Published in final edited form as:

Food Qual Prefer. 2019 January ; 71: 301–310. doi:10.1016/j.foodqual.2018.08.002.

Sensory variety in shape and color influences fruit and vegetable intake, liking, and purchase intentions in some subsets of adults: a randomized pilot experiment

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Abstract

Dietary variety increases food intake, but it is unclear if sensory differences elicit increases in eating-related behaviors. Using a 4×3 between-subject pilot experiment, we examined if increasing sensory variety (control, color, shape, both color and shape) and priming individuals to notice differences or similarities in the foods (positive, neutral, negative) influenced *ad libitum* proximal intake, liking, and willingness to purchase pears and peppers among 164 Greater Boston adults >18y/o. MANOVA was used to examine associations between sensory variety (independent variable) and six dependent measures. We tested for interactions between sensory variety condition and individual-level factors that may influence food intake. There was no main effect of sensory variety condition for any dependent measure. However, interactions between sensory variety condition and age, overweight status, and prime were detected. Adults with overweight (vs. adults of normal weight) ate more pear with color variety (7.2 vs. 4.4 oz, $p=0.01$). Pear intake was also higher among adults with overweight in the color variety (7.2 oz) vs. combination variety (4.4 oz) condition. Adults >36y/o ate more peppers (3.5 oz) in the color variety condition versus other conditions (2.1–2.2 oz, $p=0.04$). Participants primed to notice differences were more willing to purchase pears in the color variety (5.0 ± 0.5) versus control (3.7 ± 0.5) condition. Color variety

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Authors' contributions: MV designed the study, supervised data collection, analyzed and interpreted the data, and was a major contributor in writing the manuscript. LP coordinated the research assistants, collected data, and was a major contributor in writing the manuscript. VM was a major contributor in writing the manuscript. JM was a major contributor in writing the manuscript and supervising the entire project. All authors read and approved the final manuscript.

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Conflicts of Interest: The authors have no conflicts of interest to disclose.

may modestly increase proximal intake, liking, and purchase intentions for fruits and vegetables in some subsets of adults. Our preliminary findings encourage more research to determine if color variety can be used to improve diet quality of targeted populations.

Keywords

sensory variety; fruit; vegetable; color variety; shape variety; food intake

BACKGROUND

Adequate fruit and vegetable intake is associated with innumerable health benefits including lower risk of chronic disease and overall mortality (He, Nowson, & MacGregor, 2006; Rolls, Ello-Martin, & Tohill, 2004; Veerman, Barendregt, Mackenbach, & Brug, 2006; Wang et al., 2014) and improved weight control (Alinia, Hels, & Tetens, 2009; Rolls, 2012). National statistics suggest that 70–80% of US adults inadequately consume fruits and vegetables, (Blanck, Gillespie, Kimmons, Seymour, & Serdula, 2008; Guenther et al., 2013; Wang et al., 2014) due to barriers including low socio-economic status, (Baxter, Jack, & Schröder, 1998; Kirby, Baranowski, Reynolds, Taylor, & Binkley) poor availability and accessibility (Baranowski et al., 1993; Blanchette & Brug, 2005; Burchett, 2003; Neumark-Sztainer, Wall, Perry, & Story, 2003) and individual taste preferences (Nicklas et al., 2013). While all these barriers are important, palatability remains a primary driver of food choice (McCrickerd & Forde, 2016) and a compelling target, since subtle stimuli can modify food preferences. For example, individuals that tasted a food framed as healthy reported being hungrier and ate more food compared to those who tasted the same item framed as tasty or those who did not eat anything (Finkelstein & Fishbach, 2010). Similarly, research suggests that labeling food as “healthy” reduced consumers’ taste expectations, post-intake taste experience, and overall intake (Raghunathan, Naylor, & Hoyer, 2006).

Visual cues may also be important sensory inputs that stimulate or inhibit food intake (Wadhera & Capaldi-Phillips, 2014). Color in particular has robust associations with perceived palatability and flavor intensity (Wadhera & Capaldi-Phillips, 2014). Greater color contrast between a food and serving dish can enhance taste and flavor expectations, and presenting food in an organized (rather than chaotic manner) further promotes intake (Wadhera & Capaldi-Phillips, 2014). For example, arranging multi-colored candies into distinctive bins, as opposed to presenting people with a mixed dish, may increase enjoyment and intake (Redden, 2008). Conversely, flavor in the absence of color variation may not increase intake (Rolls et al., 1981).

Taken together, this body of work suggests that a number of factors work in concert to increase food enjoyment and stimulate intake, which may be beneficial if directed toward fruits and vegetables. Color variation and discrete food presentation techniques may enhance the perceived variety of the foods served, and several studies have shown that greater food variety enhances the pleasure of eating, and increases short-term food intake for both energy-dense and nutrient dense-foods (Bellisle & Le Magnen, 1981; Epstein, Temple, Roemmich, & Bouton, 2009; Rolls, 1985; Rolls et al., 1981; Spiegel & Stellar, 1990;

Wadhera & Capaldi-Phillips, 2014), including vegetables (Keim, Forester, Lyly, Aaron, & Townsend, 2014; Meengs, Roe, & Rolls, 2012; Parizel, Laboure, Marsset-Baglieri, Fromentin, & Sulmont-Rosse, 2017). It is theorized that people have an innate preferences for variety, and when more foods are available within and across meals, satiety is reduced, and intake increases (Rolls, 1986). It is further hypothesized that the 'variety effect' may be driven by a decrease in sensory-specific satiety, defined as a reduced desire for a food that has just been consumed while appetite for uneaten foods remains high (Rolls, 1986; Rolls et al., 1981). Some evidence suggests that appearance- specific satiety also exists, and that the decline in enjoyment for a particular food is more strongly related to color than to other sensory characteristics like shape (Hetherington, Rolls, & Burley, 1989; Rolls, Rowe, & Rolls, 1982).

Although dietary variety (i.e. different foods) is consistently associated with promoting food intake (Raynor & Epstein, 2001; Vadiveloo, Dixon, & Parekh, 2013), less is known about the extent to which sensory variety (e.g. color and shape) can increase the liking and intake of targeted foods (Epstein, Robinson, Roemmich, Marusewski, & Roba, 2010; McCrory, Burke, & Roberts, 2012). To date, the effect of sensory variety on consumption has primarily been investigated in children and there is a lack of knowledge whether altering and drawing attention to differences in sensory characteristics using discrete food presentation or subconscious priming can increase intake of healthful foods. Similarly, in adults, it is unclear how individual-level differences in other factors that may influence food intake (e.g. age (Rolls & McDermott, 1991), weight status (Brondel et al., 2006; Johnson & Wardle, 2014), or sex (Wansink, Cheney, & Chan, 2003)) modify associations between sensory variety and food intake. Wansink et al. (Wansink, Payne, & Shimizu, 2011) found that pre-portioned packaging only reduced intake among individuals with overweight versus normal weight, potentially suggesting that some external (vs. internal) cues that regulate food intake may have stronger effects on intake in some groups more than others. Existing research has also detected differences in the influence of variety on food intake among women of different body weights (Spiegel & Stellar, 1990).

Therefore, the purpose of the present pilot study was to investigate if increasing sensory variety within fruits and vegetables by manipulating shape, color, or both shape and color within a meal, increased proximal intake, liking, and purchase intentions among adults. To support the hypothesis that greater perceived variety explains differences in the outcome variables, a secondary objective was to explore whether priming individuals to perceive sensory differences (versus sensory similarities or neither) strengthened or attenuated observed associations. Finally, this study explored whether individual-level characteristics modified the effect of sensory variety on study outcomes.

METHODS

Participants

Between February and August 2015, potential participants were recruited from the greater Boston area via flyers, online Craigslist announcements, and active recruitment by research assistants. The eligibility criteria included an age between 18–65 years, the ability to speak English, and no self-reported allergies to fruits and vegetables. Twenty participants were

recruited initially to pre-test our study procedures, but not included in the final study. The targeted sample size was 600 participants, to allow us to detect a small to medium effect size ($n^2 = 0.022$, Cohen's $d = 0.31$) with 80% power and a two-sided $\alpha = 0.05$ for the exploratory 4×3 interaction (Campbell & Thompson, 2012). However, we encountered numerous barriers to participant recruitment including scheduling difficulties, insufficient incentive, severe inclement weather, and unexpected construction in the research space, and ultimately recruited a total of 164 participants for our final analysis. Because the sample size was smaller than intended, we could only detect large effects, and therefore the study is perhaps best considered a pilot. All recruited participants met eligibility criteria. Written informed consent was obtained from all participants, and the Institutional Review Board at the Harvard T.H. Chan School of Public Health approved all study materials and procedures.

Recruited volunteers received a \$10 Amazon gift card as incentive, and were informed that they were participating in a consumer research study on attitudes for locally-grown produce, as a way to prevent the study's true purpose from influencing participants' eating behavior. Prior to scheduling participants, research assistants queried whether they were willing to eat pears and sweet bell peppers. The intervention was conducted in one weekday visit (11 am – 2 pm) estimated to last 40–60 minutes. Pears (red and green) and sweet bell peppers (yellow and red) were selected as test foods because they were readily available in the winter, of high quality, exhibited natural color variation with minimal differences in taste, and are both commonly consumed fruits and vegetables in the US (Produce for Better Health Foundation, 2015; The Packer, 2017).

Study design

We conducted a 4×3 between subject experiment to examine the effect of sensory variety in pears and peppers on food intake, liking, and purchase intentions. Red and green pears and yellow and red sweet bell peppers were used throughout the study. A blocked randomization design was used in order to ensure that the randomization scheme would be preserved regardless of total enrollment, such that every twelve participants enrolled would be randomized to one of the possible combinations. Participants were assigned to receive one of twelve conditions that could arise from four sensory variety treatment conditions (50 blocks of 12): (1) shape sensory variety (slices and cubes of pears in one bin, and of peppers in another bin; all in the same color), (2) color sensory variety (yellow and red peppers, and green and red pears; all in the same shape), (3) shape and color sensory variety (two shapes plus two colors of peppers and pears, in separate bins for peppers versus pears), or (4) control (no variety, one color and one shape of pears and peppers), and one of three priming conditions: (1) positive prime (attending to differences), (2) negative prime (attending to similarities), or (3) control prime (neutral task).

The positive and negative primes involved a thought listing protocol where participants were instructed to list five factors that differed (positive prime) or were similar (negative prime) in a picture of fruits and vegetables. The control prime consisted of a sentence scramble task using neutral words. Within each condition, pears and peppers were presented to participants sequentially and in a balanced manner (i.e. some participants randomly received the pears first, while others received the peppers first).

Procedure

The experiment took place in the Landmark Center cafeteria (located in Boston, MA) between March and July 2015. Before the experiment, the research assistants cut and weighed standardized portions of pears (8 oz (224g)) and sweet bell peppers (5 oz (140g)). The initial portions of pears and peppers that were offered to participants were measured using calibrated food scales and corresponded to approximately three times the standard serving for each food. We selected a larger portion size to ensure that participants would eat until they were sated (rather than until the food was gone), in order to better detect differences between the experimental conditions. Our estimates about pear and pepper acceptance, time to complete the study, and portion sizes were informed by the pre-test with 20 volunteer participants before beginning the study (data not included). Printed copies of all study materials were available at individual tables set up for each participant. Each participant was assigned an ID number, which had been randomized to one of the twelve possible experimental conditions prior to their arrival.

After signing the informed consent, participants were led by a research assistant to a table that corresponded with their randomization condition where they completed the study alone without viewing other participants. Participants were told that they would be evaluating locally- grown pears and peppers. When they sat at the table, participants first completed their assigned priming activity. Then, they were asked to complete a brief demographic questionnaire administered using Qualtrics survey software on iPads, which queried age, sex, race, education, income, height, weight, usual fruit and vegetable intake, and questions about the test foods. The research assistant then provided the participant with a plate of pears or a plate of peppers corresponding to the experimental condition assigned to the participant 186 and instructed the participant to consume them in the amount desired and continue with the Qualtrics survey to respond to questions about the food's palatability, and the participant's dietary habits.

The iPad-administered survey instructed participants to indicate when they had completed consuming the first food, at which point the research assistant cleared their table and provided them with the second test food (pears or peppers, also corresponding to experimental condition) and asked to complete the remainder part of the survey. After participants indicated that they had completed consuming the second food, the research assistant debriefed each participant about the true intention of the study, asked them to re-sign the informed consent, and provided the incentive. The research assistants then weighed the remaining food to determine the amount consumed.

Dependent Variables

(i) Pear and pepper intake: Research assistants provided an 8 oz weighed portion of pears, and separately, a 5 oz weighed portion of peppers to participants (weighed to the nearest tenth of an ounce). After each course, researcher assistants weighed the remainder using calibrated food scales to determine total intake.

(ii) Pear and pepper liking: Participants were queried about their enjoyment of the test foods by rating them using 7-point Likert scales (Likert, 1932). Enjoyment was measured

across several dimensions including an assessment of overall quality (“how was the overall quality of the pears/peppers you ate today”), flavor (“how was the flavor of the pears/peppers you ate today”), taste (“how was the tastiness of the pears/peppers you ate today” and “the pears/peppers I ate today were tasty”). A summary variable was created by averaging these four measures to compute an overall “liking” measure for each test food type. The Cronbach’s alpha levels for the pepper and pear summary measures were 0.92 and 0.93, respectively.

(iii) Pear and pepper purchase intentions: Using 7-point Likert scales, participants were asked about their intentions to purchase the test foods. Purchase intentions were measured with the following 2 questions “I would be likely to purchase these pears/peppers if they were available at my usual grocery store,” and “I would pay more for these pears/peppers if they were available at my usual grocery store.” The Cronbach’s alpha levels for pepper and pear purchase intentions were 0.66 and 0.77, respectively. A summary “willingness to purchase” variable was created by averaging these two measures for pear and pepper purchase intentions, respectively.

Independent Variables:

Sensory variety condition (4-levels initially) was our primary independent variable. Based on our *a priori* hypotheses and existing literature, we tested interactions between sensory variety condition and a number of secondary independent variables: (1) body mass index, (2) age, (3) prime, (4) usual fruit and vegetable intake, and (5) sex.

Body mass index was computed from self-reported height (feet and inches) and weight (pounds) and a binary variable was created to distinguish individuals with overweight (25–29.99 kg/m²) versus individuals of normal weight (18.5 –24.99 kg/m²). Usual daily intake of fruits and vegetables was assessed using the validated National Cancer Institute’s Fruit and Vegetable AllDay Screener (Thompson et al., 2000).

Statistical Methods

We computed descriptive statistics across sensory variety condition using ANOVA. Due to the large number of experimental conditions, we planned *a priori* to combine some sensory variety conditions (e.g. shape, color, or shape and color manipulation) if no differences between those conditions were detected to increase power, particularly since existing research suggests that shape variety influences intake less than other forms of sensory variety (Wadhera & Capaldi-Phillips, 2014). We examined mean intake, liking, and purchase intentions in each sensory variety condition, and tested whether each sensory variety condition differed from the other two sensory variety conditions. Pear and pepper intake and liking were similar across the three sensory variety and control conditions, suggesting no main effect of sensory variety on intake or liking of pears or peppers. Because color variety was the only condition that differed from the other two sensory variety conditions for some dependent measures, we combined the shape (n=42) and shape/color (n=42) variety conditions (herein referred to as combination variety) in final analyses to increase power.

We examined data for normality assumptions, and Pearson correlations were used to examine the correlation between our dependent variables (intake, liking, and purchase intentions). MANOVA was used to examine the main effects of sensory variety condition (primary independent variable) on intake, liking, and willingness to purchase the test foods in three separate models. MANOVA model 1 examined the influence of sensory variety condition (primary independent variable) on pear intake and pear liking (dependent variables). MANOVA model 2 examined the association between sensory variety condition (primary independent variable) and pepper intake and pepper liking (dependent variables). MANOVA model 3 separately examined the associations between sensory variety condition (primary independent variable) and purchase intentions for each food (dependent variables) due to the high correlations ($r > 0.7$) between purchase intentions and liking for both pears and peppers. Post-hoc ANOVA models with Tukey adjustment for multiple comparisons were examined for a single dependent variable only if the overall MANOVA was significant at $p < 0.1$. We also tested whether presentation order significantly influenced any of the dependent measures.

Because dietary intake generally differs by age, sex, and overall healthfulness (Hiza, Casavale, Guenther, & Davis, 2013; Vadiveloo, Dixon, Mijanovich, Elbel, & Parekh, 2015), we conducted exploratory analyses to test for effect modification by age, sex, weight status (BMI categorized as overweight (25–29.99 kg/m²) versus normal weight (18.5–24.99 kg/m²), and usual fruit and vegetable intake. However, due to a reduced sample size, it is important to interpret these results as hypothesis generating. We centered both age and usual fruit and vegetable intake prior to testing the interaction with sensory variety condition. We conducted post-hoc contrasts between meaningful subgroups for any interaction detected at a significance level of $p = 0.10$. If a significant interaction with a continuous covariate was found, rather than use an arbitrary cut-point (e.g. median split), we conducted floodlight analysis; this involved examining the effect of the sensory variety condition at each level of age to detect the point at which the simple effect was significant and the point at which it lost significance (i.e. the Johnson-Neyman Point) (Spiller, Fitzsimons, Lynch, & McClelland, 2013). All analyses were conducted with SAS 9.4.

RESULTS

Results from the original sensory variety and control conditions (40–42 per condition) and priming and control conditions (52–57 per condition) are presented in Supplemental Table 1. Pear and pepper intake and liking were similar across the three sensory variety and control conditions, suggesting no main effect of sensory variety on intake or liking of pears or peppers. Because color variety was the only condition that differed from the other two sensory variety condition, the remaining analyses are presented across three treatment conditions (combination ($n=84$), color ($n=40$) and control ($n=40$)).

Descriptive characteristics of the sample are presented in Table 1. Baseline demographic characteristics did not differ according to assigned sensory variety condition. Study volunteers had a mean age of 34.8 years and were predominately male (>2/3 of participants) and White (55%). Most participants reported having high educational attainment (>70% college graduates), a body mass index in the normal range (24.4 kg/m²), and with usual

intakes of fruits and vegetables of nearly 4 servings per day. No differences were detected for any of the dependent variables (intake, liking, and purchase intentions) across sensory variety conditions (primary independent variable).

Prior to using MANOVA to examine the main effects of sensory variety condition on our dependent measures (pear and pepper intake, liking, and purchase intentions), we examined the correlation between each of the six dependent variables. Pear and pepper intake were significantly and strongly correlated ($r=0.64$, $p<0.0001$), and pear and pepper liking were each weakly correlated with intake of the respective food ($r=0.17$, $p=0.03$ for pears and $r=0.21$, $p=0.01$ for peppers). Finally, pear and pepper liking were strongly correlated with purchase intentions ($r=0.76$, $p<0.0001$ for pears and $r=0.69$, $p<0.0001$ for peppers).

Using MANOVA, we tested for interactions between sensory variety condition (primary independent variable) and prime, weight status, age, sex, and usual fruit and vegetable intake (secondary independent variables). We also tested whether presentation order influenced the dependent variables. Presentation order did not influence the results, and no significant interaction between sensory variety condition and sex (range of p-values: 0.16 – 0.74), or usual fruit and vegetable intake (range of p-values: 0.45 – 0.58) was detected for any of the dependent variables. We detected significant interactions in the MANOVAs between sensory variety condition (primary independent variable) and weight status (secondary independent variable 1) for pear intake and liking ($p=0.06$), between sensory variety condition and age (secondary independent variable 2) for pepper intake and liking ($p=0.09$), and between sensory variety condition and prime (secondary independent variable 3) for pear and pepper purchase intentions ($p<0.1$).

Figure 1 presents pear intake and liking stratified by overweight status (24% of participants). The post-hoc ANOVA interaction between sensory variety condition and overweight status was only significant for pear intake ($p=0.06$). Individuals with a self-reported BMI in the overweight range consumed more pear in the color variety condition than individuals with a self-reported BMI in the normal weight range (7.2 oz vs. 4.4 oz, $p=0.01$); this effect remained significant even after adjusting for age, sex, prime, and usual fruit intake (data not shown). Participants with a BMI in either the normal or overweight range consumed similar amounts in the combination variety and in the control condition. Similarly, adults with overweight consumed more pear in the color variety condition (7.2 oz) as compared to the combination variety (4.4 oz) condition, but similar to the control condition (6.4 oz). No differences for pepper intake were observed among individuals who were overweight versus normal weight.

Pepper intake and liking stratified by sensory variety condition and age are presented in Figure 2; the post-hoc ANOVA was only significant for the interaction between sensory variety and age for pepper intake ($p=0.04$). Floodlight analysis revealed that the effect of age became significant at age 36 (i.e. the Johnson-Neyman Point) (38% of participants ≥ 36 years). Adults ≥ 36 years in the color variety condition had significantly greater pepper intake than adults <36 years in the color variety condition (3.5 ± 0.4 vs. 2.1 ± 0.3 oz, $p<0.05$). Additionally, adults ≥ 36 years in the color variety condition had significantly greater pepper

intake (3.5 ± 0.4) than adults >36 years in the combination variety condition (2.2 ± 0.2), but not significantly different from those in the control condition (2.6 ± 0.3).

Figure 3 presents pear and pepper purchase intentions stratified by sensory variety condition and prime (13–15 participants per cell). The post-hoc ANOVA interaction between sensory variety condition and priming condition was only significant for pear purchase intentions ($p=0.02$). Within the control variety condition, participants were more willing to purchase pears in the negative priming (5.5 ± 0.5) condition as compared to the control (4.0 ± 0.5) or positive (3.7 ± 0.5) priming conditions ($p<0.05$). Within the negative priming condition, willingness to pay for pears was also higher in the control variety (5.5 ± 0.5) versus combination (4.3 ± 0.3) or color (4.0 ± 0.5) variety conditions. Conversely, within the positive priming condition, willingness to pay for pears was lower in the control (3.7 ± 0.5) versus color (5.0 ± 0.5) variety condition.

DISCUSSION

The purpose of this pilot study was to examine whether subtle manipulations in the sensory characteristics of fruits and vegetables and priming individuals to notice those differences could increase proximal intake, liking, and purchase intentions for fruits and vegetables. Overall, our preliminary results did not support the hypothesis that sensory variety influences intake, liking, or purchase intentions for pears or peppers. However, overweight status, age, and priming did modify the associations between color variety and some of the dependent measures, which may be informative for future interventions. After accounting for heterogeneity in responses, the color variety condition appeared to increase proximal intake and purchase intentions among some groups including individuals with overweight (vs. normal weight), adults older than 36 y/o (vs. younger), and adults primed to notice differences (vs. control).

Notably, the color variety condition (as opposed to other variety conditions) seemed to positively influence dependent measures within different subgroups. The positive effect of color on consumption behavior is consistent with previous literature (Piqueras-Fiszman & Spence, 2014), and expands upon it by demonstrating that color variety within the same food may enhance actual intake among some individuals. The ability for color variety to override some people's experience of sensory specific satiety within the produce domain is a promising target for behavioral interventions, given that both fruits and vegetables are under-consumed by many individuals (Rehm, Penalvo, Afshin, & Mozaffarian, 2016). Thus, strategies that augment color variety to increase the perceived variety of an already familiar and accessible fruit or vegetable, such as offering natural color variety packs – like mixed grape, tomato, or small pepper packs – may be an effective and inexpensive strategy to enhance produce intake in target populations.

Although we had initially hypothesized that variety in both shape and color would have the greatest effect on our dependent measures, our results suggest that color variety, rather than shape variety, is more effective, and that manipulating multiple sensory characteristics may negatively influence intake, liking, and purchase intentions. The color manipulation for the pears and peppers was more visually noticeable than the shape manipulation, suggesting that

it may be necessary to use more obvious manipulations to achieve the ‘variety effect’ (Kahn & Wansink, 2004; Redden, 2008). This is consistent with existing evidence in children where manipulating shape to enhance perceived variety did not influence intake as compared to classical variety (Bergamaschi et al., 2016). Furthermore, in some instances, the color variety condition only differed from the combination variety condition and not from the control condition, which supports the notion that excess variety can adversely affect consumer choice (Berger, Draganska, & Simonson, 2007; Iyengar & Lepper, 2000).

It is important to be cautious about this conclusion, however, as it is also possible that other factors related to food presentation affected our results. For example, the color manipulation was achieved using natural variation in the colors of pears and peppers whereas shape manipulation was achieved through human processing, which may have influenced people’s perceptions. Additionally, imposing variety on participants by providing them with pre-plated food may have insufficiently reduced the boredom associated with repeated consumption of a single food (Piqueras-Fiszman & Spence, 2014); it remains to be tested if allowing participants to serve themselves from an assortment of pear and pepper shapes has a stronger effect on sensory-specific satiety, intake and liking. A recent study among normal weight French adults (Parizel et al., 2017) found that only choice (and not variety) increased the intake of well- liked vegetables, and the authors hypothesized that the perceived variety of assortment from three green vegetables was low as compared to other studies where color was also varied. Evidence also suggests the effect of factors like choice and variety may vary based on the extent to which a food is within a preferred versus less preferred category (Parizel et al., 2016). Using choice or variety to increase food intake may only be effective when the food is within a preferred category (e.g. desserts), when it is among dissimilar alternatives (i.e. not different preparations of the same food), or when contextual factors like meal timing are optimal (Parizel et al., 2016). Kahn and Wansink’s work also suggests that asymmetry in the presentation of variety (i.e. unequal rather than an equal distribution of choices) has a stronger effect on consumption, and the present study used a balanced presentation (Kahn & Wansink, 2004). Finally, because our study was underpowered to detect a small to medium effect, it is possible that we were unable to detect small, but meaningful differences in other sensory variety conditions. Thus, this study is perhaps best considered as a pilot, and we urge replication in future studies with larger samples.

Our exploratory findings also suggest that sensory variety may exert a stronger effect on some subgroups than others. We detected an interaction between overweight status and sensory variety condition that may warrant further exploration. Our results suggest that individuals who are affected by overweight may be susceptible to subtle sensory differences that may encourage them to consume larger quantities of a given food. This would be beneficial when the assorted food is healthier (Vadiveloo et al., 2015), or harmful if it is energy-dense (McCrory et al., 1999; Sea, Woo, Tong, Chow, & Chan, 2004). Research suggests that individuals who are affected by overweight have eating behaviors that are more strongly influenced by external cues (Herman & Polivy, 2008), such as sensory variety. Future research should explore whether manipulating external food cues like sensory variety may be an effective strategy to promote eating behavior change among individuals who are affected by overweight. Moreover, using such cues in conjunction with behavioral weight

loss programs may help alter taste preferences to increase acceptance of healthier foods (Demos et al., 2017).

Similarly, there was some suggestion that adults 36 years old were more responsive to the sensory variety manipulation than younger adults. This is consistent with the choice literature, which also finds that age modulates the association between food choice and intake in adults and children (Altintzoglou et al., 2015; Rortveit & Olsen, 2007). A small pilot study also found that women > 65 years old consumed more food when variety within a meal was enhanced (Wijnhoven, van der Meij, & Visser, 2015). Because diet quality tends to improve with age (Imamura et al., 2015), it is possible that adult (vs. young adult) populations are more receptive to subtle cues to increase healthier eating patterns. Making variety manipulations more apparent may be a potential strategy to promote intake, liking, and purchase intentions for these healthy foods among young adults who consume fewer servings of fruits and vegetables compared to other age groups globally (Allman-Farinelli, Partridge, & Roy, 2016).

Finally, the effect of the prime on pear purchase intentions warrants further consideration. Consistent with expectation confirmation theory (Oliver, 1977, 1980), in the control sensory variety condition, participants were most willing to purchase pears when they were primed to think about the similarities between foods, suggesting that the prime strengthened purchase intentions only if the prime and sensory variety condition were aligned (e.g. participants randomized to the control condition with no sensory characteristics manipulated were more willing to buy the pears if they were primed to think about similarities rather than differences). Similarly, in the positive priming condition (i.e. considering the differences), participants were more willing to purchase pears in the color variety (versus other conditions), and in negative priming condition, participants were more willing to purchase pears in the control variety (vs. other conditions). Taken together, this suggests that it is critical for public health advocates or marketers using sensory variety and priming to promote fruit and/or vegetable consumption must proceed cautiously - if differences are not apparent, encouraging consumers to focus on those differences may backfire.

Some limitations of the present study must be noted. First, we were unable to achieve our targeted recruitment of 600 participants, which reduced the power of the study and required the effect sizes to be relatively large in order to detect a statistically significant result. Based on the observed main effect size for pear intake, we only achieved 30% power to detect a difference between the groups should one exist. Given the subtlety of a sensory manipulation, it may not be feasible to achieve a large effect size, and this limitation may have masked modest yet meaningful improvements in fruit and vegetable intake. Additionally, research has previously demonstrated the importance of perceiving the variety of the assortment (Kahn & Wansink, 2004; Redden, 2008), and it is possible that the two shapes (as opposed to the two colors) used in the present study were too visually similar to be perceived as varied by participants randomized to the shape variety condition. Finally, some participants, while willing to consume pears and peppers, indicated that they did not especially enjoy these foods.

Despite these limitations, the present study contributes new insight to the research examining sensory variety and intake, liking, and willingness to purchase healthy foods. The procedure effectively examined *ad libitum* proximal intake of a fruit and vegetable relatively well-accepted by participants. Additionally, while study volunteers were drawn from a convenience sample and may have been more willing to consume fruit and vegetables, participants were racially diverse and with a wide age range, compared to the usual university-based laboratories that conduct these types of studies. By examining multiple dimensions of consumer acceptance (intake, liking, and purchase intentions), we were able to robustly investigate the effect of sensory variety, and examine the consistency of association among these measures. Finally, most research examining sensory variety (particularly color variety) has been conducted in children (Bergamaschi et al., 2016), and often using less healthful foods (Piqueras-Fiszman & Spence, 2014). The present study explored the utility of sensory manipulation in adults using two nutrient-dense foods. Future research could expand upon this work by examining whether individual-level changes are sustained using a pre-post design.

CONCLUSIONS

Taken together, the present pilot study suggests that sensory variety may have a modest influence on the intake, liking, and purchase of fruits and vegetables that is worth further exploration. Adding to existing research (Zampollo, Kniffin, Wansink, & Shimizu, 2012), the present study supports the notion that sensory variety in the absence of food variety may increase both intake and liking of fruits and vegetables for some groups of adults. In particular, color variety may enhance intake, liking, and purchase intentions for fruits and vegetables among certain subgroups of adults including those with overweight status and adults older than 36y. If effective, using sensory manipulation to increase the perception of variety within fruits and vegetables may be especially important since their higher cost and limited access can be barriers for consumption for many adults (Gans et al., 2016; Jennings et al., 2012). Further research is warranted to examine the effect of sensory variety in targeted adult subgroups using multiple healthful foods, and potentially, alternate presentation strategies and more obvious sensory manipulations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

The authors would like to thank Christina A. Roberto, PhD for her role in obtaining the Produce for Better Health grant, her contributions to the design of the study, and for allowing the use of her laboratory to conduct the study. The authors would also like to thank the research assistants (Ludovica Principato (project coordinator), Alvin Chan, Leo Brown, Ngoan Tran Le, Cameron Speyer, Layonne De Sousa Carvalho, and Martha Tamez) who recruited and enrolled participants, prepared the produce, and assisted with data collection.

Funding: This project was supported by a grant from the Produce for Better Health Foundation (MV JM), which was used to support research assistants, participant incentives, and food costs. J.M. was supported by a Mentored Career Development Award to Promote Faculty Diversity in Biomedical Research from the NHLBI (J.M., grant number K01-HL120951), and M.V. was supported by an NIH Ruth L Kirschstein Postdoctoral Fellowship (M.V., grant number 5 T32 DK 7703-19). The Produce for Better Health Foundation and NIH had no role in the study

design, collection, analysis, and interpretation of data, writing the report, or the decision to submit the report for publication.

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Highlights

- Sensory variety did not affect intake, liking, or purchase intentions
- Overweight adults ate more pear and adults 36y ate more pepper with color variety
- Purchase intentions are higher for color-varied pears among primed adults

Figure 1:

Pear intake and liking by sensory variety condition and weight status

Panel A: Pear intake (oz) (Mean $\pm$ SEM) across sensory variety condition and stratified by overweight versus normal weight Panel B: Mean liking scores ($\pm$ SEM) for pears across sensory variety condition and stratified by overweight versus normal weight. Means with different letters (a, b) stand for significant differences ($p < 0.05$) derived from post-hoc contrasts for differences between subgroups

Figure 2:

Pepper intake and liking among adults <36 years and ≥ 36 years by sensory variety condition Panel A: Pepper intake (oz) (Mean ± SEM) across sensory variety condition and stratified by age (≥ 36 years and <36 years) Panel B: Mean pepper liking scores across sensory variety condition and stratified by age (≥ 36 years and <36 years). Means with different letters (a, b) stand for significant differences ($p < 0.05$) derived from post-hoc contrasts for differences between subgroups.

A.

B.

Figure 3:

Pear and pepper purchase intentions by sensory variety condition and prime

Panel A: Pear purchase intentions (±SEM) across sensory variety condition and stratified by prime (negative, control, positive). Panel B: Pepper purchase intentions (±SEM) across sensory variety condition and stratified by prime (negative, control, positive). Means with different letters (a, b) stand for significant differences ($p < 0.05$) derived from post-hoc contrasts for differences between subgroups.

Table 1:

Participant characteristics of Boston-area adults participating in a randomized experiment examining fruit and vegetable intake, liking, and purchase intentions across different sensory variety conditions (n=164)¹

	All Participants (n=164)	Control ² (n=40)	Combination ² (n=84)	Color ² (n=40)	P-value ³
Age (years)	34.8 (14.1)	34.2 (12.7)	35.2 (14.7)	34.7 (12.2)	0.93
Female (%)	31.7	35.0	27.4	37.5	0.46
White race (%)	55.2	50.0	57.1	55.0	0.95
Body Mass Index,⁴ (kg/m²)	24.4 (5.19)	24.0 (5.35)	24.8 (5.33)	24.0 (4.79)	0.63
> College graduate or higher (%)	72.0	70.0	70.2	77.5	0.42
Usual fruit and vegetable intake (servings/d)	3.97 (3.52)	4.21 (4.33)	4.23 (3.29)	3.16 (2.99)	0.26
Dietary Behaviors					
Pear intake (oz)	4.49 (2.59)	4.71 (0.41)	4.18 (0.28)	4.93 (0.41)	0.27
Pepper intake (oz)	2.21 (1.42)	2.25 (0.22)	2.03 (0.15)	2.60 (0.22)	0.09
Pear liking⁵	5.39 (1.33)	4.99 (0.21)	5.56 (0.14)	5.44 (0.21)	0.09
Pepper liking⁵	5.57 (1.22)	5.66 (0.19)	5.58 (0.13)	5.46 (0.19)	0.76
Willingness to purchase pears⁵	4.52 (1.66)	4.41 (0.26)	4.57 (0.18)	4.58 (0.26)	0.89
Willingness to purchase peppers⁵	4.88 (1.45)	5.33 (0.23)	4.69 (0.16)	4.81 (0.23)	0.07

¹Values are presented as mean (SD) or percentages

²Participants in the control condition received a single color and shape of pears and peppers; the combination variety condition represents those initially randomized to receive two shapes of pears and peppers (n=42) and those randomized to receive both two shapes and two colors of pears and peppers (n=42) for a total of 84 participants; these two conditions were combined because no differences between shape and combination variety for our primary dependent measures were detected. Participants in the color variety condition (n=40) received two colors of pears and peppers.

³The p-value is for the overall ANOVA model.

⁴Body mass index (kg/m²) was computed based on self-reported height and weight

⁵Measured using 7-point Likert scales with 1 representing lowest levels of agreement and 7 representing highest levels of agreement.