3-2022

Less Light, Better Bite: How Ambient Lighting Influences Taste Perceptions

Sarah Lefebvre
slefebvre@murraystate.edu

Laura Boman
Mercer University, boman_lk@mercer.edu

Jonathan Hasford
University of Tennessee, Knoxville, jhasford@utk.edu

Recommended Citation
Lefebvre, S., Hasford, J., & Boman, L. (2022). Less light, better bite: How ambient lighting influences taste perceptions. Journal of Retailing and Consumer Services, Vol. 65. https://doi.org/10.1016/j.jretconser.2021.102732

Abstract

Atmospheric factors within a retail environment provide efficient and effective methods for influencing customer behavior. Drawing on the concept of sensory compensation, this research investigates how ambient lighting influences taste perceptions. Three studies demonstrate that dim lighting enhances taste perceptions. The results of Studies 1a and 1b provide support that low lighting positively influences consumers' perceived taste of single taste dimension foods (e.g., sweet). Study 2 shows the number of taste dimensions (e.g., sweet vs. sweet and salty) stimulated serves as a boundary condition, attenuating the significant effect of dim lighting on taste perceptions.

Keywords: Atmospherics, Ambient Lighting, Taste Perception

1. Introduction

Atmospherics, such as ambient scents, sounds, temperature, and lighting, impact the customer experience (Bitner, 1992). Importantly, customers rely on these heuristic cues to form opinions about product attributes which may be unrelated to the cues themselves (Yan and Dando, 2015). Ambient scents (Biswas and Szocs, 2019; Chebat and Michon, 2003; Guéguen and Petr, 2006; Lefebvre and Biswas, 2019), sounds (Biswas et al., 2019; Petruzzellis et al., 2014; Ryu and Han, 2011), temperature (Huang et al., 2014), textures (Bitner, 1992), and lighting (Biswas et al., 2017; Ryu and Han, 2011; Scheibehenne et al., 2010) have been shown to impact customers' emotions, perceptions, and behaviors. One possibility with both theoretical and managerial relevance pertaining to atmospherics exists within the domain of on-premise food consumption, where atmospheric cues are manipulated relatively easily and can impact customer behavior. Specifically, lighting serves as an easy and inexpensive method of altering the customer experience (Biswas et al., 2017). In the U.S., some restaurants, such as Washington, DC, steakhouse Mastro's, and San Francisco's Opaque, serve dishes in near-complete or complete darkness (Kaplan, 2011) in the hopes of intensifying the flavors of foods (Sietsema, 2015). While these anecdotes highlight the important role visual perception plays in the dining experience, research has yet to consider how ambient lighting may limit information communicated through visual input and the potential impact this may have on other sensory perceptions associated with food, such as taste.

Taste is ubiquitous to customer food decisions and evaluations, so much so that Americans report taste as the most important attribute when making food choices (Glanz et al., 1998). It is unsurprising, therefore, that many restaurants rely on taste perceptions and evaluations to alter consumer behavior, such as to increase satisfaction (Mathe-Soulek et al., 2015) and spending (Lefebvre and Orlowski, 2019). Prior research has identified various means by which restaurants may enhance customer perceptions of the taste of the food served, including the color of the servingware (Piqueras-Fiszman et al., 2013), the shape or composition of beverage vessels (Stewart and Goss, 2013; Lefebvre and Orlowski, 2019), and the amount of background noise (Stafford et al., 2013). Despite this important work, however, the influence of ambient lighting on taste perceptions remains underexplored.

In the present research, we focus on ambient lighting as a sensory cue which has the ability to subconsciously influence customer perceptions. Across three experiments, we investigate the effect of ambient lighting on taste perceptions. Further, the number of taste dimensions (single vs. multiple) is examined as a boundary condition. In Studies 1a and 1b, we examine how dimmed lighting enhances taste perceptions for foods that consist of a single taste dimension (i.e., sweet, salty). In Study 2, we replicate the results of Studies 1a-b and investigate how the effect is attenuated when a food contains multiple taste dimensions (i.e., sweet and salty). Together, our research contributes to the study of atmospherics and the customer experience by examining how limiting an individual's visual sensory input through ambient lighting influences taste perceptions.

2. Literature Review

2.1 Restaurant Atmospherics and Food Consumption

Restaurant operators have countless options when considering the servicescape, such as social, design, and environmental factors, for their establishments (Baker et al., 1994). Specifically, in terms of sensory aspects, restaurant operators can choose the layout, colors, fixtures and more, all of which influence the customers overall experience. The recognition of the potential impact of atmospherics has led to extant research examining how ambient factors in an eating environment influence customer perceptions and behaviors. Previous research has identified that the color of a room impacts the amount of food consumed (Stroebele and De Castro, 2004), perceived crowding in a restaurant impacts approach-avoidance behaviors (Hwang et al., 2012), and music preference increases the time spent in a restaurant (Caldwell and Hibbert, 2002). Further, emitting an ambient scent associated with cleaning products leads individuals to be tidier when eating (Liljenquist et al., 2010). Ambient scents also impact consumption, as limited exposure (< 30 seconds) to an indulgent scent increases purchases of unhealthy foods, while the reverse was found for an extended exposure (> 2 minutes) to the scent (Biswas and Szocs, 2019).

The sense receiving the most attention by researchers to date has been that of vision, likely because of the multiple dimensions within visual input such as color, shape, and size. Furthermore, visual cues typically provide the first sensory contact a consumer has with a food item (Wadhera and Capaldi-Phillips, 2014). Ambient light impacts visual input and may differ in color (Özkul et al., 2020), distribution (focal vs. general; Wu et al., 2021), and luminescence (i.e., brightness or dimness; Biswas et al., 2017). Of these dimensions, luminescence is commonly adjusted because of the ease at which managers may control the brightness in a room (Biswas et al., 2017). Measured in lumens per square meter (i.e., lux; Thimijan and Heins, 1983), luminescence has been shown to influence food preferences, perceptions, and consumption (Bschaden et al., 2020; Biswas et al., 2017; Xu and Labroo, 2014). Research has identified that inhibiting one’s vision influences the quantity of food consumed and the amount spent on a dining experience (Wansink and van Ittersum, 2012). Scheibehenne et al. (2010) found that providing consumers with larger portions in a dark room led them to consume approximately 36% more food relative to participants with standard portions. Related research from Renner et al. (2016) demonstrated that perceived food consumption differs vastly from actual food consumption in dark environments unless individuals become more introspective about their choices. This is highly relevant in the restaurant industry where visual input resulting from the brightness of the lighting is a relatively inexpensive way to alter the sensory experience for the customer (Biswas et al., 2017).

The limited research that has examined the effect of ambient lighting on taste perceptions has produced mixed results. For instance, van der Heijden et al. (2021) found taste intensity of a four-course meal was rated stronger under bright lighting compared to dim lighting. In contrast, Bschaden et al. (2020) found no difference in overall taste of tomato soup, yet it was perceived as saltier in dim lighting compared to bright lighting. These contradicting results found related to ambient lighting and taste perceptions highlights the need to untangle the effect and factors that may alter the relationship. For instance, Bschaden et al. (2020) used tomato soup as their stimuli, which consists of savory and salty taste dimensions, while van der Heijden et al. (2021) describe the dish provided to customers as containing sweet, sour, salty and bitter taste dimensions, while also consisting of crispy and creamy textures. Since the use of multiple taste dimensions increases the sensory information provided to a customer through the gustatory and olfactory senses (Crolic and Janiszewski, 2016), the number of taste dimensions a food consists of may aid in explaining the inconsistent results found in previous research. This is particularly important given that sensory deficits in one area are frequently compensated for by an enhancement of one’s other senses (i.e., cross-modal inferences; Hoover et al., 2012; Kupers and Ptito, 2014; Spence et al. 2014). Given these important theoretical and practical implications, we examine how short-term limitations in vision influence taste perceptions. In the following section, we explore sensory compensation in more detail to form predictions regarding visual information limitations through lighting and their impact on taste perceptions.

2.2 Taste Formation and Sensory Compensation

Taste perceptions are created through the integration of information provided by the visual, olfactory (smell), and gustatory (taste) senses (Prescott, 2012; Stevenson et al., 2008). Visual input is easily understood as the information communicated through the eyes, while olfactory and gustatory information is more complex (Biswas and Szocs, 2019). Olfactory information is communicated by the receptors in the sinus passages that perceive odorants that are received through sniffing and from air pushed into the nasal passages while chewing. Gustatory information is provided by taste receptors located on the tongue which perceive the five accepted taste dimensions of food (i.e., sweet, salty, sour, bitter, and savory; Breslin, 2013). The removal of a source of sensory information alters the taste experience with the food item (Stevenson et al., 2008; Miller and Thayer, 2008). So much so, if you were to close your eyes and plug your nose, eliminating visual and olfactory information, it would be nearly impossible to ascertain the difference between an apple and an onion (Prescott, 2012). Further, temporary nasal blockages due to congestion reduce olfaction input and can produce taste abnormalities (Stevenson et al., 2008; Miller and Thayer, 2008).

Research has shown taste perceptions to be influenced by a wide range of factors not directly related to chemosensory properties. For instance, consumer taste perception may be altered with product packaging, which in turn affects willingness to pay (Lefebvre and Orlowski, 2019), and the perceived attractiveness of a meal has a positive effect on taste ratings (Zellner et al., 2014). Atmospherics have also been shown to influence taste perceptions (Bschaden et al. 2020; Biswas and Szocs 2019; Stafford et al., 2013; Stroebele and De Castro, 2004; van der Heijden et al., 2021). The hue of ambient lighting altered the evaluation of white wine, such that wine tasted better in blue and red ambient lit environments compared to rooms with green or white ambient lighting (Oberfeld et al., 2009). Thus, atmospherics provide information that is used in the formation of taste perception. This is unsurprising since flavor/taste is created through a combination of visual, gustatory (taste), and olfactory (smell) information (Prescott, 2012; Stevenson et al., 2008).

Visual input holds a strong influence over taste, providing information about food products (de Liz Pocztaruk et al., 2011) and serving as the first and preferred sensory modality for customers (Morrot et al., 2001; Wadhera and Capaladi-Phillips, 2014). In low luminescence conditions, consumers' ability to perceive visual inputs becomes impaired. To this end, decreased luminescence provides customers with reduced information about the food they are consuming (Walker et al., 2014). Incomplete information influences consumer choices, outcomes, and evaluations (Kivetz and Simonson, 2000; Walker et al., 2014). For example, low visual contrast can influence difficulty visualizing portion sizes, thus causing customers to underestimate serving sizes (Walker et al., 2014).

With reduced visual input as a result of lower luminance, other sensory inputs are likely to be relied on to gain information and form perceptions about the experience. In the case of taste perceptions, olfactory and gustatory information would counteract the loss in visual input. We refer to this as sensory compensation, when the reduction of information from one sensory input enhances the input of information from another sense (Biswas and Szocs 2019). Sensory compensation is a widespread phenomenon in humans, such that the absence of one sense leads to strengthened processing of another sense (Hoover et al., 2012; Kupers and Ptito, 2014; Lazzouni and Lepore, 2014). For example, research with visually impaired individuals has supported enhanced sensory processing of tactile and auditory cues (Gagnon et al., 2015; Kupers et al., 2011). Further, smelling indulgent food scents reduces the desire to consume indulgent foods because exposure to ambient scent for these types of foods induces pleasure, thus reducing the desire for unhealthy food choices (Biswas and Szocs, 2019).

Similar effects have been identified when visual input is reduced, thereby enhancing tactile and auditory senses (Hoover et al., 2012; Kupers and Ptito, 2014). Further, by utilizing compensatory strategies, consumers are able to overlook discrepancies (Mandel et al., 2017). For example, brand familiarity can serve as a compensatory mechanism for privacy concerns, leading to lower concern for risk (Nepomuceno et al., 2014).

Thus, developed from the prior discussion, we propose that when visual input is reduced, due to dimmed ambient lighting, taste perception will be more favorable given the compensation of sensory information provided by one's heightened gustatory and olfactory senses (Biswas, 2019). Formally stated:

H1: Reduced visual input through dimmed ambient lighting will enhance taste perception compared to bright ambient lighting.

2.3 Single vs. Multi-Dimension Taste Perceptions

In terms of taste, foods may consist of multiple taste dimensions (e.g., sweet, salty, sour, bitter, and savory). Certain foodservice operations, such as dessert bars and concessionaires, may specialize in foods that consist of a single taste dimension. For instance, bakeries primarily sell foods that are sweet such as pastries and cookies. It is not uncommon for customers to experience multiple sensory cues during consumption experiences, which are characterized as superadditive multisensory interactions (Spence et al., 2014). While the reduction of one form of sensory information can enhance the input from another sense, there is still the opportunity for increased sensory input to occur. Often multiple taste dimensions are combined in a single product (Berry, 2013; Crolic and Janiszewski, 2016). For example, a salad may contain fruit (sweet), nuts (salty), and marinated chicken (savory). Restaurants commonly layer flavors such as savory and sweet in order to provide consumers with unique sensory experiences (Berry, 2013). Therefore, when a food consists of multiple taste dimensions (e.g., sweet and salty) there is increased information from the gustatory and olfactory senses that is available to form taste perceptions than when the food consists of only a single taste dimension (e.g., sweet; Crolic and Janiszewski, 2016).

Foods consisting of multiple taste dimensions inherently provide additional sensory information in comparison to single-flavor dimensional foods (Crolic and Janiszewski, 2016). The reduction in visual input will not need to be compensated for when a food consists of multiple taste dimensions, because the increased amount of information available from the gustatory sense eliminates the need for sensory compensation. Thus, we propose that the increased information from multi-taste dimensions will offset the sensory compensation experienced with reduced visual input.

> **H2:** The number of taste dimensions will moderate the effect of ambient lighting on taste perceptions such that the effect will be attenuated when the product contains multiple-taste dimensions.

3. Study 1a

Study 1a was designed to examine how reduced visual input influences taste perceptions for a sweet food item (chocolate).

3.1 Method

Eighty-seven undergraduates (52% female, M_{age} = 22 years) were recruited to participate in this study for course credit. Participants were randomly assigned to a single-factor (visual input: reduced or control) between-subjects design.

To begin, participants arrived at a lab and were told they would be taking part in a series of research-related tasks. Participants were seated at an individual work cubicle that contained a paper instructions packet, pen, and pair of glasses. Step by step instructions were provided in the information packet along with the study measures. Participants were instructed to not skip ahead and to follow the instructions as closely as possible. Participants were told they would be evaluating a pair of sunglass frames and asked to put on a pair of black plastic, unbranded sunglasses that had either darkened lenses (black tint) that reduced visual input or clear lenses to serve as a control condition. Apart from the clear versus darkened lenses, the glasses were identical across conditions (see Appendix). The sunglasses served as our manipulation of visual input to mimic bright and dimmed lighting commonly found in restaurants. Participants were also instructed to wear the glasses throughout the study while they worked on other tasks. Next, participants were asked to indicate how hungry they were “right now” (1 = not at all, 7 = extremely hungry) and how long it had been since they last ate, both as indicators of hunger (Briers et al., 2006; Szocs and Lefebvre, 2016). Then, the researcher provided participants with a snack item in a clear, disposable plastic bag. The snack item consisted of a one-inch by one-inch square of a popular brand of milk chocolate. The chocolate had been removed from its packaging and was identical in both experimental conditions. After sampling the snack, participants responded to measures of taste perception of the chocolate on a two-item scale adapted from an existing taste perception scale (“How would you rate the taste of the chocolate?”, 1 = very bad, 7 = very good; and “How flavorful is the chocolate?”, 1 = not at all flavorful, 7 = very flavorful; adapted from

Lefebvre and Orlowski, 2019). The two taste items ($r = .74$) were averaged to form our dependent variable.

After completing the taste perception measures, participants were asked a series of evaluative items about the sunglasses that they were wearing. These items were included to avoid raising suspicion of the true purpose of the study. Lastly, participants provided their age and gender. To attenuate ethical concerns related to using a cover story, at the conclusion of the lab session participants were provided with a debriefing statement informing them of the purpose of the study and why they were not told all of the details at the beginning. All studies were approved by the respective university Institutional Review Board.

3.2 Results

To examine how visual input affected taste perceptions of the single taste dimension food (i.e., sweet, chocolate), a t-test was conducted. Results revealed that taste perceptions were marginally more favorable when visual input was reduced in the dark lenses condition ($M = 5.88$) compared to the clear lens control condition ($M = 5.44$; $t(85) = 1.86$, $p = .067$).[1] This finding supports H1. Furthermore, we analyzed whether participant hunger impacted taste perceptions. Neither hunger measure was significant when included as a covariate ($ps > .34$), and our effect of visual input on taste perceptions remained marginally significant ($F(1, 83) = 3.10$, $p = .08$) when these covariates were included in our analysis. To examine the potential impact of participant sex, an ANOVA was conducted with visual input and sex as the independent variables. The result found

[1] Marginally significant results have been included in recent research published within the marketing discipline when further studies are included that provide statistical significance below $p = .05$ (see Hagen, 2021; Gill, 2020; and Lee et al., 2018 for examples). Furthermore, Cohen (1994, p 999), in referring to this arbitrary criterion, suggests, “the ritual dichotomous reject-accept decision, however objective and administratively convenient, is not the way any science is done” and thus impedes scientific progress.

the main effect of sex ($p = .38$) and the interaction of visual input and sex on taste to be nonsignificant ($p = .36$)

A post-test was conducted to assess the manipulation of visual input through the use of the sunglass lenses. Due to limitations in data collection caused by the COVID-19 pandemic, an online study was conducted. Fifty-four participants (39% female, $M_{age} = 36$ years) completed the study through Amazon Mechanical Turk (MTurk) in exchange for fair monetary compensation. Each participant reviewed an image of either the sunglasses with clear lenses or with black tinted lenses, and then responded to the key measure, “If wearing the glasses shown above, how bright would the room be?” (1 = very dark, 7 = very bright). An independent-samples t-test found participants in the clear lens condition expected the brightness to be greater ($M = 5.04$) than participants in the tinted lens condition ($M = 3.19$; $t(52) = -4.91$, $p < .001$).

3.3 Discussion

Study 1a provides initial support for our predictions regarding visual input and taste perceptions. When visual input was reduced via dark-tinted sunglasses, participants rated the taste of single dimension food more favorably. This suggests that reduced visual input that occurs when restaurant lighting is dimmed results in more positive taste perceptions. Next, Study 1b generalizes our findings by examining foods containing different singular taste dimensions.

4. Study 1b

The purpose of Study 1b was to examine the robustness of the effect of visual input on taste perceptions. Study 1a used milk chocolate as the stimuli. However, since there are multiple taste dimensions (e.g., sweet, salty, sour, bitter), to enhance the generalizability of findings Study 1b utilized multiple snack items that consisted of either a sweet or salty taste dimension. In addition, the items varied in texture and consistency to further examine the robustness of the effect across food items.

One-hundred and thirty-five undergraduate students (50% female; M_{age} = 21 years) were recruited to participate in this study for extra credit. Participants were randomly assigned to a 2 (visual input: reduced or control) x 2 (food flavor: sweet or salty) x 2 (food texture: crunchy or chewy) between-subjects design.

4.1 Method

Participants were told they would be completing a series of tasks as part of a research study which followed a similar design as Study 1a. Participants followed the same introduction and seating as in Study 1A. Task 1 was the same manipulation of visual input used in Study 1a. In task 2, participants were asked the two hunger items used in Study 1a and then asked to sample a snack provided by the researcher and answer the questions that followed. Participants were randomly given one of four snack items that varied across taste and texture dimensions. The snack items were raisins (sweet and chewy), cookies (sweet and crunchy), cheese (salty and chewy), and potato chips (salty and crunchy). After sampling the snack, participants completed the two-item measure of taste used in Study 1a. Again, to maintain the scenario of the sunglasses being of interest, participants then completed a series of evaluative questions about the glasses. Then, participants provided their age and gender. To conclude, participants were debriefed of the study purpose.

4.2 Results

One-hundred and thirty-two participants completed the study in full and were included in the final analysis. A 2 (visual input) x 2 (food flavor) x 2 (food texture) ANCOVA was conducted with the taste measure as the dependent variable and the two hunger measures as covariates. Complete results are provided in table 1. The hunger covariates were both significant in our analysis (hunger: $F(1, 123) = 4.34$, $p = .04$; last ate: $F(1, 123) = 4.01$, $p = .05$). Importantly, a significant main effect of visual input was found ($F(1, 123) = 6.11$, $p = .015$), where participants in the reduced visual input condition rated the taste of the snack more favorably ($M = 5.46$) than those in the control condition ($M = 4.90$). Means by individual food items are available in table 2. Additionally, the effect of food texture was also significant ($F(1, 123) = 10.94$, $p = .001$), such that participants rated the taste of crunchy foods more favorably relative to the taste of chewy foods ($M_{crunchy} = 5.57$ vs. $M_{chewy} = 4.78$). However, this effect is not central to our predictions and further discussion is omitted. All other effects were nonsignificant (ps > .1).

Table 1: Study 1b ANCOVA Table Predicting Taste Perceptions

Source	Effect	Partial η^2	F	Sig.
Visual Input (A)	12.78	0.05	6.11	0.02
Food Flavor (B)	2.07	0.01	0.99	0.32
Food Texture (C)	22.89	0.08	10.94	<.01
A*B	0.08	<.01	0.04	0.85
A*C	1.26	0.01	0.60	0.44
B*C	4.92	0.02	2.35	0.13
A*B*C	0.51	<.01	0.24	0.62
Hunger (Covariate)	9.08	0.03	4.34	.04
Last Ate (Covariate)	8.39	.03	4.01	.05

Table 2: Study 1b Taste Perception Means by Factor

	Sweet	Salty	Crunchy	Chewy	Total
Reduced Visual Input	5.36	5.58	5.80	5.11	5.46
Control	4.72	5.10	5.32	4.44	4.90

4.3 Discussion

Study 1b provides additional support for our primary hypothesis that customers' perception of single-flavor foods to be more favorable as visual input decreases through reduced lighting. Furthermore, our results were robust across multiple taste dimensions and multiple food textures, demonstrating the influence of reduced visual input on taste perceptions is not limited to a specific type of food. Next, Study 2 examines the boundary condition of multiple flavor dimensions.

5. Study 2

In Studies 1a and 1b, we examined foods with a single flavor dimension. While prior literature on ambient lighting suggests that bright lighting enhances taste intensity, the stimuli employed included four flavor dimensions and multiple textures (van der Heijden et al., 2021). Many foods consist of multiple flavor dimensions (e.g., sweet and salty). When a food consists of these multiple flavor dimensions, taste receptors experience enhanced stimulation, which thus provides additional information to the consumer. Thus, we propose for foods with multiple dimensions of flavor (e.g., sweet and salty) the amount of visual input will not impact taste perceptions. In a multi-dimensional food, the addition in taste dimension serves as a compensatory mechanism, thus increasing consumers' evaluation of the food. Thus, cross-modal sensory compensation is no longer necessary to provide consumers with enough information to effectively develop perceptions of taste.

To examine this boundary condition, 88 undergraduates (46% female, M_{age} = 25 years) completed the study for course credit. Participants were randomly assigned to a 2 (visual input: reduced vs. control) x 2 (flavor dimension: single vs. multiple) mixed-design experiment. Visual input served as the between-subjects factor and number of flavor dimensions as the within-subjects factor.

5.1 Method

Rather than manipulating visual input with glasses as in previous studies, we altered the luminance in the room as our manipulation of visual input in Study 2 to mimic ambient lighting in a restaurant environment. Individuals entered a lab in groups of four to eight to participate in the study. The lab layout consisted of a table with eight chairs, similar to seating in a casual restaurant. Each table setting was prepared identically across sessions before participants entered the room to further simulate a restaurant environment. Each table setting consisted of a plate with a meal, napkins, and a questionnaire. The small meal consisted of approximately one cup of plain popcorn which served as the single-flavor dimension food (salty), and a peanut butter and jelly sandwich (smooth peanut butter, grape jelly, and two slices of white bread) which served as the multi-dimensional food (sweet and salty). Furthermore, the windowless lab had seven settings for room lighting ranging from 100% to 0% (no lighting). Prior to participants entering the room, the lighting of the room was manipulated. In the control condition, the room lighting was set to a standard level where the highest lumen setting was used. In the reduced visual input condition, the lights were set to the lowest preset level available where some visibility was still present (approximately 15% lumens in comparison to the highest setting). The lab environment contained no windows eliminating concerns of natural lighting entering the room. Once seated and prior to sampling the food items, participants were asked to complete the same two hunger measures used previously and were asked to sample as much or as little of the food provided to them. After sampling the foods, participants rated the taste of both items using the two-item scale previously used. To conclude, participants provided their gender and age and were debriefed.

5.2 Results

A repeated-measures ANCOVA with taste ratings for the two foods as within-subject factors, visual input as a between-subjects factor, and the hunger measures as covariates was conducted. A significant between-subjects effect of participants' current hunger ("How hungry are you right now") was observed ($F(1, 85) = 3.80$, $p = .054$). All other covariate main effects and interactions were non-significant ($ps > .1$). Importantly, a significant interaction was found for visual input and taste dimensions ($F(1, 85) = 4.76$, $p = .03$). Post-hoc comparisons revealed that participants with reduced visual input rated the taste of the popcorn more favorably than those in the control condition ($M_{reduced} = 3.63$, $M_{control} = 3.03$, $t(85) = -2.35$, $p = .02$). In contrast, there were no differences in taste ratings for the peanut butter and jelly sandwich between participants with reduced visual input and those in the control condition ($M_{reduced} = 5.70$, $M_{control} = 5.76$, $p > .77$). Together, these findings support H2.

A post-test was conducted to provide support for the flavor dimension manipulation. Due to restrictions on data collection because of COVID-19, an online post-test was conducted with 29 participants (35% female, $M_{age} = 36$ years) recruited through MTurk. Participants were asked to "Imagine that you are having a [peanut butter and jelly sandwich/plain popcorn] as a snack". In the multidimensional condition (peanut butter and jelly sandwich), participants were told, "The sandwich is made with plain white sandwich bread, creamy peanut butter and grape jelly." After being asked to imagine the snack item, participants were asked, "What taste dimensions would you expect from the [peanut butter and jelly sandwich/plain popcorn] you were asked to imagine? (select all that apply)." The options were salty, sweet, sour, and bitter. Each participant completed the procedure for both snack items. In support of the flavor dimension manipulation, 90% of participants identified popcorn as unidimensional, while 66% indicated a peanut butter and jelly sandwich was multidimensional. Table 3 provides the frequencies for each flavor dimension selected by snack item.

Table 3: Post-Test of Taste Dimensions by Snack Item (Frequency [Percentage])

	Salty	Sweet	Sour	Bitter	Single-Selected	Multi-Selected
Popcorn	24 (83%)	3 (10%)	0 (0%)	5 (17%)	26 (90%)	3 (10%)
PB&J	18 (62%)	29 (100%)	1 (3%)	0. (0%)	10 (35%)	19 (66%)

5.3 Discussion

Study 2 provides additional support for our predictions regarding reduced visual input and taste perceptions. When sampling a single-flavor food in a dimly lit room, results replicated the results of Studies 1a and 1b. However, when a multi-dimensional flavored food was consumed, taste perceptions were not impacted by room lighting. Together, these findings highlight the impact of visual inputs on taste perceptions.

6. General Discussion

Three studies demonstrate that dim ambient lighting impacts taste perception of foods that have a single taste dimension. In contrast, when a food consists of multiple flavor dimensions (e.g., sweet and salty) the effect is attenuated. We find these effects across a robust set of stimuli varying in both taste dimensions (i.e., sweet, salty) and texture (i.e., crunchy, chewy). By exploring the impact of lighting on taste percseption, theoretical advancements to the study of atmospherics, sensory compensation and managerial implications associated with the use of lighting as an atmospheric element in restaurants.

The findings extend the current literature on sensory cues and food consumption behaviors. Previous research has shown effects of ambient lighting on food consumption volume (Scheibehenne et al., 2010), perceived compared to actual consumption amount (Renner et al., 2016), and choice of healthy versus unhealthy foods (Biswas et al., 2017). Our research contributes to this literature by examining the impact of reduced visual input on taste perceptions. Our findings also help untangle contradicting results in recent research on ambient lighting and taste perceptions. Specifically, we provide evidence of a boundary condition, the number of taste dimensions present, that aids in explaining previous findings (Bschaden et al., 2020; van der Heijen et al., 2021). Since taste is an important factor in determining consumer satisfaction of food products (Mathe-Soulek et al., 2015), our findings suggest that lighting not only affects how much and what type of food is consumed, but also the enjoyment consumers derive from eating.

We also contribute to research on cross-modal sensory compensation. We show that when visual inputs are only temporarily limited by a reduction in ambient lighting, taste is perceived more favorably. We propose that this effect occurs from increased olfactory input providing additional information to aid in evaluation.

From a managerial perspective, atmospherics are increasingly being used to enhance the customer experience. The foodservice industry is no exception to this, recognizing that sensory cues have the ability to enhance the culinary experience. The National Restaurant Association (2017) recognizes the influence of lighting in the consumption experience, stating, “Lighting can set the mood in your restaurant, creating a soothing ambience that encourages customers to linger or a vibrant atmosphere that helps turn tables.” Based on our findings, venues serving single taste dimension foods can dim their lighting to reduce visual input and enhance taste perceptions. This can apply to venues such as movie theaters, where snacks typically consist of a salty (popcorn) or sweet (candy) taste dimension, and bakeries, where most product are dominant on the sweet dimension of taste.

Dessert-focused establishments can also implement these findings to enhance consumer satisfaction. For instance, Sugar Factory's menu features food and beverages created around sweet flavors such as the Energy Bear, a cocktail made with watermelon vodka, tropical fruits, Red Bull, and topped with gummy bears (Sugar Factory, 2018). In these or other settings where one flavor dimension is predominant across the menu, reducing ambient lighting should enhance taste perception and subsequent customer satisfaction with the consumption experience. Restaurants must also consider their brand image when making lighting decisions due to a priori associations of consumers. For instance, consumers may associate dimmed lighting with a romantic dinner, thus forming expectations for the dining experience and food attributes (e.g., taste). However, a romantic dinner may not align with the image of the brand, creating false expectations. Sugar Factory's brand image is centered on fun, over-the-top desserts, and parties; dimmed lighting may form expectations for a tasty romantic meal that cannot be met. This provides an interesting boundary condition to be explored.

Furthermore, the results of Study 2 demonstrate that dimming ambient lighting does not enhance taste perceptions of menu items that consist of multiple flavor dimensions. For establishments serving complex, multi-flavored foods, other atmospherics could be considered that impact the consumption experience. For example, extended exposure to indulgent ambient scents can lead individuals to consume healthier foods (Biswas and Szocs, 2019). By positioning itself as providing healthy options and serving complex-flavored foods, incorporating various ambient scents into the restaurant could further nudge customers toward making healthier choices.

Reduced lighting can also have financial implications. Lighting costs derived from both design and energy are typically substantial investments. Our findings present a method that can help reduce these costs by dimming the ambient lighting in the establishment or reducing the initial lighting investment when opening a venue, particularly one that serves predominantly single-flavor foods.

6.1 Limitations and Future Directions

Our results were found for hedonic food items where taste is positively valenced (e.g., chocolate, cookies, and chips). However, we did not examine the effect on foods that are perceived to taste negatively or serve utilitarian needs. Prior research has identified that taste perceptions can become heightened for both good and bad tasting foods based on visual cues in the consumption environment. For instance, Lin et al. (2018) found that the attractiveness of a server made good foods taste better but bad food taste worse. Future research could investigate if unpleasant tasting or utilitarian foods are rated more unfavorably from dim lighting as well.

A limitation of our research is that our stimuli consisted only of food items, specifically snack foods. Future research should consider examining full meal scenarios as found in most restaurants. Though food and beverages are often consumed together, they are separate elements of the dining experience and research should not assume that effects found for one extend to the other. Future research should examine the effect of ambient lighting on beverages. This is particularly relevant to bar managers where lighting is often dim and the creation of menu items is typically driven around taste dimensions (e.g., salty foods that compliment alcoholic beverages). A practical limitation of our findings is the lack of a field study where full meals rather than snacks could be examined. Inclusion of a field study could reveal a dampening of the effect of ambient lighting when not experienced in isolation. In other words, a single atmospheric cue, such as ambient lighting, is unlikely to exist in a real-world setting. Instead, multiple atmospheric cues are likely (Babin et al. 2004; Spence et al., 2014), some of which may be deemed inappropriate or incongruent, thus influencing consumer behavior (Babin et al. 2004; Morrin and Chebat 2005). Future research should consider the interplay of multiple ambient cues in the consumption environment.

Future research should also directly investigate the underlying mechanism of olfactory information input. We predict more favorable taste perceptions result from the increased input of olfactory information made available by the reduced visual input. It would be useful to measure olfactory input to provide additional support for our conceptual framework. This could potentially create an opportunity for collaboration with neuroscience and physiology research to further explore the implications of sensory compensation.

The downstream effects of our findings also remain an area for further research. Specifically, since previous research has shown dimmer lighting influences consumption volume (Scheibehenne et al., 2010), it may be that dim lighting influences taste perceptions, which in turn increase consumption volume. Research should examine the interplay of taste perceptions and behavioral outcomes to create a comprehensive theoretical model of sensory compensation and physiological responses. In addition, research has recognized the consumption experience is influenced by the interactive effect of the different senses (Spence et al., 2014). Future research should continue exploring the impact of various cross-modal relationships on consumer food preferences and taste perceptions.

Lastly, our research is not without methodological limitations that should be considered for future research. Two manipulations of illuminance were used across three studies, eyewear with darkened versus clear lenses and ambient room lighting. Though the manipulations altered visual input, participants were not asked to rate the ambient lighting or level of visual input. Future research may consider the degree to which visual input is altered, potentially identifying a threshold for the effect on taste perceptions. In addition, in our examination of multiple flavor dimensions (Study 2), participants did not identify the dominant flavors in the multidimensional flavor condition. It would be interesting for future research to consider what flavor dimension dominates consumer perceptions and how this may influence the interaction with visual input on taste perceptions.

6. References

Babin, B. J., Chebat, J. C., & Michon, R., 2004. Perceived appropriateness and its effect on quality, affect and behavior. Journal of Retailing and Consumer Services, 11(5), 287-298. https://doi.org/10.1016/j.jretconser.2003.09.002

Baker, J., Grewal, D., & Parasuraman, A., 1994. The influence of store environment on quality inferences and store image. Journal of the Academy of Marketing Science, 22(4), 328-339. https://doi.org/10.1177/0092070394224002

Berry, D., 2013. Layer upon flavor layer. Food Business News. Retrieved from http://www.foodbusinessnews.net/

Biswas, D., 2019. Sensory aspects of retailing: Theoretical and practical implications. Journal of Retailing, 95(4), 111-115. https://doi.org/10.1016/j.jretai.2019.12.001

Biswas, D., & Szocs, C., 2019. The smell of healthy choices: Cross-modal sensory compensation effects of ambient scent on food purchases. Journal of Marketing Research, 56(1), 123-141. https://doi.org/10.1177/0022243718820585

Biswas, D., Szocs, C., Wansink, B., & Chacko, R., 2017. Shining light on atmospherics: How ambient light influences food choices. Journal of Marketing Research, 54(1), 111-123. https://doi.org/10.1509/jmr.14.0115

Bitner, M. J., 1992. Servicescapes: The impact of physical surroundings on customers and employees. Journal of Marketing, 56(2), 57-71. https://doi.org/10.1177/002224299205600205

Breslin, P. A. S., 2013. An evolutionary perspective on food and human taste. Current Biology, 23(9), R409-R418. https://doi.org/10.1016/j.cub.2013.04.010

Briers, B., Pandelaere, M., Dewitte, S., & Warlop, L., 2006. Hungry for money: The desire for caloric resources increases the desire for financial resources and vice versa. Psychological Science, 17(11), 939-943. https://doi.org/10.1111/j.1467-9280.2006.01808.x

Bschaden, A., Dörsam, A. F., Cvetko, K., Kalamala, T., & Stroebele-Benschop, N., 2020. The impact of lighting and table linen as ambient factors on meal intake and taste perception. Food Quality and Preference, 79, 103797. https://doi.org/10.1016/j.foodqual.2019.103797

Caldwell, C., & Hibbert, S.A., 2002. The influence of music tempo and musical preference on restaurant patrons' behavior. Psychology & Marketing, 19(11), 895 - 917. http://doi.org/10.1002/mar.10043

Cohen, J., 1994. The earth is round (p<. 05). American Psychologist, 49(12), 997. https://doi.org/10.1037/0003-066X.49.12.997

Chebat, J.C., & Michon, R., 2003. Impact of ambient odors on mall shoppers' emotions, cognitions, and spending: A test of competitive causal theories. Journal of Business Research, 56(7), 529-539. https://doi.org/10.1016/S0148-2963(01)00247-8

Crolic, C., & Janiszewski, C., 2016. Hedonic escalation: When food just tastes better and better. Journal of Consumer Research, 43(3), 388-406.

de Liz Pocztaruk, R., Abbink, J. H., de Wijk, R. A., da Fontoura Frasca, L. C., Gavião, M. B. D., & van der Bilt, A., 2011. The influence of auditory and visual information on the perception of crispy food. Food Quality and Preference, 22(5), 404-411. https://doi.org/10.1016/j.foodqual.2010.11.008

Gagnon, L., Kupers, R., & Ptito, M., 2015. Neural correlates of taste perception in congenital blindness. Neuropsychologia, 70, 227-234. https://doi.org/10.1016/j.neuropsychologia.2015.02.027

Gill, T., 2020. Blame it on the self-driving car: how autonomous vehicles can alter consumer morality. Journal of Consumer Research, 47(2), 272-291. https://doi.org/10.1093/jcr/ucaa018

Glanz, K., Basil, M., Maibach, E., Goldberg, J., & Snyder, D. A. N., 1998. Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. Journal of the American Dietetic Association, 98(10), 1118-1126. https://doi.org/10.1016/s0002-8223(98)00260-0

Guéguen, N., & Petr, C., 2006. Odors and consumer behavior in a restaurant. International Journal of Hospitality Management, 25(2), 335-339. https://doi.org/10.1016/j.ijhm.2005.04.007

Hagen, L., 2021. Pretty healthy food: How and when aesthetics enhance perceived healthiness. Journal of Marketing, 85(2), 129-145. https://doi.org/10.1177/0022242920944384

Hoover, A. N., Harris, L. R., & Steeves, J. E., 2012. Sensory compensation in sound localization in people with one eye. Experimental Brain Research, 216(4), 565-574. https://doi.org/10.1007/s00221-011-2960-0

Huang, X. I., Zhang, M., Hui, M. K., & Wyer Jr, R. S., 2014. Warmth and conformity: The effects of ambient temperature on product preferences and financial decisions. Journal of Consumer Psychology, 24(2), 241-250. https://doi.org/10.1016/j.jcps.2013.09.009

Hwang, J., Yoon, S.Y., & Bendle, L.J., 2012. Desired privacy and the impact of crowding on customer emotions and approach-avoidance responses: waiting in a virtual reality restaurant. International Journal of Contemporary Hospitality Management, 24(2), 224 - 250. https://doi.org/10.1108/09596111211206150/full/html

Kaplan, M., 2011. Smart Mouth: Dining in the dark will keep you guessing about what's on your plate. Retrieved November 18, 2020, from https://www.washingtonpost.com/lifestyle/travel/smart-mouth-dining-in-the-dark-will-keep-you-guessing-about-whats-on-your-plate/2011/07/27/gIQAid2KhI_story.html

Kivetz, R., & Simonson, I., 2000. The effects of incomplete information on consumer choice. Journal of Marketing Research 37(4) 427-448. https://doi.org/10.1509/jmkr.37.4.427.18796

Kupers, R., Beaulieu-Lefebvre, M., Schneider, F.C., Kassuba, T., Paulson, O.B., Siebner, H.R., & Ptitio, M., 2011. Neural correlates of olfactory processing in congenital blindness. Neuropsychologia, 49(7), 2037-2044.

Kupers, R., & Ptito, M., 2014. Compensatory plasticity and cross-modal reorganization following early visual deprivation. Neuroscience & Biobehavioral Reviews, 41 (April), 362. https://doi.org/10.1016/j.neubiorev.2013.08.001

Lazzouni, L., & Lepore, F., 2014. Compensatory plasticity: time matters. Frontiers in Human Neuroscience, 8, 340.

Lee, N., Noble, S.M. & Biswas, D., 2018. Hey big spender! A golden (color) atmospheric effect on tipping behavior. Journal of the Academy of Marketing Science, 46(2), p. 317 – 337.

Lefebvre, S., & Biswas, D., 2019. The influence of ambient scent temperature on food consumption behavior. Journal of Experimental Psychology: Applied. https://doi.org/10.1037/xap0000226

Lefebvre, S., & Orlowski, M., 2019. Can, cup, or bottle? The influence of beverage vessel on taste and willingness to pay. International Journal of Hospitality Management, 76, 194-205. https://doi.org/10.1016/j.ijhm.2018.05.009

Lin, L., Hoegg, J., & Aquino, K., 2018. When beauty backfires: the effects of server attractiveness on consumer taste perceptions. Journal of Retailing, 94(3), 296-311. https://doi.org/10.1016/j.jretai.2018.04.003

Liljenquist, K., Zhong, C. B., & Galinsky, A. D., 2010. The smell of virtue: Clean scents promote reciprocity and charity. Psychological Science, 21(3), 381-383. https://doi.org/10.1177/0956797610361426

Mandel, N., Rucker, D. D., Levav, J., & Galinsky, A. D., 2017. The compensatory consumer behavior model: How self-discrepancies drive consumer behavior. Journal of Consumer Psychology, 27(1), 133-146. https://doi.org/10.1016/j.jcps.2016.05.003

Mathe-Soulek, K., Slevitch, L., & Dallinger, I., 2015. Applying mixed methods to identify what drives quick service restaurant's customer satisfaction at the unit-level. International Journal of Hospitality Management, 50, 46 - 54. https://doi.org/10.1016/j.ijhm.2015.07.007

Morrin, M., & Chebat, J. C., 2005. Person-place congruency: The interactive effects of shopper style and atmospherics on consumer expenditures. Journal of Service Research, 8(2), 181-191. https://doi.org/10.1177/1094670505279420

Morrot, G., Brochet, F., & Dubourdieu, D., 2001. The color of odors. Brain and Language, 79(2), 309-320. https://doi.org/10.1006/brln.2001.2493

National Restaurant Association, 2017. Lighting the way to success. Retrieved from https://restaurant.org/Manage-My-Restaurant/Operations/Front-of-House/Lighting-the-way-to-success

Nepomuceno, M. V., Laroche, M., & Richard, M. O., 2014. How to reduce perceived risk when buying online: The interactions between intangibility, product knowledge, brand familiarity, privacy and security concerns. Journal of Retailing and Consumer Service, 21(4), 619 - 629. https://doi.org/10.1016/j.jretconser.2013.11.006

Oberfeld, D., Hecht, H., Allendorf, U., & Wickelmaier, F., 2009. Ambient lighting modifies the flavor of wine. Journal of Sensory Studies, 24(6), 797-832. https://doi.org/10.1111/j.1745-459X.2009.00239.x

Özkul, E., Bilgili, B., & Koç, E., 2020. The Influence of the color of light on the customers' perception of service quality and satisfaction in the restaurant. Color Research & Application, 45(6), 1217-1240. https://doi.org/10.1002/col.22560

Petruzzellis, L., Chebat, J.C., & Palumbo, A., 2014. Hey dee-jay let's play that song and keep me shopping all day long: The effect of famous background music on consumer shopping behavior. Journal of Marketing Development and Competitiveness, 8(2), 756-765. https://doi.org/10.1007/978-3-319-10951-0_278

Piqueras-Fizsman, B., Alcaide, J., Roura, E., & Spence, C., 2012. Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on perception of the food placed on it. Food Quality and Preference, 24, 205 - 208. https://doi.org/10.1016/j.foodqual.2011.08.011

Prescott, J., 2013. Taste matters: Why we like the foods we do. Reaktion Books.

Renner, B., Sproesser, G., Stok, F. M., & Schupp, H., 2016. Eating in the dark: A dissociation between perceived and actual food consumption. Food Quality and Preference, 50, 145-151. https://doi.org/10.1016/j.foodqual.2016.02.010

Ryu, K., & Han, H., 2011. New or repeat customers: How does physical environment influence their restaurant experience? International Journal of Hospitality Management, 30(3), 599-611. https://doi.org/10.1016/j.ijhm.2010.11.004

Scheibehenne, B., Todd, P.M., & Wansink, B., 2010. Dining in the dark. The importance of visual cues for food consumption and satiety. Appetite, 55(3), 710-713. https://doi.org/10.1016/j.appet.2010.08.002

Sietsema, T., 2015. Restaurants Are so Dark These Days It's Impossible to Even Read the Menu: Dim Illumination Is the New Noisy Dining Room, or My Kvetch Du Jour. The Washington Post.

Spence, C., Puccinelli, N. M., Grewal, D., & Roggeveen, A. L., 2014. Store atmospherics: A multisensory perspective. Psychology & Marketing, 31(7), 472-488. https://doi.org/10.1002/mar.20709

Stafford, L. D., Agobiani, E., & Fernandes, M., 2013. Perception of alcohol strength impaired by low and high volume distraction. Food Quality and Preference, 28, 470-474. https://doi.org/10.1016/j.foodqual.2012.12.005.

Stevenson, R. J., Miller, L. A., & Thayer, Z. C., 2008. Impairments in the perception of odor-induced tastes and their relationship to impairments in taste perception. Journal of Experimental Psychology: Human Perception and Performance, 34(5), 1183. https://doi.org/10.1037/0096-1523.34.5.1183

Stewart, P. C., & Goss, E., 2013. Plate shape and colour interact to influence taste and quality judgments. Flavour, 2(27). https://doi.org/10.1186/2044-7248-2-27

Stroebele, N. & De Castro, J. M., 2004. Effect of ambience on food intake and food choice. Nutrition, 20(9), 821-838. https://doi.org/10.1016/j.nut.2004.05.012

Sugar Factory, 201. Menu. Retrieved from https://sugarfactory.com/wp-content/uploads/2016/11/SF_DC_Menu.pdf.

Szocs, C., & Lefebvre, S., 2016. The blender effect: physical state of food influences healthiness perceptions and consumption decisions. Food Quality and Preference, 54, 152-159. https://doi.org/10.1016/j.foodqual.2016.07.009

Thimijan, R. W., & Heins, R. D., 1983. Photometric, radiometric, and quantum light units of measure: a review of procedures for interconversion. HortScience 18(6), 818-822.

van der Heijden, K., Festjens, A., & Goukens, C., 2021. On the bright side: The influence of brightness on overall taste intensity perception. Food Quality and Preference, 88, 1-5. https://doi.org/10.1016/j.foodqual.2020.104099

Wadhera, D. & Capaldi-Phillips, E. D., 2014. A review of visual cues associated with food on food acceptance and consumption. Eating Behaviors, 15(1), 132-143. https://doi.org/10.1016/j.eatbeh.2013.11.003

Wansink, B., & Van Ittersum, K., 2012. Fast food restaurant lighting and music can reduce calorie intake and increase satisfaction. Psychological Reports, 111(1), 228-232. https://doi.org/10.2466/01.PR0.111.4.228-232

Wu, L., He, Z., King, C., & Mattila, A. S., 2021. In darkness we seek light: The impact of focal and general lighting designs on customers' approach intentions toward restaurants. International Journal of Hospitality Management, 92, 1-10. https://doi.org/10.1016/j.ijhm.2020.102735

Xu, A. J., & Labroo, A. A., 2014. Incandescent affect: Turning on the hot emotional system with bright light. Journal of Consumer Psychology, 24(2), 207-216. https://doi.org/10.1016/j.jcps.2013.12.007

Yan, K. S., & Dando, R., 2015. A crossmodal role for audition in taste perception. Journal of Experimental Psychology: Human Perception and Performance, 41(3), 590. https://psycnet.apa.org/doi/10.1037/xhp0000044

Zellner, D. A., Loss, C. R., Zearfoss, J., & Remolina, S., 2014. It tastes as good as it looks! The effect of food presentation on liking for the flavor of food. Appetite, 77, 31-35. https://doi.org/10.1016/j.appet.2014.02.009

7. Appendix

Study 1a and 1b: Glasses used for visual input manipulation