

Neural Mechanisms and Post-Intervention Traces of Working Memory in Overweight/Obese Individuals

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Abstract

The global population of overweight/obese individuals is growing rapidly; in 1997, the World Health Organization identified obesity as a global epidemic. Currently, the prevalence of overweight/obesity among Chinese adults has exceeded 50%, with unhealthy dietary behaviors accounting for 70% of obesity's etiology. This project proposes to investigate food-specific working memory, elucidating the neural mechanisms underlying food-specific working memory in overweight/obese individuals and their divergence from general working memory neural mechanisms. Subsequently, employing a prospective research design, we will examine the gradual relationship between food-specific working memory and the development of overweight/obesity, exploring the predictive utility of food-specific working memory and its neural activity for individual dietary management and physical constitution changes. Finally, through food-specific inhibitory control training, we aim to enhance food-specific working memory capacity in overweight/obese individuals and foster healthy eating behaviors. This project seeks to identify safe and effective methods for shaping healthy eating behaviors, providing theoretical and practical recommendations for overweight/obesity prevention and intervention, and is characterized by its practical significance, cutting-edge nature, and forward-looking perspective.

Full Text

Preamble

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Conceptual Framework Neural Mechanisms and Intervention of Working Memory in Overweight/Obese Individuals

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Abstract

The global population of overweight/obese individuals is growing rapidly, with the World Health Organization identifying obesity as a global epidemic in 1997. Currently, the prevalence of overweight and obesity among Chinese adults has exceeded 50%, with unhealthy dietary behaviors accounting for 70% of obesity causes. This project investigates food-specific working memory to elucidate its neural mechanisms in overweight/obese individuals and identify potential differences from general working memory neural patterns. Using a prospective research design, we will examine the dynamic relationship between food-specific working memory and the development of overweight/obesity, exploring the predictive role of food-specific working memory and its neural activity on dietary management and physical health changes. Finally, we will employ food-specific inhibition control training to enhance food-specific working memory capacity and foster healthy eating behaviors in overweight/obese individuals. This project aims to explore safe and effective methods for shaping healthy eating behaviors, providing theoretical and practical recommendations for overweight/obesity prevention and intervention, with significant practical, cutting-edge, and forward-looking value.

Keywords: working memory, cognitive control, overweight/obesity, cognitive neural mechanism, intervention

Classification Code: B845

1. Research Significance

China's 14th Five-Year Plan for Scientific and Technological Development emphasizes "extensive national fitness campaigns to enhance people's physical health," highlighting physical health as a national priority. With rapid economic development and improved living standards, overweight and obesity rates in China are increasing at an alarming pace. A 2014 *Lancet* study reported obesity prevalence rates of 3.8% for men and 5.0% for women, making China second only to the United States in obesity population [?, ?]. Research from the Chinese Center for Disease Control and Prevention in 2019 found that 14% of adults had generalized obesity (BMI ≥ 28 kg/m²) and 31.5% had abdominal obesity (waist circumference ≥ 90 cm for men, ≥ 85 cm for women) [?, ?]. Overweight/obesity

is placing an increasing burden on China's healthcare system, making effective prevention and control a critical and pressing issue.

The Healthy China Action Plan (2020–2030) explicitly proposes “reasonable dietary actions” and targets for “continuously slowing obesity growth rates.” Reasonable diet emphasizes not only nutritional structure but also healthy eating patterns. Previous research shows that reward-related brain regions in obese individuals are hyperactivated by food cues, while inhibition control-related regions show insufficient suppression [?, ?, ?]. Meta-analytic studies demonstrate that obese individuals exhibit widespread executive function deficits, including inhibition control, working memory, cognitive flexibility, and decision-making, while overweight individuals show deficits primarily in working memory and inhibition control [?, ?]. Thus, working memory and inhibition control may serve as effective indicators for weight-related problems.

Working memory refers to the ability to maintain and manipulate information in mind over short periods [?, ?] and is closely associated with successful self-control and goal-directed behavior [?, ?]. Stronger working memory capacity enables individuals to maintain healthy eating as a long-term goal, directing attention toward this goal and resisting short-term temptations [?, ?]. Enhanced working memory correlates with self-reported consumption of more fruits and vegetables [?, ?] and selection of low-calorie foods in experimental tasks [?, ?]. Therefore, working memory plays a crucial role in healthy eating behaviors.

This project focuses on working memory, specifically the updating component, to investigate the neural mechanisms of food-specific working memory updating in overweight/obese individuals and examine differences from general working memory. Through cross-sectional and prospective designs, we will explore the dynamic relationship between food-specific working memory updating and overweight/obesity development, investigating its predictive role in dietary management and physical health changes. Finally, we will use food-specific inhibition control training to enhance food-specific working memory updating capacity and shape healthy eating behaviors. This project is realistic, cutting-edge, and forward-looking, providing theoretical and practical recommendations for overweight/obesity prevention and intervention, with significant implications for advancing the Healthy China strategy.

2.1 Working Memory in Overweight/Obese Individuals

Working memory involves maintaining and manipulating information and can be divided into verbal and non-verbal domains, which are essential for understanding connections between seemingly unrelated concepts and isolating elements from wholes [?, ?]. Meta-analytic research indicates that obesity impairs working memory consistently across studies, with overweight individuals already showing working memory deficits [?, ?], suggesting that working memory may be a sensitive indicator of BMI effects.

Behavioral evidence using various experimental tasks demonstrates that over-

weight/obese individuals perform significantly worse on working memory tasks than normal-weight individuals [?, ?, ?]. Event-related potential (ERP) studies on working memory have focused on components such as N2, P3, and late positive potential (LPP). Overweight/obese individuals show smaller N2 amplitudes but larger P3 and LPP components during food-specific executive function tasks [?, ?, ?, ?, ?, ?]. Additionally, LPP amplitude increases when individuals consider long-term consequences of eating high-calorie foods [?, ?]. Working memory tasks involving food cues elicit larger P3, LPP, and sustained posterior contralateral negativity (SPCN) responses, indicating that memory and maintenance of food cues require greater cognitive resource allocation [?, ?]. Individuals showing larger LPP responses to food cues report more food addiction symptoms [?, ?].

Neural oscillation studies of working memory have primarily examined theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (>30 Hz) frequencies [?, ?]. During working memory maintenance, theta power increases with memory load and correlates positively with the number of items maintained [?, ?, ?]. Alpha rhythms primarily inhibit interference from irrelevant stimuli, increasing with the number of working memory items to protect target information from distraction [?, ?, ?, ?]. Lower beta frequencies are associated with working memory maintenance [?, ?, ?], with increased beta activity in prefrontal cortex when working memory is no longer required [?, ?]. Beta is involved in top-down processing and inhibition in deep brain regions, while gamma in superficial cortical regions reflects bottom-up processing related to maintaining input information [?, ?]. Studies show that gamma, alpha, and beta oscillations are critical for understanding information transmission between sensory cortex and frontoparietal networks in working memory [?, ?]. However, neural oscillations of working memory (particularly food-specific working memory) in overweight/obese individuals remain largely unexplored.

Functional magnetic resonance imaging (fMRI) studies reveal that working memory primarily relies on prefrontal and parietal regions, whose activation facilitates content-specific maintenance and processing [?, ?, ?, ?, ?, ?]. Research indicates that posterior parietal cortex and prefrontal cortex participate in attentional scope and control during visual working memory, emphasizing their distinct roles [?, ?]. In working memory updating tasks, overweight/obese individuals show longer reaction times and lower accuracy, with right dorsolateral prefrontal cortex (DLPFC) activity positively correlating with BMI, suggesting that poorer working memory updating may relate to diminished inhibition control [?, ?]. During executive function tasks, overweight/obese individuals show reduced activation in control-related regions including lateral prefrontal cortex, ventrolateral prefrontal cortex, medial prefrontal cortex, superior frontal gyrus, and middle frontal gyrus [?, ?, ?]. When viewing unhealthy food advertisements, overweight/obese individuals show lower bilateral middle and inferior frontal cortex activation, indicating greater susceptibility to advertising temptations [?, ?]. At rest, overweight/obese individuals show significantly reduced right angular gyrus activity and weaker functional connectivity between right angular gyrus

and left middle temporal cortex compared to normal-weight individuals [?, ?].

Current research on working memory in overweight/obese individuals has focused primarily on general stimuli, showing universal deficits. However, food-specific working memory remains understudied. Research indicates that cues receiving more attention show weaker working memory performance [?, ?]. Since overweight/obese individuals allocate more attention and cognitive resources to food cues, does food-specific working memory show greater impairment than general working memory? Moreover, existing studies are predominantly behavioral, leaving the neural mechanisms of food-specific working memory unknown. Therefore, Study 1 of this project will use a cross-sectional design combined with EEG to investigate the electrophysiological mechanisms of food-specific working memory updating in overweight/obese individuals from temporal dynamics and neural oscillation perspectives, comparing behavioral and neural patterns between general and food-specific working memory.

2.3 Inhibition Control, Working Memory, and Eating Behavior

Inhibition control refers to the ability to suppress dominant responses, involving control over attention, behavior, thoughts, or emotions. Without inhibition control, we would be more impulsive [?, ?]. Inhibition control facilitates working memory by reorganizing multiple ideas or facts and using innovative approaches for expression while suppressing interference from irrelevant information [?, ?]. Inhibition control can prevent irrelevant information from entering working memory space and delete no-longer-useful information to keep our mental workspace clean [?, ?, ?]. Individual differences in working memory primarily reflect variations in control ability [?, ?, ?], with inhibition of specific information directly determining performance on complex working memory tasks [?, ?, ?]. Ineffective suppression of task-irrelevant representations severely impairs working memory performance [?, ?].

Working memory updating is a key factor in eating behavior, helping individuals maintain long-term goals like healthy eating and resist short-term desires inconsistent with these goals. High working memory updating capacity enables effective representation of long-term goals by maintaining goal-relevant information or suppressing inconsistent information, thereby diverting attention from tempting stimuli. When long-term goals are “protected” in tempting environments, craving desires are effectively down-regulated [?, ?, ?]. Larger visual-spatial working memory span for general cues correlates with lower proportions of high-calorie food intake among dieters [?, ?], suggesting that general working memory can facilitate dietary management. Among individuals with healthy eating goals, working memory updating capacity correlates with healthier long-term outcomes such as more frequent fruit and vegetable consumption [?, ?]. Therefore, stronger working memory updating capacity may promote healthy eating behavior development.

Lopez et al. used prospective methods to explore how brain activity predicts dietary management. After dieters completed fMRI scans with food cues, they conducted experience sampling of dietary management for one week, randomly surveying participants seven times daily about food cravings, craving resistance, and food intake. The study found that stronger reward region activity (nucleus accumbens) predicted poorer dietary management, while stronger control region activity (inferior frontal gyrus) predicted more successful dietary management, indicating that reward and control neural activity play important roles in real-life temptation experiences [?, ?, ?, ?]. Top-down attention to food cues can predict weight changes over the subsequent year [?, ?]. Greater activation in reward-related regions including insula, ventral tegmental area, putamen, and fusiform gyrus predicts lower weight maintenance success rates nine months later in overweight/obese individuals [?, ?]. Activity in amygdala and orbitofrontal cortex can also predict future weight changes [?, ?, ?].

A meta-analysis of 66 independent experiments covering 5,787 participants examined cognitive training effects on eating behavior and weight, finding that inhibition control training (e.g., go/no-go training with food stimuli) effectively improves dietary behavior [?, ?]. Inhibition control training can reduce food cravings, with food-specific inhibition control training promoting suppression of unwanted food-related impulses. For example, Houben et al. (2015) randomly assigned participants to food no-go training versus food go training, finding that food no-go training significantly reduced eating desires [?, ?]. Food-specific inhibition control training (approximately 10 minutes daily for one week) significantly reduced unhealthy food choice frequency and self-reported attractiveness and liking of unhealthy foods among unsuccessful restrained eaters [?, ?]. Since inhibition control can facilitate working memory, can food-specific inhibition control training significantly improve food-specific working memory updating in overweight/obese individuals and promote healthy eating behavior? Based on this, the final key scientific question this project addresses is exploring effective intervention techniques for overweight/obesity from the perspective of food-specific working memory updating.

4.1 Neural Electrophysiological Activity of Working Memory in Overweight/Obese Individuals

Study 1 uses EEG to investigate the electrophysiological activity of working memory updating in overweight/obese individuals from temporal dynamics and neural oscillation perspectives. This study aims to elucidate the cognitive neural mechanisms of working memory updating in overweight/obese individuals and includes one EEG experiment (Protocol 1) using both general 2-back tasks and food-specific 2-back tasks. The study examines temporal characteristics of brain activity during general and food-specific working memory updating and explores whether these processes show similar behavioral and neural patterns. The study employs a 2 (participant type: overweight/obese vs. normal-weight) × 3 (stimulus type: high-calorie food, low-calorie food, and general stimuli)

mixed design, with participant type as a between-subjects factor and stimulus type as a within-subjects factor. High- and low-calorie food images for the food 2-back task are selected from our team's established food picture database [?, ?, ?, ?, ?]. Before and after the food 2-back task, all participants rate food images on pleasantness (liking) and wanting using 5-point scales to control for changes in food reward value and desire. We hypothesize that overweight/obese individuals will show significantly poorer performance on working memory tasks than normal-weight individuals, with neural manifestations including changes in N2 amplitude, P3 amplitude, and theta and alpha power. Additionally, due to the reward effects of food, general and food-specific working memory updating may show different neural patterns in overweight/obese individuals.

4.2 Gradual Relationship Between Food-Specific Working Memory and Overweight/Obesity Development

Study 2 examines the gradual relationship between food-specific working memory updating and overweight/obesity development from the perspective of brain activation. This study uses a combined cross-sectional and prospective design with fMRI technology, comprising two experiments. Protocol 2 investigates the predictive role of food-specific working memory updating and its neural basis on dietary management in overweight/obese individuals. Protocol 3 examines the predictive effect of food-specific working memory updating and its neural basis on physical health changes. The cross-sectional phase uses a 2 (participant type: overweight/obese vs. normal-weight) \times 2 (stimulus type: high-calorie vs. low-calorie food images) mixed design, with participant type as a between-subjects factor and stimulus type as a within-subjects factor. We adapted a food 1-back task requiring both working memory updating and inhibition control. Participants respond quickly to stimuli (background task) but must inhibit their response when the current stimulus is identical to the previous one (memory task). Before and after the working memory task, participants rate food images on pleasantness and wanting. After completing the cross-sectional task, we conduct a one-week experience sampling of participants' dietary management, randomly sending seven daily surveys about current food cravings, craving resistance, and food intake. Six months after the experiment, all participants are invited back to the laboratory for body composition measurements (BMI, waist-to-hip ratio, body fat percentage, etc.). We hypothesize that overweight/obese individuals will show poorer working memory updating performance than normal-weight individuals, and that better food-specific working memory updating will predict more successful dietary management and lower BMI and waist-to-hip ratio. Additionally, compared to normal-weight individuals, overweight/obese individuals will show reduced activation in control-related brain regions but increased activation in reward-related regions. Greater activation in control-related regions during food-specific working memory tasks will predict more successful dietary management and lower BMI and waist-to-hip ratio, whereas greater activation in reward-related regions will predict less successful dietary management and higher BMI and waist-to-hip ratio.

4.3 Intervention Study on Food-Specific Working Memory in Overweight/Obese Individuals

Building on the first two studies, Study 3 explores effective intervention techniques for overweight/obesity from an applied perspective. Using food-specific inhibition control training (Protocol 4) combined with fMRI, we examine the effectiveness of food-specific inhibition control training in enhancing food-specific working memory updating in overweight/obese individuals. The study employs a 2 (training group: food-specific inhibition control vs. general inhibition control) \times 2 (testing session: pre-test vs. post-test) \times 2 (stimulus: high-calorie vs. low-calorie food images) mixed design, with training group as a between-subjects factor and testing session and stimulus as within-subjects factors. The task is the same food 1-back task used in Study 2. Food-specific inhibition control training uses a food go/no-go task where go stimuli are flower images and no-go stimuli are high-calorie food images, requiring participants to respond quickly to flowers but inhibit responses to high-calorie foods. General inhibition control training uses consonant letters “M”(go) and “W”(no-go). We hypothesize that both general and food-specific inhibition control training will significantly improve food-specific working memory performance in overweight/obese individuals, but that food-specific training will be more effective. Both training types should enhance activation in control-related brain regions during food-specific working memory tasks, but may have different effects on neural patterns.

Conclusion

This project focuses on food-specific working memory, examining both behavioral performance and neural mechanisms, investigating dynamic temporal characteristics of cognitive processing and spatial patterns of brain activation in overweight/obese individuals to provide more robust evidence for clarifying their cognitive-behavioral patterns and neuropsychological mechanisms. By exploring the gradual relationship between food-specific working memory and overweight/obesity development, we aim to achieve a more complete understanding of the cognitive neural mechanisms in overweight/obese individuals and provide evidence for establishing a more comprehensive neuropsychological theoretical model. Using inhibition control training interventions, we will provide a practical foundation for effectively addressing obesity and innovatively translating basic research findings into applications.

This project uses working memory as a breakthrough point, employing a combination of cross-sectional, prospective, and intervention study designs focused on working memory updating. From perspectives of temporal dynamics and neural oscillations, brain spatial activation, and application, we aim to: (1) reveal the cognitive neural mechanisms of food-specific working memory updating in overweight/obese individuals; (2) characterize the gradual relationship between food-specific working memory updating and its neural activity with dietary management and physical health changes; and (3) explore effective in-

intervention techniques to enhance food-specific working memory updating and shape healthy eating habits. The research design is interlinked and logically progressive.

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Figure 1 Project Framework Diagram

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