Melanie Gao

Personal Section

Hundreds of years ago, human beings worked with their hands and often walked from place to place. Nowadays, muscle power is no longer in high demand and cars have replaced walking; concurrently, modern society has created cheaper food markets, increasingly more restaurants, and a multi-million dollar fast food industry. Recent technology has decreased the need for physical activity while increasing the availability of food. Though these modern advances are a blessing, they have also brought harmful consequences for the human population. These conveniences cause individuals to consume more calories than they use; in general, people's energy consumption is greater than their energy expenditure. This condition has lead to a recent phenomenon—the obesity epidemic.

First noted in the United States in 1980, the obesity epidemic has since increased twofold in recent decades. In the 21st century, obesity has become one of the leading health problems in the United States; over 34% of all adults age 20 years and over and 18% of all children age 6-11 years are obese (CDC Faststats, *Obesity and Overweight*). In fact, obesity is more prevalent in the United States than in other Westernized country. With obesity comes a vast array of health concerns including hypertension, glaucoma, cardiovascular disease, type 2 diabetes, high blood pressure, certain cancers and heart disease. According to the National Institutes of Health, obesity is one of the leading cause of preventable death in the US, second only to tobacco usage; obesity-related conditions cause approximately 300,000 deaths a year.

As a sophomore in high school, I did not know much about the obesity epidemic and I vaguely understood the concept of eating healthy and exercising regularly. When I first entered the basement of the Neurological Institute of New York, I did not plan on applying to the Intel

Competition nor had I decided to obesity research. Rather, I joined the Columbia University Medical Center's Program for Imaging and Cognitive Sciences (PICS) at the end of sophomore year because a strange fascination with the brain. I found it fascinating how a three-pound pudding of cells and circuits control the thoughts and habits that make up who we are. I was determined to learn more about the brain's function and awaited the many discoveries and surprises ahead with enthusiasm. I was infected with the research bug.

In the lab, I worked on various projects with other researchers in the lab, ranging from an autism study to a study on auditory processes. Independently, I developed an interest in hunger and satiety. At that time, a mentor recommended David Kessler's book, *The End of Overeating*, which revealed shocking statistics about obesity in America and attempted to explain why humans are so attracted to food. I wanted to understand why individuals found food so mouthwateringly attractive, and how the brain normally controls food intake; using the resources provided at the fMRI lab, I hope to better understand and prevent obesity and save lives. David Kessler's book ultimately became the basis for my Intel project investigating how individuals respond to healthy food and junk food, and the particular salience of junk food.

Despite a two-hour commute via boat, subway and bus to the lab on the Upper West Side of Manhattan, I have interned at the lab for almost two years. I had to learn basic computer science and statistics to use the main software at the lab, Presentation, and to analyze data. My experience at the lab has challenged me to think scientifically, tuning myself to ask the right questions. There are just so many questions one can ask that cannot be pursued, for reasons of practicality or time or simply because technology has not advanced far enough. At the same time, there are so many that have been answered in every field of neurology, small steps trekked on the uncharted territory of the brain by hundreds of scientists.

Through my experience at the lab, I have acquired a better understanding of the difficulty of doing science; research is not as picture perfect as it appears in science journals. I have changed my original project idea countless times and repeated the same experiment multiple times. As a scientist, one must have patience and one must truly enjoy doing science. To me, science is a hobby; I enjoy spending time playing around with computer programming, reading science articles, running studies on subjects, analyzing countless data sets and finding the connections that lie underneath beneath the numbers. Research offers me the chance to satisfy an almost insatiable curiosity and a thirst for knowledge and I plan to continue the exploration of science I began in high school. I aspire to impact the scientific world, one data set at a time.

Research Section

Abstract:

In western cultures, food images can be found everywhere in the environment—from large restaurant ads to fast food restaurants located at many intersections. Despite the high prevalence of obesity and eating disorders, the factors and systems that regulate human eating behavior remain poorly understood. Understanding the relationship between control mechanisms and food stimuli and the factors that affect this relationship may provide a better understanding of the factors underlying obesity, and may reveal better methods for individuals seeking to regulate their eating behaviors and maintain a healthy weight. This pilot study developed a unique Stroop paradigm using biologically relevant food images (the "Food Stroop") to investigate the relationship between junk (high-calorie) food, compared with healthy (low-calorie) food, and control mechanisms. To do so, this study evaluated the response times and accuracies of individuals identifying junk and healthy food stimuli in a Stroop task. The analysis was done comparing congruency conditions between each trial and the trial preceding it; analysis of the effect of BMI, gender, age and education level on response times was completed to determine the translational relevance and effect of various demographics. This study revealed

that not only did junk food cues elicit a significantly faster response from individuals, but it also prevented potential conflict and is sustained longer in the memory trace compared to healthy food cues. Junk food is more potent than healthy food is and induces faster processing. This implicates separate neural processing mechanisms for junk and healthy food and suggests that a unique neural network may exist to specifically process junk food images at a significantly faster speed.

1. Introduction:

1.1. Recent Prevalence of Obesity

The recent rise in obesity and food-related disorders is a major source of concern and expense in the US and other westernized countries. In April 2009, Dr. David Kessler, former US Surgeon General, published a best-selling book "The End of Overeating", in which he documents the rise in obesity and food-related health concerns, and identifies the consumption of junk-food as the primary cause. He states that most individuals, despite differences in weight, age and ethnicity, find it difficult to resist junk food. Importantly, Kessler concludes that the primary defense against succumbing to the health perils of junk food must come from the individual's education about junk food's power to overcome their innate cognitive control mechanisms, which control individuals' ability to choose a healthy diet. Unfortunately, very little is known about cognitive mechanisms for controlling one's appetite, specifically in the presence of junk food. In addition, there is little understanding on the difference in responses induced by healthy or "low-calorie" food cues and junk or "high-calorie" food cues. Accordingly, this study specifically investigates, for the first time, a measure of individuals' cognitive control relative to junk-food images. Using a Stroop task, this study was able to identify quantitatively, the power of junk food images to overcome conflict situations and induce faster cognitive processing.

1.2. The Stroop Task

Since its introduction in 1935 (Stroop, 1935), the Stroop task has been used to monitor cognitive conflict and derive models of cognitive control. In a typical Stroop task, the natural processing of task-irrelevant stimuli (distracters) often interferes with an individual's performance on an identification task. In the classic Stroop task, participants are instructed to identify the ink color of a color word in congruent and incongruent conditions. For example, in the congruent condition, the stimuli consists of color words printed with the same color ink (i.e., the word RED printed in red ink), while in the incongruent condition, color words are printed in a different ink color (i.e., the word RED printed in green ink). By comparing the response times in these two conditions, an interference effect can be observed. The conflict in incongruent conditions causes impaired cognitive performance; the "Stroop interference effect" is derived from observations that participants are generally slower to identify ink colors in the incongruent condition than in the congruent condition. These participants are distracted by the word because reading is a more automatic process than color identification and thus, more difficult to inhibit (Macleod & Macdonald, 2000). Interestingly, the interference, or "conflict", produced by incongruent task-irrelevant information in the incongruent condition is reduced if the incongruent trial is preceded by another incongruent trial (incongruent-incongruent), compared with when an incongruent trial is preceded by a congruent trial (congruent-incongruent) (Egner and Hirsch 2005a; Notebaert et al. 2006). The superior performance on the second consecutive task reveals an improved conflict resolution and suggests that the brain can rapidly adjust processing mechanisms when exposed to consecutive conflict situations. This improved conflict resolution mechanism helps overcome the conflict and induces better performance on the second incongruent task. The "Conflict adaptation effect" describes the improved conflict resolution following the presentation of two consecutive incongruent stimuli.

1.3 Food as a Biologically Relevant Stimuli

Food consumption is one of the most important human behaviors. Many factors influence a person's attraction to certain foods; certain physical characteristics of food, such as taste, smell and appearance affect an individual's attraction to food. Furthermore, through learning and experience, the visual characteristics of food can act as reinforcers, capable of inducing eating-related behavior (Lappalainen and Sjoden, 1992; Killgore et al., 2003). Food is salient because, with experience and time, humans have developed an innate response to food and food cues. Even through a passive viewing of pictures of high-calorie or low-calorie food, subjects in fMRI studies have demonstrated activation in the orbitofrontal cortex and the striatum, brain regions usually responsive to physical food stimuli (Wang et al., 2009).

1.5. Aims & Methods

This study designed an experimental protocol with three runs: a trial run and two trial runs. Twenty, right-handed human subjects performed two versions of the Food Stroop; in each version, subjects were shown food images with incongruent and congruent interfering words written across the food image. Subjects were asked to identify the food in the image as a high-calorie JUNK food or as a low-calorie HEALTHY food.

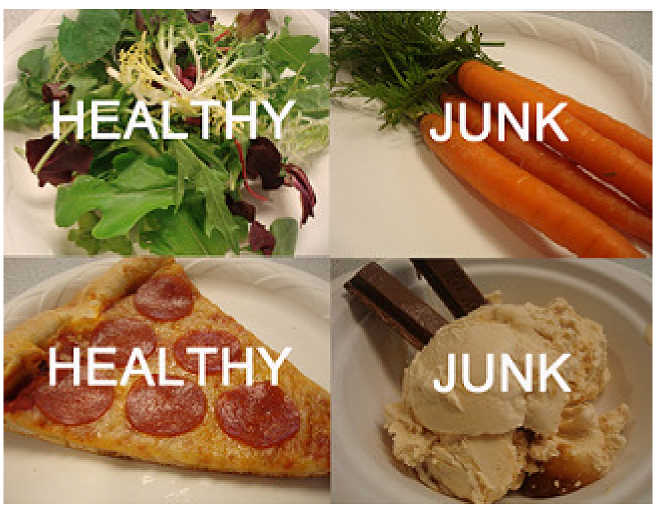


Figure 1. Sample screens. To the left are four trials from the actual study; in the study, each trial would be displayed separately. 74 colorful food images (37 junk and 37 healthy) were presented with either HEALTHY or JUNK superimposed in white letters, creating 148 Stroop trials (74 incongruent, 74 congruent) in each

3. Results:

3.1. Behavioral Results for the food Stroop task

At debrief, no participants reported the use of specific strategies to "override" the innate interference effects of the food Stroop task. Two immigrant participants were removed from the data analysis due to culture confounds; they had difficulty categorizing typical "American" food. The food Stroop task revealed the main effect of congruency, as individuals responded slower to incongruent trials (average reaction time 658 ms), the interference effect, than congruent trials (average reaction time 612 ms). These results are comparable with those obtained in previous studies of the Stroop Task (e.g., Barch et al., 2001; Egner and Hirsch, 2005b). Reaction times for healthy and junk images relative to the Stroop task reveal that the conflict effect existed for both healthy and junk images.

Figure 2
Descriptive statistics of Stroop (averages)

Trial	Food Stroop	
	RT (ms)	SD
CC	617	65
CI	673	101
IC	637	82
II	641	87

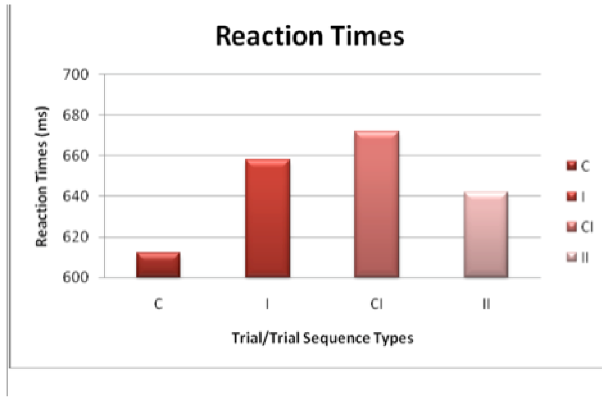


Figure 2. Note: Data are split by prior and current trial congruency. CC = prior trial congruent-current trial congruent; CI = prior trial congruent-current trial incongruent; IC = prior trial incongruent-current trial congruent; II = prior trial incongruent-current trial incongruent; C = all congruent trials; I = all incongruent trials.

3.2. Healthy Food vs. Junk Food and Conflict Adaptation

Participants reported a slightly greater sensation of hunger after the completion of the study. Results revealed that subjects consistently responded with a faster reaction time to junk stimuli compared to healthy stimuli. When the analysis was extended to find the impact of the prior trial, the conflict adaptation effect described in previous Stroop studies (Kerns et al. 2004; Egner and Hirsch 2005a; Notebaert et al. 2006; Egner et al., 2007) was observed. Individuals responded on average 32 ms ± 1.3 faster on an incongruent stimuli preceded by an incongruent stimuli (incongruent-incongruent) than when preceded by a congruent stimuli (congruent incongruent). Congruent stimuli preceded by an incongruent stimulus (incongruent-congruent) received a slower response than congruent stimuli preceded by a congruent stimulus (congruent-congruent). *Figure 2* documents the conflict adaptation effect for the food Stroop. In addition, the trials in the study were separated into two data sets for analysis: the “Healthy” Stroop and the “Junk” Stroop. The main effect of congruency was observed in both the healthy Stroop and the junk Stroop. Individual reaction times to healthy images relative to the Stroop task were consistently slower than reaction times to junk food images ($p < 0.05$). By comparing the impact of the prior trial on the Healthy Stroop and the Junk Stroop, a greater difference was observed between the congruent-incongruent sequence and the incongruent-incongruent sequence in the Junk Stroop as compared to the Healthy Stroop. The presentation of an incongruent trial subsequent to an incongruent trial in the Healthy Stroop led to a 20 ms average response; in comparison, individuals responded, on average, 44 ms faster after the presentation of the second consecutive incongruent trial. *Figure 3* illustrates the "Healthy" Stroop and the "Junk" Stroop.

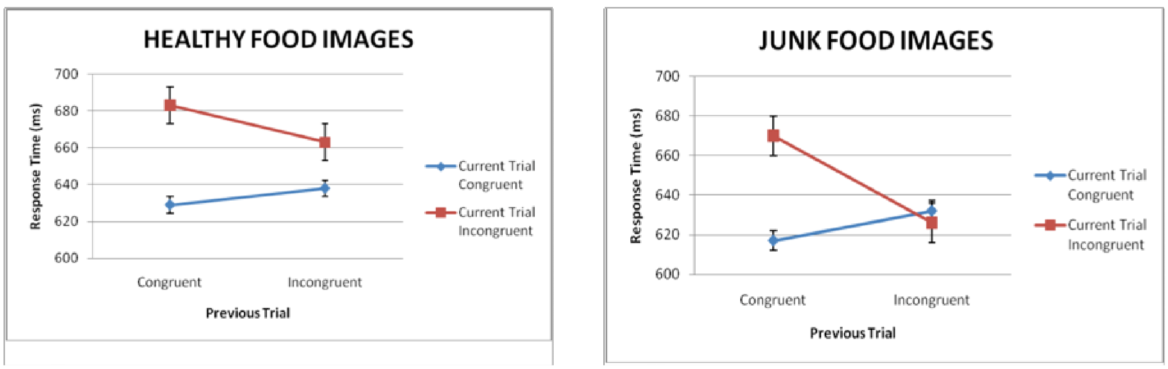
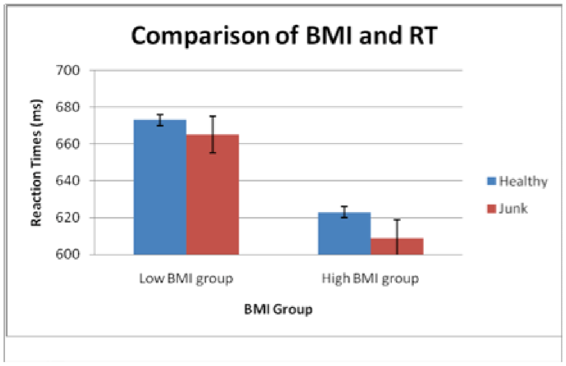


Figure 3. The red line depicts the reaction times of the current incongruent trial when it is preceded by a congruent trial and an incongruent trial. The blue line depicts the reaction times of the current congruent trial when followed by a congruent trial and an incongruent trial. Note the significant difference from the CI point to the II point in the junk food graph compared to the healthy food graph. Note, also the faster response times in the junk graph.

3.4. Analysis of Results using BMI, Age, Education Level

Acquiring a disparate participant pool enabled us to compare the interactions effects of body mass index (BMI), gender, age, and education level with responses to certain food images. To analyze the relationship between BMI and responses to food, all included participants were separated into a "high BMI" data group (*M 26 ± 3.7)* or a "low BMI" data group (*M 21.5 ± 0.8)*. The results showed that the nine individuals in the "high BMI" data group responded faster than the nine individuals in the "low BMI" group ($p < 0.05$). This suggests that high-BMI participants found food stimuli more powerful than low-BMI participants did. Subjects with a higher BMI exhibited a greater difference in response rates between Healthy and Junk food images than participants in the "low BMI" group. Figure 4 describes the statistics of behavioral data for the BMI comparison.



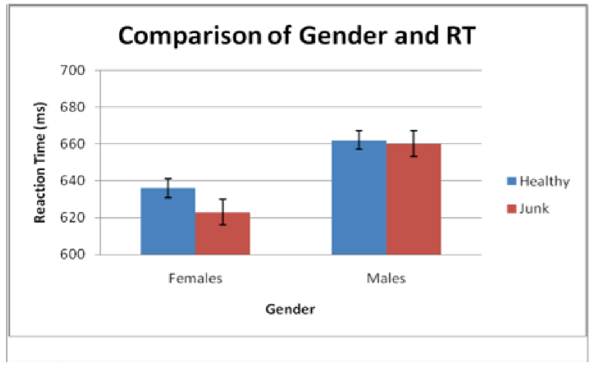


Figure 4. BMI and RT comparisons: Note the faster reaction times from the "low BMI" group compared to the "high BMI" group. Gender and RT comparisons: Note the difference between the reaction times for females compared to males.

Participants were separated into two groups to analyze the relationship between age and response to food stimuli: the 20-40 years old group and the 40-60 years old group. The younger participants in the 20-40 year old range responded faster to food stimuli than the older participants in the 40-60 year old range ($p < 0.05$). Subjects in the 20-40s exhibited the greatest difference in response rates to healthy and junk food stimuli.

Subjects' response rates relative to gender were analyzed; both conflict effect and resolution in both females and males was observed. Interestingly, in this study, the ten females responded faster to food stimuli than the eight males ($p < 0.05$). This information further validates a previous study on women's weaker inhibition of food stimuli compared to men (Wang et al., 2009) by revealing women's specific attraction to junk stimuli. See *Figure 4* for the descriptive statistics for the gender and reaction rate comparison.

4. Discussion:

In this investigation, we examined the hypothesis that high calorie, or "junk" food items are more salient and powerful than "healthy" food items and in addition, have the power to quickly overcome conflict situations. This is the first reported study using a healthy-junk food

Stroop to examine how the brain responds to the visual presentation of foods that differ according to caloric content and therefore, in salience.

By using a food Stroop to test for cognitive control relative to food images and assessing the behavioral effects of conflict and conflict resolution, we obtained three main findings. First, we observed the prepotency of junk as an image as individuals responded significantly faster to the passive presentation of high-calorie "junk" food stimuli relative low-calorie "healthy" food stimuli. Second, the Junk Stroop effect is less than the Healthy Stroop effect as the difference between the average response times of congruent and incongruent stimuli is smaller in the Junk Stroop than the Healthy Stroop. Third, analyzing the impact of the prior trial revealed the conflict adaptation effect produced by sequential incongruent stimuli in the Food Stroop are similar and comparable to those observed in the nonemotional (Egner and Hirsch 2005b) and emotional (Etkin et al., 2006) tasks. Upon comparison of the healthy Stroop and the junk Stroop, we observed a significantly greater difference in response rate between congruent-incongruent trials and incongruent-incongruent trials in the Junk Stroop than in the Healthy Stroop. We also observed that participants with higher BMI responded to food stimuli, particularly junk food stimuli, faster. In addition, women had faster reaction rates than men in this Stroop task, younger individuals responded faster than older individuals did, and a greater education level reflected slower response rates for healthy and junk stimuli.

The main goal of the study was to probe a measure of individuals' cognitive control relative to two types of food stimuli: junk-food stimuli and healthy food stimuli. The use of a Stroop task is ideal for investigating cognitive control and conflict adaptation; in a Stroop task, individuals must consciously ignore a distracter while performing an identification task. In this study, we designed a Stroop task, using food images as stimuli, similar to the conflict tasks used in the selective attention literature (Etkin et al., 2006); results of the study revealed that using healthy and junk food stimuli reliably produced a Stroop effect comparable to the traditional Stroop task and other Stroop tasks (Stroop, 1935). In addition, comparisons of reaction times elicited by junk food images compared to healthy food images for participants revealed the strength of junk stimuli; individuals, on average, responded with significantly lower reaction times to junk food images. Since the task in this study was to categorize the caloric content of a food image as "healthy" or "junk", the results of the study demonstrate that individuals are much better at identifying junk cues compared to healthy cues, revealing that junk cues are processed faster than healthy cues. Participants reported a slightly greater sensation of hunger after the completion of the study. We attributed this effect to the appetitive nature of junk food. The results of the simple comparison between average reaction rates for healthy and junk stimuli further validate previous findings of the high saliency of junk food (Killgore et al., 2003; Stoeckel et al., 2008; Kessler, 2009).

Not only did participants respond to junk food images faster than healthy food images, but further analysis of the Healthy Stroop and the Junk Stroop also revealed that the Healthy Stroop is greater than the Junk Stroop. The Stroop effect implies that individuals respond faster to congruent stimuli than to incongruent stimuli. In this study, we observed this classic Stroop effect, but in addition, we noticed that the difference between the average of the incongruent stimuli and the average of the congruent stimuli was comparatively greater for the healthy stimuli than the junk stimuli. Individuals responded to the incongruent junk stimuli much faster than they responded to the incongruent healthy stimuli, providing evidence that despite conflict, junk retains its strength and lessens the impact of the Stroop effect. Figure 6 illustrates the difference in average response times to healthy and junk incongruent stimuli. Junk cues are so salient that it does not take much thinking to process junk food. Junk food is very potent and prevents the interference of the task-irrelevant stimuli; it prevents conflict and helps overcome conflict during incongruent tasks. Although previous studies have revealed that a neurological networks exists for both healthy and junk food (Stoeckel et al., 2008), this study validates that claim and provides further evidence for the prepotency of junk cues and junk food. Results suggest the neural mechanism used by the brain to identify healthy stimuli is not as sustained as the neural network that recognizes junk food. The neural mechanism for junk food is more reinforced and thus, less palatable to distractions, hence the superior performance on incongruent tasks.

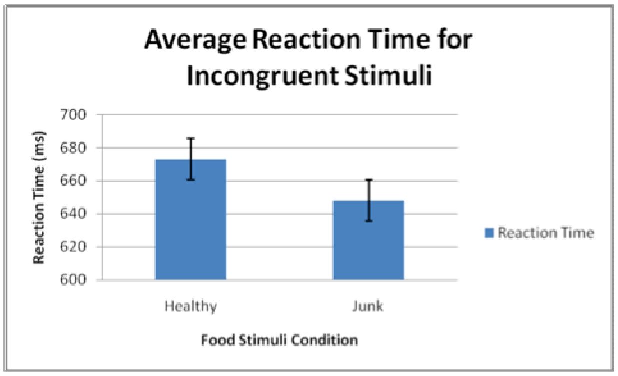


Figure 5. Participants responded with faster reaction times to junk stimuli compared to healthy stimuli.

Extending analysis to the impact of the prior trial revealed the effect produced by sequential incongruent stimuli in this Food Stroop are consistent with the conflict and conflict resolution effects found in previous Stroop studies (Botvinick et al., 1999; Egner and Hirsch, 2005b; Etkin et al., 2006). We interpreted the sequence effects as reflecting the workings of a cognitive control mechanism protecting the task-relevant information from interference from task-relevant information. Furthermore, we separated the healthy stimuli from the junk stimuli and for each case, dubbed the "Healthy Stroop" and "Junk Stroop" respectively, reexamined the reaction times for the presence of the Stroop effect and the conflict adaptation effect. Results revealed that the conflict adaptation effect existed for both the junk stimuli and the healthy stimuli. We noted, however, that the difference between the reaction time of a second incongruent stimulus following an incongruent stimulus (incongruent-incongruent) and the reaction time of an incongruent stimulus following a congruent stimulus (congruent-incongruent) in the Junk Stroop is significantly greater than the difference between the sequences in the Healthy Stroop. See Figure 6 for a descriptive documentation of these differences. Interestingly, after simple calculations in which we subtracted the speed advantage from the junk food (calculated to be 17 ms; $p < 0.05$) from the improved performance on the II trial, we found the conflict adaptation effect of the healthy (*M 198*) and the junk stimuli (*M 175*) to be similar. This reveals that the significant speed difference in the Junk Stroop from CI to II is the result of both a conflict adaptation effect and the quicker speed of cognitive processing of junk food images. These results suggest that junk food has a longer memory trace compared to healthy food; a 1.5 s presentation of junk food lingers in the memory and facilitates the superior performance on a subsequent incongruent trial, once again providing evidence for the power of junk food. This effect is not as apparent in the healthy stimuli. In addition, we provide further confirmation of Dr. David Kessler's work. If healthy and junk are the same, the Stroop should be the same. However, as our data suggests, this is not the case—junk food is different and is processed differently than healthy food.

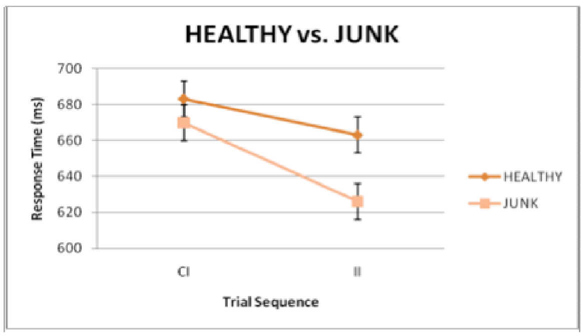


Figure 6. This graph describes the differences in response times to incongruent healthy and junk food stimuli relative to the condition of the prior trial. Note: CI = prior congruent trial-current incongruent trial. II = prior incongruent trial-current incongruent trial

In this current study, we compared the reaction times from nine participants with "high BMI" and nine participants with "low BMI". Certain participants in the "high BMI" data group were overweight or obese. We observed extensive differences between individuals with "high BMI" and "low BMI" as participants with high BMI responded faster to food stimuli than participants with low BMI. Interestingly, we noted that individuals with high BMI responded faster to junk stimuli in particular than healthy stimuli. This difference was not as apparent for individuals in the low BMI group.

Analysis of various demographic characteristics (gender, age, and education level), and reaction times to junk and healthy food stimuli were consistent with previous behavioral and neurological studies. We observed that the ten females responded significantly faster to food stimuli than the eight males in the study, reinforcing a recent finding regarding women's weak inhibition of food stimuli compared to men (Wang et al., 2009). Lower cognitive control and faster response rates to food stimulation may contribute to gender differences in the prevalence of obesity rates and other eating disorders. We also observed that individuals with a graduate-level education responded as lower response rates for both healthy and junk stimuli. Those with only a high school degree responded faster to the food stimuli. In addition, an analysis probing the interplay of age on responses to food revealed that the younger individuals (aged 20-30s) responded significantly and consistently faster than older adults (40-60s) did to food cues and to junk food cues, in particular. This information reveals the vulnerability of younger individuals to food cues and suggests that younger individuals are more attracted to food cues, especially junk food cues in particular. In this study, young individuals and women's fast response rates imply an innate neurological attraction to food cues and may predispose them to overeating.

5. Conclusions:

In summary, our behavioral study reveals three main finding regarding the prepotency of junk food. First, junk food is processed faster than healthy food as demonstrated by a faster reaction time; second, junk food is so salient that it lessens the impact of the Stroop effect and nearly overcomes the conflict; and third, junk food remains in the memory trace longer, as demonstrated by the significant speed in junk in the trial pairing of conflict adaptation. These results strongly support previous studies that observe and predict the salience of junk food and reflect real world observations of the attraction of junk food: once you see that cookie, it remains in your mind and encourages eating-related behavior. Moreover, we noted that individuals with a high BMI, women and younger individuals responded with a faster reaction time to food cues, but to junk cues in particular, suggesting an innate attraction to junk food that may predispose them to overeating and weight gain.

References:

Bishop S, Duncan J, Brett M, Lawrence AD. 2004. Prefrontal cortical function and anxiety: controlling attention to threat-related stimuli. Nat Neurosci. 7:184—188.

Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD. 2001. Conflict monitoring and cognitive control. Psychol Rev. 108:624-652.

Egner T, Hirsch J. 2005a. The neural correlates and functional integration of cognitive control in a Stroop task. NeuroImage. 24:539-547.

Egner T, Hirsch J. 2005b. Cognitive control mechanisms resolve conflict through cortical amplification of task-relevant information. Nat Neurosci. 8:1784-1790.

Etkin A, Egner T, Peraza DM, Kandel ER, Hirsch J. 2006. Resolving emotional conflict: a role for the rostral anterior cingulated cortex in modulating activity in the amygdale. Neuron. 51:871-882.

Hommel B, Proctor RW, Vu KP. 2004. A feature-integration account of sequential effects in the Simon Task. Psychol Res. 68:1-17.

Kerns JG, Cohen JD, Macdonald AW, 3rd, Cho RY, Stenger VA, Carter CS. 2004. Anterior cingulated conflict monitoring and adjustments in control. Science. 303:1023-1026.

Killgore W, *et al.* 2003. Cortical and limbic activation during viewing of high-versus low-calorie foods. NeuroImage. 19:1381-1894.

Kessler DA. 2009. The End of Overeating. New York, NY: Rodale Inc.

Lappalainen RI, Sjoden PO. 1992. A functional analysis of food habits. Scand. J. Nutr. 36:125-133.

MacDonald AW, 3rd, Cohen JD, Stenger VA, Carter CS. 2000. Dissociating the role of the dorsolateral prefrontal and anterior cingulated cortex in cognitive control. Science. 288:1835-1838.

MacLeod CM. 1991. Half a century of research on the Stroop effect: an integrative review. Psychol Bull. 109:163-203.

Mathews AM, MacLeod C, 1985. Selective processing of threat cues in anxiety states. Behav Res Ther. 23:563-569.

Mayr U, Awh E, Laurey P. 2003. Conflict adaptation effects in the absence of executive control. Nat Neurosci. 6:450-452.

Notebaert W, Gevers W, Verbruggen F, Liefooghe B. 2006. Top-down and bottom-up sequential modulations of congruency effects. Psychon Bull Rev. 13:112-117.

Rothemund Y, *et al*. 2007. Differential activation of the dorsal striatum by high-calorie visual food stimuli in obese individuals. NeuroImage. 37:410-421.

Stoeckel LE, Weller RE, Cook III EW, Twieg DB, Knowlton RC, Cox JE. 2008. Widespread reward-system activation in obese women in response to pictures of high-calorie foods. NeuroImage. 41:636-647.

St-Onge M-P, Sy M, Heymsfield SB, Hirsch J. 2005. Food-related brain activity: a functional magnetic resonance imaging study. J Nutr. 135:1014-8.

Stroop JR. 1935. Studies of interference in serial verbal reactions. J Exp Psychol. 18:643-662.

Volkow ND, *et al*. 1999. Methylphenidate and cocaine have a similar in vivo potency to block dopamine transporters in the human brain. Life Sci. 65:7-12.

Vuilleumier P, Armony JL, Driver J, Dolan RJ. 2001. Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. Neuron. 30:829-841.

Vuilleumier P, Richardson MP, Armony JL, Driver J, Dolan RJ. 2004. Distant influences of amygdale lesion on visual cortical activation during emotional face processing. Nat. Neurosci. 7:1271-1278.

Wang GJ, Volkow ND, Telang F, Jayne M, Ma Y, Pradhan K, Shu W, Wong CT, Thanos, PK, Feliebter A, Biegon A, Fowler JS. 2009. Evidence of gender difference in the ability to inhibit brain activation elicited by food stimulation. PNAS. 106:1249-1254.

Williams JM, Mathews A, Macleod C. 1996. The emotional Stroop task and psychopathology. Psychol Bull. 120:3-24.