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Authors: Xie Jiaquan, Xie Changyi, Yang Wendeng, Yang Wendeng

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Abstract

From a psychological perspective, this review synthesizes the extensive effects of hunger on individual cognition and social behavior. Hunger impairs general cognitive functions, potentially induces decision-making and cognitive biases, and gives rise to phenomena including diminished moral judgment standards, altered social attitudes, and increased aggressive behavior. Building upon previous research, three hypotheses concerning the intrinsic mechanisms through which hunger influences cognition and social behavior are delineated: the ego depletion hypothesis, the cognitive activation hypothesis, and the coordination mechanism hypothesis. Finally, the review identifies limitations in current research, such as variations in subjective hunger experience and insufficient measurement accuracy, and proposes that future studies should enhance the measurement validity of hunger and explore the underlying mechanisms of its effects across physiological, psychological, and social levels.

Full Text

The Effects of Hunger on Cognition and Social Behavior and Their Mechanisms

XIE Jiaquan^{1,2}, XIE Changyi³, YANG Wendeng^{1,2}

¹Center for Psychology and Brain Science, Guangzhou University; The Key Laboratory for Juveniles' Mental Health and Educational Neuroscience in Guangdong Province, Guangzhou 510006

³Faculty of Education, Monash University, Melbourne 3800

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Corresponding author: YANG Wendeng, E-mail: yangwendeng@163.com

Abstract

This paper reviews the extensive effects of hunger on individual cognition and social behavior from a psychological perspective. Hunger has been shown to impair general cognitive function, potentially lead to decision-making and cognitive biases, and trigger phenomena such as lowered moral judgment standards, altered social attitudes, and increased aggressive behavior. Building upon previous research, we summarize three hypotheses concerning the internal mechanisms through which hunger influences cognition and social behavior: the ego-depletion hypothesis, the cognitive activation hypothesis, and the coordination mechanism hypothesis. Finally, we identify current research limitations, including individual differences in subjective hunger perception and inadequate measurement methods. Future research should aim to improve the validity of hunger measurement and explore the mechanisms of hunger's effects across multiple levels—physiological, psychological, and social.

Keywords: hunger; cognitive function; moral cognition; social attitude; aggressive behavior

Hunger is a subjective sensation—an unpleasant or painful bodily feeling caused by nutrient deficiency in an organism, also known as hunger pang (Lin, Yang, & Huang, 2003). Simultaneously, hunger is considered a motivational state that drives behavior when physiological needs are unmet (Maslow, 1943). As early as World War II, researchers began investigating hunger's effects on humans through the renowned Minnesota Starvation Experiment, which recruited healthy young men and restricted their food intake to half their baseline caloric needs for 24 consecutive weeks while requiring them to run approximately 5 kilometers daily. The results showed that participants not only lost nearly a quarter of their body weight on average but also experienced physiological and psychological problems including cardiac atrophy and depression (Keys, Brožek, Henschel, Mickelsen, & Taylor, 1950). In the decades since, numerous studies across physiology, psychology, sociology, and even ethics have emerged, comprehensively documenting hunger's impact on humans. However, domestic researchers have paid relatively little attention to the psychological and behavioral effects of hunger. This paper adopts a psychological perspective to review how hunger affects cognition and social behavior in generally healthy populations (non-eating-disordered individuals)¹, summarizes three hypotheses regarding the underlying mechanisms, and examines current research problems and future directions.

1.1 General Cognitive Function

Hunger influences human perception and attention in multiple ways. Research investigating the relationship between hunger and time perception abilities has found that moderate hunger enhances the accuracy of time interval estimation (Vicario, Kuran, & Urgesi, 2017). Both hungry and satiated individuals tend to underestimate the size of objects in their mouths, but hungry participants show significantly less underestimation, suggesting greater perceptual sensitivity to object volume during hunger states (Crutchfield et al., 2018). Doniger et al. (2006) discovered that hunger impairs spatial perception abilities, with hungry participants performing significantly worse than control groups across multiple tasks requiring spatial perception, including nonverbal memory, problem-solving tasks, and visuospatial tests. Seno et al. (2012) found that hunger enhances vertical self-motion illusions, leading to spatial perception distortion. Furthermore, intervention studies demonstrate that compared to control groups, hungry participants show significantly improved visual attention abilities after eating breakfast, with shorter reaction times and fewer errors in cognitive tasks (Tian et al., 2011).

Memory function is also affected by hunger. Benton (1992) examined immediate recall and spatial memory abilities in normal-eating versus fasting groups, finding that fasting participants showed significantly increased recall reaction times in both tests, though error rates did not differ significantly. Benton and Parker (1998) explored the relationship between hunger and working memory using the Brown-Peterson task, revealing that fasting participants correctly recalled significantly fewer letters than the control group. Additionally, after listening to and recalling stories, the fasting group's memory performance was significantly worse than the control group's, indicating that hunger impairs working memory.

Hunger additionally impairs cognitive executive function. A study using the Wisconsin Card Sorting Test (WCST) showed that under hunger conditions, participants exhibited decreased cognitive flexibility and made more errors (Piech, Hampshire, Owen, & Parkinson, 2009). In Stewart et al.'s (1995) Stroop interference task experiment, hungry participants showed degraded task performance, with increased reaction times and reduced accuracy. Doniger et al. (2006) conducted a series of cognitive tests with Muslim participants during both fasting and non-fasting periods, finding that participants in the fasting state performed poorly on the Stroop task and showed significantly reduced accuracy in abstract reasoning tests.

In summary, substantial research indicates that hunger leads to reduced stimulus discrimination ability, lower response accuracy, and slower reaction speeds. In tasks requiring sustained rapid responding and high-speed information processing, hungry participants are more likely to exhibit related cognitive impairments.

1.2 Decision-Making and Cognitive Biases

Loewenstein et al. (2003) propose that an individual's current hunger state leads to erroneous projection of personal preferences, thereby affecting cognitive judgment and decision-making (resulting in cognitive biases). Hunger triggers a typical cognitive bias—projection bias—which refers to the tendency to incorrectly project current preferences or action readiness onto future events (Loewenstein, O' Donoghue, & Rabin, 2003). In Read and Van Leeuwen's (1998) study, experimenters tested two groups of company employees at different times (post-lunch satiated state vs. pre-dinner hungry state), asking them to imagine their snack choices one week later when they would be in either hungry or satiated states. The snacks included both healthy options (e.g., apples) and unhealthy options (e.g., chocolate bars). Results showed that compared to post-lunch satiated employees, pre-dinner hungry employees selected more unhealthy snacks regardless of whether they imagined being hungry or satiated in the future, demonstrating that hungry participants projected their current hunger state onto future events, leading to biased choices.

Beyond affecting evaluations of future events, hunger also influences food-related consumer decisions. Research confirms the commonsense view that hungry people purchase more food (Nisbett & Kanouse, 1969) or tend to buy higher-calorie foods (Tal & Wansink, 2013). Another effect of hunger on consumer behavior appears in product premiums. Briz et al. (2015) studied projection bias in hunger using auction experiments, finding that under immediate gratification conditions, hungry participants bid nearly 50% higher than satiated participants. In similar research, Tiziana et al. (2016) found that hungry participants also expressed higher willingness to pay for food. Individuals may be in a high-arousal state when hungry, making them more susceptible to the immediacy effect of food and overestimating the duration of this state, thereby affecting related judgments and decisions (Xu, Li, Deng, Li, & Shi, 2016).

Hunger's influence also manifests in risk preferences and decision-making. Ditto et al. (2006) found that individuals in hunger-cue conditions show reduced sensitivity to high-risk information. Consistently, Symmonds et al. (2010) demonstrated that individuals' risk aversion decreases as hunger increases, potentially making them more prone to risk-taking tendencies. Levy et al. (2013) also argue that hunger has more complex effects on risky decision-making: originally conservative individuals show increased risk preferences when hungry, while those initially inclined toward risky decisions show the opposite trend.

2.1 Moral Cognition and Behavior

Hunger can lower individuals' moral judgment standards. Vicario et al. (2018) asked participants to evaluate moral stories in an experiment, finding that higher self-reported hunger in the hunger group correlated with lower moral disapproval ratings, which were significantly lower than the control group. Danziger et

al. (2011) discovered that in judicial decision-making, hunger makes judges less tolerant of moral and legal violations. During parole hearings, judges granted favorable rulings to 65% of parole requests at the start of their workday after eating. However, this proportion gradually decreased over time, dropping to 0% before meal breaks. After recess and eating, the proportion of favorable rulings suddenly returned to the initial 65%, then gradually decreased again. These findings suggest that individuals' moral judgment standards may undergo temporary changes due to hunger.

Similar results have emerged in research on the relationship between hunger and moral behavior. Studies show that when individuals experience physiological deprivation or unsatisfied states (e.g., hunger, thirst), they are more likely to engage in unethical behavior, such as reporting solving more math problems to obtain greater rewards (Yam, Reynolds, & Hirsh, 2014) or falsely reporting higher dice rolls in dice games (Williams, Pizarro, Ariely, & Weiberg, 2016). These studies indicate that hunger states may lower individuals' rejection standards for unethical events to satisfy underlying needs.

2.2 Social Attitudes

Hunger affects people's social attitudes. Aarøe et al. (2013) confirmed that hunger influences individuals' political attitudes toward social welfare. In their experiment, participants were randomly assigned to drink beverages containing either carbohydrates or artificial sweeteners, then completed questionnaires assessing their support for social welfare policies. Results showed that participants with experimentally induced hypoglycemia expressed greater support for social welfare policies. Interestingly, in a subsequent Dictator Game, the hypoglycemia group and control group showed no significant differences in actual sharing behavior. This "costless prosocial effect" may result from the balance between evolutionary adaptation to social life and resource conservation tendencies. In another large-scale online survey, Petersen et al. (2014) also found that hungry participants held more positive attitudes toward social welfare and expressed stronger intentions for social cooperation.

Hunger also potentially affects stereotypes. Generally, stereotype activation leads to cognitive biases and interpersonal discord. An intervention study demonstrated that drinking sugary beverages to increase blood glucose levels effectively reduced stereotypical word usage about homosexuals in the experimental group, suggesting that alleviating hunger reduces stereotyping (Gailliot, Peruche, Plant, & Baumeister, 2009). However, hunger's effect on stereotypes also depends on the target. For example, when female participants experienced stereotype threat regarding women's inferior math performance, their math test scores significantly decreased. Alleviating hunger not only failed to reduce this stereotype threat but actually exacerbated its effects (Willer & Robb, 2011). This may occur because hunger has different impacts when processing stereo-

types about self versus others.

2.3 Aggressive Behavior

Research has found that hunger triggers aggressive behavior or increases its frequency. Bushman et al. (2014) conducted a 21-day experiment requiring married couples to measure their blood glucose levels both before breakfast and before bedtime daily. During the experimental period, participants secretly stuck pins in voodoo dolls, with the number of pins indicating their anger toward their spouse. After 21 days, couples returned to the laboratory to vent their anger through a computer game, with noise intensity expressing their willingness to aggress against their spouse. Results showed that participants with low bedtime blood glucose levels reported higher anger toward their spouses and greater aggression. In another study, Dewart et al. (2011) confirmed the causal relationship between blood glucose levels and aggressive behavior: compared to the low blood glucose control group, the experimental group showed significantly reduced aggressive behavior toward experimental partners (measured by noise intensity) after drinking sugary beverages.

Emotion may play an important role in the relationship between hunger and aggressive behavior. Researchers have found that hunger generates negative emotions, most commonly manifested as irritability and anger (Solianik, Sujeta, Terentjeviene, & Albertas, 2016; MacCormack & Lindquist, 2018), thereby potentially leading to aggressive behavior. Studies on individuals with antisocial personalities have also confirmed the relationship between hunger and aggression. Virkkunen and Närvänen (1987) found that individuals with antisocial personalities secrete high levels of insulin, causing rapid blood glucose drops. This tendency toward hypoglycemia may make them more prone to aggression.

3 Mechanisms of Hunger's Effects on Cognition and Social Behavior

The aforementioned studies confirm that hunger affects individual cognition and behavior, yet the underlying mechanisms have rarely been addressed. This paper synthesizes perspectives from various literatures and outlines three hypotheses regarding the internal mechanisms through which hunger influences cognition and social behavior.

3.1 Ego Depletion Hypothesis

Ego depletion is a classic theory that can explain hunger's effects on cognition and behavior. This theory was proposed under the Strength Model of self-control, which posits that the mental resources utilized by self-control or willpower are limited and exhaustible (Baumeister, 1998). Glucose, as the most important energy source for humans, provides

most of the energy required by the brain to maintain psychological functions. Gailliot and Baumeister (2007) linked ego depletion to blood glucose fluctuations, demonstrating that consuming glucose could restore mental resources depleted by self-control. This provides physiological evidence for the Strength Model, suggesting that physiological hunger leads to reduced mental resources and consequent cognitive and behavioral outcomes. Therefore, the ego depletion hypothesis argues that hungry individuals have fewer available mental resources, resulting in impaired cognitive ability, increased negative emotions, and enhanced behavioral impulsivity.

The Strength Model of self-control seems capable of explaining various psychological processes including cognitive function, emotion, and decision-making. However, criticism of this model has grown. Physiologically, some argue that short-term enhancement of cognitive activity does not correspond to blood glucose depletion (Coker & Kjaer, 2005; Peters et al., 2004). From a cognitive neuroscience perspective, no relevant neurophysiological processes have been found to prove the existence of mental resource materialization (Kurzban, 2010). Moreover, the ego depletion effect faces a replication crisis (Hagger & Chatzisarantis, 2016), with meta-analytic results still controversial and even contradictory. For instance, Hagger et al. (2010) conducted the first meta-analysis of the ego depletion effect, reporting an effect size (Cohen's d) of 0.62, but Carter and McCullough (2014) refuted this result, arguing it was influenced by publication bias. Subsequent meta-analyses by Carter et al. (2015) indicated that the effect is indeed very weak.

3.2 Cognitive Activation Hypothesis This hypothesis suggests that hunger affects human cognition and behavior because physiological states like hunger activate a series of related concepts, increasing the cognitive accessibility of certain ideas or thoughts, which subsequently leads to changes in cognitive processes and social behaviors. Kavanagh and Andrade's (2005) Elaborated Intrusion Theory of desire indicates that when individuals experience physiological unsatisfaction, they spontaneously generate "intrusive thoughts" that increase the cognitive accessibility of information related to satisfaction states in memory (Berry, Andrade, & May, 2007). Other research proposes that perception of resource scarcity activates a "competitive orientation," thereby increasing self-interested behavior (Roux, Goldsmith, & Bonezzi, 2015). In Berry et al.'s (2007) lexical decision task, hungry participants responded slower to neutral words than satiated participants but showed no difference in response speed to food words, indicating that hunger activates food-related cognition.

Roux et al. (2015) also used lexical decision tasks to demonstrate that a resource scarcity arousal group (who recalled and described scarcity experiences such as hunger) identified competition-related words faster than the control group. Individuals' perception of resource scarcity maintains cognitive priority

for self-interest, so merely activating competitive orientation through experiential arousal can affect judgments and decisions unrelated to scarce resources. Kristofferson et al. (2016) found that scarcity promotions trigger consumers' perception of scarcity, making them feel competitive threat, increasing testosterone levels (a hormone predictive of aggressive behavior), and consequently increasing aggressive behavior. Xu et al. (2015) obtained similar results when investigating hunger's effects on non-food consumption: hungry people did not particularly like or need the items they purchased (e.g., binders), but hunger increased the cognitive accessibility of concepts like "acquisition," leading to unplanned purchases of non-food items. Aarøe et al. (2013) showed that hunger increases support for social welfare policies without manifesting in actual behavior, consistent with Roux et al.'s (2015) conclusion that although hungry participants express support for welfare policies (or donations), they only take actual action when they can obtain personal benefit. The underlying reason is that hunger-induced cognitive activation leads to self-interested tendencies, resulting in superficial prosocial behavior. Therefore, the cognitive activation hypothesis can explain why a physiological state like hunger can activate and influence psychological processes and behaviors not directly related to physiological needs, though current empirical research remains limited and requires further testing.

3.3 Coordination Mechanism Hypothesis Evolutionary psychology adapts the emotional coordination mechanism framework to explain hunger mechanisms, proposing that hunger serves an evolutionary function of coordinating various mechanisms to solve foraging problems faced across generations (Alshawaf, 2016). From an evolutionary perspective, the human brain possesses numerous programs for solving different adaptive problems (e.g., mate selection, sleep management)—different physiological or psychological mechanisms. To avoid conflicts between these mechanisms, higher-order programs are needed to coordinate various physiological and psychological functions to operate consistently toward specific goals (Tooby, 2000). According to Alshawaf (2016), hunger is precisely such a higher-order program that coordinates a series of psychological and physiological mechanisms—including perception, attention, memory, motivation, and physiological processes—to serve the goal of obtaining food. For example, hunger causes attentional bias toward food-related stimuli while reducing attention to other stimuli (Forestell, Lau, Gyurovski, Dickter, & Haque, 2012); hunger prioritizes foraging motivation, reducing interest in other activities such as social interaction (Pettijohn, Ahmed, & Pettijohn, 2012); hunger may also prompt individuals to adaptively classify objects, people, and events in ways that facilitate food acquisition, forming social attitudes and behavioral patterns conducive to survival and development. Additionally, this hypothesis posits that eating serves as a deactivation mechanism for hunger's coordinating function, eliminating or reversing hunger's effects. Although lower-level needs have motivational priority, overcoming hunger to engage

in higher-level psychological activities is also common because individuals may simultaneously face different adaptive problems. Some have proposed compromise strategies, suggesting that individuals allocate physiological or cognitive resources simultaneously across different mechanisms to achieve true adaptation (Crabbe, 2007). Currently, the evolutionary coordination mechanism of hunger explains its functional mechanisms from multiple perspectives, but it remains in the validation stage, lacking sufficient empirical support, and many psychological phenomena remain inadequately explained.

Overall, the three hypotheses described above each offer explanatory power for hunger's cognitive and behavioral effects. The ego depletion hypothesis focuses on how physiological factors like reduced blood glucose deplete limited mental resources, explaining hunger's impairment of general cognitive abilities. The cognitive activation hypothesis emphasizes that hunger states increase cognitive accessibility of scarcity and competition concepts at the cognitive level, explaining hunger's effects on non-food needs and behavioral decisions. The coordination mechanism hypothesis proposes that hunger evolved into an integrative function that coordinates physiological and psychological mechanisms through high-level regulation to ensure foraging priority, solving survival problems faced across human generations. While these hypotheses can explain most of hunger's effects on cognition and behavior, all lack systematic empirical support and urgently require further research.

4 Problems and Future Directions

Hunger does affect human cognition and behavior, but how large these effects are and what mechanisms underlie them remain unresolved, with some research conclusions or theoretical explanations even contradicting each other. The reasons for this phenomenon may primarily involve three issues (which also suggest three possible directions for future psychological research on hunger):

4.1 Individual Differences in Subjective Hunger Perception

Inconsistent conclusions across studies likely relate to individual differences in hunger sensitivity. As a subjective interoceptive sensation, hunger intensity varies across individuals. Hunger is primarily caused by periodic peristaltic contractions after gastric emptying, changes in blood composition (e.g., blood glucose) (peripheral responses), and hypothalamic activation (central responses). However, prolonged hunger and extreme fatigue can suppress hunger sensations, significantly reducing their intensity. Although gastric contractions are considered the most common hunger signal, research shows they are not necessary for hunger, as patients with complete gastric removal still experience hunger (Janowitz & Grossman, 1949). Meanwhile, individuals differ in their interoceptive abilities regarding internal bodily states; some people do not perceive

hunger even after long periods without food (Stevenson, Mahmut, & Rooney, 2015). Therefore, differences in sensitivity to internal states and their changes lead to different levels of physiological arousal, which differentially affect emotions and behavior, providing a possible explanation for inconsistent experimental results.

Furthermore, obesity and eating disorders have been linked to impaired interoceptive ability (Stevenson et al., 2015; Jenkinson, Taylor, & Laws, 2018). Therefore, questions about how to accurately perceive hunger levels and how to effectively avoid cognitive and behavioral biases caused by hunger should receive more attention in future research. Hunger differences may also have group-level foundations. PET studies have shown that brain activity in hunger and satiety states is not identical between men and women, with hunger-related emotional processing brain regions showing higher activation in hungry men than hungry women (Parigi, Chen, Gautier, Salbe, & Tataranni, 2002). Regarding age differences, no cross-age hunger research has been conducted to date. Therefore, age differences in hunger sensation and hunger effects should also be a future research direction.

4.2 Need to Improve Measurement Validity Blood glucose level measurement and Visual Analog Scale (VAS) scoring are the two primary methods for measuring hunger levels. However, recent research indicates these methods cannot consistently and effectively predict hunger's effects on cognition or behavior, with some studies producing contradictory conclusions. Skrynka and Vincent (2017) showed that subjective hunger ratings could reflect time preference differences between hunger and control groups, but blood glucose measurement had no predictive power. Maytal et al. (2018) argued that VAS is susceptible to demand characteristics and has low test-retest reliability, making it an unreliable hunger measurement. They proposed using α -amylase as a physiological indicator of hunger, finding that hunger levels reflected by α -amylase showed consistent changes with participants' risk-taking tendencies and monetary fairness distributions, whereas VAS ratings differed substantially and could not accurately reflect hunger's aftereffects. Individual differences in hunger sensation suggest that the subjective nature of hunger levels likely contributes to inconsistent experimental results. To achieve accurate measurement of individual hunger levels, systematic comparisons of psychological and biological measurement methods are necessary to explore accurate and efficient approaches.

Regarding hunger's effects on healthy individuals' cognitive abilities, substantial research has been conducted, but hunger's effects are sometimes non-significant in some cognitive ability studies (Benau, Orloff, Janke, Serpell, & Timko, 2014), suggesting that hunger's effects on cognitive abilities may be moderated by other factors such as task type, sample composition, and different fasting types and durations. For example, food type may be an important cause of inconsistent research findings. In manipulating hunger variables, control groups (or eat-

ing groups) typically consume standardized food prepared by researchers after fasting for a period, while experimental groups only undergo fasting treatment. Consuming fiber-rich foods can promote short-term satiety and reduce hunger (Williams, Grafenauer, & O' Shea, 2008), while low glycemic index foods can produce better cognitive performance later in the morning (150 and 210 minutes post-meal) (Benton et al., 2003; Benton, Maconie, & Williams, 2007). This indicates that foods with different nutritional compositions and ratios produce varying effects on hunger sensations and glucose utilization efficiency, potentially causing inconsistent research results. For these reasons, future research should establish standardized experimental procedures to improve the validity of hunger measurement.

4.3 Multi-Level Investigation of Mechanisms The ego depletion, cognitive activation, and coordination mechanism hypotheses each explain hunger's effects on cognition and behavior from different perspectives, yet no single theoretical mechanism can perfectly explain all of hunger's effects. Therefore, future research should, on one hand, empirically validate the mechanisms discussed in existing theories to enhance their explanatory power, and on the other hand, seek stronger theoretical foundations or explanatory frameworks from different perspectives. MacCormack and Lindquist (2018) investigated the psychological mechanisms through which hunger generates negative emotions and aggressive tendencies from the perspective of constructed emotion theory, which posits that consciousness level and processing of environmental information are key to generating negative emotions when hungry. Their experiments validated this view and demonstrated that hunger causes anger not through ego depletion. This raises the question: when individuals are not consciously aware of being hungry, does hunger still affect cognition and behavior? Future research should further investigate such questions.

Beyond exploring hunger's mechanisms at the cognitive level, mechanistic investigations should also proceed at the physiological level. For example, research has discovered connections between hunger and emotion/aggressive behavior through hormones. Hepburn et al. (1995) found that when people are hungry, the autonomic nervous system is activated, and related physiological systems release large amounts of stress-related hormones including adrenaline and cortisol, making individuals feel tense and unpleasant. Hunger is also often accompanied by reduced brain serotonin levels, with low serotonin causing anxiety and irritability that negatively correlates with increased aggressive behavior (Benton, 2008). Additionally, research has found that hunger-induced ghrelin positively correlates with testosterone levels (Greenman, Rouach, Limor, Gilad, & Stern, 2009), and the correlation between testosterone and aggressive behavior has been confirmed in both animal and human studies (Liu et al., 2013). Based on these findings, future research could more extensively investigate hormonal changes during hunger and their interactions with human social cognition and

behavior. Overall, current physiological mechanism research on hunger focuses mainly on clinical aspects, with less research on cognition and behavior, and most studies remain correlational with few experimental studies. Urgent multi-level research across physiological, psychological, behavioral, and social dimensions is needed to further investigate hunger's internal mechanisms.

References

- Lin, C., Yang, Z., & Huang, X. (2003). *Dictionary of psychology*. Shanghai Educational Publishing House.
- Liu, J., Liu, S., Qu, L., Zhong, R., Zhan, J., Jiang, Y., & Wu, Y. (2013). Testosterone and human social behavior. *Advances in Psychological Science*, 21(11), 1956-1966.
- Xu, F., Li, O., Deng, Y., Li, Y., & Shi, Y. (2016). Projection bias in judgment and decision-making. *Advances in Psychological Science*, 24(3), 422-430.
- Aarøe, L., Petersen, M. B., & Bang, M. (2013). Hunger games: Fluctuations in blood glucose levels influence support for social welfare. *Psychological Science*, 24(12), 2550-2556.
- Alsharidah, A. M., Murtaza, G., Alsharidah, M. M., & Bashir, S. (2016). Fasting in Ramadan affects cognitive and physiological function in normal subjects (pilot study). *Neuroscience & Medicine*, 7(2), 60-65.
- Al-Shawaf, L. (2016). The evolutionary psychology of hunger. *Appetite*, 105, 591-595.
- Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, 74(5), 1252-1265.
- Benau, E. M., Orloff, N. C., Janke, E. A., Serpell, L., & Timko, C. A. (2014). A systematic review of the effects of experimental fasting on cognition. *Appetite*, 77, 52-61.
- Benton, D. (2008). Sucrose and behavioral problems. *Critical Reviews in Food Science and Nutrition*, 48(5), 385-401.
- Benton, D., & Parker, P. Y. (1998). Breakfast, blood glucose, and cognition. *The American Journal of Clinical Nutrition*, 67(4), 772S-778S.
- Benton, D., & Sargent, J. (1992). Breakfast, blood glucose and memory. *Biological Psychology*, 33(2-3), 207-210.
- Benton, D., Maconie, A., & Williams, C. (2007). The influence of the glycaemic load of breakfast on the behaviour of children in school. *Physiology and Behavior*, 92(4), 717-724.

- Benton, D., Ruffin, M. P., Lassel, T., Nabb, S., Messaoudi, M., & Vinoy, S., et al. (2003). The delivery rate of dietary carbohydrates affects cognitive performance in both rats and humans. *Psychopharmacology*, 166(1), 86–90.
- Berry, L. M., Andrade, J., & May, J. (2007). Hunger-related intrusive thoughts reflect increased accessibility of food items. *Cognition and Emotion*, 21(4), 865–878.
- Briz, T., Drichoutis, A. C., & House, L. (2015). Examining projection bias in experimental auctions: The role of hunger and immediate gratification. *Agricultural and Food Economics*, 3(1), 22.
- Burnett, C. J., Li, C., Webber, E., Tsaousidou, E., Xue, S. Y., Brüning, J. C., & Krashes, M. J. (2016). Hunger-driven motivational state competition. *Neuron*, 92(1), 187–201.
- Bushman, B. J., Dewall, C. N., Pond, R. S., & Hanus, M. D. (2014). Low glucose relates to greater aggression in married couples. *Proceedings of the National Academy of Sciences*, 111(17), 6254–6257.
- Carter, E. C., & McCullough, M. E. (2014). Publication bias and the limited strength model of self-control: Has the evidence for ego depletion been overestimated? *Frontiers in Psychology*, 5(823), 37–55.
- Carter, E. C., Kofler, L. M., Forster, D. E., & McCullough, M. E. (2015). A series of meta-analytic tests of the depletion effect: Self-control does not seem to rely on a limited resource. *Journal of Experimental Psychology: General*, 144(4), 796–815.
- Coker, R. H., & Kjaer, M. (2005). Glucoregulation during exercise: The role of the neuroendocrine system. *Sports Medicine*, 35, 575–583.
- Crabbe, F. L. (2007). Compromise strategies for action selection. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 362(1485), 1559–1571.
- Crutchfield, P., Pazdernik, V., Hansen, G., Malone, J., & Wagenknecht, M. (2018). Being hungry affects oral size perception. *i-Perception*, 9(3), 2041669518777513.
- Danziger, S., Levav, J., & Avnaim-Pesso, L. (2011). Extraneous factors in judicial decisions. *Proceedings of the National Academy of Sciences*, 108(17), 6889–6892.
- DeWall, C. N., Deckman, T., Gailliot, M. T., & Bushman, B. J. (2011). Sweetened blood cools hot tempers: Physiological self-control and aggression. *Aggressive Behavior*, 37(1), 73–80.
- Ditto, P., Pizarro, D. A., Epstein, E. B., Jacobson, J. A., & Macdonald, T. K. (2006). Visceral influences on risk-taking behavior. *Journal of Behavioral Decision Making*, 19(2), 99–113.

- Doniger, G. M., Simon, E. S., & Zivotofsky, A. Z. (2006). Comprehensive computerized assessment of cognitive sequelae of a complete 12-16 hour fast. *Behavioral Neuroscience*, 120(4), 804-816.
- Forestell, C. A., Lau, P., Gyurovski, I. I., Dickter, C. L., & Haque, S. S. (2012). Attentional biases to foods: The effects of caloric content and cognitive restraint. *Appetite*, 59(3), 748-754.
- Gailliot, M. T., & Baumeister, R. F. (2007). The physiology of willpower: Linking blood glucose to self-control. *Personality and Social Psychology Review*, 11(4), 303-327.
- Gailliot, M. T., Peruche, B. M., Plant, E. A., & Baumeister, R. F. (2009). Stereotypes and prejudice in the blood: Sucrose drinks reduce prejudice and stereotyping. *Journal of Experimental Social Psychology*, 45(1), 288-290.
- Greenman, Y., Limor, R., Rouach, V., Gilad, S., & Stern, N. (2008). Testosterone is a strong correlate of ghrelin levels in men and postmenopausal women. *Neuroendocrinology*, 89(1), 79-85.
- Hagger, M. S., & Chatzisarantis, N. L. D. (2016). A multilab preregistered replication of the ego-depletion effect. *Perspectives on Psychological Science*, 11(4), 546-573.
- Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin*, 136(4), 495-525.
- Hepburn, D. A., Deary, I. J., Munoz, M., & Frier, B. M. (1995). Physiological manipulation of psychometric mood factors using acute insulin-induced hypoglycaemia in humans. *Personality and Individual Differences*, 18(3), 385-391.
- Herman, C. P., Ostovich, J. M., & Polivy, J. (1999). Effects of attentional focus on subjective hunger ratings. *Appetite*, 33(2), 181-193.
- Horne, B. D., Muhlestein, J. B., & Anderson, J. L. (2015). Health effects of intermittent fasting: Hormesis or harm? A systematic review. *American Journal of Clinical Nutrition*, 102(2), 464-470.
- Janowitz, H. D., & Grossman, M. I. (1949). Hunger and appetite; some definitions and concepts. *Journal of the Mount Sinai Hospital New York*, 16(4), 231.
- Jenkinson, P. M., Taylor, L., & Laws, K. R. (2018). Self-reported interoceptive deficits in eating disorders: A meta-analysis of studies using the eating disorder inventory. *Journal of Psychosomatic Research*, 110, 38-45.
- Kavanagh, D. J., Andrade, J., & May, J. (2005). Imaginary relish and exquisite torture: The elaborated intrusion theory of desire. *Psychological Review*, 112(2), 446-467.

- Keys, A., Brožek, J., Henschel, A., Mickelsen, O., & Taylor, H. L. (1950). *The Biology of Human Starvation* (2 Vols). Oxford, England: University of Minnesota Press.
- Koufakis, T., Karras, S. N., Antonopoulou, V., Angeloudi, E., Zebekakis, P., & Kotsa, K. (2017). Effects of orthodox religious fasting on human health: A systematic review. *European Journal of Nutrition*, 56(7), 1-17.
- Kurzban, R. (2010). Does the brain consume additional glucose during self-control tasks? *Evolutionary Psychology*, 8, 244-259.
- Levy, D., Thavikulwat, A. C., & Glimcher, P. W. (2013). State dependent valuation: The effect of deprivation on risk preferences. *PLoS ONE*, 8(1), e53978.
- Loewenstein, G., O' Donoghue, T., & Rabin, M. (2003). Projection bias in predicting future utility. *Quarterly Journal of Economics*, 118(4), 1209-1248.
- Maccormack, J. K., & Lindquist, K. A. (2018). Feeling hangry? When hunger is conceptualized as emotion. *Emotion*, 19(2), 301-319.
- Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, 50(4), 370-396.
- Maytal, S. S., Anastasia, S., Tal, S., & Levy, D. J. (2018). Objective physiological measurements but not subjective reports moderate the effect of hunger on choice behavior. *Frontiers in Psychology*, 9, 750.
- Nisbett, R. E., & Kanouse, D. E. (1969). Obesity, food deprivation, and super-market shopping behavior. *Journal of Personality and Social Psychology*, 12(4), 289-294.
- Parigi, A. D., Chen, K., Gautier, J. F., Salbe, A. D., & Tataranni, P. A. (2002). Sex differences in the human brain's response to hunger and satiation. *American Journal of Clinical Nutrition*, 75(6), 1017-1022.
- Penner, A. M., & Robb, W. (2011). Stigma and glucose levels: Testing ego depletion and arousal explanations of stereotype threat effects. *Current Research in Social Psychology*, 16. Retrieved January 18, 2019, from <http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2014-37808-001&site=ehost-live&scope=site>
- Peters, A., Schweiger, U., Pellerin, L., Hubold, C., Oltmanns, K. M., Conrad, M., Schultes, B., Born, J., & Fehm, H. L. (2004). The selfish brain: Competition for energy resources. *Neuroscience and Biobehavioral Reviews*, 28(2), 143-180.
- Petersen, M. B., Aarøe, L., Jensen, N. H., & Curry, O. S. (2014). Social welfare and the psychology of food sharing: Short-term hunger increases support for social welfare. *Political Psychology*, 35(6), 757-773.
- Pettijohn, T. F., Ahmed, S. F., & Pettijohn, T. F. (2012). Hunger and social motivation: Hungry people are less interested in social activities than satiated people. *Current Psychology*, 31(1), 1-5.

- Piech, R. M., Hampshire, A., Owen, A. M., & Parkinson, J. A. (2009). Modulation of cognitive flexibility by hunger and desire. *Cognition & Emotion*, 23(3), 528–540.
- Read, D., & Van Leeuwen, B. (1998). Predicting hunger: The effects of appetite and delay on choice. *Organizational Behavior and Human Decision Processes*, 76(2), 189–205.
- Roux, C., Goldsmith, K., & Bonezzi, A. (2015). On the psychology of scarcity: When reminders of resource scarcity promote selfish (and generous) behavior. *Journal of Consumer Research*, 42(4), 615–631.
- Seno, T., Ito, H., Sunaga, S., & Palmisano, S. (2012). Hunger enhances vertical vection. *Perception*, 41(8), 1003–1006.
- Skrynka, J., & Vincent, B. T. (2017, July 26). Hunger increases delay discounting of food and non-food rewards. Retrieved January 18, 2019, from psyarxiv.com/qgp54
- Stevenson, R. J., Mahmut, M., & Rooney, K. (2015). Individual differences in the interoceptive states of hunger, fullness and thirst. *Appetite*, 95, 44–57.
- Stewart, S. H., & Samoluk, S. B. (1997). Effects of short-term food deprivation and chronic dietary restraint on the selective processing of appetitive-related cues. *International Journal of Eating Disorders*, 21(2), 129–135.
- Symmonds, M., Emmanuel, J. J., Drew, M. E., Batterham, R. L., & Dolan, R. J. (2010). Metabolic state alters economic decision making under risk in humans. *PLoS ONE*, 5(6), e11090.
- Tal, A., & Wansink, B. (2013). Fattening fasting: Hungry grocery shoppers buy more calories, not more food. *JAMA Internal Medicine*, 173(12), 1146–1148.
- Tian, H. H., Aziz, A. R., Png, W., Wahid, M. F., Yeo, D., & Png, A. L. C. (2011). Effects of fasting during Ramadan month on cognitive function in Muslim athletes. *Asian Journal of Sports Medicine*, 2(3), 145–153.
- Tiziana, D. M., Azucena, G., & Pablo, B. G. (2016). Assessing projection bias in consumers' food preferences. *PLoS ONE*, 11(2), e0146308.
- Tooby, J., & Cosmides, L. (2008). The evolutionary psychology of the emotions and their relationship to internal regulatory variables. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of Emotions* (3rd ed., pp. 3–16). New York & London: Guilford.
- Vicario, C. M., Kuran, K. A., Rogers, R., & Rafal, R. D. (2018). The effect of hunger and satiety in the judgment of ethical violations. *Brain and Cognition*, 125(May), 32–36.
- Vicario, C. M., Kuran, K. A., & Urgesi, C. (2017). Does hunger sharpen senses? A psychophysics investigation on the effects of appetite in the timing of reinforcement-oriented actions. *Psychological Research*, 83(3), 395–405.

Virkkunen, M., & Närvänen, S. (1987). Plasma insulin, tryptophan and serotonin levels during the glucose tolerance test among habitually violent and impulsive offenders. *Neuropsychobiology*, 17, 19-23.

Williams, E. F., Pizarro, D., Ariely, D., & Weinberg, J. D. (2016). The valjean effect: Visceral states and cheating. *Emotion*, 16(6), 897-902.

Williams, P. G., Grafenauer, S. J., & O' Shea, J. E. (2008). Cereal grains, legumes, and weight management: A comprehensive review of the scientific evidence. *Nutrition Reviews*, 66(4), 171-182.

Xu, A. J., Schwarz, N., & Wyer, R. S. (2015). Hunger promotes acquisition of nonfood objects. *Proceedings of the National Academy of Sciences*, 112(9), 2688-2692.

Yam, K. C., Reynolds, S. J., & Hirsh, J. B. (2014). The hungry thief: Physiological deprivation and its effects on unethical behavior. *Organizational Behavior and Human Decision Processes*, 125(2), 123-133.

¹ Hunger, as one of the most fundamental concerns in human life, profoundly influences human behavior at both conscious and subconscious levels. These effects can be either positive or negative. In fact, real-life experiences and related research have shown that moderate intermittent fasting may produce certain positive effects on individual cognition and behavior (Horne, Muhlestein, & Anderson, 2015; Koufakis et al., 2017). Unless otherwise specified, this paper primarily discusses the negative effects of short-term hunger on cognition and behavior in generally healthy individuals (non-eating-disordered populations).

² Glycemic index, also known as glycemic generation index, refers to the relative ability of a carbohydrate-containing food to raise blood glucose levels compared to the change in blood glucose concentration after consuming glucose. A lower glycemic index indicates that a food causes blood glucose to rise and peak more slowly.

Note: Figure translations are in progress. See original paper for figures.

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