). Formally stated:

H3: The oral haptics–calorie estimation (OHCE) effect, whereby consumers perceive foods with soft (vs. hard) or smooth (vs. rough) textures as being higher in calories will be magnified when consumers mindfully focus on the mastication process (vs. when they do not).

Design, Participants, and Procedure

A 2 (oral haptics: hard vs. soft) x 2 (focus on mastication: absent vs. present) between-subjects experiment was conducted. Chocolate was used as the product, and was procured through a customized order from a specialty confectionary shop. Ninety six university students (average age 24 years, 47% female) participated in exchange for course credit and complimentary chocolate. Participants were given equal sized chocolate pieces with a toothpick inserted in the center and were asked to pick up a chocolate piece using the toothpick and put the chocolate in the mouth without touching it by hand. The focus on the mastication process was manipulated by asking (vs. not asking) participants to pay attention to their chewing while they were eating the chocolate.

Results

Manipulation Check. As a manipulation check, towards the end of the study, participants were asked to indicate the extent to which they paid attention to their chewing while eating the chocolate on a 7-point scale (where 1 = very low, 7 = very high). Consistent with the intended manipulation, participants paid greater attention to their chewing when they were asked to focus on the chewing (vs. when not asked) (4.92 vs. 3.18; $F(1, 94) = 22.62$, $p < .01$).

Main Tests. The results of a 2 (oral haptics) x 2 (focus on mastication) ANOVA showed a marginally significant interaction effect on calorie estimation ($F(1, 92) = 3.0$, $p < .09$). While calorie estimations were higher for the soft (vs. hard) chocolate when participants were not asked to focus on mastication ($M_{soft} = 94.09$ vs. $M_{hard} = 60.45$; $F(1, 92) = 3.54$, $p < .07$), the effect was stronger when participants paid attention to their chewing (i.e., focused on mastication) ($M_{soft} = 119.65$ vs. $M_{hard} = 43.86$; $F(1, 92) = 20.98$, $p < .01$). These results support hypothesis 3.

Discussion

The results of study 3 provide additional evidence regarding mastication related to oral haptics influencing calorie estimation. Specifically, consumers had higher calorie estimations for soft (vs. hard) chocolates and this effect got magnified when consumers mindfully focused on the mastication process. Next, study 4 provides further process evidence and also demonstrates potential downstream effects of the OHCE phenomenon. Also, while studies 1-3 examined the haptic property of food hardness, study 4 focuses on the haptic property of surface texture in terms of roughness versus smoothness. Since mastication and orosensory perception are influenced by both hardness/softness and texture (e.g., roughness/smoothness) of foods (Foster et al. 2006; Mioche et al. 2003), in the interest of robustness, it is important to demonstrate that the OHCE effect holds in the context of rough versus smooth textured foods also.

STUDY 4: ORAL HAPTICS, OHCE ATTRIBUTION, AND SUBSEQUENT FOOD CHOICES

Effects of Attribution

Study 4 examined the underlying process related to oral haptics influencing calorie estimation through an attribution task (Schwarz et al.1991; Schwarz and Clore 1983). Research shows that when decision makers are made aware of the causes (or attributions) for potentially biased judgments, their judgment biases tend to get corrected (Biswas, Keller, and Burman 2012; Schwarz et al. 1991; Schwarz and Clore 1983). Accordingly, we propose that when consumers are made aware that their calorie estimations might be influenced by perceived oral haptics related to processing the food, any potential judgment biases due to oral haptics, will be corrected. In other words, the OHCE effect, observed in study 1 will be attenuated when consumers are able to attribute the basis of their calorie estimation judgment to their perceived oral haptics when consuming the food. Formally stated:

H4: The oral haptics–calorie estimation (OHCE) effect, whereby consumers perceive foods with soft (vs. hard) or smooth (vs. rough) textures as being higher in calories will be attenuated when consumers are made aware of the OHCE effect.

The Effects of OHCE on Subsequent Choices

Can oral haptics influence subsequent choices? That is, would sampling a food item with smooth (vs. rough) or soft (vs. hard) haptic properties influence subsequent food choices? Consumers tend to balance their overall food intake, such that the intake of unhealthy foods is often accompanied by choices for healthier options and vice versa (Chandon and Wansink 2007; Dhar and Simonson 1999). For instance, when choosing multiple products to have in a single consumption episode (e.g., a multi-course meal), consumers tend to make complementary choices so that a healthy appetizer is often followed up with an unhealthy entrée (Dhar and Simonson 1999). Along similar lines, when consumers estimate the calorie content of a main dish to be low, they balance this relatively healthier item with a higher calorie side dish (Chandon and Wansink 2007). In the context of the present research, this balancing strategy should lead consumers who sample a soft (hard) food or a food with a smooth (rough) surface texture to subsequently choose a relatively more (less) healthy food option. However, as discussed in the context of hypothesis 4, this effect will get attenuated when consumers are made aware of the OHCE effect. Formally, we predict:

H5: After consuming a food with soft (vs. hard) or smooth (vs. rough) texture, consumers will subsequently choose a healthier option.
This effect will be attenuated when consumers are made aware of the OHCE effect.

Design, Participants, and Procedure

Hypotheses 4 and 5 were tested with the help of a 2 (oral haptics: rough vs. smooth) x 2 (OHCE attribution information: absent vs. present) between subjects design experiment. Milk chocolate fudge was used as the product in this experiment. One hundred twenty eight university students (average age 23 years, 48% female) participated in exchange for course credit. Each participant was given a chocolate fudge piece (weighing 7 grams) in a small white cup with a toothpick inserted in the center. The rough textured fudge pieces were cut with a special garnishing tool so that the four sides as well as the top and bottom surface of the fudge piece had a ridged texture. The smooth textured fudge pieces were cut with a non-serrated knife so that all four sides as well as the top and bottom surfaces were smooth.

OHCE attribution was manipulated as in prior studies (e.g., Biswas et al. 2012; Schwarz and Clore 1983). Specifically, in the "attribution present" conditions, participants were informed that thoughts related to how the chocolate fudge feels in their mouth might influence their evaluation of the chocolate fudge. They were told that they should ignore any such thoughts when evaluating the chocolate. In the "attribution absent" conditions, participants were not told anything about the thoughts they might experience or how the thoughts can influence their responses. After sampling the fudge, participants were asked to estimate the calorie content and the calorie estimation variable was measured in the same way as in our earlier studies. Towards the end of the study, participants were asked to make a choice between a fruit salad and a piece of chocolate cake.

Results

There was an interaction effect between oral haptics and OHCE attribution on calorie estimation ($F(1, 122) = 3.54$, $p < .07$). Consistent with hypothesis 4, in the absence of attribution, the smooth (vs. rough) textured fudge was perceived as higher in calories ($M_{smooth} = 95.66$ vs. $M_{rough} = 62.24$; $F(1, 122) = 4.96$, $p < .05$) and the effects got attenuated in the presence of attribution ($M_{smooth} = 87.12$ vs. $M_{rough} = 97.96$; $F(1, 122) = .36$, $p = .55$).

We also examined how subsequent choices between healthy versus unhealthy options (i.e., between a fruit salad and a chocolate cake) might be affected. The results of a logistic regression showed an interaction effect between oral haptics and attribution on subsequent choice (Wald $\chi^2 = 3.59$, $p < .06$). Follow-up tests showed that consistent with hypothesis 5, in the absence of attribution, there was greater preference for the healthy option after sampling the smooth (vs. rough) textured fudge ($M_{smooth} = 75.61\%$ vs. $M_{rough} = 52.94\%$; $\chi^2 = 4.22$, $p < .05$), with the effects getting attenuated in the presence of attribution ($M_{smooth} = 57.69\%$ vs. $M_{rough} = 68\%$; $\chi^2 = .58$, $p = .45$). Figure 3 graphically presents these findings.

Insert figure 3 about here

Discussion

The results of this study provide additional evidence regarding the role of orosensory perception in the OHCE phenomenon. The results of study 4 also highlight an important behavioral outcome of oral haptics in terms of subsequent choices. Specifically, sampling a smooth (vs. rough) textured food item led to subsequent preferences for a healthier food option. This is presumably because the higher calorie estimate associated with the smooth (vs. rough) textured food item led to balancing the overall food portfolio through a subsequent choice of the healthier option. Study 4 also identifies a relevant boundary condition, whereby attribution can attenuate the effects of OHCE. Next, study 5 examines the effects of oral haptics on overall food consumption.

STUDY 5: ORAL HAPTICS AND CONSUMPTION

Will overall consumption of a food item be greater when the food has soft versus hard haptics? Since soft foods require lower mastication, there should be greater consumption of soft (vs. hard) food in a given amount of time because the amount of time spent consuming a food is inversely related to its consumption (Andrade, Greene, and Melanson 2008). On the other hand, the results of our studies show that soft (vs. hard) food is perceived as higher in calories. If calorie estimations are equated with perceived fullness, consumers would need to consume a lower volume of the soft (vs. hard) food. So which of these opposing outcomes is more likely? We propose that in the absence of any conscious or mindful calorie estimation, in a given period of time, there will be higher consumption of food with soft (vs. hard) haptics. However, when primed to make mindful calorie estimations, the effects will be reversed, whereby there will be lower consumption of food with soft (vs. hard) haptics. Formally, we predict:

H6: In the absence of mindful calorie estimation, there will be higher volume of consumption of food with soft (vs. hard) haptics.
When primed to undertake mindful calorie estimation, there will be lower volume of consumption of food with soft (vs. hard) haptics.

Design, Participants, and Procedure

Study 5 was a 2 (oral haptics: soft vs. hard) x 2 (mindful calorie estimation priming: absent vs. present) between subjects experiment. Eighty-three university students (average age 21 years, 57% female) participated in exchange for course credit and complimentary brownies. Brownies (soft and hard) were used in this study. Similar to the approach used in study 1, hard versions of the brownies were prepared by having them exposed to dry air for 5 hours.

Participants were brought into the lab and told that one of the researchers was working with a local advertising firm to understand how college students might evaluate international advertisements (ads). Participants were asked to watch and evaluate a series of ads. They were also told that the advertising firm had provided complimentary brownie bits for them as a token of appreciation and that they could eat as much of the brownies as they liked while watching the ads. Participants were given a six-ounce white Styrofoam cup containing 64 grams of brownie bits (which filled the cup approximately 80% of the way to the top). To create the brownie bits, circular brownies of approximately two inches in diameter were cut into equal bite-sized (4 gram) pieces. Participants were told that they could have additional cup(s) of brownies if they wanted. A series of timed international ad clips, none of which were food-related, were played to ensure that every participant had exactly the same amount of time for eating the brownies. To avoid hypothesis guessing, no questions were asked regarding the brownies, except in the "mindful calorie estimation priming" conditions, where a calorie estimation question was asked; specifically, participants were asked to guess how many calories each brownie piece contained (Chandon and Wansink 2007).

Results

The results of a 2 (oral haptics) x 2 (mindful calorie estimation) ANOVA revealed an interaction effect on overall consumption of the brownies ($F(1, 79) = 8.52$, $p < .01$). Consistent with hypothesis 6, in the absence of any calorie estimation question (i.e., absence of mindful calorie estimation), there was higher consumption of the soft (vs. hard) brownies ($M_{soft} = 55.86$ grams vs. $M_{hard} = 40.86$ grams; $F(1, 79) = 4.80$, $p < .05$). In contrast and also consistent with hypothesis 6, when primed to undertake mindful calorie estimation, the effects reversed, whereby there was lower consumption of the soft (vs. hard) brownies ($M_{soft} = 34.79$ grams vs. $M_{hard} = 48.95$ grams; $F(1, 79) = 3.79$, $p < .06$). Figure 4 graphically presents these findings.

Insert figure 4 about here

Discussion

The results of study 5 demonstrated an important behavioral outcome in terms of consumption volume being affected by oral haptics. In the absence of mindful calorie estimation, participants consumed a higher volume of brownies with soft (vs. hard) haptics. However, when primed to undertake mindful calorie estimation, the effects reversed, with participants consuming a lower volume of brownies with soft (vs. hard) haptics. Hence, the results of study 5 identified an important downstream behavioral outcome of the OHCE effect. The results of this study also suggest that in mindless consumption contexts, oral haptics can lead to over consumption of foods with soft haptic properties. However, this effect can be reversed when consumers are encouraged or primed to undertake mindful calorie estimation.

GENERAL DISCUSSION

Summary and Conclusions

The results of five experimental studies provide evidence for the oral haptics–calorie estimation (OHCE) effect. These results are consistent with theories related to mastication and orosensory perception. Specifically, fatty and creamy foods with high orosensory perception and requiring lower mastication tend to be considered more calorific. Over time, through associative learning, other foods that provide similar high orosensory perceptions and require low mastication are also considered more calorific. Thus, soft (vs. hard) and smooth (vs. rough) food items are perceived as higher in calories. In other words, foods requiring higher mastication and providing low orosensory perception are considered as lower in calories.

Direct process evidence to show that mastication mediates the OHCE effect is provided in study 2. Specifically (in study 2), we directly recorded the number of chews as an indicator of the mastication level and found that mastication mediates the effects of oral haptics on calorie estimations. Moreover, orosensory perception (as reflected in the perceived oral fattiness of the food) mediates the effects of mastication on calorie estimation. Study 3 provides further evidence regarding the role of mastication in influencing calorie estimations by demonstrating that the OHCE effect gets magnified when consumers focus on the mastication process versus when they do not. We then provide additional process evidence for the OHCE effect (in study 4) through an attribution task (Biswas et al. 2012; Schwarz and Clore 1983).

We also demonstrate important downstream behavioral outcomes of the OHCE effect (in studies 4 and 5). Study 4 shows that the OHCE effect influences subsequent food choices between healthy versus unhealthy options. Specifically, in the absence of any moderators, sampling a food with smooth (vs. rough) oral haptics led to greater subsequent preference for the healthier option. In the presence of an attribution task, these effects got attenuated. Study 5 demonstrated that the OHCE effect can influence consumption volume. In particular, in the absence of OHCE (i.e., when participants were not primed to mindfully estimate calories), there was higher consumption of brownies with soft (vs. hard) haptics, in a given period of time. The presence of the OHCE effect (i.e., when participants were primed to mindfully estimate calories) reversed the outcome. That is, mindful calorie estimation led participants to consume a lower volume of brownies with soft (vs. hard) haptics, in a given time period.

The findings of this research have strong conceptual implications. While there is interesting emerging research in the domain of haptics (Krishna 2012), these studies tend to focus on how haptic properties of non-food products perceived through the hand influence product evaluations (Krishna, Elder, and Caldara 2010) or how the haptic properties of a medium, such as the cup a beverage is sampled from, influence food/beverage evaluations (Krishna and Morrin 2008). To the best of our knowledge, no published research has focused on how oral haptics, and the related concepts of mastication and orosensory perception, influence calorie estimations of food or any potential downstream behavioral outcomes (such as subsequent choices or volume of consumption). Hence, this research takes an important first step in this direction.

Across all our studies, we found that participants overestimated the calorie content irrespective of the food's haptic properties. This by itself is not surprising since prior research has demonstrated that for small-sized food servings, participants tend to overestimate the calorie level (Chandon and Wansink 2006a; Livingstone and Black 2003). However, more interestingly, the haptic properties of the food (e.g., softness or smoothness) further inflated this calorie overestimation.

Implications, Limitations, and Future Research Directions

The findings of this research have intriguing practical implications. Marketers can quite easily change the haptic properties of food, which in turn can have implications for calorie estimations, subsequent choices, and consumption volume. For instance, it is possible that granola bars, trail mixes, nuts, and many cereals, in spite of being high in calories often, are perceived to be healthy probably because of their hard and rough haptic properties, the sensations of friction they generate in the mouth, the greater mastication, and the low level of orosensory perception experienced when consuming these foods. Thus, it is not surprising that FRS, which is sold as a "healthy energy" supplement highlights its "hard shell chews" on its packages (FRS Healthy Performance 2012). Interestingly, when Burger King recently launched its new lower calorie French fries (labeled "Satisfries"), they gave these fries a rougher texture by making them crinkled (in comparison to the regular higher calorie fries which have a smooth texture) (Strom 2013). Based on the results of our research, this seems like a sound business strategy since oral haptics related to the rough textured new fries will lead to perception of lower calories than if the fries had smooth textures.

The results of study 4 demonstrated that sampling a smooth (vs. rough) textured food item led participants to have higher subsequent preferences for a healthy (vs. unhealthy) option. Such a finding is important since consumers often sample foods prior to making subsequent food choices, such as at mall food courts, at cocktail receptions before formal dinners, and at grocery stores (Biswas et al. 2014). Thus, marketers might consider strategically varying the roughness/smoothness or hardness/softness of sampled foods to increase the likelihood that consumers will subsequently select healthy versus unhealthy food options.

The results of our studies also show that changing the focus on mastication can influence calorie perceptions. This implies that marketers can potentially influence consumers' calorie estimations by influencing the mastication process of food items through imagery in advertising or through encouraging eating certain foods in specific ways. Interestingly, some food product manufacturers are calling their products "meltaways" (e.g., Pecan Meltaway Cookies and Hershey's Bliss with Meltaway Centers), which might enhance the orosensory perception associated with eating these food items and even influence consumption volume.

If calorie estimations are linked with perceived fullness and if oral haptics related to food influence subsequent food choices or volume of consumption, then restaurants can strategically alter the haptic properties of foods based on the timing of consumption (e.g., for an appetizer versus a dessert). Also, as the results of study 5 show, being primed to undertake mindful calorie estimation versus not can have consequential effects on consumption. Since marketers often highlight calorie information on packages and restaurant menus (e.g., labeled as "low calorie items”), focusing on such information can lead to different consumption outcomes based on perceived oral haptics related to the food being consumed. More specifically, as highlighted by the findings of study 5, in mindless consumption contexts, there will be higher consumption of foods with soft (vs. hard) oral haptics. In contrast, the effects will be reversed when consumers are primed to mindfully estimate calories, such that there will be lower consumption of foods with soft (vs. hard) oral haptics.

At a broader level, given the alarming rates of obesity around the world and the potential negative consequences related to obesity, findings that can enhance healthful consumption behaviors have strong conceptual and practical implications. In essence, since oral haptics of hardness/softness and roughness/smoothness and the related aspects of mastication and orosensory perception influence calorie estimations, subsequent food choices (between healthy and unhealthy options), and consumption volume, our findings can have important implications for nudging consumers towards making healthier choices.

In terms of strategic decision making, although marketers usually tend to change food haptic properties to accommodate different consumer preferences, there can be unintended consequences of a food’s haptic properties influencing calorie estimations, subsequent food choices, and consumption volume. Hence, marketers need to be aware of this phenomenon while modifying haptic properties of foods. For example, frozen yogurt might be considered as a more appealing alternative to ice cream if it has the same creamy and rich mouthfeel and hence is associated with a higher level of orosensory perception. Clearly, additional research is needed to determine how consumer preferences for certain types of haptic properties of food items might influence their overall product evaluations.

Also, the amount of time people keep food in their mouth might have implications for the OHCE effect. It can be argued that keeping a food in the mouth for a longer time period might enhance the overall orosensory perception and hence strengthen the OHCE effects. Future research needs to examine this issue in further depth. Along these lines, the time spent in the mouth could be confounded with the number of chews. Additional research is needed to tease out these issues.

In this research, we focused on oral haptics related to solid foods. However, food manufacturers also vary the haptic properties of beverages. For instance, *Simply Orange* juices are offered in pulp free, medium pulp, and high pulp versions. Holding the actual nutritional content constant, would consumers perceive differences in the calorie content of beverages based on varying haptics? This question awaits future empirical investigation.

In our studies, we mainly examine food items that are generally considered unhealthy (such as chocolates, brownies, and fudge). One potential limitation of the OHCE effect is that it is expected to hold mainly for foods that in general have relatively high fat contents. In fact, one can argue that a certain level of fat content might be necessary to have orosensory perceptions. It will be interesting to examine the OHCE effect in the context of healthy foods such as fruits. Future research should also examine if perceived healthfulness of a food product might moderate the OHCE effects. Similarly, there can be other potentially interesting moderators (e.g., flavor characteristics and type of product–utilitarian vs. hedonic) that can influence the OHCE effect.

Finally, we focused on oral haptics related to haptic properties of hardness versus softness and roughness versus smoothness foods, its influence on the mastication process and orosensory perception, and how it influences calorie estimations, subsequent choices, and consumption volume. However, other haptic properties, such as temperature, can also potentially influence other food-related oral haptic processes, such as the length of time a food is kept in the mouth before swallowing, which in turn might influence food evaluations. Along similar lines, the degree of oral friction generated in the mouth can also influence food evaluations. These can be potentially interesting areas of future research. We hope that we have piqued interest in the area of oral haptics – there is much in this area to chew on!

Data Collection Paragraph

The first and second authors conducted the studies at the University of South Florida, with support from research assistants. The first and second authors jointly analyzed the data. The data for studies 1-3 were collected and analyzed between September 2011 and November 2012. The data for studies 4 and 5 were collected and analyzed between February 2013 and June 2013.

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FIGURE 1
CONCEPTUAL MODEL OF ORAL HAPTICS ON CALORIE ESTIMATION, MEDIATING EFFECTS OF MASTICATION AND OROSENSORY PERCEPTION, AND SUBSEQUENT BEHAVIORAL OUTCOMES

FIGURE 2
SOFT AND HARD CHOCOLATE SAMPLES USED IN STUDY 1

FIGURE 3
STUDY 4: EFFECTS OF ORAL HAPTICS AND OHCE ATTRIBUTION INFORMATION ON (A) CALORIE ESTIMATION AND (B) SUBSEQUENT CHOICE

FIGURE 4
STUDY 5: EFFECTS OF ORAL HAPTICS AND MINDFUL CALORIE ESTIMATION PRIMING ON CONSUMPTION VOLUME

FIGURE 1: CONCEPTUAL MODEL OF ORAL HAPTICS ON CALORIE ESTIMATION, MEDIATING EFFECTS OF MASTICATION AND OROSENSORY PERCEPTION, AND SUBSEQUENT BEHAVIORAL OUTCOMES

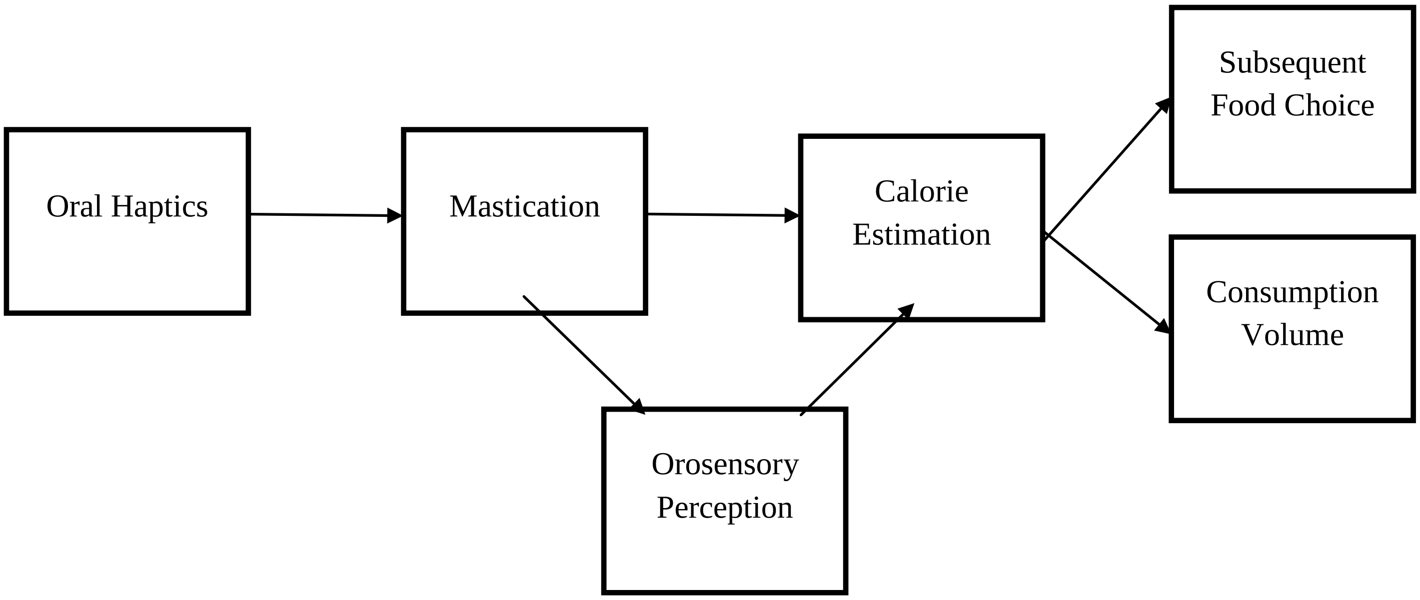
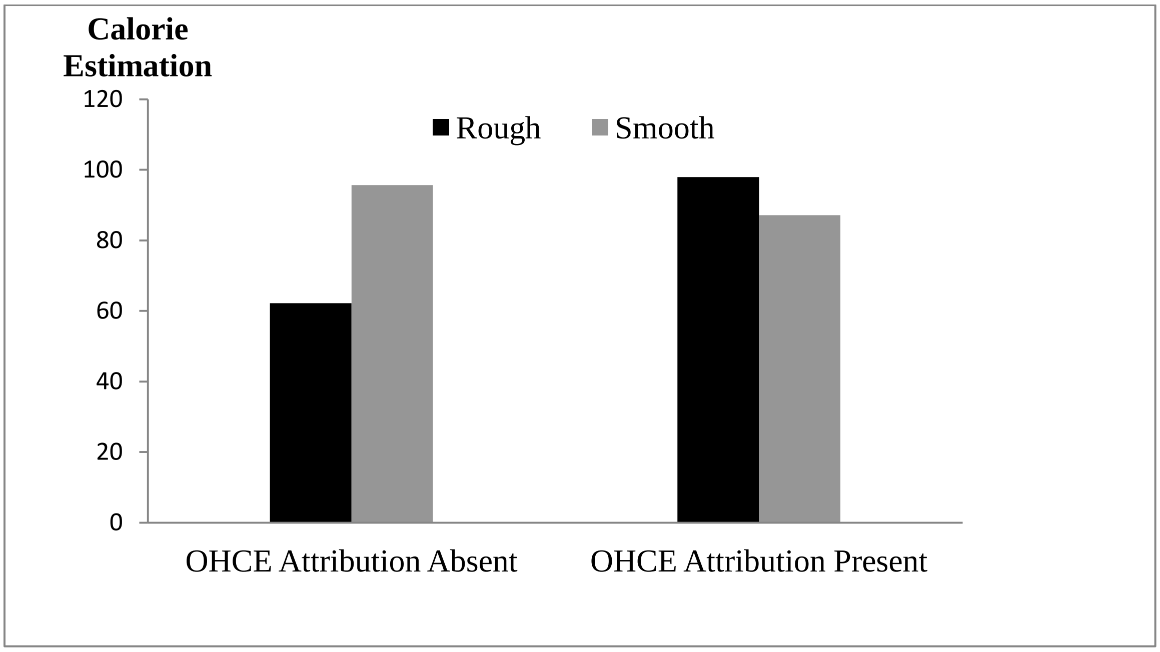


FIGURE 2: SOFT AND HARD CHOCOLATE SAMPLES USED IN STUDY 1

FIGURE 3
STUDY 4: EFFECTS OF ORAL HAPTICS AND OHCE ATTRIBUTION INFORMATION ON (A) CALORIE ESTIMATION AND (B) SUBSEQUENT CHOICE

A



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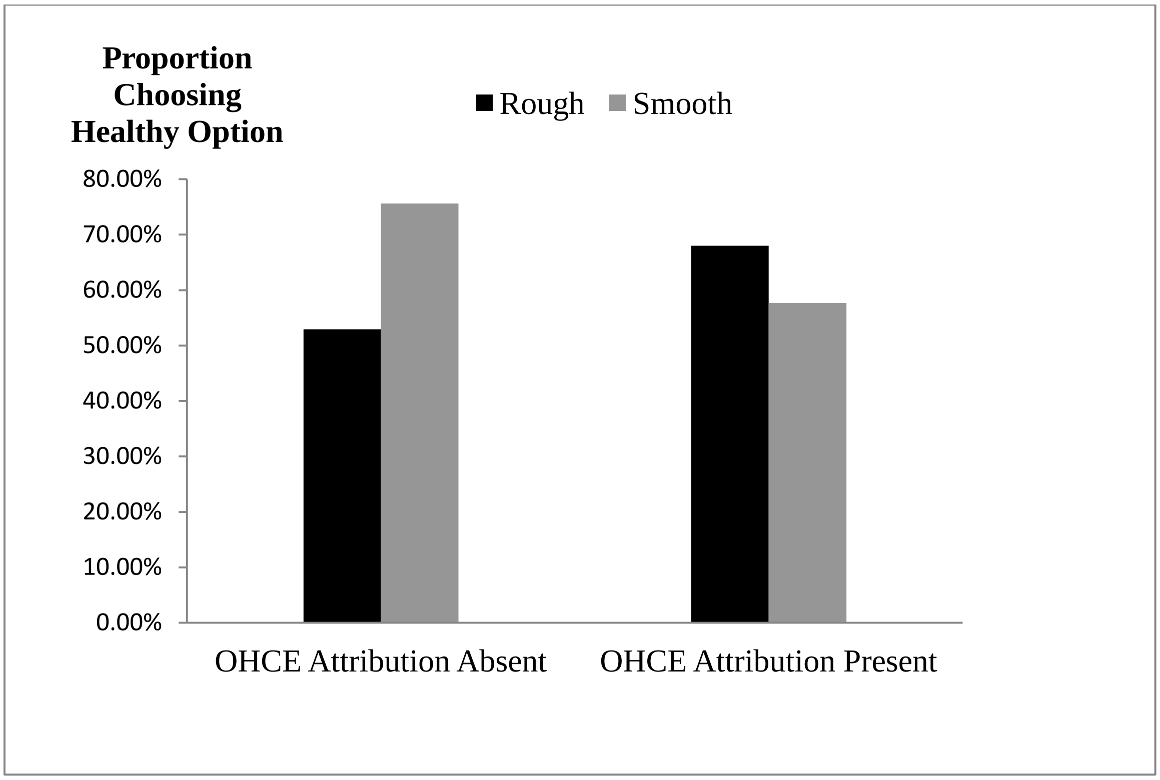
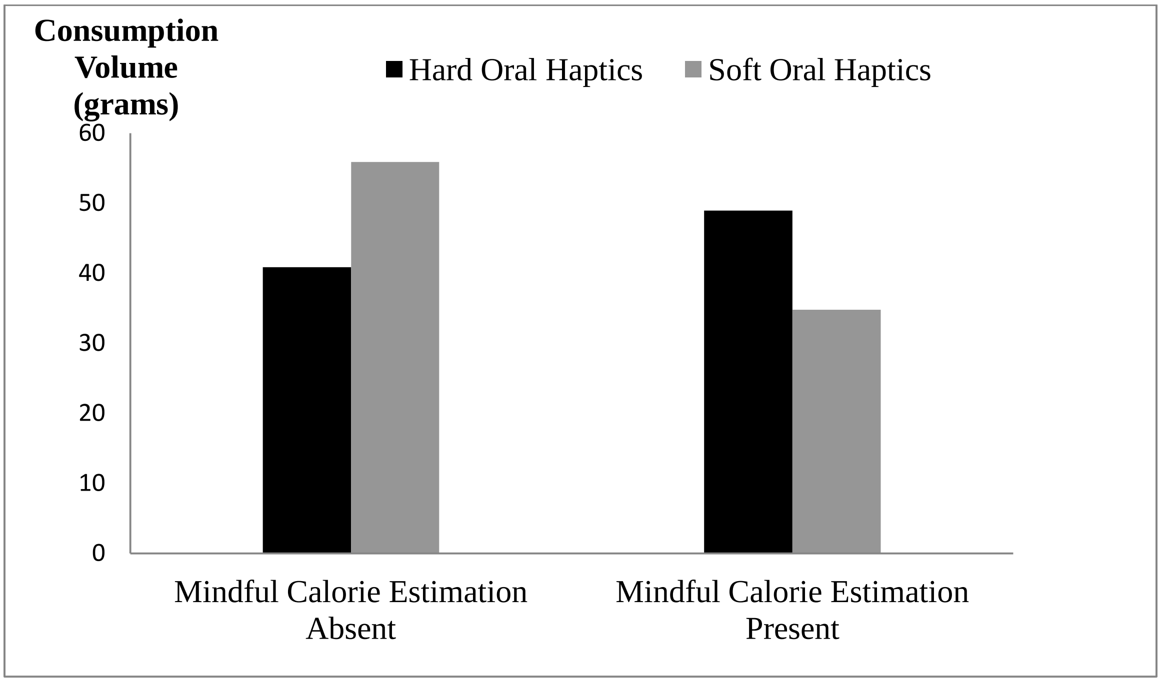


FIGURE 4

STUDY 5: EFFECTS OF ORAL HAPTICS AND MINDFUL CALORIE ESTIMATION PRIMING ON CONSUMPTION VOLUME



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