Assessing Most Effective Estimation Strategy For Food Portions Using An Eye Tracker

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1 ABSTRACT

One common technique for weight loss is the practice of using food journals to increase self-awareness for the eating activity and increase the likelihood of maintaining a normal weight over time. However, users often underestimate their portion sizes when eating a meal or recording their intake in a food journal. This leads to unknowingly overeating despite deliberate self monitoring. Instead of measuring portions in imperial or metric units, sometimes individuals use hand or object size to estimate portions. For example, a serving of pretzels is approximately one ounce, an adult handful, or the size of a tennis ball. The purpose of this study was to see if people are more likely to use a standard measurement tool or the fist to estimate portion size when presented both next to a bowl of food. Also, this study assessed how accurate their estimations were (to the nearest half portion size) based on their object of fixation. It was hypothesized that participants would be more accurate when focusing on the hand in order to estimate the portion size. It was also hypothesized that participants would use the hand more often to estimate portion size. Lastly, it was hypothesized that participants would underestimate portions larger than one serving regardless of object fixation. Results showed a significant difference in accuracy based on condition, $F(2, 27)= 5.017$, $p= .014$. There was not a significant difference in accuracy based on whether participants fixated on the hand or cup first or for total fixation time. This could demonstrate the potential effectiveness of an object, such as a tennis ball or hand, on general estimation attempts. If people are just as accurate at looking at a fist and a measuring device, then they have a handheld portion estimator everywhere they go. This could prove to be a simpler way of helping people reduce their portion size without needing to carry around a food scale or measuring cup.

2 KEY WORDS

Eye tracking, fixations, portion estimation

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3 INTRODUCTION

It is important to establish techniques to aid weight loss due to the growing number of overweight individuals, both in the United States and worldwide. According to the Center for Disease Control in 2016, 37.9 percent of adults in the United States are obese and another 32.8 percent are considered overweight. While there are many diets and methods for losing weight, one prominent method is daily self-monitoring. This is done through the practice of using food journals to increase self-awareness for the eating activity and therefore increase the likelihood of maintaining a normal weight over time. However, users often underestimate their portion sizes when eating a meal or recording their intake in a food journal. This leads to people unknowingly overeating despite deliberate self monitoring.

Instead of measuring portions in imperial or metric units, sometimes individuals use hand or object size to estimate portions. For example, a serving of pretzels is approximately one ounce, an adult handful, or the size of a tennis ball. The purpose of this study is to observe which measurement device (measuring cup or fist) is used more often to estimate portion size and assess the accuracy of the responses. It is hypothesized that participants will be more accurate when focusing on the fist in order to estimate the portion size. Also, it is hypothesized that participants will use the fist more often to estimate portion size. Lastly, it is hypothesized that participants will underestimate portions larger than one serving regardless of object fixation.

4 BACKGROUND

4.1 Self-Monitoring

The number of adults and children in the United States who are overweight is increasing at a steady rate. While there are many diets and aids for losing weight, one prominent method is daily self-monitoring. Self-monitoring is one of the most reliable ways to promote weight loss [2]. This usually takes the form of weight, exercise, or food monitoring. The self-monitoring technique of daily weighing gives individuals a greater sense of self-awareness for their situation and increases the likelihood of maintaining a normal weight over time [20]. Consistent exercise monitoring can lead to significantly greater weight loss and fewer difficulties with exercise than those who do not monitor [4]. Exercise monitoring with smart devices has become a popular trend that gives users a sense of accomplishment. Smart fitness devices, such as Fitbits, allow for goal-setting, provide immediate feedback, and display performance review on the device screen or smartphone application [8].

Goal setting works most efficiently when individuals set personal, attainable goals [11]. Users are able to select their own goals for steps, flights of stairs, miles traveled, and active minutes for the day. Fitbit users receive immediate feedback through device alerts when specific goals have been reached. Performance data

is delivered through alerts or "badges" within the application for completing milestones. Compiled data is delivered weekly to the user via email. These aspects of fitness monitoring encourage users to stay consistently aware of their actions and goals.

Self-monitoring food intake can also be beneficial for losing weight or simply maintaining a healthy lifestyle. Diet diaries are a common means of self-monitoring by tracking daily food intake. There are smartphone applications where users can digitally record daily food intake by scanning barcodes to easily input prepackaged foods. This method works well when used properly; however, users must be willing to consistently input their daily intake. Self-monitoring can also bring unwanted attention to the user, which makes them reluctant to consistently record their data. One of the biggest problems with self-monitoring is the fact that people are bad at estimating proper portion sizes [18].

4.2 Environmental Eating Cues

Environmental cues influence the amount of food an individual consumes rather than what types of food they consume [17]. It is imperative that eaters are aware of these cues because their behavior is often unknowingly changing due to environmental influences. Wansink discusses two main categories of environmental cues that impact total consumption volume per eating activity: the eating environment and the food environment.

The cues from the eating environment, the sensory stimuli surrounding the eater, can have just as big an impact as the presence of food itself. The overall atmosphere of the environment can increase or decrease consumption based on a number of characteristics [17]. Temperature is a significant factor; when the room is cold, more energy is used by the body to warm up and accommodates greater food consumption [19]. Also, dim lighting in an eating area can lengthen eating activity duration and increase comfort. People will feel less inhibited by social factors when consuming food in a darker space [10]. Another factor is the amount of effort needed to access the food supply. When food is already opened, people will be more likely to consume the food than if they have to put forth effort to access the food. This was exemplified by a study where people ate more ice cream when the lid was already off and another where people ate more almonds when they were already shelled [12][15]. Another notable environmental cue is the presence of other eaters. Eating with friends or family increases duration of the meal and comfort in eating a greater amount of food [1]. It has been shown that the number of people eating in a group is positively correlated with food volume consumption. On the other hand, food consumption decreases if there are high levels of self-awareness, such as during job interviews or on a date [5]. Environmental distractions such as reading, watching television, or viewing a sporting event can also have an effect on food consumption. One survey found that the cessation of a particular eating activity for some individuals occurred synchronously with the end of their television program [16]. This demonstrates how eating can be used as a secondary task when taking part in a distracting activity and can lead to consumption beyond necessary levels.

Much like the eating environment, the food environment plays an important role for influencing eat behavior. Food saliency, or the prominence of the food to the eater, is a significant contributing factor to how much food an individual consumes. When food is sensed by the visual and olfactory systems, individuals are more likely to eat - even if not previously anticipating engagement in an eating activity. Another aspect of saliency is the amount of food displayed, particularly when food is purchased in bulk. Food purchased at wholesale stores can take up large amounts of storage space, so individual are more likely to see the item and consume (or over-consume) that food item [6]. In another study, Wansink (2004) assessed total consumption with yogurt flavors, M&M colors, and jelly bean varieties. He found that when multiple food options are available, people will consume significantly greater quantities than when a smaller assortment is present. Another food environmental factor is the size of the container in which the food is served. According to Wansink, this may be due to the fact that larger packages give an altered view of an appropriate amount to consume.

Similarly, using larger bowls, plates, and drinking glasses lead to larger portions served and consumed [18]. People use these containers to estimate appropriate amounts to consume, which can be very misleading. For example, patients at a health care facility took liquid medicine with either a regular spoon or larger spoon; those that used the larger spoon overestimated the dosage size by 22 percent [18]. A study by Scisco and colleagues (2012) examined portion estimation when a fixed amount of JELL-O was divided into different sized pieces. Participants reported that the plate of JELL-O that was divided into more pieces was a greater portion than that divided into fewer pieces[14]. This demonstrates the importance of awareness for portion size when not using specific measurement tools. As mentioned before, people are generally bad at estimating portion sizes. According to Wansink (2004), "determining how much to eat or drink is a relatively low-involvement behavior that is a nuisance to monitor continually and accurately, so they instead rely on consumption norms to help them determine how much they should consume." This is why using a specific measurement tool or object guide can help people make better estimations. For example, a deck of cards is approximately 3 ounces of meat, a computer mouse is one serving of baked potato, and a woman's thumb is about a teaspoon of butter [13]. Promoting awareness of servings consumed during an eating activity can lead to a decrease in overall consumption.

4.3 Eye Tracking Fixation

Eye tracking has been successfully utilized for eating studies in previous work. Doolan et al. (2014) examined visual attention given to low and high energy density foods through a visual probe task[7]. The high energy density foods consisted of items such as pizza and chocolate while the low energy density foods consisted of fruits and vegetables. Data were collected within-subjects in conditions of high satiety (the absence of hunger) and low satiety (the presence of hunger). Regardless of BMI or hunger condition, results demonstrated that participants had greater visual attention for the high energy density foods over the low energy density foods. The significance was greatest for overweight male participants, which could demonstrate an altered reward perspective on food-related visual cues.

One important aspect of eye tracking in this context is the examination of visual attention or fixations on food and food-related items.

According to Starker and Bolt (1990), eye fixations are strongly correlated with a person's interest and attention to the presented stimuli[3]. Fixations are most useful to analyze when there are rules in place to guide the processing of the task. This includes giving the participants a reference point to look for within the stimulus or simply giving them a task that directs their attention. This reduces general scanning of the stimulus and directs eye movements to the specific aspects being examined [9].

5 METHODOLOGY

5.1 Apparatus

Eye movements were tracked in this study using a Gazepoint GP3 eye tracker. This model has a visual angle accuracy of 1 degree, according to the manufacturer. The Gazepoint GP3 recorded eye position at a rate of 60 Hz. The stimuli were displayed on a 22" Dell Professional LED monitor with a resolution of 1680 x 1050 (Figure 1).

Figure 1: Image of participant using Gazepoint GP3 on Dell Professional LED monitor.

5.2 Stimulus

The stimulus used in this study included three different pictures of a bowl of cereal (see Figure 2, Figure 3, and Figure 4). Each picture has a medium-sized human fist to the left and a 1 cup measuring device to the right of the bowl. The first image contains a half portion of cereal in the bowl. The second image contains 1.5 portions of cereal in the bowl. The third image contains 2.5 portions of cereal in the bowl. These portion sizes were chosen to ensure the changes were distinguishable to participants and the difference between the portion sizes were evenly spaced.

5.3 Participants

Thirty participants were recruited for this study via word of mouth. All participants were undergraduate or graduate students at Clemson University (M=21.37, SD=2.70). The mean Body Mass Index (BMI) was 23.98 (SD = 3.25). Zero participants were underweight (less than 18.5), twenty-two participants were "healthy" weight

Figure 2: Bowl of cereal with 1/2 serving.

Figure 3: Bowl of cereal with 1 1/2 servings.

Figure 4: Bowl of cereal with 2 1/2 servings.

(18.5-24.9), seven were overweight (25-29.9), and one was considered obese (30 or greater). Participant data were excluded based

on eye conditions including cataracts, glaucoma, eye implants, or permanent dilation.

5.4 Experimental Design and Procedure

The study was a single factor between-subjects design. The independent variable had three levels: .5, 1.5, and 2.5 portion sizes. Each participant was randomly assigned to one of the three conditions using a random pattern generator in R. Prior to the experiment, participants received an informational letter and gave verbal consent to participate in the study. Next, they completed a short demographic survey that asked for their age, sex, ethnicity, height, weight, and eye conditions (if applicable). Participants with eye conditions were excluded from the study. After the completion of all preliminary materials, the eye tracker position was adjusted and the calibration process was initiated. Once the calibration yielded a satisfactory result, participants were given the instructions for the task. Participants were informed that they would be looking at a photo of a bowl of cereal and would be asked to estimate the portion to the nearest half serving. Next they were verbally given two points of reference for estimating size: one serving of cereal is 3/4 of a cup or about the size of a medium fist. Once participants were given the instructions and had any questions clarified, they were given ten seconds to view the image. At the completion of the ten second period, participants were immediately asked to give their estimation size. Their answer was recorded and they were debriefed on the study.

5.5 Measures and Dependent Variables

The first dependent variable was the object of fixation- the fist, measuring cup, or neither. This variable was measured using fixation time for each area of interest (AOI). AOIs were created to outline the fist (AOI 1) and measuring cup (AOI 2) to assess total fixation time and time of first view within these areas. An AOI was also drawn around the bowl as a third area to reference. The AOI size was kept constant for the fist and measuring cup in all three conditions. The pattern of fixation was also analyzed in order to gain further information on the estimation strategy.

The second dependent variable was accuracy of response to the nearest half portion estimation. This estimation was communicated verbally by the participant and recorded by a researcher immediately following the trial. Accuracy was analyzed as the absolute difference of their answer from the actual value of the portion size.

6 RESULTS

6.1 Effect of Condition on Accuracy

The 0.5 portion condition was the most accurate in terms of absolute difference of estimated value from the portion size (M= .15, SD=.337), followed by the 1.5 condition (M=.55, SD=.369), and lastly the 2.5 condition (M=.7, SD=.483). A one-way ANOVA was conducted to assess mean differences for condition. There was a significant effect for condition, $F(2, 27)= 5.017$, $p= .014$. A post-hoc analysis was conducted given the statistically significant result. Tukey's HSD tests found that the 0.5 condition was significantly different ($p< .05$) from the 2.5 condition. The 0.5 condition was marginally significantly different from the 1.5 condition, but the p-value was greater than 0.05. There was no significant difference in accuracy between the 1.5 condition and 2.5 condition. There was also no significant interaction between object fixation and condition. Figure 5 illustrates the differences in accuracy based on condition.

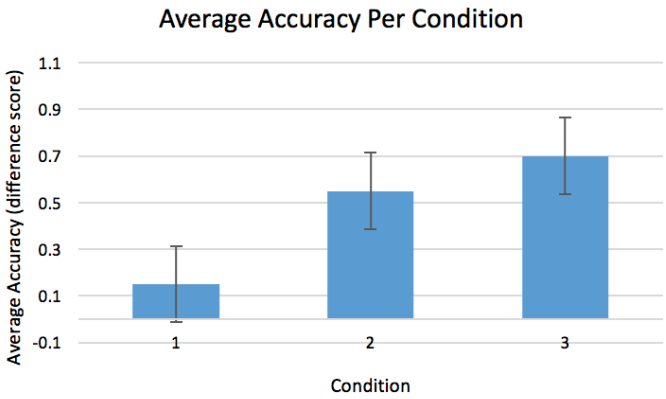

Figure 5: Graph of average accuracy per condition. Accuracy scores are the absolute difference between estimated answer and actual value.

Condition	Average Cup Time	Average Hand Time	Accuracy
1	0.9021	0.6376	0.15
2	0.3024	0.7561	0.55
3	0.7741	0.9216	0.7

Figure 6: Chart depicting average accuracy (in terms of an estimation's absolute difference from the actual value), along with the average time (in seconds) for each condition and area of interest.

6.2 AOI Fixations

83.3% of participants looked at the fist first to estimate portion size. 96.7% of participants looked at the fist at some point during their trial, but only 56.7% of participants looked at the measuring cup. Figure 7 shows the aggregated fixation pattern for condition 3. The bowl accounted for 65.1% of participant fixations during the viewing period. There were no significant differences in accuracy of the estimation between participants that looked at the hand first (M=.44, SD= .416) and those that looked at the cup first (M=.6, SD=.65). Figure 8 illustrates the average fixation duration for each AOI (hand and cup) based on condition. It shows that participants viewed the hand more than the cup, except in condition 1.

6.3 Additional Analyses

Age was separated into three groups: 1 (18-20), 2 (21-24), and 3 (24-27). Group 2 was the most accurate (M=.33, SD= .49), followed

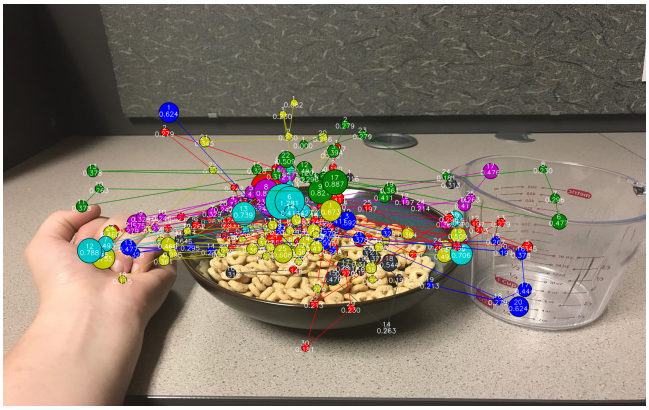

Figure 7: Fixation map for condition 3.

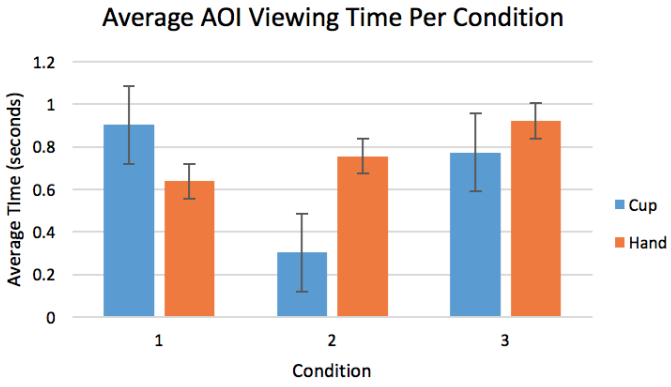

Figure 8: Average time viewing each area of interest per condition.

by group 3 (M=.5, SD= .41), and then group 1 (M=.64, SD= .39). A one-way ANOVA showed there were no significant differences in accuracy based on age. There were also no significant differences based on BMI. Those that were a healthy BMI (M=.43, SD= .47) scored slightly better than the overweight/obese group (M= .56, SD= .42). Not enough data points were collected to analyze group differences based on ethnicity. These will be explained further in the discussion section.

7 DISCUSSION

This study examined the preference of a measuring tool such as a measuring cup to an object estimator like a human fist. Further, the accuracy of the results were assessed based on fixation object and the portion size presented. A Gazepoint GP3 eye tracker was used to measure the areas of interest within the image, specifically in regards to order of first fixation and average fixation time. It was hypothesized that participants would be more accurate when focusing on the hand in order to estimate the portion size. According to the results, this was not the case. Participants were equally accurate when viewing the measuring cup as viewing the fist. This could still demonstrate the potential effectiveness of an object, such as a tennis ball or hand, on general estimation attempts. If people are just as accurate at looking at a fist and a measuring device, then they have a handheld portion estimator everywhere they go. This could prove to be a simpler way of helping people reduce their portion size without needing to carry around a food scale or measuring cup.

It was also hypothesized that participants would use the hand more often to estimate portion size. Almost all participants fixated on the hand at some point during the trial, but only a little over half of participants fixated on the measuring cup. Figure 9 illustrates the areas of interest for condition 3. This supported our hypothesis that participants would have an easier time estimating a portion size with the fist. This could be the result of Americans reading left to right and automatically looking there first. However, that would not explain why half of participants did not even look at the cup during their trial or how the total time viewed was generally higher for the hand. This could be useful as well in helping people estimate portion sizes since participants felt comfortable using the fist as a tool and did not perform significantly worse than the measuring cup group. Lastly, it was hypothesized that participants

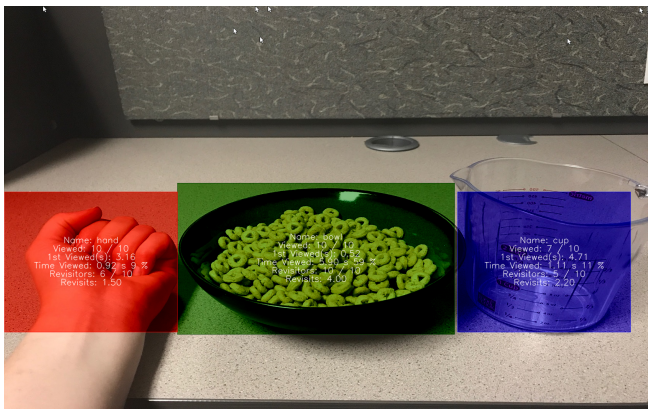

Figure 9: Areas of interest for condition three.

would underestimate portions larger than one serving regardless of object fixation. Participants were the most accurate in the first condition, which was the only condition under one serving. While most participants in the second and third conditions underestimated the portion size, there were a few who overestimated their portion. This demonstrates a general lack of estimation accuracy in both directions. The overestimations could also be due to experimenter effects and knowing that they are in a study. They did not want to underestimate the amount, so they gave a response slightly greater than what they actually thought. The most likely explanation is the fact that people often eat more cereal in one sitting than they think.

Participants in the 0.5 condition were very confident in their choice, often yelling it before the trial was over. They perceived a lack of cereal in the bowl, leading them to conclude that it was less than one portion. Participants in the other two groups were not as sure if it was more or less than one portion. They sometimes hesitated an extra second after the trial ended before answering.

They were also very surprised that their estimation was incorrect, though they did not answer as confidently as the 0.5 condition. This is most likely due to the fact that people usually consume more than one portion of cereal at a time, often just filling up whatever bowl they have all the way. Unless they are on a specific diet, people do not take the time to pour their cereal in a measuring cup before putting it in a bowl. They use the bowl as their portion estimation, which can lead to significant overestimation. This study used a fairly large bowl that could easily hold over three servings of cereal. If asked to estimate portions of a bowl of cereal without the presence of the cup or hand, it is likely that participants would significantly underestimate their portions. This would be an interesting concept to compare in a future study.

7.1 Limitations

Several aspects of the study could be altered in a future iteration in order to improve the validity. First, we had a relatively small sample (10 per condition) that was mostly Caucasian males with a normal BMI. In future studies, a more diverse sample could be used to test for effects of gender, BMI, and ethnicity on their estimation accuracy. Next, we used a convenience sample to gather participants for the study. While this was a fast and inexpensive method, this meant that most people had used an eye tracking device before or were in the school of computing. Participants were not randomly selected, but they were randomly assigned their group.

Another limitation was the fact that we constrained the time participants had to view the image to exactly 10 seconds. Some participants, particularly those in condition 1 (0.5 servings), did not need the entire time to make their guess. Because of this, their eyes could have wandered during the remaining seconds of the trial. This could also explain why more participants in condition 1 viewed the cup more than the other two conditions. Lastly, we did not have a condition that was actually 1 serving, solely to keep the condition intervals evenly spaced (0.5, 1.5, 2.5). In a future study, whole serving sizes should also be compared to these values in order to assess their ease of estimation in comparison to a half serving interval.

8 CONCLUSION

This study demonstrates the usefulness of eye tracking in assessing most effective estimation strategy of portion sizes. Results showed that participants who initially used the hand as their estimation tool were slightly more accurate than those that viewed the cup first; however these did not significantly differ. This shows the effectiveness of using an object, such as a human fist, to estimate portion size. Further, a significant difference was found between portion conditions, meaning that people are better at estimating portions smaller than one serving as opposed to those greater than one serving.

A future iteration could utilize a head-mounted eye tracking device in order to repeat this study with real food and objects placed in front of the participants. Actually viewing a bowl of cereal is different than viewing a photo, so this could be a more reliable way of measuring estimation strategies. Also, this could be used with different foods in order to compare different health levels (unhealthy food versus healthy with same portion sizes) or food consistency (solid foods versus liquid foods). Overall this study suggests that people are inaccurate at portion estimation, but using an estimation tool such as a fist can assist people in making slightly more accurate guesses.

REFERENCES

[1] Bell R, Pliner PL. 2003. Time to eat: the relationship between the number of people eating and meal duration in three lunch settings. Appetite 41:215-18

[2] Burke, L. E., Wang, J., and Sevick, M. A. (2011). Self-monitoring in weight loss: A systematic review of the literature. Journal of the American Dietetic Association, 111(1), 92-102.

[3] Bolt, R. A. (1990, March). A gaze-responsive self-disclosing display. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 3-10). ACM.

[4] Carels, R. A., Darby, L. A., Rydin, S., Douglass, O. M., Cacciapaglia, H. M., and O'Brien, W. H. (2005). The relationship between self-monitoring, outcome expectancies, difficulties with eating and exercise, and physical activity and weight loss treatment outcomes.?Annals of Behavioral Medicine,30(3), 182-190.

[5] Chaiken S, Pliner P. 1990. Eating, social motives, and self-presentation in women and men. J. Exp. Soc. Psychol. 26:240? 54

[6] Chandon P, Wansink B. 2002. When are stockpiled products consumed faster? A convenience-salience framework of post-purchase consumption incidence and quantity.

[7] Doolan, K. J., Breslin, G., Hanna, D., Murphy, K. and Gallagher, A. M. (2014), Visual attention to food cues in obesity: An eye-tracking study. Obesity, 22: 2501-2507. doi:10.1002/oby.20884

[8] Fitbit, Inc. (2017). Why Fitbit. Retrieved from https://www.fitbit.com/whyfitbit

[9] Just, M. A., and Carpenter, P. A. (1976). Eye fixations and cognitive processes. Cognitive psychology, 8(4), 441-480.

[10] Lavin JG, Lawless HT. 1998. Effects of color and odor on judgments of sweetness among children and adults. Food Qual. Pref. 9:283-89

[11] Locke EA, Latham GP. Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey. American Psychologist, 2002 57(9) 705-17.

[12] Meyers AW, Stunkard AJ, Coll M. 1980. Food accessibility and food choice. A test of Schachter?s externality hypothesis. Arch. Gen. Psychiatry 37:1133- 35

[13] Patritto, L. (2013). Estimate food portions with handy, everyday items. Retrieved from http://msue.anr.msu.edu/new/estimate_food_portions_with_handy_everyday_items

[14] Scisco, J. L., Blades, C., Zielinski, M. J., and Muth, E. R. (2012). Dividing a fixed portion into more pieces leads to larger portion size estimates of JELL-O squares. Perception, 41(8), 988-990.

[15] Schachter S, Friedman LN. 1974. The effects of work and cue prominence on eating behavior. See Ref. 115a, pp. 11? 20

[16] Tuomisto, T., Tuomisto, M. T., Hetherington, M., and Lappalainen, R. (1998). Reasons for initiation and cessation of eating in obese men and women and the affective consequences of eating in everyday situations.?Appetite,?30(2), 211-222.

[17] Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers.?Annu. Rev. Nutr.,?24, 455-479.

[18] Wansink B, Van Ittersum K. 2004. Illusive consumption behavior and the DelBoeuf illusion: Are the eyes really bigger than the stomach? In press

[19] Westerterp-Platenga MS. 1999. Effects of extreme environments on food intake in human subjects. P. Nutr. Soc. 58:791? 98

[20] Wing, R. R., Tate, D. F., Gorin, A. A., Raynor, H. A., and Fava, J. L. (2006). A self-regulation program for maintenance of weight loss.?New England Journal of Medicine,?355(15), 1563-1571.