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Age-Related Differences in Food-Specific Inhibitory Control: Electrophysiological and Behavioral Evidence in Healthy Aging

Whitney D. Allen
Brigham Young University

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Whitney D. Allen

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Michael J. Larson, Chair
Chad D. Jensen
James LeCheminant

Department of Psychology

Brigham Young University

ABSTRACT

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Whitney D. Allen
Department of Psychology, Brigham Young University
Master of Science

The number of older adults is estimated to double from 52 million to 95 million by 2060. Approximately 80-85% of older adults are diagnosed with a chronic health condition. Many of these chronic health conditions are influenced by diet and exercise, suggesting improved diet and eating behaviors could improve health-related outcomes. One factor that might improve dietary habits in older adults is food-related inhibitory control. We tested whether food-related inhibitory control, using behavioral (response time, error rate) and scalp-recorded event-related potential (ERP; N2 and P3 components) measures of food-related inhibitory control differed between younger and older adults over age 55. Fifty-nine older adults (31 females [52.5%], M_{age}=64, SD_{age}=7.5) and 114 younger adults (82 females [71.9%], M_{age}=20.8) completed two go/no-go tasks, one inhibiting to high-calorie stimuli and one inhibiting to low-calorie stimuli, while electroencephalogram (EEG) data were recorded. Older adults had slower overall response times than younger adults, but this was not specific to either food task. There was not a significant difference for accuracy between younger and older adults, but both groups' accuracy and response times were significantly improved during the high-calorie task than the low-calorie task. For both the N2 and P3 ERP components, younger adults had greater amplitude than older adults, but this effect was not food-specific, reflecting overall generalized lower inhibitory processing in older adults. Of note, P3 amplitude for the younger adults demonstrated a specific food-related effect (greater P3 amplitude for high-calorie no-go) that was not present for older adults. Findings support previous research demonstrating age related differences in inhibitory control though those differences may not be specific to inhibiting to high-calorie foods.

Keywords: food-related inhibitory control, cognitive aging, older adults, N2 ERP, P3 ERP

TABLE OF CONTENTS

ABSTRACT ii
Table of Contents iii
LIST OF TABLES AND FIGURES iv
1. Introduction 1
2. Methods 7
2.1 Participants 7
2.2 Sensitivity Analysis 8
2.3 Experimental Protocol 8
2.3.1 Inhibitory Control Tasks 10
2.3.2 EEG Data Acquisition and Analyses 11
2.3.3 ERP Reliability Analyses 12
2.4 Statistical Analyses Plan 13
2.4.1 Demographic Information 13
2.4.2 Manipulation Check: Visual Analog Scales. 13
2.4.3 Behavioral Data and Event-Related Potentials 13
3. Results 14
3.1 Demographic Information 14
3.2 Manipulation Check: Visual Analog Scales 14
3.3 Behavioral Results 15
3.4 Event-Related Potentials 16
N2 ERP Component 16
P3 ERP Component 18
3.5 Role of Biological Sex and Body Mass Index 20
4. Discussion 22
5. Summary and Conclusions 31

LIST OF FIGURES AND TABLES

Figure 1. Grand average ERP Waveforms for the P3 and N2 amplitude 49

Table 1. Dependability estimates for each group, condition, and ERP, for correct trials..... 50

Table 2. Demographic Information..... 51

Table 3. Visual analog scale (VAS)..... 52

Table 4. Means of response times (in ms) and accuracy divided by group 53

Table 5. Means of ERP amplitude for the P3 and N2 components by task..... 54

Age-Related Differences in Food-Specific Inhibitory Control: Electrophysiological and Behavioral Evidence in Healthy Aging

The risk of developing chronic diseases, such as coronary heart disease, cardiovascular disease, and cancer, increases with age (Niccoli & Partridge, 2012). Approximately 80-85% of older adults (ages 65+) in the United States are living with a chronic health condition, with 50-60% living with two or more conditions (Dwyer et al., 1991; Wan et al., 2005; Ward et al., 2014). Many of these chronic health conditions are influenced by diet and exercise, suggesting that improved diet and eating behaviors in older adults could improve incidence rates and outcomes (Dwyer et al., 1991; Ford & Mokdad, 2001; Joshipura, 1999; Liu et al., 2000; Saffel-Shrier et al., 2019; Steinmetz & Potter, 1996). Declines in mobility and the ability to perform activities of daily living in older adults are also associated with a poor diet (Agarwal et al., 2019; Parsons et al., 2019). Despite the connection between diet and physical health, the majority of older adults do not adhere to current nutrition and dietary recommendations (Andrés et al., 2008; Aschenbrenner & Balota, 2015; Boeckner et al., 2007; Foote et al., 2000; Guenther et al., 2006; Larson et al., 2016; Ledikwe et al., 2004; Saffel-Shrier et al., 2019; Vitolins et al., 2007). Specifically, older adult diet can be improved by increasing intake of whole grains, fruits, vegetables, legumes, and dairy products, while decreasing intake of sodium, solid fats, and added sugars (Johnson et al., 1998; Prochaska et al., 2006; Saffel-Shrier et al., 2019; Sahyoun et al., 2006).

Poor diet in older adults is also linked to negative cognitive and mental health outcomes (Starr et al., 2015). Inadequate consumption of micronutrients, such as choline and Vitamin B_2, is associated with poorer memory and cognitive functioning (Angeloni et al., 2020; Donini et al., 2013; Goldberg et al., 2019). Consumption of foods rich in nutrients, such as fruits, vegetables, and seeds, help reduce normal age-related cognitive decline and the development of

neurodegenerative diseases (e.g., Alzheimer's disease), potentially by reducing neuroinflammation (Angeloni et al., 2020; Donini et al., 2013). Poor nutrition has also been connected with low morale and increased depression, loneliness, and bereavement to loss in older adults (Starr et al., 2015).

Of note, the population of older adults in the United States is on the rise, with the numbers of older adults estimated to double from 52 million (2018) to 95 million by 2060 (U.S. Census Bureau, 2018). Given the rapid growth of the older adult population in the United States (Administration for Community Living, 2020), the physical and mental ailments that are related to poor dietary practices in older adults will also continue to grow. These ailments affect the quality of life for many individuals, but also place a significant economic burden on individuals and agencies that pay health care costs associated with treatment, hospitalization, and long-term care (Harris-Kojetin et al., 2013; Saffel-Shrier et al., 2019). Thus, there are updated recommendations for improving nutrition intake in older adults (Saffel-Shrier et al., 2019), and a call to implement preventative diet-based interventions in older adults (Angeloni et al., 2020).

One factor that may inform researchers and clinicians on improving dietary habits and interventions in older adults is cognitive functioning. Although there are many factors that can influence diet, research in young and middle-aged adults suggest cognitive functioning and, more specifically inhibitory control, may play an important role in managing diet and food intake (e.g., Carbine et al., 2017; Guerrieri et al., 2007; Jansen et al., 2009). Given the general cognitive decline that can be observed in older adults and the negative impact a poor diet can have on cognition (e.g., Angeloni et al., 2020), cognitive functioning may play a key but different role in managing food intake in older adults compared to younger adults. Understanding how age-related changes in cognition for older adults impacts dietary habits may elucidate as to why we

see the negative dietary practices we do in older adults and what diet interventions may be more effective for older adults than other populations.

A specific aspect of cognitive functioning that is particularly relevant for diet management in older adults is food-related inhibitory control. Food-related inhibitory control refers to the ability to withhold dominant urges to consume palatable or hedonic foods to adhere to some food-related goal (such as eating healthier or sticking with a diet; Carbine et al., 2017). Higher levels of inhibitory control may help individuals withstand food cravings, withhold from emotional eating, and resist eating palatable foods high in fat and sugar (Appelhans et al., 2011; Blundell & Gillett, 2001; Davis et al., 2007; Guerrieri et al., 2007; Hall, 2012; Jasinska et al., 2012). For example, individuals with lower compared to higher levels of inhibitory control (as measured by self-report and behavioral data) tend to eat more when presented with a variety of foods (Guerrieri et al., 2007; Jansen et al., 2009).

When measuring general inhibitory control, older adults tend to have longer response times and commit more errors when completing inhibition tasks compared to younger adults (e.g., Heilbronner & Münte, 2013; Hong et al., 2014; Langenecker & Nielson, 2003; Nielson et al., 2002; Vallesi et al., 2010). Functional magnetic resonance imaging (fMRI) studies suggest that older adults compared to younger adults tend to show decreased activation in the right frontal cortex when inhibiting dominant responses (an area associated with successful inhibition in younger adults; Coxon et al., 2016; Nielson et al., 2002; Sebastian et al., 2013). Further, older adults compared to younger adults tend to activate additional brain regions in the parietal and left frontal lobes during successful inhibition, potentially compensating for the functional deficits they experience during inhibition tasks (Cabeza & Nyberg, 1997; Grady, 2012; Nielson et al., 2002; Sebastian et al., 2013). As general inhibitory control tends to decline with age, it is

possible that food-related inhibitory control in particular also declines with age (Andrés et al., 2008; Andrés & Van der Linden, 2000; Aschenbrenner & Balota, 2015; Healey et al., 2008; S. Kim et al., 2007).

One way to quantify food-related inhibitory control is using event-related brain potentials (ERPs). ERPs are scalp recorded changes of the brain's electrical waveforms that are larger or smaller in amplitude depending on how an individual processes or responds to stimuli (Luck, 2014; Rugg & Coles, 1995). ERPs can reflect a variety of different cognitive functions, such as visual processing, emotional processing, or attention (e.g., Folstein & Van Petten, 2008; Hajcak et al., 2010; Krolak-Salmon et al., 2001). Two ERP components known as the N2 and P3 reflect inhibitory control functioning during go-no-go tasks or similar tasks that require inhibition. The N2 is a frontrocentral negative-going ERP component that typically occurs between 200 to 350 milliseconds (ms) after stimulus presentation (Folstein & Van Petten, 2008). During go/no-go tasks, N2 ERP amplitude is larger (i.e., more negative) when withholding a dominant or prepotent response, supporting its use as a measurement of inhibitory control (Folstein & Van Petten, 2008). In terms of food-related inhibitory control, N2 amplitude is larger (i.e., more negative) when withholding responses to food compared to neutral cues (Watson & Garvey, 2013) and when inhibiting to high-calorie compared to low-calorie food images (Carbine, Christensen, et al., 2017; Carbine, Rodeback, et al., 2018), suggesting there is an increased recruitment of inhibitory control processes when withholding dominant responses towards palatable foods. Larger (i.e., more negative) N2 amplitude when inhibiting towards high-calorie foods has also been associated with decreased overall calorie and carbohydrate intake (Carbine, Larson, et al., 2017), although this effect has not always been consistent (Carbine, Duraccio, et al., 2018).

The P3 is a positive-going ERP component that typically occurs between 300 and 600 ms after stimulus presentation (Albert et al., 2013; Falkenstein et al., 1999). During go/no-go tasks, individuals show a larger (i.e., more positive) frontocentral P3 amplitude when withholding a dominant or prepotent response (Kaiser et al., 2003; Wessel & Aron, 2015). However, there is some debate as to whether the larger amplitude reflects attention suppression to non-relevant stimuli (Polich, 2007), evaluation of an inhibitory response (Huster et al., 2013), or the inhibition of a motor response (Gajewski & Falkenstein, 2013; Smith et al., 2008). Similar to the N2 ERP component, P3 amplitude during food go/no-go tasks suggests there is increased recruitment of inhibitory control resources (i.e., larger P3 amplitude) when withholding responses to food compared to neutral stimuli (Watson & Garvey, 2013) and to high-calorie compared to low-calorie food cues (Carbine, Duraccio, et al., 2018).

Taken together, ERPs are a unique tool that can provide an objective neural index of food-related inhibitory control in older adults (Carbine, Duraccio, et al., 2018), opening the door to see how differences or deficits in inhibitory control relate to poor eating habits and reduced health. The N2 and P3 ERP components have previously been measured in older adults during non-food go/no-go and stop signal tasks. Older adults compared to younger adults tend to show attenuated P3 amplitudes at frontal, central, and parietal sites when inhibiting dominant responses (Barry et al., 2016; Hsieh & Lin, 2017; Kardos et al., 2020; Kropotov et al., 2016; Niessen et al., 2017), although this effect has not always been consistent for frontal P3 amplitudes (Barry et al., 2016; Falkenstein et al., 2002; Kropotov et al., 2016). Similarly, frontocentral N2 amplitude during inhibition trials is also attenuated in older adults compared to younger adults (Kropotov et al., 2016), although this effect is also not consistent (Falkenstein et al., 2002; Kardos et al., 2020; Niessen et al., 2017). In sum, it may be that older adults have

attenuated N2 and P3 amplitudes due to general inhibitory control deficits; however, this effect is not robust and we do not yet know if there are declines in measures of inhibitory control in older adults when specifically recruiting food-related inhibitory control processes.

We aimed to test if food-related inhibitory control, as measured by the N2 and P3 ERP components, differed between younger and older adults. Results from our study lay the foundation to test how food-related inhibitory control in older adults relates to poor diet and health outcomes and better inform potential interventions. Previous studies suggest palatable foods require increased recruitment of inhibitory control resources (e.g., Carbine, Christensen, et al., 2017), older adults show deficits in inhibitory control (e.g., Nielson et al., 2002), and older adults may demonstrate attenuated N2 and P3 amplitudes on go/no-go tasks (e.g., Kardos et al., 2020; Kropotov et al., 2016). Due to these previous findings, our first hypothesis was that both younger- and older-adult groups would show increased inhibitory control towards images of high-calorie foods compared to low-calorie foods (i.e., task difference). Our second hypothesis was that older adults compared to younger adults would show disproportionately less inhibitory control (i.e., smaller N2 and P3 amplitudes) to high-calorie foods (i.e., group difference). Then, considering older adults demonstrate longer response times and decreased accuracy during inhibition tasks (Hong et al., 2014; Langenecker & Nielson, 2003; Nielson et al., 2002; Vallesi et al., 2010), our third hypothesis was that older adults compared to younger adults would have longer response times and decreased accuracy during go/no-go tasks, and particularly during a task that requires them to inhibit towards high-calorie than low-calorie foods.

2. Methods

Our complete dataset, code used for analyses, and study materials are available on a study-specific Open Science Framework (OSF) webpage and can be downloaded here: https://osf.io/qe3g7/

2.1 Participants

Older adult participants were recruited from the local community using flyers, Facebook ads, and newspaper ads for monetary compensation. Young adult participants were recruited from undergraduate courses for course credit or monetary compensation. Inclusion/exclusion criteria for all participants included: native English speakers, psychiatrically and neurologically healthy, no chronic or metabolic diseases, absence of previous head injury resulting in loss of consciousness, no current use of recreational drugs, or current pregnancy/lactation. The original sample consisted of 85 older adult participants (45 females [52.9%]; M_{age}=63.9, SD_{age}=7.7) and 157 younger adult participants (103 females [65.6%]; M_{age}=20.9, SD_{age}=3.3).

Of the original sample, three older adults were excluded for previous head injuries with loss of consciousness, two were excluded for a previous diagnosis of depression or psychiatric illness, and 11 were excluded for other exclusions criteria: vegetarian diet, thyroid concerns, metabolic diseases (e.g., diabetes), use of psychotropic medication, and Celiac disease. One older adult was subsequently excluded for less than 50% accuracy for the task (go and no-go trials) and four were excluded for noisy data or missing data; ERP data from remaining participants were then subjected to reliability analyses (see Section 2.2.3). An additional five older adults were excluded from analyses due to low reliability. For the younger adults, one was excluded for a previous diagnosis of depression or psychiatric illness, and nine were excluded for other exclusion criteria: vegetarian diet, thyroid concerns, diabetes, use of psychotropic medication,

Guillain-Barre Syndrome, and Celiac disease. Ten younger adults were subsequently excluded for less than 50% accuracy for the task (go and no-go trials) and 11 were excluded for noisy data or missing data; ERP data from remaining participants were then subjected to reliability analyses (see Section 2.2.3). An additional 12 younger adults were excluded from analyses due to low reliability. Thus, our final sample for the ERP analyses consisted of 59 older adult participants (31 females [52.5%]; M_{age}=64, SD_{age}=7.5, M_{bmi}=30.3, SD_{bmi}=8.3) and 114 younger adult participants (82 females [71.9%]; M_{age}=20.8, SD_{age}=3.5, M_{bmi}=22.9, SD_{bmi}=3.0). The same sample of 59 older adult participants and 114 younger adult participants were included for all behavioral analyses (e.g., response time and accuracy).

2.2 Sensitivity Analysis

We conducted a sensitivity analysis in G*Power (v3.1; University of Dusseldorf; Harris-Kojetin et al., 2013) for our Group by Task by Trial AVOVAs to determine what size of an effect we were powered to detect based on our final sample size. An ANOVA: Repeated measures, within-between interaction sensitivity analysis was conducted for 80% power, 134 participants, 2 groups, and 2 measurements. Correlation of repeated measures was set at the conservative level of 0.4 and the non-sphericity correction remained at 1. Based on the sensitivity analyses, our current study is powered at 80% to detect a Cohen's *f* effect size of at least 0.13 (a small effect; Selya et al., 2012).

2.3 Experimental Protocol

A list of all study procedures can be found on the study's OSF webpage: https://osf.io/qe3g7/ For the current manuscript, only the demographic questionnaire, visual analog scales (VAS), and inhibitory control data from the go/no-go tasks (behavioral and ERP)

were analyzed, as decided *a priori*. The passive viewing ERP data will be presented separately elsewhere and are noted here only for transparency.

Before arriving at the lab, participants were instructed to refrain from vigorous physical activity 24 hours before participation to control for potential confounds due to exercise (Hanlon et al., 2012). Additionally, participants were asked to refrain from consuming caffeine 24 hours before participation. Upon arrival, participants provided written consent and verbally confirmed completion of requirements listed above. Written consent and all procedures were approved by the local Institutional Review Board and in accordance with the Declaration of Helsinki. After consent, participants completed a demographic survey.

After the completion of the demographics survey, VAS questionnaires that focused on hunger and sleep were administered. For sleep, participants were asked when they went to sleep, when they woke up, and given a single VAS item that asked what their quality of sleep was, anchored from very low to very high. Hunger was assessed using six VAS items, which asked about current levels of hunger, fullness, desire to eat, how much you could eat, urge to eat, and preoccupation with thoughts of food (see https://osf.io/qe3g7/). Each VAS consisted of a 100-millimeter line, anchored from "Not at all" to "Extremely" (Blundell & Gillett, 2001; Stratton et al., 1998) and participants were asked to indicate their response with a vertical mark. VAS scores reliably predict the initiation of food intake, quantity of food consumed, and are sensitive to experimental manipulations (Stubbs et al., 2000). To score the VAS, the distance from the bottom anchor to the participant's mark was measured to the nearest millimeter. The fullness question was then reversed scored, and the six questions were averaged together for an overall hunger score. After completing the VAS, participants were then fitted with a 128-channel electroencephalogram (EEG) sensor net and completed two food go/no-go tasks and a passive

viewing task in a counterbalanced fashion, which concluded study participation. The results of the passive viewing task were not included in the current study due to our primary interest in measuring inhibitory control processes.

2.3.1 Inhibitory Control Tasks. For both go/no-go tasks, participants completed two blocks of 100 trials each, 70 of which were go trials (where they were asked to make a response) and 30 of which were no-go trials (where they were asked to withhold their response). A 70/30 ratio was used to establish a prepotency to responding to go trials and elicit an inhibitory response during no-go trials (e.g., Benikos et al., 2013; Ramos-Loyo et al., 2013). For the high-calorie go/no-go task, participants were asked to respond with a button press when they saw a low-calorie food (go stimuli) and withhold their response when they saw a high-calorie food (no-go stimuli). For the low-calorie go/no-go task, participants were asked to respond with a button press when they saw a high-calorie food (go stimuli) and withhold their response when they saw a low-calorie food (no-go stimuli). Using both tasks allowed measurement of inhibitory control to both high- and low-calorie foods. For both tasks, stimuli were shown for 500 milliseconds, with a random inter-stimulus interval fixation cross that varied between 1200 and 1400 milliseconds.

For both go/no-go tasks, stimuli were presented using E-prime 2.0 (Psychology Software Tools, Inc., 2012). The food stimuli were taken from the Food-Pics database, a large normed picture database that contains food and non-food items (Blechert et al., 2014). In the database there are 568 food pictures with provided calorie content. In a previous study sample collected from Brigham Young University undergraduates, food pictures from the Food-Pics database were quantified as high-calorie foods if they had a caloric density of at least 3 kcal/g (e.g., chocolate, donuts, cake) or as low-calorie foods if they had a caloric density of 1 kcal/g or less

(e.g., apples, celery, carrots; Carbine et al., 2021). This resulted in 180 “high-calorie” foods and 200 “low-calorie” foods. A group of 100 undergraduates then rated each of the 380 pictures as a high- or low-calorie food. Of these pictures, 112 were classified at a 95% accuracy rate or better as a high-calorie food, and 114 pictures were classified at a 95% accuracy rate or better as a low-calorie food. From these pictures, 100 high-calorie foods and 100 low-calorie foods were randomly selected to be used as food stimuli in the go/no-go tasks (Carbine et al., 2021). The list of the specific images used in each of the tasks are located on the study specific OSF page: https://osf.io/qe3g7/

2.3.2 EEG Data Acquisition and Analyses. EEG data collection and reporting procedures follow the EEG/MEG reporting guidelines (Clayson et al., 2019; Keil et al., 2014). Specifically, EEG data were recorded using a high-density, equidistant 128-channel EEG sensor net with passive Ag/AgCl electrodes and an Electrical Geodesics, Inc. amplifier system (20K nominal gain, bandpass = 0.10-100 Hz). EEG data were referenced online to the vertex electrode (Cz) and digitized continuously at 250 Hz during data collection. Electrode impedance was maintained at 50kΩ or less per manufacturer recommendations. Offline using NetStation v.5.3, data were first high-pass filtered at .1 hz Butterworth FIR 12db/octave filter with a .3 hz roll off and then low-pass filtered at 15 hz (Butterworth FIR 12db/octave filter with a 2 hz roll off). After, ERP data were segmented into epochs from 200 milliseconds prior to stimulus onset to 1000 milliseconds after stimulus onset for both go/no-go tasks. All epochs were then baseline adjusted using the 200 milliseconds pre-stimulus window.

After baseline correction, eye blinks were removed using independent components analysis (ICA) in the ERP PCA Toolkit (Dien, 2010). If ICA components correlated at .9 or higher with two blink templates (one generated from previous data collected by the authors and

one provided by ERP PCA Toolkit), they were removed from the data (Dien et al., 2010). Channels were also identified as bad if the fast average amplitude exceeded 100 microvolts (μV) or if the differential average amplitude exceeded 50μV, as recommended by the author and creator of the ERP Toolkit (Dien, 2010). If a bad channel was identified, the nearest neighbor method (consisting of the six nearest electrodes) was used to interpolate data. Epochs were then classified by their trial type in each task and were averaged accordingly. Finally, data was re-referenced offline to the average signal.

As decided *a priori,* we extracted N2 amplitude using an adaptive mean approach, averaging from 16 ms before to 16 ms after the most negative peak in the 200 to 300ms post-stimulus time window (Folstein & Van Petten, 2008). N2 amplitude was averaged across four *a priori* selected fronto-central electrode cites (6 [FCz], 7, 106, and 129 [Cz]), consistent with previous research (Carbine, Christensen, et al., 2017; Carbine, Duraccio, et al., 2018; Clawson et al., 2013; Clayson et al., 2011; Clayson & Larson, 2012, 2013; Larson et al., 2011) for electrode montage). For high-density EEG, averaging over multiple electrodes improves the reliability of the signal relative to using only a single electrode (Clayson & Larson, 2013). It was also decided *a priori* to extract the P3 amplitude using an adaptive mean approach, averaging from 16 ms before to 16 ms after the most positive peak in the 300 and 600ms post-stimulus time window (Falkenstein et al., 1999). The P3 amplitude was averaged across the same four *a priori* selected fronto-central electrodes (6 [FCz], 7, 106, and Cz), consistent with previous food go/no-go research (Carbine, Rodeback, et al., 2018).

2.3.3 ERP Reliability Analyses. To be included in our final analyses, reliability analyses were conducted on the final set of EEG data (Clayson & Miller, 2017a, 2017b). Reliability analyses were conducted via the ERA Reliability Analysis (ERA) Toolkit v 0.4.4 (Clayson &

Miller, 2017a), which uses CmdStan v 2.0.1 (Stan Development Team, 2016) to implement the statistical models in Stan (Carpenter et al., 2017). The formulas used 6 chains and 6000 iterations to calculate dependability estimates for each group, condition, go/no-go task, and ERP, and participants were excluded if their data lacked the required number of trials necessary to meet a 0.7 reliability threshold cutoff set *a priori* (Baldwin et al., 2015; Clayson & Miller, 2017a, 2017b).

Dependability estimates, 95% credible intervals for dependability estimates, trial cut offs, and the average and range of final trial numbers are reported in Table 1. Dependability estimates were consistently high across groups, tasks, and trials (all dependabilities > .89). The minimum number of trials required for each ERP per group, task, and trial category ranged from 23 to 79 (see Table 1). Average number of trials ranged from 46 to 123 (see Table 1). Five older adult and 12 older adults were excluded from the analysis due to not meeting the required minimum number of trials for dependability.

2.4 Statistical Analyses Plan

2.4.1 Demographic Information. Group differences in body mass index and education level were analyzed using independent samples *t*-tests. We used a chi-square test to assess for any male/female ratio differences between the two groups.

2.4.2 Manipulation Check: Visual Analog Scales. Separate independent samples *t*-tests were completed for self-reported time asleep (e.g., individuals were asked to report when they went to bed and when they woke up the previous night), VAS sleep quality, and average VAS hunger to determine any differences between older and younger adults.

2.4.3 Behavioral Data and Event-Related Potentials. To analyze accuracy, a 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated

measures ANOVA was conducted. Since correct no-go trials do not have a response time (the response is withheld for no-go trials), response time data were only analyzed for correct go trials using a 2-Group (Older, Younger) x 2-Task (High-calorie, Low-calorie) repeated measures ANOVA. To test whether there was a difference between older adults and younger adults on ERP measures of food-related inhibitory control processes, a 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated measures ANOVA was conducted separately on N2 and P3 amplitude. Generalized eta-squared was reported as a measure of effect size for all ANOVAs. Follow-up tests of simple effects were used to decompose any significant interactions. If there was a significant three-way interaction, separate 2-Task by 2-Trial Type ANOVAs with corresponding tests of simple effects (noted above) were used to decompose the interactions.

3. Results

3.1 Demographic Information

Demographic information for both older adult and younger adult participants are presented in Table 2. There was a significant difference between older and younger adults for years of education, $t(171) = 9.48$, $p < .001$, with older adults reporting more years of education. There was also significant difference between younger and older adults for proportion of participants for each biological sex, $X^2(1, 173) = 5.6$, $p = .02$, with males making up 53% of the older adult sample and males making up 28% of the younger adult sample (see Table 2). Additionally, older adults had significantly higher BMI (M_{bmi}=30.3, SD_{bmi}=8.3) than younger adults (M_{bmi}=22.9, SD_{bmi}=2.98), $t(171) = 8.52$, $p < .001$.

3.2 Manipulation Check: Visual Analog Scales

Means and standard deviations for sleep and hunger VAS are reported in Table 3. The independent samples *t*-test for the hunger VAS showed no significant difference between older and younger adults, $t(101.2) = 1.65$, $p = .10$. There was also no significant difference for the VAS of previous night's sleep quality between older and younger adults, $t(108) = .32$, $p = .75$. There was, however, a significant difference in self-reported hours of sleep between older and younger adults, $t(99) = -3.45$, $p < .001$, with older adults self-reporting an average of 7.4 (SD = 1.09) hours of sleep and younger adults self-reporting an average of 8.0 (SD = .88) hours of sleep.

3.3 Behavioral Results

Means and standard deviations for accuracy and for correct go-trial response times by trial type, task, and group are reported in Table 4. The 2-Group (Older, Young) by 2-Task (High-calorie, Low-calorie) repeated measures ANOVA on go-correct response times showed a significant main effect of group, $F(1,171) = 42.03$, $p < .001$, $\eta_g^2 = .18$, with older adults having significantly slower response times than younger adults. There was also a main effect of task, $F(1,171) = 40.95$, $p < .001$, $\eta_g^2 = .03$, with significantly faster response times overall during the high-calorie task than the low-calorie task. There was not a significant interaction between group and task, $F(1,171) = .27$, $p = .60$, $\eta_g^2 < .001$.

The 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated measures ANOVA for accuracy revealed a main effect of trial type, $F(1, 171) = 83.45$, $p < .001$, $\eta_g^2 = .15$, with go trials having significantly higher accuracy than no-go trials, as expected. There was also a main effect of task, $F(1, 171) = 9.02$, $p = .003$, $\eta_g^2 = .008$, with greater accuracy for the high calorie task. There was not a significant main effect of group, $F(1, 171) = .006$, $p = .94$, $\eta_g^2 < .001$. There was a significant interaction between group and trial

type, $F(1, 171) = 5.12$, $p = .02$, $\eta_g^2 = .01$. There was not a significant interaction between group and task, $F(1, 171) < 0.001$, $p = .994$, $\eta_g^2 < .001$, or between task and trial type, $F(1, 171) = 0.22$, $p = .64$, $\eta_g^2 < .001$. There was also not a significant three way interaction between group, task, and trial type, $F(1, 171) = 0.16$, $p = .69$, $\eta_g^2 < .001$.

Follow-up tests of simple effects on the interaction between group and trial type showed that accuracy was greater for go trials than no-go trials for both the younger, $p < .001$, and older adults, $p < .001$. There was also a significant difference for go-trial accuracy between older and younger adults, with younger adults having greater go-trial accuracy than older adults, $p < .001$. Of note, the same pattern was not statistically significant for no-go trials, $p = .10$.

Overall, for response times, older adults responded slower than younger adults regardless of task. Additionally, all participants responded faster to the high-calorie task than the low-calorie task. For accuracy, the main effect of task indicated that participants performed with higher accuracy during the high-calorie task than the low-calorie task. Additionally, younger adults had greater accuracy on go trials than the older adults which was not present for the no-go trials.

3.4 Event-Related Potentials

N2 ERP Component. N2 and P3 ERP waveforms by trial, task, and group are shown in Figure 1. Means and standard deviations for N2 and P3 amplitude by trial, task, and group are reported in Table 5. The 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated measures ANOVA on the N2 component demonstrated a significant main effect for trial type, $F(1, 171) = 40.0$, $p < .001$, $\eta_g^2 = .005$, with no-go trials having larger N2 amplitude than the go trials, as expected. There was also a main effect of group, $F(1, 171) = 13.86$, $p < .001$, $\eta_g^2 = .06$, with younger adults having larger (i.e., more negative) N2

amplitude than older adults. There was no main effect of task, $F(1, 171) = 2.59$, $p = 0.11$, $\eta_g^2 = .002$.

There were also two significant interactions: a two way interaction between group and trial type, $F(1, 171) = 5.7$, $p = .02$, $\eta_g^2 < .001$, and a three way interaction between group, task, and trial type, $F(1, 171) = 13.9$, $p < .001$, $\eta_g^2 = .001$. There was not a significant interaction between group and task, $F(1, 171) = 3.3$, $p = .07$, $\eta_g^2 = .002$, or task and trial type, $F(1, 171) = 2.46$, $p = .12$, $\eta_g^2 < .001$.

Follow-up tests of simple effects for the Group by Trial Type interaction revealed that no-go N2 amplitudes were significantly larger (i.e., more negative) than go trials in both older adults, $p = .005$, and younger adults, $p < .001$, as reflected in the trial main effect. When comparing between groups, the younger adults' no-go N2 amplitudes were significantly larger than the older adults, $p < .001$, and the same relationship was significant for the go trials, $p < .001$, with the younger adults having a larger go N2 amplitude, as reflected in the group main effect. When looking at the means for each group and trial type, the significant interaction suggests that the difference between go and no-go trials was larger in younger adults (go = -2.47 microvolts [SD = 2.49], no-go = -2.94 microvolts [SD = 2.51]) than older adults (go = -1.36 microvolts [SD = 1.75], no-go = -1.56 microvolts [SD = 1.80]).

To decompose the three-way interaction between the three factors, a 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) ANOVA was ran separately for the older and younger adult N2 amplitudes. The older adult ANOVA revealed a main effect of trial type, $F(1, 58) = 8.58$, $p = .005$, $\eta_g^2 = .003$, but no significant main effect for task, $F(1, 58) = 3.17$, $p = .08$, $\eta_g^2 = .01$, or task by trial interaction, $F(1, 58) = 2.40$, $p = .13$, $\eta_g^2 < .001$. The main effect of trial type indicated no-go trials had a significantly larger N2 amplitude than the go trials, as expected.

The younger adults 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) ANOVA revealed a significant main effect of trial type, $F(1, 113) = 39.76$, $p < .001$, $\eta_g^2 = .01$, with no-go trials eliciting a larger N2 amplitude than go trials, as expected. Like the older adults ANOVA, there was not a significant main effect for task, $F(1, 113) = 0.04$, $p = .84$, $\eta_g^2 < .001$. In addition, the younger adults ANOVA demonstrated a significant interaction between task and trial type, $F(1, 113) = 18.1$, $p < .001$, $\eta_g^2 = .003$, which was not present in the older adult ANOVA. Follow-up tests of simple effects on this interaction demonstrated that for both the high-calorie, $p < .001$, and low-calorie task, $p = .02$, the no-go trials elicited a larger N2 amplitude than the go trials. Additionally, the low-calorie tasks' go amplitude was significantly larger than the high-calorie tasks' go amplitude, $p = .03$, while there was no significant difference between the two tasks on no-go trials, $p = .13$.

P3 ERP Component. The 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated measures ANOVA on the P3 component demonstrated a significant main effect for trial type, $F(1, 171) = 148.77$, $p < .001$, $\eta_g^2 = .05$, with no-go trials eliciting a larger (i.e., more positive) P3 amplitude than the go trials. There was also a significant main effect of group, $F(1, 171) = 30.08$, $p < .001$, $\eta_g^2 = .12$, with younger adults demonstrating a larger (i.e., more positive) P3 amplitude than older adults. The main effect of task was not significant $F(1, 171) = 1.39$, $p = .24$, $\eta_g^2 = .001$.

The 2-Group (Older, Younger) by 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) repeated measures ANOVA on the P3 component also demonstrated three significant interactions; a two way interaction between group and trial type, $F(1, 171) = 24.16$, $p < .001$, $\eta_g^2 = .01$, a two way interaction between task and trial type, $F(1, 171) = 5.41$, $p = .02$, $\eta_g^2 < .001$, and a three way interaction between group, task, and trial type, $F(1, 171) = 5.13$, $p = .03$,

$\eta_g^2 < .001$. There was not a significant interaction for group and task, $F(1, 171) = .13$, $p = .72$, $\eta_g^2 < .001$.

The follow-up tests of simple effects for the Group by Trial type interaction revealed that no-go trials had significantly larger (i.e., more positive) P3 amplitudes than go trials in both older adults, $p < .001$, and younger adults, $p < .001$, as reflected in the trial main effect. When comparing between the two groups, the younger adults' no-go trials P3 amplitudes were significantly larger than the older adults' no-go trials, $p < .001$, and the same relationship was statistically significant with the go trials, $p < .001$, with the younger adults having a larger go P3 amplitude, as reflected in the group main effect. The means for the two groups suggest that a larger difference exists between the younger adults (go = 2.24 microvolts [SD = 2.48], no-go = 3.96 microvolts [SD = 3.07]) for the two trial types than for the older adults (go = 0.68 microvolts [SD = 2.10], no-go = 1.41 microvolts [SD = 2.91]). The tests of simple effects for the Task by Trial type interaction revealed that no-go trials had a larger P3 amplitude than go trials for both the high-calorie, $p < .001$, and low-calorie task, $p < .001$. When comparing tasks, there was not a significant difference between the high-calorie and low-calorie tasks for no-go trials, $p = .08$, or for go trials, $p = .77$.

To decompose the three-way interaction between the three factors, a 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) ANOVA was completed for both the older and younger adult P3 amplitudes separately. The older adult ANOVA revealed a main effect for trial type, $F(1, 58) = 26.76$, $p < .001$, $\eta_g^2 = .02$, with no-go trials eliciting a larger (i.e., more positive) P3 amplitude than go trials. There was no significant main effect for task, $F(1, 58) = .16$, $p = .69$, $\eta_g^2 < .001$, or significant interaction between task and trial type, $F(1, 58) = .002$, $p = .96$, $\eta_g^2 < .001$.

The younger adults 2-Task (High-calorie, Low-calorie) by 2-Trial Type (Go, No-go) ANOVA revealed a significant main effect of trial type, $F(1, 113) = 190.42$, $p < .001$, $\eta_g^2 = .09$, with no-go trials eliciting a larger (i.e., more positive) P3 amplitude than go trials. There was no significant main effect for task, $F(1, 113) = 2.52$, $p = .15$, $\eta_g^2 = .003$. However, unlike the older adults, the younger adult ANOVA demonstrated a significant interaction between task and trial type, $F(1, 113) = 13.35$, $p < .001$, $\eta_g^2 = .003$. The follow-up tests of simple effects on this interaction demonstrated that no-go trials elicited a larger P3 amplitude than go trials for both the high-calorie, $p < .001$, and low-calorie task, $p < .001$. When comparing tasks, there was a significant difference in P3 amplitude between the high-calorie and low-calorie task for no-go trials with the high-calorie tasks' no-go trials having a larger P3 amplitude, $p = .004$, but not for the go trials, $p = .83$.

In summary, both the N2 and P3 showed a main effect of trial type with no-go trials eliciting a larger amplitude than go-trials. Additionally, both the N2 and P3 showed a main effect of group with younger adults having larger amplitudes than older adults. Of note, for N2 the younger adults demonstrated a task by trial interaction that was driven by the go trials (e.g., low-calorie task had larger go trials than high-calorie task). For the P3, there was a task by trial interaction demonstrating that for both tasks the no-go trials had a larger P3 amplitude than go trials. Of note, for the younger adults the task by trial type interaction demonstrated that the high-calorie no-go trials had a larger amplitude than the low-calorie no-go trials.

3.5 Role of Biological Sex and Body Mass Index

We did not have an *a priori* hypothesis regarding body mass index (BMI) or biological sex; however, the older-adult and younger-adult samples were significantly different for BMI and biological sex ratio (older adults [52.5% female, M_{bmi}=30.3, SD_{bmi}=8.3]; younger adults

[71.9% female, M_{bmi}=22.9, SD_{bmi}=2.98]). Due to the potential impact of BMI and biological sex on inhibitory control processes (Barrington et al., 2014; Houben et al., 2014), we conducted a *post-hoc* analyses to see if any of our primary results (e.g., N2, P3, accuracy, and response time) were consistent in groups balanced for BMI and biological sex between older and younger adults.

ANCOVA is not appropriate for equalizing groups on differing baseline or demographic variables (Miller & Chapman, 2001). Thus, we created a matched subset between the older-adult and younger-adult groups on BMI and biological sex using the SPSS case-control matching function. The case-control function picks the matched participants based on input variables (in this case BMI and biological sex) rather than incorporating potential experimenter biases with the experimenter hand-picking matched groups. The matched sample included a total of 72 participants, 36 in each group (older adults [M_{bmi}=25.7, SD_{bmi}=4.04] and younger adult participants [M_{bmi}=24.6, SD_{bmi}=3.7]) with equal number of males and females in each group (19 males and 17 females in each group). There was no longer a significant difference for BMI between the two groups, $p = .24$.

In analyses of this matched sample, the primary main effects remained consistent across all primary variables (N2, P3, accuracy, and response time) for the BMI and biological sex matched data set, Fs > 4.33, $ps < .04$, $\eta_g^2 < .08$. Of note, there were a few differences in the interaction effects for the N2 and accuracy. For the N2, there was no longer a significant interaction for group and trial type $F(1, 70) = 0.17$, $p = .68$, $\eta_g^2 < .001$, but there was now a significant interaction between group and task, $F(1, 70) = 6.25$, $p = .02$, $\eta_g^2 = .001$. Follow-up tests of simple effects on the group by task interaction showed that for the older adults, the N2

amplitude for the high calorie task was significantly larger than the low-calorie task, $p = .001$, but this was not the case for the younger adult participants, $p = .41$.

Most importantly, the significant three-way interaction between group task and trial type was still present with consistent findings and directions for the younger adults but not the older adults. For the older adults, there was now a main effect of task, $F(1, 35) = 5.8$, $p = .02$, $\eta_g^2 = .05$, with the high calorie task eliciting a larger N2 than the low-calorie task which was not present for either samples of younger adults $F(1, 35) < .54$, $p < .47$, $\eta_g^2 < .001$. For accuracy, there was no longer an interaction between group and trial type, $F(1, 70) = 1.17$, $p = .28$, $\eta_g^2 = .006$, which was present in the non-matched data set.

In conclusion, many of the primary findings hold in the matched subsample. Overall, the differences that were statistically significant for the BMI and biological sex matched participants reside in the N2 (e.g., older adult's high-calorie task elicited a greater N2 than the low-calorie task). Additionally, there was no longer an interaction between group and trial type for the N2 which was present in the original data set (e.g., no-go amplitudes greater than go for both older and younger adults). Additionally, for accuracy younger adults no longer had greater go trials accuracy than older adults. Of note, the P3 three-way interaction directions were consistent across both data sets. The BMI and biological sex matched data set is also available on OSF: https://osf.io/qe3g7/

4. Discussion

We used ERP (N2 and P3 components) and behavioral measures (response time and accuracy) to test whether food-related inhibitory control differed between older adult and younger adult samples. Behaviorally, we expected that younger adults would have faster response times and greater accuracy compared to older adults on both high-calorie and low-

calorie tasks. Previous research supports the notion that older adults tend to have slower response times and lower accuracy than younger adults on inhibitory control tasks (Hong et al., 2014; Langenecker & Nielson, 2003; Vallesi et al., 2010). For the N2 and P3, we expected there to be a calorie effect, with both younger and older adults recruiting increased inhibitory control processes (i.e., greater N2 and P3 amplitude) towards high-calorie food when compared to low-calorie food. Due to previous evidence of decreased inhibitory control processes in older adults, we expected older adults to recruit a disproportionate amount of cognitive resources (i.e., smaller difference between go and no-go trials) to high calorie foods when compared to younger adults (Andrés et al., 2008; Andrés & Van der Linden, 2000; Aschenbrenner & Balota, 2015; Healey et al., 2008; S. Kim et al., 2007).

In support of our original hypothesis, older adults had slower overall response times than younger adults regardless of task reflecting generalized slowing in the older adult sample. Previous research supports this trend of generalized slowing that occurs as older adults age (Heilbronner & Münte, 2013; Hong et al., 2014; Langenecker & Nielson, 2003; Larson et al., 2016; Nielson et al., 2002; Vallesi et al., 2010). Functional declines in the prefrontal cortex (PFC) and the dopamine system have been suggested as a mechanism underlying the general performance differences seen when comparing an older adult and younger adult sample (Braver et al., 2001). Overall, older adults had slower response times, most likely due to typical slowing that occurs with aging (Heilbronner & Münte, 2013; Hong et al., 2014; Langenecker & Nielson, 2003; Larson et al., 2016; Nielson et al., 2002; Vallesi et al., 2010).

Our original hypothesis that response times would be slower for the high-calorie task than the low-calorie was not supported. Instead, response times faster for the high-calorie task than the low-calorie task. Our original hypothesis was based on previous research and assumed

that inhibiting to palatable foods would result in increased response times due the salient nature of high calorie food and the expected increase difficulty inhibiting to more palatable foods (Carbine, Christensen, et al., 2017; Guerrieri et al., 2007; Jansen et al., 2009). The opposite finding might indicate that both younger and older adults were more engaged during the high-calorie task than during the low-calorie task resulting in decreased response time (Weissman et al., 2009). Of note, previous EEG research has shown increased response times during high-calorie inhibitory task (Carbine, Christensen, et al., 2017). The decreased response times when inhibiting to high calorie stimuli seen in the current study might indicate increased attention when inhibiting to high calorie food (Meule & Kübler, 2014).

As expected, go trials had greater accuracy than no-go trials regardless of age or task. Regardless of group status (i.e., older or younger), participants performed with greater accuracy during the high-calorie task than the low-calorie task. Other food-related studies have demonstrated greater accuracy on high-calorie tasks compared to the lower-calorie tasks (Carbine, Christensen, et al., 2017; Smith et al., 2021). For the current study, there was greater accuracy and faster response times for the high-calorie task, supporting the idea of increased engagement to the high-calorie task and not a speed-accuracy trade-off.

Unlike response times, younger adults did not have greater accuracy than older adults. Previous research looking at accuracy differences between older and younger adults have shown evidence of older adults performing with greater accuracy during go/no-go tasks (Heilbronner & Münte, 2013). Yet other findings demonstrate the opposite pattern of younger adults having greater accuracy (Hong et al., 2014). Previous studies have also suggested a speed-accuracy trade off which seems to be present in the older adults as they performed with similar accuracy to the younger adults but demonstrated slower response time (Heitz, 2014; van Maanen, 2016). In the

current study, the younger adult sample demonstrated greater accuracy for the go trials than the older adults, which was not present for the no-go trials. The lack of difference between the go and no-go trials for older adults' accuracy supports the notion that cognitive decline tends to be generalized (Andrés et al., 2008; Aschenbrenner & Balota, 2015; Larson et al., 2016). The relationship between go trials for accuracy was not present in the BMI matched sample, therefore the difference seen for younger adults for go trials might only exist with larger sample sizes and unlikely reflects a difference in inhibitory control processes (Meule, 2017).

As expected, both the N2 and P3 ERPs demonstrated the expected trial effect with the no-go trials eliciting a larger N2 and P3 amplitude--indicating that both tasks were successful at measuring the expected neurophysiological processes underlying inhibitory control (Carbine, Duraccio, et al., 2018; Folstein & Van Petten, 2008; Watson & Garvey, 2013). When considered by group, younger adults had a larger N2 and P3 amplitude than older adults, supporting part of our initial hypothesis that older adults would show disproportionately less inhibitory control. Previous EEG research measuring inhibitory control processes in older adults has demonstrated a pattern of decreased neurophysiological processes when compared to a younger adult sample (Andrés et al., 2008; Andrés & Van der Linden, 2000; Aschenbrenner & Balota, 2015; Healey et al., 2008; C. Kim et al., 2014). The main effect of group also supported previous older adult EEG research demonstrating attenuated P3 and N2 amplitude during inhibitory tasks (Barry et al., 2016; Hsieh & Lin, 2017; Kardos et al., 2020; Kropotov et al., 2016; Niessen et al., 2017). Notably this relationship of attenuated ERP amplitude seen in older adults is not always consistent across all research (Barry et al., 2016; Falkenstein et al., 2002, 2002; Kardos et al., 2020; Kropotov et al., 2016; Niessen et al., 2017). Previous research has suggested that this lower recruitment of inhibitory control neural resources might be the result of a different neural

map of activity to compensate for the decrease activity in regions seen in younger adults (Cabeza & Nyberg, 1997; Grady, 2012; Nielson et al., 2002; Sebastian et al., 2013). Overall, older adults demonstrated a pattern of attenuated N2 and P3 amplitude when compared to younger adults and regardless of calorie type.

There was not a difference in N2 amplitude between the high-calorie and the low-calorie tasks, indicating that differences in inhibitory control processes might not be food specific. The lack of difference due to food type (e.g., high calorie vs low-calorie) was present for both younger and older adults. The lack of task difference for the N2 did not support our original hypothesis that both younger and older adults would show increased recruitment of inhibitory control to high calorie food when compared to low calorie food. Of note, there was a significant difference for older adults between the high and low-calorie task for the BMI and biological sex matched data set, with greater N2 amplitude occurring during the high calorie task. This relationship was not statistically significant for younger adults, thereby reflecting that the N2 might be sensitive to BMI status or biological sex for older adults (Barrington et al., 2014; Houben et al., 2014). The differential neural activation patterns seen in older adults are sometimes explained by the compensatory hypothesis. The compensatory hypothesis states that older adults demonstrate recruitment of different structures in order to perform or compensate for the effects of the aging process (Grady, 2012; Vallesi et al., 2010). Therefore the differences seen between the younger and older adults may have been compensatory in nature and implemented by older adults to maintain similar level of functioning on measures like accuracy (Cabeza & Nyberg, 1997; Grady, 2012; Nielson et al., 2002; Sebastian et al., 2013). Yet, the ability to engage the mechanisms underlying the compensatory hypothesis might be influenced by BMI or biological sex (Barrington et al., 2014; Houben et al., 2014).

For the P3, the was a difference in amplitude seen between groups with younger adults having a greater P3 amplitude when inhibiting to high calorie food but not low-calorie stimulus. This food type difference was not seen in the older adult sample. This pattern was similar to the behavioral data where younger adults showed differential patterns between task type that wasn't present in the older adult sample. Previous research in a younger adult sample have shown a difference between calorie type, with higher calorie stimuli resulting in a larger P3 and N2 amplitude (Carbine, Christensen, et al., 2017; Carbine, Rodeback, et al., 2018). The different patterns seen between older and younger adults suggest that overall, younger adults demonstrated greater differentiation between task types (i.e., high or low-calorie) on both behavioral and neural measures reflecting inherent differences. These age differences might reflect a compensatory mechanism or difference in inhibitory control and food-processing (Cabeza et al., 2002; Vallesi et al., 2010). Indicating that older adult might not process or interact with food in the same manner that younger adults do.

Although the difference between the high calorie and low-calorie tasks was not statistically significant for the N2, the difference (i.e., larger amplitude) between the no-go and go trial types for the younger adults was larger than the older adults' difference for both the N2 and P3. Indicating that younger adults recruited more inhibitory resources when compared to older adults. This difference further supports previous research indicating that older adults recruit less inhibitory control resources when compared to younger adults (Andrés et al., 2008; Andrés & Van der Linden, 2000; Aschenbrenner & Balota, 2015; Healey et al., 2008; C. Kim et al., 2014).

For the younger adults, the larger N2 difference seen between go and no/go trials for the high calorie task was driven by the go trials rather than the no-go trials indicating that while

there was a difference in neural processes it wasn't a result of differing inhibitory control processes. Go trials reflect the ability of an individual to quickly evaluation food category and perform a motor response and is not a measure of inhibitory control processes (Meule, 2017). Therefore, the difference seen between just the go trials on the N2 might reflect that the younger adults recruited more neural processes when responding to low-calorie foods than they did when responding to high-calorie food.

Based on the P3, younger adults recruit more inhibitory control resources to withhold dominant responses to high calorie than lower calorie foods, which is pattern seen in previous research (Carbine, Rodeback, et al., 2018; Watson & Garvey, 2013). Yet, older adults do not demonstrate the same recruitment of cognitive resources. The lower indices of inhibitory control abilities (e.g., smaller N2 amplitude and lower accuracy) seen in the older adults may lead to increased consumption of higher calorie foods and overall poorer dietary habits (Appelhans et al., 2011; Blundell & Gillett, 2001; Davis et al., 2007; Guerrieri et al., 2007; Hall, 2012; Jasinska et al., 2012). Previous research has shown that hunger levels influence food related inhibitory control (Meule et al., 2014). The two groups reported similar hunger levels prior to completing the food-related tasks. Therefore, it is unlikely that any differences observed for ERPs can be attributed to differing hunger levels between groups.

As with any study, there were limitations in our current study. There was a difference in education between the younger and older adult samples. The older adults reported a significantly more years of education (*M*=16.9 years, *SD*=2.8 years) than the younger adult sample (*M=13*.6 years, *SD*=1.8 years). This was likely a result of our younger adult sample being recruited from a population of college students still in their undergraduate degrees. Previous research has shown that education level may affect EEG signal (e.g, gamma frequency) and processes related to

inhibitory control (Põld et al., 2019) and overall cognitive functioning (Guerra-Carrillo et al., 2017). As our older adult sample still demonstrated lower performance (e.g., disproportionately less inhibitory control) when compared to younger adults despite higher education, we assume that any differences that are statistically significant are more likely a result of age rather than reported education. Future research should consider controlling for education levels as part of their demographic sampling to help elucidate the influence of education on age related inhibitory control.

An additional limitation of the current study design was not specifically sampling an overweight/obese group. Previous research has shown that weight status can influence food-related inhibitory processes (Chen et al., 2018; Houben et al., 2014). Our aim was to test food-related inhibitory control in an older adult sample regardless of weight or BMI statues. Therefore, we sought to establish patterns in a normal weight sample first before extending the results to an overweight older adult sample. Of note, our sample of older adults were in the overweight category based on BMI. Therefore, we completed post-hoc analyses to establish if differences existed due the BMI difference inherent in our sample. Additionally, younger adults reported a significantly larger amount of sleep the night before (i.e., 30 minutes). Decreased reported sleep time is a common side effect reported during aging with older adults reporting on average less sleep time (Hirshkowitz et al., 2015). Previous research has shown that poor sleep quality can influence ERP amplitude (Breimhorst et al., 2008) and there was not a significant difference between self-reported previous night's sleep quality. Therefore, any differences in EEG findings are unlikely attributed to difference in sleep quality.

A strength of the current study was the large sample size included for both groups (e.g., 59 older adults and 114 younger adults). As a result of this large sample size, we were powered

to detect small effect size (Selya et al., 2012). Additionally, reliability estimates for the ERP data were high (e.g., dependability >.89), ensuring we were consistently measuring actual ERP indices of inhibitory control and not noise. Lastly, we excluded participants for a variety of potential confounding demographics factors that could have altered the ERPs such as metabolic diseases, diets, and neurological diseases which makes us confident that observed differences were due to the variables of interest (i.e., food type and age).

Future research should consider replicating and extending the methods of this study into comparing both an overweight younger and older adult sample. Understanding how the neural patterns measured in this study differ or are the same for an overweight sample has implications for health-related behaviors. Additionally, future research might benefit from seeing the effects of exercise training as exercise has been shown to improve older adults' cognitive functioning (Falck et al., 2019). Improving cognitive functioning has the potential to be a modifiable mechanism that might increase older adults' inhibitory control and subsequent health outcomes (Carbine, Larson, et al., 2017; Guerrieri et al., 2007; Jansen et al., 2009). An additional avenue of research in older adults includes inhibitory control trainings designed to train individuals to better withhold dominant responses (Forman et al., 2019). Previous research has focused on a younger to middle age sample, but inhibitory control training might be an effective technique to improve older adults' food-related inhibitory control and subsequent dietary outcomes (Carbine et al., 2021; Forman et al., 2019; Houben, 2011). Overall, this study was one the first to look at how established food-related inhibitory control patterns in a younger adult sample might differ in an older adult sample. Future research should continue to consider how food-related cognitive functioning changes as a sample ages to help inform future health-related interventions and overall understanding of health-related behaviors.

5. Summary and Conclusions

In conclusion, older adults demonstrated attenuated N2 and P3 amplitude when compared to younger adults. This relationship was not task dependent, reflecting that this difference was not food specific. Of note, this sample of older adults did demonstrate slower response times than younger adults yet a similar relationship on the ERP measures was seen with older adults not demonstrating a difference between task type. Reflecting that an older adult sample might not be as effective at recruiting inhibitory control processes without it being specific to the caloric content of food. This pattern of decreased inhibitory processes has been seen in previous research, but this was the first study to look at whether these inhibitory processes might differ based on caloric content for an older adult sample. Future research should confirm whether generalized inhibitory differences in older adults are not food specific as understanding whether food-related inhibitory control changes as we age is important to inform future dietary habits and dietary interventions which can impact overall health. Additionally, recognizing how age-related changes in cognition for older adults impacts dietary habits may elucidate the reasons for the negative dietary practices seen in older adults and what specific diet interventions may be more effective for older adults.

References

Administration for Community Living. (2020). *2019 Profile of Older Americans* (p. 26). U.S. Department of Health and Human Services.

Agarwal, P., Wang, Y., Buchman, A. S., Bennett, D. A., & Morris, M. C. (2019). Dietary patterns and self-reported incident disability in older adults. *The Journals of Gerontology: Series A*, *74*(8), 1331–1337. https://doi.org/10.1093/gerona/gly211

Albert, J., López-Martín, S., Hinojosa, J. A., & Carretié, L. (2013). Spatiotemporal characterization of response inhibition. *NeuroImage*, *76*, 272–281. https://doi.org/10.1016/j.neuroimage.2013.03.011

Andrés, P., Guerrini, C., Phillips, L. H., & Perfect, T. J. (2008). Differential effects of aging on executive and automatic inhibition. *Developmental Neuropsychology*, *33*(2), 101–123. https://doi.org/10.1080/87565640701884212

Andrés, P., & Van der Linden, M. (2000). Age-related differences in supervisory attentional system functions. *The Journals of Gerontology: Series B*, *55*(6), P373–P380. https://doi.org/10.1093/geronb/55.6.P373

Angeloni, C., Businaro, R., & Vauzour, D. (2020). The role of diet in preventing and reducing cognitive decline. *Current Opinion in Psychiatry*, *33*(4), 432–438. https://doi.org/10.1097/YCO.0000000000000605

Appelhans, B. M., Woolf, K., Pagoto, S. L., Schneider, K. L., Whited, M. C., & Liebman, R. (2011). Inhibiting food reward: Delay discounting, food reward sensitivity, and palatable food intake in overweight and obese women. *Obesity*, *19*(11), 2175–2182. https://doi.org/10.1038/oby.2011.57

Aschenbrenner, A. J., & Balota, D. A. (2015). Interactive effects of working memory and trial history on Stroop interference in cognitively healthy aging. *Psychology and Aging*, *30*(1), 1–8. https://doi.org/10.1037/pag0000012

Baldwin, S. A., Larson, M. J., & Clayson, P. E. (2015). The dependability of electrophysiological measurements of performance monitoring in a clinical sample: A generalizability and decision analysis of the ERN and Pe. *Psychophysiology*, *52*(6), 790–800. https://doi.org/10.1111/psyp.12401

Barrington, W. E., Beresford, S. A. A., McGregor, B. A., & White, E. (2014). Perceived stress and eating behaviors by sex, obesity status, and stress vulnerability: Findings from the vitamins and lifestyle (VITAL) study. *Journal of the Academy of Nutrition and Dietetics*, *114*(11), 1791–1799. https://doi.org/10.1016/j.jand.2014.03.015

Barry, R. J., De Blasio, F. M., & Cave, A. E. (2016). Sequential processing in young and older adults in the equiprobable auditory Go/NoGo task. *Clinical Neurophysiology*, *127*(5), 2273–2285. https://doi.org/10.1016/j.clinph.2016.02.010

Benikos, N., Johnstone, S. J., & Roodenrys, S. J. (2013). Varying task difficulty in the Go/Nogo task: The effects of inhibitory control, arousal, and perceived effort on ERP components. *International Journal of Psychophysiology*, *87*(3), 262–272. https://doi.org/10.1016/j.ijpsycho.2012.08.005

Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: An image database for experimental research on eating and appetite. *Frontiers in Psychology*, *5*, 617. https://doi.org/10.3389/fpsyg.2014.00617

Blundell, J. E., & Gillett, A. (2001). Control of food intake in the obese. *Obesity Research*, *9*(S11), 263S-270S. https://doi.org/10.1038/oby.2001.129

Boeckner, L. S., Pullen, C. H., Walker, S. N., Oberdorfer, M. K., & Hageman, P. A. (2007). Eating behaviors and health history of rural midlife to older women in the midwestern United States. *Journal of the American Dietetic Association*, *107*(2), 306–310. https://doi.org/10.1016/j.jada.2006.11.012

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J. D., Kaye, J. A., Janowsky, J. S., Taylor, S. F., Yesavage, J. A., Mumenthaler, M. S., Jagust, W. J., & Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General*, *130*(4), 746–763. https://doi.org/10.1037/0096-3445.130.4.746

Breimhorst, M., Falkenstein, M., Marks, A., & Griefahn, B. (2008). The relationship between poor sleep and inhibitory functions indicated by event-related potentials. *Experimental Brain Research*, *187*(4), 631–639. https://doi.org/10.1007/s00221-008-1333-9

Bureau, U. C. (n.d.). *Older People Projected to Outnumber Children for First Time in U.S. History*. Census.Gov. Retrieved January 6, 2022, from https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-projections.html

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R. (2002). Aging gracefully: Compensatory brain activity in high-performing older adults. *NeuroImage*, *17*(3), 1394–1402. https://doi.org/10.1006/nimg.2002.1280

Cabeza, R., & Nyberg, L. (1997). Imaging cognition: An empirical review of PET studies with normal subjects. *Journal of Cognitive Neuroscience*, *9*(1), 1–26. https://doi.org/10.1162/jocn.1997.9.1.1

Carbine, K. A., Christensen, E., LeCheminant, J. D., Bailey, B. W., Tucker, L. A., & Larson, M. J. (2017). Testing food-related inhibitory control to high- and low-calorie food stimuli: Electrophysiological responses to high-calorie food stimuli predict calorie and carbohydrate intake. *Psychophysiology*, *54*(7), 982–997. https://doi.org/10.1111/psyp.12860

Carbine, K. A., Duraccio, K. M., Kirwan, C. B., Muncy, N. M., LeCheminant, J. D., & Larson, M. J. (2018). A direct comparison between ERP and fMRI measurements of food-related inhibitory control: Implications for BMI status and dietary intake. *NeuroImage*, *166*, 335–348. https://doi.org/10.1016/j.neuroimage.2017.11.008

Carbine, K. A., Larson, M. J., Romney, L., Bailey, B. W., Tucker, L. A., Christensen, W. F., & LeCheminant, J. D. (2017). Disparity in neural and subjective responses to food images in women with obesity and normal-weight women. *Obesity*, *25*(2), 384–390. https://doi.org/10.1002/oby.21710

Carbine, K. A., Muir, A. M., Allen, W. D., LeCheminant, J. D., Baldwin, S. A., Jensen, C. D., Kirwan, C. B., & Larson, M. J. (2021). Does inhibitory control training reduce weight and caloric intake in adults with overweight and obesity? A pre-registered, randomized controlled event-related potential (ERP) study. *Behaviour Research and Therapy*, *136*, 103784. https://doi.org/10.1016/j.brat.2020.103784

Carbine, K. A., Rodeback, R., Modersitzki, E., Miner, M., LeCheminant, J. D., & Larson, M. J. (2018). The utility of event-related potentials (ERPs) in understanding food-related cognition: A systematic review and recommendations. *Appetite*, *128*, 58–78. https://doi.org/10.1016/j.appet.2018.05.135

Carpenter, B., Gelman, A., Hoffman, M. D., Lee, D., Goodrich, B., Betancourt, M., Brubaker, M., Guo, J., Li, P., & Riddell, A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software*, *76*(1), 1–32. https://doi.org/10.18637/jss.v076.i01

Chen, S., Jia, Y., & Woltering, S. (2018). Neural differences of inhibitory control between adolescents with obesity and their peers. *International Journal of Obesity*, *42*(10), 1753–1761. https://doi.org/10.1038/s41366-018-0142-x

Clawson, A., Clayson, P. E., & Larson, M. J. (2013). Cognitive control adjustments and conflict adaptation in major depressive disorder. *Psychophysiology*, *50*(8), 711–721. https://doi.org/10.1111/psyp.12066

Clayson, P. E., Carbine, K. A., Baldwin, S. A., & Larson, M. J. (2019). Methodological reporting behavior, sample sizes, and statistical power in studies of event-related potentials: Barriers to reproducibility and replicability. *Psychophysiology*, *56*(11), e13437. https://doi.org/10.1111/psyp.13437

Clayson, P. E., Clawson, A., & Larson, M. J. (2011). Sex differences in electrophysiological indices of conflict monitoring. *Biological Psychology*, *87*(2), 282–289. https://doi.org/10.1016/j.biopsycho.2011.03.011

Clayson, P. E., & Larson, M. J. (2012). Cognitive performance and electrophysiological indices of cognitive control: A validation study of conflict adaptation. *Psychophysiology*, *49*(5), 627–637. https://doi.org/10.1111/j.1469-8986.2011.01345.x

Clayson, P. E., & Larson, M. J. (2013). Psychometric properties of conflict monitoring and conflict adaptation indices: Response time and conflict N2 event-related potentials. *Psychophysiology*, *50*(12), 1209–1219. https://doi.org/10.1111/psyp.12138

Clayson, P. E., & Miller, G. A. (2017a). ERP Reliability Analysis (ERA) Toolbox: An open-source toolbox for analyzing the reliability of event-related brain potentials. *International Journal of Psychophysiology*, *111*, 68–79. https://doi.org/10.1016/j.ijpsycho.2016.10.012

Clayson, P. E., & Miller, G. A. (2017b). Psychometric considerations in the measurement of event-related brain potentials: Guidelines for measurement and reporting. *International Journal of Psychophysiology*, *111*, 57–67. https://doi.org/10.1016/j.ijpsycho.2016.09.005

Coxon, J. P., Goble, D. J., Leunissen, I., Van Impe, A., Wenderoth, N., & Swinnen, S. P. (2016). Functional brain activation associated with inhibitory control deficits in older adults. *Cerebral Cortex*, *26*(1), 12–22. https://doi.org/10.1093/cercor/bhu165

Davis, C., Patte, K., Levitan, R., Reid, C., Tweed, S., & Curtis, C. (2007). From motivation to behaviour: A model of reward sensitivity, overeating, and food preferences in the risk profile for obesity. *Appetite*, *48*(1), 12–19. https://doi.org/10.1016/j.appet.2006.05.016

Dien, J. (2010). The ERP PCA Toolkit: An open source program for advanced statistical analysis of event-related potential data. *Journal of Neuroscience Methods*, *187*(1), 138–145. https://doi.org/10.1016/j.jneumeth.2009.12.009

Dien, J., Michelson, C. A., & Franklin, M. S. (2010). Separating the visual sentence N400 effect from the P400 sequential expectancy effect: Cognitive and neuroanatomical implications. *Brain Research*, *1355*, 126–140. https://doi.org/10.1016/j.brainres.2010.07.099

Donini, L. M., Scardella, P., Piombo, L., Neri, B., Asprino, R., Proietti, A. R., Carcaterra, S., Cava, E., Cataldi, S., Cucinotta, D., Di Bella, G., Barbagallo, M., & Morrone, A. (2013). Malnutrition in elderly: Social and economic determinants. *The Journal of Nutrition, Health & Aging*, *17*(1), 9–15. https://doi.org/10.1007/s12603-012-0374-8

Dwyer, J., White, J., Ham, R. J., Lipschitz, D., & Wellman, N. S. (1991). Screening older americans' nutritional health: Future possibilities. *Nutrition Today*, *26*(5), 21–24. https://journals.lww.com/nutritiontodayonline/Abstract/1991/09000/Screening_Older_Americans__Nutritional_Health_.4.aspx

Falck, R. S., Davis, J. C., Best, J. R., Crockett, R. A., & Liu-Ambrose, T. (2019). Impact of exercise training on physical and cognitive function among older adults: A systematic review and meta-analysis. *Neurobiology of Aging*, *79*, 119–130. https://doi.org/10.1016/j.neurobiolaging.2019.03.007

Falkenstein, M., Hoormann, J., & Hohnsbein, J. (1999). ERP components in Go/Nogo tasks and their relation to inhibition. *Acta Psychologica*, *101*(2), 267–291. https://doi.org/10.1016/S0001-6918(99)00008-6

Falkenstein, M., Hoormann, J., & Hohnsbein, J. (2002). Inhibition-related ERP components: Variation with modality, age, and time-on-task. *Journal of Psychophysiology*, *16*(3), 167–175. https://doi.org/10.1027/0269-8803.16.3.167

Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: A review. *Psychophysiology*, *45*(1), 152–170. https://doi.org/10.1111/j.1469-8986.2007.00602.x

Foote, J. A., Giuliano, A. R., & Harris, R. B. (2000). Older adults need guidance to meet nutritional recommendations. *Journal of the American College of Nutrition*, *19*(5), 628–640. https://doi.org/10.1080/07315724.2000.10718961

Ford, E. S., & Mokdad, A. H. (2001). Fruit and vegetable consumption and diabetes mellitus incidence among U.S. adults. *Preventive Medicine*, *32*(1), 33–39. https://doi.org/10.1006/pmed.2000.0772

Forman, E. M., Manasse, S. M., Dallal, D. H., Crochiere, Rebecca. J., Loyka, C. M., Butryn, M. L., Juarascio, A. S., & Houben, K. (2019). Computerized neurocognitive training for improving dietary health and facilitating weight loss. *Journal of Behavioral Medicine*, *42*(6), 1029–1040. https://doi.org/10.1007/s10865-019-00024-5

Gajewski, P. D., & Falkenstein, M. (2013). Effects of task complexity on ERP components in Go/Nogo tasks. *International Journal of Psychophysiology*, *87*(3), 273–278. https://doi.org/10.1016/j.ijpsycho.2012.08.007

Goldberg, E., Kindilien, S., Roberts, M., & Cohen, D. (2019). Working memory and inadequate micronutrient consumption in healthy seniors. *Journal of Nutrition in Gerontology and Geriatrics*, *38*(3), 247–261. https://doi.org/10.1080/21551197.2019.1627269

Grady, C. (2012). The cognitive neuroscience of ageing. *Nature Reviews Neuroscience*, *13*(7), 491–505. https://doi.org/10.1038/nrn3256

Guenther, P. M., Dodd, K. W., Reedy, J., & Krebs-Smith, S. M. (2006). Most Americans eat much less than recommended amounts of fruits and vegetables. *Journal of the American Dietetic Association*, *106*(9), 1371–1379. https://doi.org/10.1016/j.jada.2006.06.002

Guerra-Carrillo, B., Katovich, K., & Bunge, S. A. (2017). Does higher education hone cognitive functioning and learning efficacy? Findings from a large and diverse sample. *PLOS ONE*, *12*(8), e0182276. https://doi.org/10.1371/journal.pone.0182276

Guerrieri, R., Nederkoorn, C., & Jansen, A. (2007). How impulsiveness and variety influence food intake in a sample of healthy women. *Appetite*, *48*(1), 119–122. https://doi.org/10.1016/j.appet.2006.06.004

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: An integrative review. *Developmental Neuropsychology*, *35*(2), 129–155. https://doi.org/10.1080/87565640903526504

Hall, P. A. (2012). Executive control resources and frequency of fatty food consumption: Findings from an age-stratified community sample. *Health Psychology*, *31*(2), 235–241. https://doi.org/10.1037/a0025407

Hanlon, B., Larson, M. J., Bailey, B. W., & LeCheminant, J. D. (2012). Neural response to pictures of food after exercise in normal-weight and obese women. *Medicine and Science in Sports and Exercise*, *44*(10), 1864–1870. https://doi.org/10.1249/mss.0b013e31825cade5

Harris-Kojetin, L., Sengupta, M., Park-Lee, E., & Valverde, R. (2013). Long-term care services in the United States: 2013 overview. *National Center for Health Statistics Vital Health Stat*, *3*(37), 1–107.

Healey, M. K., Campbell, K. L., & Hasher, L. (2008). Chapter 22 cognitive aging and increased distractibility: Costs and potential benefits. In W. S. Sossin, J.-C. Lacaille, V. F. Castellucci, & S. Belleville (Eds.), *Progress in brain research* (Vol. 169, pp. 353–363). Elsevier. https://doi.org/10.1016/S0079-6123(07)00022-2

Heilbronner, U., & Münte, T. F. (2013). Rapid event-related near-infrared spectroscopy detects age-related qualitative changes in the neural correlates of response inhibition. *NeuroImage*, *65*, 408–415. https://doi.org/10.1016/j.neuroimage.2012.09.066

Heitz, R. P. (2014). The speed-accuracy tradeoff: History, physiology, methodology, and behavior. *Frontiers in Neuroscience*, *8*, 150. https://doi.org/10.3389/fnins.2014.00150

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., Hazen, N., Herman, J., Katz, E. S., Kheirandish-Gozal, L., Neubauer, D. N., O'Donnell, A. E., Ohayon, M., Peever, J., Rawding, R., Sachdeva, R. C., Setters, B., Vitiello, M. V., Ware, J. C., & Adams Hillard, P. J. (2015). National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Health*, *1*(1), 40–43. https://doi.org/10.1016/j.sleh.2014.12.010

Hong, X., Sun, J., Bengson, J. J., & Tong, S. (2014). Age-related spatiotemporal reorganization during response inhibition. *International Journal of Psychophysiology*, *93*(3), 371–380. https://doi.org/10.1016/j.ijpsycho.2014.05.013

Houben, K. (2011). Overcoming the urge to splurge: Influencing eating behavior by manipulating inhibitory control. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(3), 384–388. https://doi.org/10.1016/j.jbtep.2011.02.008

Houben, K., Nederkoorn, C., & Jansen, A. (2014). Eating on impulse: The relation between overweight and food-specific inhibitory control. *Obesity*, *22*(5), E6–E8. https://doi.org/10.1002/oby.20670

Hsieh, S., & Lin, Y.-C. (2017). Stopping ability in younger and older adults: Behavioral and event-related potential. *Cognitive, Affective, & Behavioral Neuroscience*, *17*(2), 348–363. https://doi.org/10.3758/s13415-016-0483-7

Huster, R. J., Enriquez-Geppert, S., Lavallee, C. F., Falkenstein, M., & Herrmann, C. S. (2013). Electroencephalography of response inhibition tasks: Functional networks and cognitive contributions. *International Journal of Psychophysiology*, *87*(3), 217–233. https://doi.org/10.1016/j.ijpsycho.2012.08.001

Jansen, A., Nederkoorn, C., van Baak, L., Keirse, C., Guerrieri, R., & Havermans, R. (2009). High-restrained eaters only overeat when they are also impulsive. *Behaviour Research and Therapy*, *47*(2), 105–110. https://doi.org/10.1016/j.brat.2008.10.016

Jasinska, A. J., Yasuda, M., Burant, C. F., Gregor, N., Khatri, S., Sweet, M., & Falk, E. B. (2012). Impulsivity and inhibitory control deficits are associated with unhealthy eating in young adults. *Appetite*, *59*(3), 738–747. https://doi.org/10.1016/j.appet.2012.08.001

Johnson, A. E., Donkin, A. J. M., Morgan, K., Neale, R. J., Pagf, R. M., & Silburn, R. L. (1998). Fruit and vegetable consumption in later life. *Age and Ageing*, *27*(6), 723–728. https://doi.org/10.1093/ageing/27.6.723

Joshipura, K. J. (1999). Fruit and vegetable intake in relation to risk of ischemic stroke. *JAMA*, *282*(13), 1233. https://doi.org/10.1001/jama.282.13.1233

Kaiser, S., Unger, J., Kiefer, M., Markela, J., Mundt, C., & Weisbrod, M. (2003). Executive control deficit in depression: Event-related potentials in a Go/Nogo task. *Psychiatry Research: Neuroimaging*, *122*(3), 169–184. https://doi.org/10.1016/S0925-4927(03)00004-0

Kardos, Z., Kóbor, A., & Molnár, M. (2020). Accurate response selection and inhibition in healthy aging: An event-related potential study. *Psychology and Aging*, *35*(5), 720–728. https://doi.org/10.1037/pag0000466

Keil, A., Debener, S., Gratton, G., Junghöfer, M., Kappenman, E. S., Luck, S. J., Luu, P., Miller, G. A., & Yee, C. M. (2014). Committee report: Publication guidelines and recommendations for studies using electroencephalography and magnetoencephalography. *Psychophysiology*, *51*(1), 1–21. https://doi.org/10.1111/psyp.12147

Kim, C., Johnson, N. F., & Gold, B. T. (2014). Conflict adaptation in prefrontal cortex: Now you see it, now you don't. *Cortex*, *50*, 76–85. https://doi.org/10.1016/j.cortex.2013.08.011

Kim, S., Hasher, L., & Zacks, R. T. (2007). Aging and a benefit of distractibility. *Psychonomic Bulletin & Review*, *14*(2), 301–305. https://doi.org/10.3758/BF03194068

Krolak-Salmon, P., Fischer, C., Vighetto, A., & Mauguière, F. (2001). Processing of facial emotional expression: Spatio-temporal data as assessed by scalp event-related potentials. *European Journal of Neuroscience*, *13*(5), 987–994. https://doi.org/10.1046/j.0953-816x.2001.01454.x

Kropotov, J., Ponomarev, V., Tereshchenko, E. P., Müller, A., & Jäncke, L. (2016). Effect of aging on ERP components of cognitive control. *Frontiers in Aging Neuroscience*, *8*. https://doi.org/10.3389/fnagi.2016.00069

Langenecker, S. A., & Nielson, K. A. (2003). Frontal recruitment during response inhibition in older adults replicated with fMRI. *NeuroImage*, *20*(2), 1384–1392. https://doi.org/10.1016/S1053-8119(03)00372-0

Larson, M. J., Clayson, P. E., Keith, C. M., Hunt, I. J., Hedges, D. W., Nielsen, B. L., & Call, V. R. A. (2016). Cognitive control adjustments in healthy older and younger adults: Conflict adaptation, the error-related negativity (ERN), and evidence of generalized decline with age. *Biological Psychology*, *115*, 50–63. https://doi.org/10.1016/j.biopsycho.2016.01.008

Larson, M. J., Farrer, T. J., & Clayson, P. E. (2011). Cognitive control in mild traumatic brain injury: Conflict monitoring and conflict adaptation. *International Journal of Psychophysiology*, *82*(1), 69–78. https://doi.org/10.1016/j.ijpsycho.2011.02.018

Ledikwe, J. H., Smiciklas-Wright, H., Mitchell, D. C., Miller, C. K., & Jensen, G. L. (2004). Dietary patterns of rural older adults are associated with weight and nutritional

status. *Journal of the American Geriatrics Society*, *52*(4), 589–595. https://doi.org/10.1111/j.1532-5415.2004.52167.x

Liu, S., Manson, J. E., Lee, I.-M., Cole, S. R., Hennekens, C. H., Willett, W. C., & Buring, J. E. (2000). Fruit and vegetable intake and risk of cardiovascular disease: The Women's Health Study. *The American Journal of Clinical Nutrition*, *72*(4), 922–928. https://doi.org/10.1093/ajcn/72.4.922

Luck, S. J. (2014). *An introduction to the event-related potential technique, second edition*. MIT Press.

Meule, A. (2017). Reporting and Interpreting Task Performance in Go/No-Go Affective Shifting Tasks. *Frontiers in Psychology*, *8*, 701. https://doi.org/10.3389/fpsyg.2017.00701

Meule, A., & Kübler, A. (2014). Double trouble. Trait food craving and impulsivity interactively predict food-cue affected behavioral inhibition. *Appetite*, *79*, 174–182. https://doi.org/10.1016/j.appet.2014.04.014

Meule, A., Lutz, A. P. C., Krawietz, V., Stützer, J., Vögele, C., & Kübler, A. (2014). Food-cue affected motor response inhibition and self-reported dieting success: A pictorial affective shifting task. *Frontiers in Psychology*, *5*, 216. https://doi.org/10.3389/fpsyg.2014.00216

Miller, G. A., & Chapman, J. P. (2001). Misunderstanding analysis of covariance. *Journal of Abnormal Psychology*, *110*(1), 40–48. https://doi.org/10.1037/0021-843X.110.1.40

Niccoli, T., & Partridge, L. (2012). Ageing as a risk factor for disease. *Current Biology*, *22*(17), R741–R752. https://doi.org/10.1016/j.cub.2012.07.024

Nielson, K. A., Langenecker, S. A., & Garavan, H. (2002). Differences in the functional neuroanatomy of inhibitory control across the adult life span. *Psychology and Aging*, *17*(1), 56–71. https://doi.org/10.1037/0882-7974.17.1.56

Niessen, E., Fink, G. R., Hoffmann, H. E. M., Weiss, P. H., & Stahl, J. (2017). Error detection across the adult lifespan: Electrophysiological evidence for age-related deficits. *NeuroImage*, *152*, 517–529. https://doi.org/10.1016/j.neuroimage.2017.03.015

Parsons, T. J., Papachristou, E., Atkins, J. L., Papacosta, O., Ash, S., Lennon, L. T., Whincup, P. H., Ramsay, S. E., & Wannamethee, S. G. (2019). Healthier diet quality and dietary patterns are associated with lower risk of mobility limitation in older men. *European Journal of Nutrition*, *58*(6), 2335–2343. https://doi.org/10.1007/s00394-018-1786-y

Põld, T., Bachmann, M., Päeske, L., Kalev, K., Lass, J., & Hinrikus, H. (2019). *EEG spectral asymmetry is dependent on education level of men* (pp. 405–408). https://doi.org/10.1007/978-981-10-9038-7_76

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128–2148. https://doi.org/10.1016/j.clinph.2007.04.019

Prochaska, J. D., Sharkey, J. R., Ory, M. G., & Burdine, J. N. (2006). Assessing healthful eating among community dwelling rural older adults using self-reported fruit and vegetable consumption via a community-wide mail-out health status assessment. *Journal of Nutrition For the Elderly*, *25*(2), 101–112. https://doi.org/10.1300/J052v25n02_07

Ramos-Loyo, J., González-Garrido, A. A., García-Aguilar, G., & Río-Portilla, Y. D. (2013). The emotional content of faces interferes with inhibitory processing: An event related potential study. *International Journal of Psychological Studies*, *5*(2), 52. https://doi.org/10.5539/ijps.v5n2p52

Rugg, M. D., & Coles, M. G. H. (Eds.). (1995). *Electrophysiology of mind: Event-related brain potentials and cognition* (pp. xii, 220). Oxford University Press.

Saffel-Shrier, S., Johnson, M. A., & Francis, S. L. (2019). Position of the academy of nutrition and dietetics and the society for nutrition education and behavior: Food and nutrition programs for community-residing older adults. *Journal of Nutrition Education and Behavior*, *51*(7), 781–797. https://doi.org/10.1016/j.jneb.2019.03.007

Sahyoun, N., Zhang, X., & Serdula, M. (2006). Barriers to the consumption of fruits and vegetables among older adults. *Journal of Nutrition For the Elderly*, *24*(4), 5–21. https://doi.org/10.1300/J052v24n04_03

Sebastian, A., Baldermann, C., Feige, B., Katzev, M., Scheller, E., Hellwig, B., Lieb, K., Weiller, C., Tüscher, O., & Klöppel, S. (2013). Differential effects of age on subcomponents of response inhibition. *Neurobiology of Aging*, *34*(9), 2183–2193. https://doi.org/10.1016/j.neurobiolaging.2013.03.013

Selya, A., Rose, J., Dierker, L., Hedeker, D., & Mermelstein, R. (2012). A practical guide to calculating cohen's f2, a measure of local effect size, from PROC MIXED. *Frontiers in Psychology*, *3*, 111. https://doi.org/10.3389/fpsyg.2012.00111

Smith, J. L., Carbine, K. A., Larson, M. J., Tucker, L. A., Christensen, W. F., LeCheminant, J. D., & Bailey, B. W. (2021). To play or not to play? The relationship between active video game play and electrophysiological indices of food-related inhibitory control in adolescents. *European Journal of Neuroscience*, *53*(3), 876–894. https://doi.org/10.1111/ejn.15071

Smith, J. L., Johnstone, S. J., & Barry, R. J. (2008). Movement-related potentials in the Go/NoGo task: The P3 reflects both cognitive and motor inhibition. *Clinical Neurophysiology*, *119*(3), 704–714. https://doi.org/10.1016/j.clinph.2007.11.042

Stan Development Team. (2016). *CmdStan: The command-line interface to Stan, version 2.9.0*. Stan-Dev.Github.Io. //mc-stan.org/

Starr, K. N. P., McDonald, S. R., & Bales, C. W. (2015). Nutritional vulnerability in older adults: A continuum of concerns. *Current Nutrition Reports*, *4*(2), 176–184. https://doi.org/10.1007/s13668-015-0118-6

Steinmetz, K. A., & Potter, J. D. (1996). Vegetables, fruit, and cancer prevention: A review. *Journal of the American Dietetic Association*, *96*(10), 1027–1039. https://doi.org/10.1016/S0002-8223(96)00273-8

Stratton, R. J., Stubbs, R. J., Hughes, D., King, N., Blundell, J. E., & Elia, M. (1998). Comparison of the traditional paper visual analogue scale questionnaire with an Apple Newton electronic appetite rating system (EARS) in free living subjects feeding ad libitum. *European Journal of Clinical Nutrition*, *52*(10), 737–741. https://doi.org/10.1038/sj.ejcn.1600636

Stubbs, R. J., Hughes, D. A., Johnstone, A. M., Rowley, E., Reid, C., Elia, M., Stratton, R., Delargy, H., King, N., & Blundell, J. E. (2000). The use of visual analogue scales to assess motivation to eat in human subjects: A review of their reliability and validity with an evaluation of new hand-held computerized systems for temporal tracking of appetite ratings. *British Journal of Nutrition*, *84*(4), 405–415. https://doi.org/10.1017/S0007114500001719

Vallesi, A., McIntosh, A. R., & Stuss, D. T. (2010). Overrecruitment in the aging brain as a function of task demands: Evidence for a compensatory view. *Journal of Cognitive Neuroscience*, *23*(4), 801–815. https://doi.org/10.1162/jocn.2010.21490

van Maanen, L. (2016). Is there evidence for a mixture of processes in speed-accuracy trade-off behavior? *Topics in Cognitive Science*, *8*(1), 279–290. https://doi.org/10.1111/tops.12182

Vitolins, M. Z., Tooze, J. A., Golden, S. L., Arcury, T. A., Bell, R. A., Davis, C., Devellis, R. F., & Quandt, S. A. (2007). Older adults in the rural South are not meeting healthful eating guidelines. *Journal of the American Dietetic Association*, *107*(2), 265-272.e3. https://doi.org/10.1016/j.jada.2006.11.009

Wan, H., Sengupta, M., Velkoff, V. A., & DeBarros, K. A. (2005). *65+ in the United States: 2005*. 254.

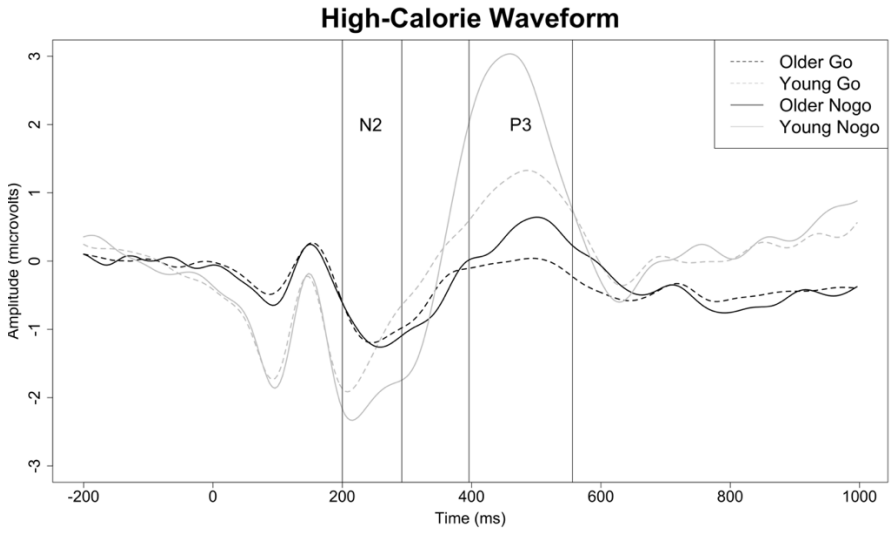
Ward, B. W., Schiller, J. S., & Goodman, R. A. (2014). Multiple chronic conditions among US adults: A 2012 update. *Preventing Chronic Disease*, *11*, E62. https://doi.org/10.5888/pcd11.130389

Watson, T. D., & Garvey, K. T. (2013). Neurocognitive correlates of processing food-related stimuli in a Go/No-go paradigm. *Appetite*, *71*, 40–47. https://doi.org/10.1016/j.appet.2013.07.007

Weissman, D. H., Warner, L. M., & Woldorff, M. G. (2009). Momentary reductions of attention permit greater processing of irrelevant stimuli. *NeuroImage*, *48*(3), 609–615. https://doi.org/10.1016/j.neuroimage.2009.06.081

Wessel, J. R., & Aron, A. R. (2015). It's not too late: The onset of the frontocentral P3 indexes successful response inhibition in the stop-signal paradigm. *Psychophysiology*, *52*(4), 472–480. https://doi.org/10.1111/psyp.12374

Figure 1. Grand average ERP Waveforms for the P3 and N2 amplitude during the high-calorie and low-calorie task. Both the P3 and N2 were averaged across four frontocentral electrodes [6(FCz), 7, 106, 129(Cz)]. The extraction window for the ERPs was 200 milliseconds prior to stimulus presentation to 1000 milliseconds following stimulus presentation. The rectangles reflect the time period for the data extraction.



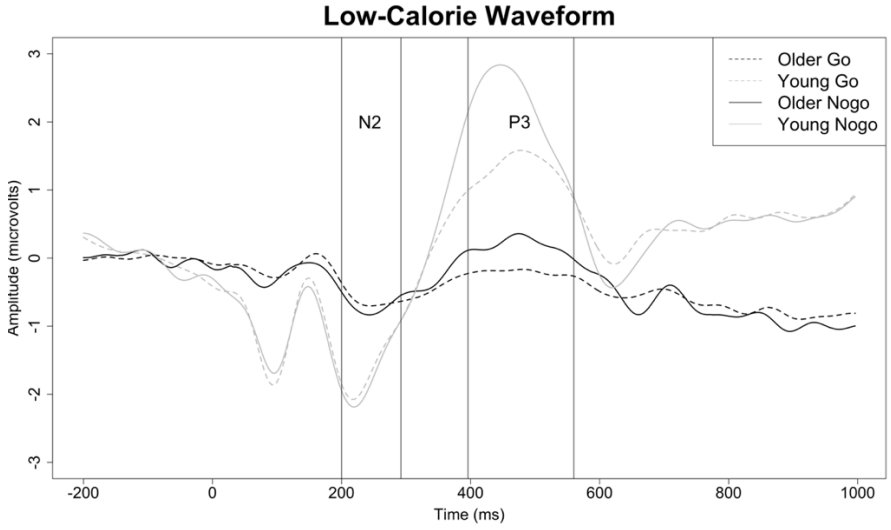


Table 1. Dependability estimates for each group, condition, and ERP, for correct trials

	Dependability	95% CI	Trial # Cutoff	Mean # Trials	Trial Range
P3 Component					
High Calorie Task					
Older Adults Go	.97	.96 – .98	55	122	55 – 140
Older Adults No-go	.96	.94 – .97	31	49	31 – 57
Younger Adults Go	.98	.98 – .99	70	123	70 – 140
Younger Adults No-go	.96	.95 – .97	30	48	30 – 59
Low Calorie Task					
Older Adults Go	.98	.97 – .98	73	116	73 – 139
Older Adults No-go	.96	.94 – .97	24	47	24 – 57
Younger Adults Go	.98	.98 – .99	76	119	76 – 140
Younger Adults No-go	.96	.95 – .97	17	46	17 – 60
N2 Component					
High Calorie Task					
Older Adults Go Correct	.95	.93 – .97	55	122	55 – 140
Older Adults No-go Incorrect	.89	.85 – .93	31	51	31 – 57
Younger Adults Go Correct	.97	.97 – .98	70	123	70 – 140
Younger adults No-go Incorrect	.94	.92 – .95	30	48	30 – 59
Low Calorie Task					
Older Adults Go Correct	.96	.94 – .97	73	116	73 – 139
Older Adults No-go Incorrect	.91	.87 – .94	24	46	24 – 57
Younger Adults Go Correct	.98	.97 – .98	76	119	76 – 140
Younger Adults No-go Incorrect	.94	.92 – .95	17	46	17 – 60

Table 2. Demographic Information (e.g., sample size, number of females, age in years, education in years, and BMI) for the total sample and split by each group.

Total Sample	*N*	173
	N female	113 (65%)
	Age in years (SD)	35.4 (21.1)
	Education in years (SD)	14.7 (2.7)
	BMI (SD)	25.4 (6.4)
Older Adults	*N*	59
	N female	31 (53%)
	Age in years (SD)	63.8 (7.5)
	Education in years (SD)	16.9 (2.8)
	BMI (SD)	30.3 (8.3)
Younger Adults	*N*	114
	N female	82 (71.9%)
	Age in years (SD)	20.8 (3.5)
	Education in years (SD)	13.6 (1.8)
	BMI (SD)	22.9 (3)

Table 3. Visual analog scale (VAS) means and standard deviations as a function of group.

Older Adults		
	Sleep Time in hours (SD)	7.4 (1.1)
	Sleep Quality in cm (SD)	7.2 (1.8)
	Hunger in cm (SD)	3.6 (2.6)
Younger Adults		
	Sleep Time in hours (SD)	8.0 (0.9)
	Sleep Quality in cm (SD)	7.1 (1.6)
	Hunger in cm (SD)	3.0 (2.1)

Table 4. Means of response times (in ms) and accuracy divided by group

	Older Adults			Younger Adults		
	Mean	SD	Range	Mean	SD	Range
High Calorie Task						
Go Correct RT	448	59	342 – 683	393	62	287 – 777
Go Accuracy %	96	10	39 – 100	98	5	59 – 100
No-go Accuracy %	91	7	65 – 98.3	90	8	58 – 100
Low Calorie Task						
Go Correct RT	471	48	354 – 583	413	69	302 – 724
Go Accuracy %	95	6	60 – 100	96	5	58 – 100
No-go Accuracy %	90	7	73 – 100	88	10	50 – 100

Table 5. Means of ERP amplitude for the P3 and N2 components by task in μV as a function of group

	Older Adults			Younger Adults		
	Mean	SD	Range	Mean	SD	Range
High Calorie Task						
P3: No-go	1.5	3.1	-3.6 – 10.9	4.3	3.2	-1.3 – 15.2
P3: Go	.75	2.1	-2.2 – 7.5	2.2	2.5	-2.8 – 11.5
N2: No-go	-1.7	1.7	-6.5 – 0.8	-3.1	2.5	-10 – 10.5
N2: Go	-1.6	1.9	-8.0 – 0.7	-2.2	2.5	-8.4 – 9.4
Low Calorie Task						
P3: No-go	1.3	2.7	-3.1 – 8.2	3.7	3.0	-3.3 – 13.1
P3: Go	0.6	2.2	-4.0 – 7.1	2.3	2.5	-4.5 – 8.3
N2: No-go	-1.4	1.9	-8.4 – 3.8	-2.8	2.5	-9.3 – 6.5
N2: Go	-1.1	1.6	-6.4 – 3.9	-2.6	2.5	-8.7 – 5.9