International Journal of Obesity (2018) 42:1500–1507
https://doi.org/10.1038/s41366-018-0121-2

ARTICLE

Behavior, Psychology and Sociology

Does weight stigma reduce working memory? Evidence of stereotype threat susceptibility in adults with obesity

Veronica Guardabassi[1] · Carlo Tomasetto[1]

Received: 18 October 2017 / Revised: 17 April 2018 / Accepted: 22 April 2018 / Published online: 18 June 2018

Abstract

Background Obesity is a highly stigmatizing condition, and reduced cognitive functioning is a stereotypical trait ascribed to individuals with obesity. In the present work, we tested the hypothesis that stereotype threat (i.e., a depletion of working memory resources due to the fear of confirming a negative self-relevant stereotype when a stereotype-related ability is assessed) contributes to cognitive deficits in individuals with obesity.

Methods Computerized tests of (a) working memory and (b) probabilistic learning—an ability unrelated with working memory—were administered to a community sample of 131 adults. Stereotype threat was manipulated by altering the alleged nature of the tasks; the tasks were alternatively labeled as intelligence tests (high stereotype threat condition), memory and learning tests (standard instructions condition), or distraction games (low stereotype threat condition).

Results A negative relation between body mass index (BMI) and working memory emerged in both the high stereotype threat (95% CIs = −0.872, −0.175, $p = 0.003$) and the standard instructions conditions (95% CIs = −0.974, −0.153, $p = 0.007$), but not in the low stereotype threat condition (95% CIs = −0.266, 0.430, $p = 0.643$). No effect emerged on probabilistic learning.

Conclusion Stereotype threat is associated with impaired working memory of individuals with obesity. Implications for researchers and clinicians are discussed.

Introduction

Intensive research has focused on health complications related with obesity (defined as a body mass index (BMI) ≥ 30) including diabetes, hypertension, cardiovascular disease, and cancers [1]. More recently, attention has also been drawn to the negative relation between body weight and cognitive functioning. Deficits in cognitive functioning associated to obesity have been observed in children, adolescents, and adults [2–4], and epidemiological studies have pointed to obesity as one of the main risk factors for cognitive decline and dementia in elder people [5, 6]. Furthermore, numerous studies have reported negative associations between BMI and executive functions, including attention shifting and flexibility [7–9], inhibition [8, 9], and working memory [10–14].

Working memory is a memory system implicated in the control, retention, and processing of information for short periods of time in the service of more complex cognitive activities [15]. Tasks assessing working memory typically require active maintenance of relevant information while simultaneously performing distracting or interfering tasks [16]. Working memory capacity positively correlates with a wide range of tasks and outcomes [17], including academic attainment [18], emotion regulation [19], decision making and problem solving [20], and self-regulation of food intake [21]. When working memory capacity is compromised, performance in complex tasks requiring controlled processing is unavoidably damaged [22]. Although some studies showed no differences in working memory performance according to participants' weight status [23], evidence of a negative relation between BMI and working memory have emerged from childhood [10] to adulthood [11–14].

Several physiological mechanisms appear to be associated with working memory deficits in individuals with obesity, ranging from metabolic dysfunctions (e.g., insulin/leptin

✉ Veronica Guardabassi
veronica.guardabassi@unibo.it

[1] Department of Psychology, University of Bologna, 90, Piazza Aldo Moro, 47521 Cesena, Italy

resistance, increased oxidative stress, cerebrovasculature change, reduced blood–brain barrier integrity, inflammation, and reduced neurotrophins) [24], to structural alterations or reduced activation in brain areas related to working memory (e.g., right superior frontal gyrus, left middle frontal gyrus, and prefontal cortex) [25–28].

Although physiological mechanisms may contribute to working memory impairments, social sigma may also play a role. Obesity is associated with social stigma in many regions, and numerous psychological correlates of obesity (e.g., depression, low self-esteem, body image disturbances, and quality of life) have been found to depend on exposure to weight stigma rather than on high body weight per se [29–31]. A crucial facet of weight stigma concerns cognitive functioning. Studies employing explicit and implicit attitudinal measures report that individuals with obesity are negatively stereotyped as lazy, unsuccessful, and unintelligent [30, 32], In a study by O'Brien et al. [33], for example, participants (a) attributed less competence to, (b) advised against hiring, and (c) recommended a lower entrance salary to a woman allegedly applying for a managerial position when she was portrayed before (vs. after) a significant reduction in BMI.

Here we argue that weight stigma may have a role in hampering the performance of individuals with obesity on working memory tasks by activating negative expectations concerning their cognitive functioning. Abundant evidence indicates that the working memory of individuals belonging to stigmatized social groups is damaged by stereotype threat, defined as the anticipated concern that one's (poor) performance in a stereotype-relevant domain may inadvertently confirm a negative stereotype [34]. In other words, stereotype threat is activated when members of a stigmatized group have to display an ability for which their group is negatively stereotyped. According to the Integrated process model of stereotype threat [22], stereotype threat can be activated in testing situations by: (a) reminding individuals of the negative cultural stereotypes associated with their group (e.g., "people say that individuals who are obese are less intelligent"); (b) emphasizing individuals' membership in the stigmatized group (e.g., "we selected individuals with obesity to take part in this study"); (c) framing the test as an index of abilities related to the negative cultural stereotype (e.g., "this test measures your intelligence"). Stereotype threatening situations trigger physiological stress responses, negative emotions (anxiety), and negative thoughts. Self-monitoring and suppression processes are then activated to buffer these negative states. However, these processes burden working memory, leading to performance decreases in stereotype-relevant tasks that recruit working memory resources [22].

Members of many stigmatized social groups (e.g., African-Americans, women) have been found to perform below their optimal level in stereotype-relevant domains when situational cues activate stereotype threat and to have their performance restored when stereotype threat is removed. Despite some skepticism [35, 36], several meta-analyses have confirmed that stereotype threat interferes with cognitive functioning with small to moderate effect sizes [37–39]. Furthermore, stereotype threat appears to operate in clinical contexts [40, 41]. For example, patients with mild brain injuries showed worse performance on neuropsychological assessment when such tests used stereotype-threat inducing vs. neutral instructions [40]. Similarly, older adults' performance on cognitive tests used in screenings for dementia was lower when task instructions emphasized the purpose of assessing a stereotype-relevant component (e.g., memory) than when this purpose was de-emphasized (i.e., when stereotype threat was removed) [37]. With regard to individuals with obesity, there is evidence that exposure to weight stigma is related to core components of the stereotype threat process, including threat appraisal [42, 43], physiological reactivity [44, 45], and psychological and physiological stress responses [22, 29]. Moreover, stereotype threat has been reported to affect executive function (namely, inhibitory control) among adult women with obesity [46].

Taken together, these findings suggest that individuals with obesity may experience stereotype threat during tests of cognitive functioning. We expected, therefore, to observe lower working memory efficiency among individuals with higher compared to lower levels of BMI when the testing situation activated stereotype-related concerns (i.e., when the purpose of assessing cognitive functioning was explicitly mentioned). That is, we expected a negative relation between BMI and working memory under stereotype threat conditions. Conversely, we expected to observe no (or limited) impairment in working memory among individuals with higher compared to lower levels of BMI when the testing situation did not activate stereotype-related concerns, i.e., when the purpose of assessing cognitive functioning was not mentioned (H1). In addition to the working memory task, participants completed a second task aimed at ruling out alternative accounts for the hypothesized fluctuations in task performance, such as disengagement [47]. Specifically, participants completed a probabilistic learning task, which does not involve working memory and thus should be unaffected by stereotype threat manipulations (H1b).

Materials and methods

Participants

After approval from the Ethical Committee of the University of Bologna (Italy), a convenience sample of 137 participants was recruited among University students and personnel, volunteers from local organizations, and patients of clinicians who agreed to advertise the study. Data from six participants were excluded because of technical problems. Inclusion criteria were being 18 years or older, and having sufficient knowledge of Italian language to understand informed consent and test instructions. Exclusion criteria included being diagnosed with Cushing syndrome, Prader–Willy syndrome, or hypothyroidism.

Procedure

After receiving information about the aim of the study and the inclusion and exclusion criteria, participants who provided signed informed consent were asked to report demographic and anamnestic information, and to complete a questionnaire concerning obesity and psycho-social wellbeing. To compute BMI, participants' weight, and height were measured using a digital stadiometer and scale. Prior to completing two computer tasks assessing working memory and probabilistic learning, participants were randomly assigned to one of the three experimental conditions: standard instructions, SI; high stereotype threat, HST; low stereotype threat, LST. As in other stereotype threat research [48], experimental condition was determined by alternating the experimental condition as participants enrolled, thereby avoiding researcher bias in the assignment of participants to condition. Recruitment was continued until a minimum of 40 individuals had participated in each condition, which was the number determined by an a-priori simple size computation to ensure an adequate statistical power (0.80) for small size effects ($f = 0.10$).

In all the experimental conditions, the salience of stereotype threat was manipulated by means of verbal instructions immediately before administering the two computer tasks. In the SI condition ($n = 40$), standard test instructions were provided for each of the two tasks ("Now you are going to take a working memory and a probabilistic learning test"). In the HST condition ($n = 47$), the diagnostic value of the tests was emphasized by explicitly stating that intelligence was the focus of the assessment ("Now you are going to perform two computer tasks that are very sensitive tools to assess intelligence"). In the LST condition ($n = 44$), the two tests were described as mere distractor tasks ("Now you are going to complete two distraction tasks, before completing the final test that is our primary interest"). Before being thanked and allowed to leave, participants were debriefed concerning true purpose of the study and asked again for their informed consent. No participant expressed suspicion about the procedure, and all confirmed their willingness to have their data included in the study.

Measures

BMI

To compute BMI, participants' weight (in kilograms) was divided by the square of their height (in meters), according to the formula kg/m^2.

Working memory

The Automatic Operation Span Test (OSPAN) [49] was used to assess working memory. In this task, participants solve a math problem, after which a letter is presented to be kept in mind. After solving a set of math problems (ranging from 3 to 7), participants were prompted to recall all the letters presented. Correct responses were summed.

Probabilistic learning

In the Probabilistic Selection Task [50], three pairs of symbols (hiragana characters) are randomly presented (AB, CD, EF) and participants are asked to pick the "winning symbol" of each pair. Feedback is provided after each selection. The win-probabilities of each symbol are 80% for A over B, 70% for C over D, and 60% for E over F. The task included 60 trials and the proportion of correct choices served as a measure of learning. Previous research has demonstrated that performance on the Probabilistic Selection Task does not change as a function of stereotype threat manipulations, even in the presence of conscious threat perception and activation of neural networks related to self-appraisal [51].

Demographic and anamnestic information

Participants were required to report their age, sex, educational background (years of school completed), and to indicate whether they were diagnosed with chronic pathologies (e.g., type II diabetes, cardiovascular diseases, sleep disorder, etc.).

Statistical analyses

All analyses were conducted using SPSS for Windows version 23 (SPSS, Inc, Chicago, IL). We computed descriptive statistics and bivariate correlations (with two-sided significance levels) among all the variables. Then, to test our hypotheses, we used the SPSS Macro PROCESS [52], which tests conditional processes using ordinary least squares regression-based models. Specifically, BMI was included as the main predictor, condition (i.e., SI, HST, LST) as the moderator, and, in two separate models, the AOSPAN score and the probabilistic learning score served

Table 1 Descriptive statistics and bivariate correlations

Variables	M	SD	Bivariate correlations 2	3	4	5	6
Age	41.43	11.213	−0.094	0.298[b]	−0.166	−0.209[a]	−0.037
BMI	34.006	10.729	—	0.165	−0.316[b]	−0.256[b]	−0.086
Health status	0.511	0.888	—	—	−0.212[a]	−0.095	0.045
Level of education	12.632	3.199	—	—	—	0.364[b]	0.124
Working memory	14.356	13.701	—	—	—	—	0.153
Probabilistic learning	0.608	0.132	—	—	—	—	—

[a]Significant at the level of 0.05 (two-tails)

[b]Significant at the level of 0.01 (two-tails)

as the dependent variables. By means of the multi-categorical option, the 3-level moderator variable (i.e., condition: SI, HST, LST) was recoded into two dummy-coded binary variables, each one comparing one condition to a reference group (in our case, the LST condition). Thus, contrast 1 compared the SI to the LST condition, whereas contrast 2 compared the HST to the LST condition. In case of significant interactions, simple slopes analysis was used to explore the association between BMI and cognitive performance within each experimental condition separately. A bootstrapping procedure with 5000 resamples was used to calculate bias-corrected 95% confidence intervals (CI) for all the effects. In addition, we used the Johnson–Neyman technique [53] to determine the region of significance of the moderation (i.e., the BMI values at which participants' performance on the outcome measures significantly differed between conditions, $p < 0.05$).

Results

Descriptive statistics for all variables are reported in Table 1. The 131 participants (33 men and 98 women) ranged from 20 to 67 years of age ($M_{age} = 41.43$, SD = 11.23). Overall, BMIs ranged from 17.85 to 62.43, with an average BMI of 34.006 kg/m^2 (SD = 10.729). Specifically, 42 individuals had BMIs equal to or higher than 40, 32 individuals had BMIs equal to or higher than 30 but below 40, 18 individuals had BMIs equal to or higher than 25 but below 30, and 39 individuals had BMIs lower than 24.99 kg/m^2. The mean BMI levels were 34.95 kg/m^2 (SD = 10.94) in the HST, 33.86 kg/m^2 (SD = 11.30) in the LST, and 33.77 kg/m^2 (SD = 10.08) in the SI conditions, respectively, with no significant difference between conditions, $F(2,128) = 0.037$, $p = 0.964$, $\eta^2_p = 0.001$. Distributions of both BMI and the test outcomes (i.e., working memory and probabilistic learning scores) were homogeneous across conditions (Levene tests: all Fs < 1.50, all ps > 0.300). Bivariate correlations indicate that BMI is negatively related with working memory proficiency ($p = 0.001$), but not with probabilistic learning ($p = 0.332$).

Stereotype threat and working memory

We explored the role of stereotype threat as a moderator of the negative relation between BMI and working memory. As predicted, results (see Table 2) indicated that the relation between body weight and working memory varied according to task diagnosticity (H1). Specifically, the significant interaction between BMI and contrast 1 ($p = 0.019$) indicated that the relation between BMI and working memory was different in the LST and SI conditions. Similarly, the significant interaction between BMI and contrast 2 ($p = 0.017$) indicated that the relation between BMI and working memory was different in the LST and the HST conditions.[1] Follow-up, simple slopes analyses (see Table 2) indicated that body weight is negatively linked to working memory in both the HST ($p = 0.003$) and the SI conditions ($p = 0.007$), but not in the LST condition ($p = 0.643$). Specifically, whereas in the LST condition body weight is unrelated with working memory performance, a reduction of 0.52 (SE = 0.17) and 0.56 (SE = 0.21) points in working memory scores (corresponding to 3.8 and 4.1% of a standard deviation) is observed in the HST and in the SI conditions, respectively, for any unit of increase in participants' BMI.

Finally, the Johnson–Neyman technique indicated that the interaction between BMI and contrast 1 is significant for BMI values of 41.36 kg/m^2 or higher, and the interaction between BMI and contrast 2 attains significance at BMI

[1] To explore in detail whether the relation between MBI and working memory varied between the HST and the S condition (contrast 3), we repeated the same analysis by maintaining the S condition as the reference group. Results confirmed that the BMI by contrast three interactions was not significant, $B = -0.040$, SE = 0.272, $p = 0.882$, 95% CIs = −0.578, 0.498, thus meaning that the relation between BMI and working memory does not differ when the task is presented as a cognitive test, regardless of its alternative labeling either an "intelligence" (HST) or a mere "working memory" (S) test.

Table 2 Moderation analyses with BMI and stereotype threat as predictors of working memory and probabilistic learning scores

	Overall model					Simple slopes					
						High stereotype threat		Low stereotype threat		Standard instructions	
	B	SE	*t*	*p*	95% CIs	*B*	SE	*B*	SE	*B*	SE
Working memory											
BMI	0.081	0.176	0.463	0.643	−0.267, 0.430	−0.520[a]	0.176	0.081	0.176	−0.564[a]	0.207
S vs. LST (contrast 1)	18.206	9.628	1.887	0.061	−0.882, 37.294						
HST vs. LST (contrast 2)	19.153	8.934	2.143	0.034	1.468, 36.839						
BMI × Contrast 1	−0.646	0.272	−2.371	0.019	−1.184, −0.106						
BMI × Contrast 2	−0.602	0.249	−2.416	0.017	− 1.096, −0.109						
Probabilistic learning											
BMI	−0.001	0.001	−0.548	0.584	−0.004, 0.002	−0.000	0.001	−0.001	0.001	−0.002	0.002
S vs. LST (contrast 1)	0.019	0.097	0.199	0.841	−0.176, 0.211						
HST vs. LST (contrast 2)	0.016	0.097	0.181	0.856	−0.161, 0.194						
BMI × Contrast 1	−0.001	0.002	−0.516	0.606	−0.006, 0.004						
BMI × Contrast 2	−0.000	0.002	−0.253	0.800	−0.004, 0.005						

BMI body mass index, *S* standard condition, *LST* low stereotype threat condition, *HST* high stereotype threat condition, *contrast 1* standard condition opposed to low stereotype threat condition, *contrast 2* high stereotype threat condition opposed to low stereotype threat condition

[a]Significant at the level of 0.05 (two-tails)

[b]Significant at the level of 0.01 (two-tails)

values of 37.43 kg/m^2 or higher. In other words, participants with values of BMI above 41.36 kg/m^2 performed significantly worse in the SI than in the LST condition, and participants with BMI higher than 37.43 kg/m^2 performed significantly worse in the HST than in the LST condition. Below these levels of BMI, participants' working memory scores do not differ significantly between conditions. To control for potential confounders, all the analyses were repeated including age and education as covariates. All the reported findings remained unchanged.

Stereotype threat and probabilistic learning

To ensure that the effect of task diagnosticity was specific to working memory, we performed the same set of analyses using the probabilistic learning performance score as the outcome. Results highlighted that BMI was unrelated with probabilistic learning efficiency; at all levels of BMI, participants' performance was unaffected by the stereotype threat manipulations (all ps > 0.584, see Table 2).

Discussion

Low intelligence is a stereotypical trait commonly ascribed to individuals with obesity [30]. Any time their cognitive functioning is under evaluation, individuals with obesity are at risk of confirming this stereotype—a predicament known as stereotype threat [22]. The primary goal of this study was to test whether weight stigma, through the mechanism of stereotype threat, is responsible for working memory deficits among individuals with obesity.

As predicted, findings revealed a negative relation between body mass index and working memory only under conditions of stereotype threat (i.e., when tests were labeled as diagnostic of intelligence or cognitive functioning). In other words, results indicated that, among individuals with obesity (but not among those with lower BMI), working memory was significantly lower in participants performing the task when it was labeled as a cognitive test than in those who were told it was a 'distractor task'. Intriguingly, working memory was negatively associated with BMI both when stereotype threat was maximized by labeling the task a test of "intelligence" and when the task was labeled as a test of "working memory." It was only when the cognitive tests were described as relatively unimportant (i.e., "distractor tasks") that BMI was unrelated to working memory (i.e., individuals with obesity performed at the same level of those with lower BMI). Specifically, we observed that—compared to the testing condition in which the working memory task was labeled as a "distractor"—participants with a BMI over 37.43 kg/m^2 performed significantly lower when the task was labeled as an intelligence test, and those with a BMI over 41.36 kg/m^2 significantly underperformed when the task was merely labeled as a test of working memory. This pattern of results is consistent with previous studies of stereotype threat [48], including work showing that African-American students underperform in progressive matrices tests both when forewarned that the test would measure their intelligence (i.e., under enhanced threat), and when provided with standard test instructions in which the word "intelligence" was never mentioned—but not when test diagnosticity was removed.

An important added-value of this study was to investigate participants' performance not only on a standard working memory test, but also on an implicit learning task that did not rely on executive functions, and therefore did not recruit working memory resources. As expected, performance on the latter task was unrelated to either participants' body weight or task diagnosticity. These findings also parallel prior work, in which stereotype threat was found to impair high-level controlled memory processes—such as explicit recall—but not unintentional information processing and retrieval [54].

Overall, these findings have implications for research and clinical practice. First, the present study demonstrates for the first time that working memory performance was lower in individuals for whom stigma-related concerns became salient (i.e., when cognitive tests were assumed to measure cognitive abilities). This association is important because working memory is at core of a variety of complex domain-specific (e.g., language and numerical processing) and domain-general skills (e.g., problem solving, reasoning, emotional, and behavioral control), which are essential to daily life. Thus, stigma-related deficits in working memory may also be regarded as one of the mechanisms underlying the reported underachievement of individuals with obesity in highly evaluative academic and professional contexts [30, 55].

Second, the findings may help explain inconsistencies in past research on cognitive deficits associated with obesity. In fact, whereas some studies reported significant deficits in working memory associated with obesity [10–12, 56, 57], others have not [23]. It may be that contextual cues related to study protocols strengthened the salience of weight-related concerns in some studies more than in others by, for example, mentioning labels such as "obesity," "testing," or "cognitive ability" in study presentation, informed consent forms, or task instructions. Unfortunately, available descriptions of study protocols do not allow a compelling test of this conjecture. It is, however, important to notice that altered functional response in neural regions involved in memory processes have been observed in participants with obesity in studies in which no behavioral evidence of working memory deficits emerged [58]. Indeed, patterns of altered neural response in the absence of objective performance decrease have also observed in other stigmatized populations (African-Americans) [51] under stereotype threat conditions. We urge researchers to use physiological measures of peripheral and central response to stereotype threat in future studies assessing cognitive functioning in individuals with obesity.

Finally, these findings provide insights regarding interventions aimed at combating obesity. Deficits in executive control (including working memory depletion) may be a cause of difficulty in food intake regulation [59]. Consistent with this notion, working memory training programs have been designed to improve self-regulation, and ultimately achieve weight loss, in children [60] and adults [21] with obesity, with promising outcomes. However, the benefits from such programs might be counteracted by stereotype threat concerns, which may simultaneously consume working memory resources. Our findings suggest that the benefits of such programs might be maximized by combining cognitive training programs—targeted at improving working memory capacity—with psycho-social interventions—aimed at combating stereotype threat. Further research is necessary to support this conjecture.

Several limitations of the current research are also important to note. First, recruiting participants via convenience sampling limits the generalizability of these findings. Participants were predominantly women, and to a large extent were born in Italy. Individuals with diverse cultural background may endorse different attitudes and stereotypes toward obesity, and may, therefore, vary in their vulnerability to obesity-related stereotype threat. Furthermore, we recruited participants from clinical contexts and thus the prevalence of high and very high levels of BMI in our sample does not reflect that in the general population. However, as stereotype threat was hypothesized to affect individuals with obesity, this sampling strategy was functional to ensure sufficient statistical power to assess the hypothesized interaction between BMI levels and test instructions. Finally, the role of known moderators (such as stigma experiences, group-based or individual threat perception, etc.) and mediators (e.g., anxiety, goal setting, etc.) of stereotype threat effects were not examined. All these limitations should be taken into consideration in future research.

In summary, the results contribute to the literature on stereotype threat [48] by demonstrating that stereotype threat substantially undermines the cognitive functioning of individuals with obesity. In addition, these findings contribute to understanding of factors associated with cognitive functioning in adults with obesity [12], by shedding light into social-psychological mechanisms that may interfere with cognitive functioning above and beyond a variety of well-known physiological correlates of obesity and working memory efficiency (e.g., insulin/leptin resistance, increased oxidative stress, inflammation, etc.) [24]. Finally, the results suggest that clinicians and researchers should use caution in the cognitive assessment of individuals with obesity, as poor test performance may reflect implicit or explicit awareness of negative obesity-related stereotypes in the testing situation, and not obesity per se.

Acknowledgements We gratefully acknowledge Angelo Schettino, the Casa di Cura Privata San Lorenzino (Cesena, Italy), and non-profit organizations who agreed to advertise this study for their helpful support. They are also grateful to Rebecca Bigler for providing insightful comments on earlier versions of this work.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. World Health Organization. Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity: report of the ad hoc Working Group on Science and Evidence for Ending Childhood Obesity. Geneva, Switzerland: WHO Press; 2016.
2. Belsky DW, Caspi A, Goldman-Mellor S, Meier MH, Ramrakha S, Poulton R, et al. Is obesity associated with a decline in intelligence quotient during the first half of the life course? Am J Epidemiol. 2013;178:1461–8.
3. Smith E, Hay P, Campbell L, Trollor JN. A review of the association between obesity and cognitive function across the lifespan: implications for novel approaches to prevention and treatment. Obes Rev. 2011;12:740–55.
4. Li Y, Dai Q, Jackson JC, Zhang J. Overweight is associated with decreased cognitive functioning among school-age children and adolescents. Obesity. 2008;16:1809–15.
5. Ravona-Springer R, Schnaider-Beeri M, Goldbourt U. Body weight variability in midlife and risk for dementia in old age. Neurology. 2013;80:1677–83.
6. Yu ZB, Han SP, Cao XG, Guo XR. Intelligence in relation to obesity: a systematic review and meta-analysis. Obes Rev. 2010;11:656–70.
7. Boeka AG, Lokken KL. Neuropsychological performance of a clinical sample of extremely obese individuals. Arch Clin Neuropsychol. 2008;23:467–74.
8. Fagundo AB, De la Torre R, Jiménez-Murcia S, Agüera Z, Granero R, Tárrega S, et al. Executive functions profile in extreme eating/weight conditions: from anorexia nervosa to obesity. PLoS ONE. 2012;7:e43382.
9. Manasse SM, Juarascio AS, Forman EM, Berner LA, Butryn ML, Ruocco AC. Executive functioning in overweight individuals with and without loss-of-control eating. Eur Eat Disord Rev. 2014;22:373–7.
10. Prickett C, Brennan L, Stolwyk R. Examining the relationship between obesity and cognitive function: a systematic literature review. Obes Res Clin Pract. 2015;9:93–113.
11. Reinert KR, Po'e EK, Barkin SL. The relationship between executive function and obesity in children and adolescents: a systematic literature review. J Obes. 2013;2013:820956.
12. Stanek KM, Strain G, Devlin M, Cohen R, Paul R, Crosby RD, et al. Body mass index and neurocognitive functioning across the adult lifespan. Neuropsychology. 2013;27:141–51.
13. Sargénius HL, Lydersen S, Hestad K. Neuropsychological function in individuals with morbid obesity: a cross-sectional study. BMC Obes. 2017. https://doi.org/10.1186/s40608-017-0143-7
14. Wu X, Nussbaum MA, Madigan ML. Executive function and measures of fall risk among people with obesity. Percept Mot Skills. 2016;122:825–39.
15. Baddeley A. Oxford psychology series, no. 11. Working memory. New York, NY: Clarendon Press/Oxford University Press; 1986.
16. Redick TS, Broadway JM, Meier ME, Kuriakose PS, Unsworth N, Kane MJ, Engle RW. Measuring working memory capacity with automated complex span tasks. Eur J Psychol Assess. 2012;28:164–71.
17. Cohen G, Conway M (editors). Memory in the real world. 3rd ed. New York, NY: Psychology Press; 2007.
18. Alloway TP, Alloway RG. Investigating the predictive roles of working memory and IQ in academic attainment. J Exp Child Psychol. 2010;106:20–9.
19. Schmeichel BJ, Volokhov RN, Demaree HA. Working memory capacity and the self-regulation of emotional expression and experience. J Pers Soc Psychol. 2008;95:1526–40.
20. Thomas R, Dougherty MR, Buttaccio DR. Memory constraints on hypothesis generation and decision making. Curr Dir Psychol Sci. 2014;23:264–70.
21. Houben K, Dassen FC, Jansen A. Taking control: working memory training in overweight individuals increases self-regulation of food intake. Appetite. 2016;105:567–74.
22. Schmader T, Johns M, Forbes C. An integrated process model of stereotype threat effects on performance. Psychol Rev. 2008;115:336–56.
23. Coppin G, Nolan-Poupart S, Jones-Gotman M, Small DM. Working memory and reward association learning impairments in obesity. Neuropsychologia. 2014;65:146–55.
24. Wang C, Chan JS, Ren L, Yan JH. Obesity reduces cognitive and motor functions across the lifespan. Neural Plast 2016; 2016:2473081.
25. Alarcón G, Ray S, Nagel BJ. Lower working memory performance in overweight and obese adolescents is mediated by white matter microstructure. J Int Neuropsychol Soc. 2016;22:281–92.
26. Yau PL, Kang EH, Javier DC, Convit A. Preliminary evidence of cognitive and brain abnormalities in uncomplicated adolescent obesity. Obesity. 2014;22:1865–71.
27. Gonzales MM, Kaur S, Eagan DE, Goudarzi K, Pasha E, Doan DC, et al. Central adiposity & the functional magnetic resonance imaging response to cognitive challenge. Int J Obes. 2014;38:1193–9.
28. Deng Z, Huang Q, Huang J, Zhang W, Qi C, Xu X. Association between central obesity and executive function as assessed by stroop task performance: a functional near-infrared spectroscopy study. J Innov Opt Health Sci. 2018;11:1750010-1–1750010-10.
29. Hunger JM, Major B, Blodorn A, Miller CT. Weighed down by stigma: how weight-based social identity threat contributes to weight gain and poor health. Soc Personal Psychol Compass. 2015;9:255–68.
30. Puhl RM, Heuer CA. The stigma of obesity: a review and update. Obesity. 2009;17:941–64.
31. Guardabassi V, Mirisola A, Tomasetto C. How is weight stigma related to children's health-related quality of life? A model comparison approach. Qual Life Res. 2018;27:173–83.
32. Schwartz MB, Chambliss HON, Brownell KD, Blair SN, Billington C. Weight bias among health professionals specializing in obesity. Obes Res. 2003;11:1033–9.
33. O'Brien KS, Latner JD, Ebneter D, Hunter JA. Obesity discrimination: the role of physical appearance, personal ideology, and anti-fat prejudice. Int J Obes. 2013;37:455–60.
34. Steele CM, Aronson J. Stereotype threat and the intellectual test performance of African Americans. J Pers Soc Psychol. 1995;69:797–811.
35. Flore PC, Wicherts JM. Does stereotype threat influence performance of girls in stereotyped domains? A meta-analysis. J Sch Psychol. 2015;53:25–44.
36. Stoet G, Geary DC. Can stereotype threat explain the gender gap in mathematics performance and achievement? Rev Gen Psychol. 2012;16:93–102.

37. Armstrong B, Gallant SN, Li L, Patel K, Wong BI. Stereotype threat effects on older adults' episodic and working memory: a meta-analysis. Gerontologist. 2017;57:S193–S205.
38. Nguyen HH, Ryan AM. Does stereotype threat affect test performance of minorities and women? A meta-analysis of experimental evidence. J Appl Psychol. 2008;93:1314–34.
39. Picho K, Rodriguez A, Finnie L. Exploring the moderating role of context on the mathematics performance of females under stereotype threat: a meta-analysis. J Soc Psychol. 2013;153:299–333.
40. Kit KA, Tuokko HA, Mateer CA. A review of the stereotype threat literature and its application in a neurological population. Neuropsychol Rev. 2008;18:132–48.
41. Suhr JA, Gunstad J. "Diagnosis threat": The effect of negative expectations on cognitive performance in head injury. J Clin Exp Neuropsychol. 2002;24:448–57.
42. Carels RA, Domoff SE, Burmeister JM, Koball AM, Hinman NG, Davis AK, et al. Examining perceived stereotype threat among overweight/obese adults using a multi-threat framework. Obes Facts. 2013;6:258–68.
43. Shapiro JR. Different groups, different threats: A multi-threat approach to the experience of stereotype threats. Pers Soc Psychol Bull. 2011;37:464–80.
44. Schvey NA, Puhl RM, Brownell KD. The stress of stigma: exploring the effect of weight stigma on cortisol reactivity. Psychosom Med. 2014;76:156–62.
45. Himmelstein MS, Incollingo Belsky AC, Tomiyama AJ. The weight of stigma: cortisol reactivity to manipulated weight stigma. Obesity. 2015;23:368–74.
46. Major B, Eliezer D, Rieck H. The psychological weight of weight stigma. Social Soc Psychol Personal Sci. 2012;3:651–8.
47. Spencer SJ, Logel C, Davies PG. Stereotype threat. Annu Rev Psychol. 2016;67:415–37.
48. Brown RP, Day EA. The difference isn't black and white: stereotype threat and the race gap on Raven's Advanced Progressive Matrices. J Appl Psychol. 2006;91:979–85.
49. Unsworth N, Heitz RP, Schrock JC, Engle RW. An automated version of the operation span task. Behav Res Methods. 2005;37:498–505.
50. Frank MJ, Seeberger LC, O'reilly RC. By carrot or by stick: cognitive reinforcement learning in parkinsonism. Science. 2004;306:1940–3.
51. Forbes CE, Leitner JB, Duran-Jordan K, Magerman AB, Schmader T, Allen JJ. Spontaneous default mode network phase-locking moderates performance perceptions under stereotype threat. Soc Cogn Affect Neurosci. 2015;10:994–1002.
52. Hayes AF. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. New York, NY: Guilford Press; 2013.
53. Preacher KJ, Curran PJ, Bauer DJ. Computational tools for probing interaction effects in multiple linear regression, multilevel modeling, and latent curve analysis. J Educ Behav Stat. 2006;31:437–48.
54. Eich TS, Murayama K, Castel AD, Knowlton BJ. The dynamic effects of age-related stereotype threat on explicit and implicit memory performance in older adults. Soc Cogn. 2014;32:559–70.
55. Cohen AK, Rai M, Rehkopf DH, Abrams B. Educational attainment and obesity: a systematic review. Obes Rev. 2013;14:989–1000.
56. McIntyre RS, Mansur RB, Lee Y, Japiassú L, Chen K, Lu R, et al. Adverse effects of obesity on cognitive functions in individuals at ultra high risk for bipolar disorder: Results from the global mood and brain science initiative. Bipolar Disord. 2017;19:128–34.
57. Stingl KT, Kullmann S, Ketterer C, Heni M, Häring HU, Fritsche A, et al. Neuronal correlates of reduced memory performance in overweight subjects. Neuroimage. 2012;60:362–9.
58. Gonzales MM, Tarumi T, Miles SC, Tanaka H, Shah F, Haley AP. Insulin sensitivity as a mediator of the relationship between BMI and working memory-related brain activation. Obesity. 2010;18:2131–7.
59. Maayan L, Hoogendoorn C, Sweat V, Convit A. Disinhibited eating in obese adolescents is associated with orbitofrontal volume reductions and executive dysfunction. Obesity. 2011;19:1382–7.
60. Verbeken S, Braet C, Goossens L, Van, der Oord S. Executive function training with game elements for obese children: a novel treatment to enhance self-regulatory abilities for weight-control. Behav Res Ther. 2013;51:290–9.