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# EFFECTS OF SUGAR CONSUMPTION ON HUMAN BEHAVIOR AND PERFORMANCE

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*It is a myth, disconfirmed by numerous studies, that sugar consumption causes hyperactivity or other behavior problems in children or adults. This myth may be maintained by confirmation bias and social reinforcement. Conversely, numerous studies show that sugar consumption improves athletic, cognitive, and academic performance and may increase self-control and reduce aggressive behavior. These effects may be most apparent shortly after sugar has been consumed. While the brain utilizes large amounts of glucose, the exact physiological mechanisms responsible for the performance-enhancing effects of sugar consumption are still debated. Psychological research and theorizing on the effects of sugar consumption should avoid speculative explanations in terms of "mind" and "willpower," and focus on observed behavioral effects. For behavior and academic problems, limiting sugar consumption should not be a treatment focus and may be counterproductive.*

Key words : sugar, self-control, hyperactivity, willpower, confirmation bias

Avoiding tooth decay, diabetes, and obesity are all good reasons to limit consumption of sugar in the human diet. But sugar consumption, even in high amounts, does not contribute to hyperactivity, inattention, juvenile delinquency, reductions in cognitive performance, or other behavior problems in children or adults. Instead, a high level of glucose, or sugar, consumption actually improves athletic, academic, and cognitive performance, and may enhance self-control. Unless medically prescribed for non-behavioral reasons, dietary restriction of sugar intake is inappropriate and may have unintended behavioral effects (e.g., Fisher & Birch, 1999), create unnecessary interpersonal conflict, and be counterproductive by precluding consideration and implementation of proven effective interventions for behavioral and performance problems, such as behavior therapy as treatment for attention-deficit/hyperactivity disorder (ADHD; e.g., Fabiano et al., 2009).

## The Sugar–Hyperactivity Myth

The myth that sugar consumption causes behavior problems may be maintained by *confirmation bias* and social reinforcement. Confirmation bias, the tendency to look for, and find, cases that confirm preexisting opinions and biases while ignoring disconfirming evidence, has been shown to aversively affect decision making in a vast range of human

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endeavors, from racial prejudice to medical diagnoses (e.g., Nickerson, 1998). Of course, the occurrence of confirmation bias itself is a function of more fundamental behavioral processes, such as reinforcement history and evaluative conditioning (but beyond the scope of the present argument).

The belief that sugar consumption has negative behavioral effects is common worldwide among laypersons and professionals alike (e.g., DiBattista & Shepherd, 1993; Dosreis et al., 2003; Ghanizadeh & Zarei, 2010). Thus, following instances that appear to confirm this preexisting belief (e.g., when a parent or teacher perceives that children seem to be more active than usual during a party at which sugar has been consumed), it is highly likely that other individuals will verbally express agreement. Agreement obtained from others, particularly from educational or medical authorities (e.g., teachers or physicians), functions as social reinforcement (e.g., Verplanck, 1955), increasing the likelihood that individuals will continue to seek confirming evidence. As a result of this history of reinforcement for attributing high activity levels to sugar consumption, environmental and situational factors that may account for the increased activity levels (e.g., the presence of friends, energetic music, gifts, or the behavior of adults during interactions with children) are likely to be overlooked, and blame is often placed on sugar consumption. Likewise, when high levels of activity occur without sugar consumption, or when sugar is consumed without subsequent high activity levels, individuals are apt to discount this disconfirming evidence of a causal connection between sugar consumption and hyperactive behavior.

Confirmation bias may be seen in the finding that mothers who stated that their children were behaviorally “sugar sensitive” rated their children’s behavior as more hyperactive when they had been told that their children had consumed a large dose of sugar, even though the children had consumed a sugar-free placebo, not sugar. In accordance with the confirmation bias, mothers who were falsely told that their sons had consumed sugar also criticized, looked at, and talked to their sons more than did mothers who had been accurately told their sons had not consumed sugar (Hoover & Milich, 1994). Thus, mothers who held the false belief that sugar caused their sons to be hyperactive erroneously found confirming instances of sugar causing hyperactivity when the facts of the matter were quite the opposite. It is possible that parental behavior (e.g., verbal criticism) may become associated with sugar consumption and, in turn, discriminate occasions when child behaviors deemed by parents as “hyperactive” or “inappropriate” will receive contingent reinforcing parental attention. That is, parental reactions when they first observe sugar consumption function as discriminative stimuli for “inappropriate” child behaviors. Consequently, child “misbehavior” may increase following sugar consumption. But the child’s behavior may be a function—under the stimulus control—of “inappropriate” parental behavior, not the result of any biological effect of sugar consumption.

Children whose parents say they are sensitive to sugar simply do not show adverse behavioral effects or decrements in cognitive performance even when consuming large amounts of sugar. In a double-blind controlled trial over 9 consecutive weeks, the families of 25 normal preschool children and 23 school-aged children who were described by their parents as sugar sensitive followed a diet high in sucrose (sugar) with no artificial sweeteners for 3 weeks, followed a diet low in sugar but high in aspartame (an artificial sweeter also falsely said to cause behavior problems) for 3 weeks, and then followed a diet low in sugar with saccharin as a sweetener for 3 weeks. The children were measured and scored on numerous behavioral and cognitive measures. The researchers found that “for the children described as sugar-sensitive, there were no significant differences among the three diets in any of 39 behavioral and cognitive variables” (Wolraich et al., 1994, p. 301), leading to the following conclusion:

> The results of this study do not support the hypothesis that a diet high in either sucrose or aspartame adversely affects the behavior or cognitive functioning of children. … The findings were negative even though the older

> children were selected because their parents believed them to be sensitive to sugar and even though the children in both groups ingested substantial amounts of the sweeteners. … We conclude from this carefully controlled nine week study that neither sucrose nor aspartame produces discernible cognitive or behavioral effects in normal preschool children or in school-age children believed to be sensitive to sugar. (Wolraich et al., 1994, pp. 305–306)

Despite such disconfirming findings, and despite the fact that this myth has been dismissed in articles in both medical (e.g., Vreeman & Carroll, 2008) and popular publications (e.g., Epstein, 2005; Fiorello, 2001), parents and professionals continue to believe, and researchers continue to suggest (e.g., Johnson et al., 2011), that sugar consumption causes hyperactivity in children. Dosreis et al. (2003) found that two thirds of parents believed that sugar and diet affect hyperactivity in their children diagnosed with ADHD. Forty percent of primary school teachers believe that there is a causal connection between ADHD and sugar or other food additives (Barbaresi & Olsen, 1998), and more than 80% think that sugar consumption contributes to increased activity levels and behavioral problems in all children (DiBattista & Shepherd, 1993). In a survey of 665 general physicians in Iran, more than a third of respondents believed that sugar consumption is a cause of ADHD (Ghanizadeh & Zarei, 2010). Contrary to these beliefs, a meta-analysis of 23 studies on the relationship between sugar and hyperactivity found no empirical support for the sugar–hyperactivity myth. There are no adverse effects of sugar consumption on the behavior or cognitive performance of children (Wolraich, Wilson, & White, 1995).

Sugar does not even adversely affect the behavior of boys said to have ADHD or attention-deficit disorder (ADD). With boys who had received the diagnosis of ADHD as participants, Milich and Pelham (1986) compared the effects of either a sugar drink or a non-caloric, aspartame drink on "actual classroom measures of academic productivity, accuracy, and on-task behavior … as well as direct observations of social interactions, noncompliance with adult requests, and peer-directed aggression in a play ground setting [and found] *no support for the purported association between sugar ingestion and ADD*" (Milich & Pelham, 1986, p. 717, emphasis added).

Nor does sugar adversely affect the behavior of children with criminal behavior patterns. When juvenile delinquent offenders who were incarcerated in a maximum-security correctional facility were fed either a sugar-filled or a sugar-free breakfast, and 40 min later given behavioral assessments lasting approximately 3 hr, with one 15 min break, the following was found:

> Stated succinctly, there was no evidence of a negative effect of sucrose ingestion on performance. The overall pattern of results, across three subject samples and numerous behavioral domains provided no support for the contention that sucrose ingestion compromises behavior. Moreover … the sucrose breakfast was associated with *improved*, rather than impaired, performance. … Contrary to popular lore, those delinquents described by their teachers as the most disruptive and behaviorally disturbed demonstrated *better* performance after the sucrose than after the no-sucrose breakfast. (Bachorowski et al., 1990, pp. 249–250, emphasis added)

## Sugar Consumption Improves Athletic, Cognitive, and Academic Performance

As the Bachorowski et al. (1990) study with juvenile delinquent participants found, rather than causing hyperactivity or problematic behavior, sugar consumption actually improves behavioral performance. In the athletic and exercise realms, it is accepted as fact that sugar consumption improves performance. Compared to consuming water or other non-caloric beverages, dozens of studies have shown beyond any scientific doubt that drinking sugar-containing beverages during athletic events enhances concentration and improves performance. Sugar (along with sodium) is the common, critical, ingredient in all effective sports beverages (see Flora, 2011, for a review). For example, Dougherty, Baker, Chow, and Kenney (2006) found that elite male adolescent basketball players' sprint times and shooting percentages were significantly better when the athletes were hydrated with a sugar–sodium sport drink than when they were hydrated with water or dehydrated. Dougherty et al. concluded, "This degree of improvement [achieved by drinking a sugar- and sodium-containing sports drink] is important in a sport where subtle changes in skill performance could be the difference between winning and losing" (Dougherty et al., 2006, p. 1657).

In addition to improving athletic performance, sugar consumption improves nonathletic performance, concentration, self-control, and academic work. Citing studies showing sugar consumption improved reaction times, visual information processing, various cognitive and memory tasks, driving simulator performance, serial subtractions, face recognition, and kinaesthetic memory, Scholey, Harper, and Kennedy (2001) concluded, "There is a wealth of evidence documenting the beneficial effects of a glucose drink on cognitive performance in healthy young adults" (p. 585). These researchers conducted a placebo-controlled, double-blind, balanced crossover study that compared the effects of "cognitive demand" on blood glucose levels and the effects of glucose consumption on cognitive performance. Their results showed that high cognitive demand lowered blood glucose levels, suggesting "increased neural energy expenditure" (p. 585). But most important for the present argument, compared to placebo, glucose consumption produced a trend for enhanced performance in verbal fluency, and "glucose consumption significantly improved performance" in the demanding serial sevens task (Scholey et al., 2001, p. 585), in which participants are given a number to start (e.g., 300) and are told to subtract by sevens (e.g., 300, 293, 286, 279, 272, 265). In a recent review of the effects of sugar ingestion on memory performance, Smith, Riby, Van Eekelen, and Foster (2011) found that numerous studies suggest improvements in verbal episodic memory in healthy young adults following sugar ingestion when memory materials are studied under divided attention conditions (e.g., studying a word list while concurrently performing a sequence of hand movements). These findings indicate that consuming sugar prior to engaging in a demanding task may improve memory performance.

Some effects of sugar consumption maybe dose dependent, with greater consumption resulting in better performance. Compared to consumption of a non-sugar fruit-flavored beverage or administration of 25 grams of sugar in a drink sweetened with glucose syrup, consumption of 60 grams of sugar significantly improved word recall and face recognition in undergraduate student participants (Owen, Finnegan, Hu, Scholey, & Sunram-Lea, 2010). During a double-blind, placebo-controlled, six-way crossover study, the same researchers found that 60 grams of sugar increased working memory performance after an overnight fast period, while 25 grams of sugar resulted in improved working memory following a 2-hr fast. These results suggest that optimal sugar dosage may be affected by fasting intervals (Owen, Scholey, Finnegan, Hu, & Sunram-Lea, 2012).

Demonstrating that the performance-enhancing effects of sugar consumption occur with children in addition to healthy young adults, Benton and Stevens (2008) found that, compared to the effects of drinking a sugar-free drink, consuming a beverage containing 25 grams of sugar improved the memory and time on task of 9- to 10-year-old British school children. Sugar consumption may be more important for the academic achievement of children than is it for adults because of the high metabolic demands of the child's brain, as Benton and Stevens argued:

> The brain is the most metabolically active organ in the body. Yet when compared to the size of their body, children have relatively larger brains than

> adults. In addition a given weight of brain tissue from a child uses more glucose than if it came from an adult (Kalhan & Kilic, 1999). From birth to 4 years the rate of glucose utilization by brain tissue increases markedly, to the extent that by 4 years, per unit weight of brain, it is twice that of an adult (Chugani, 1998). This high rate of glucose utilization remains until 9–10 years. The cerebral metabolic rate then declines to reach adult values by 16–18 years of age. [Thus] children may be particularly responsive to the provision of glucose, the major fuel of the brain. (Benton & Stevens, 2008, p. 242)

In addition to children and young adults, research suggests that sugar consumption may improve the performance of older adults on cognitive tasks. Relative to a saccharin placebo, sugar ingestion has been found to improve performance on tasks requiring verbal episodic memory (e.g., immediate recall of items on a word list) in older individuals with and without Alzheimer's disease and on tasks using visual memory, verbal fluency, and attention in healthy older adults (Korol & Gold, 1998; Smith et al., 2011). In a study examining 44 adults ages 60 to 80 years, Gagnon, Greenwood, and Bherer (2010) found that, compared to participants who ingested a saccharin placebo beverage, participants who consumed a sugar-containing beverage following a 12-hr fasting period had significantly faster reaction times on measures of attention and task switching (Trail Making Test and a modified Stroop task) and showed a smaller dual-task cost (i.e., difference in response times between a single-task trial and a dual-task trial) during a computerized divided-attention task that assessed the participant's performance on two concurrent tasks. These results indicate that sugar consumption may momentarily enhance performance on tasks that require memory and attention in older adults, domains that are often negatively affected by the aging process.

In addition to improving performance on cognitive tasks, researchers (e.g., Gailliot et al., 2007; Gailliot, Peruche, Plant, & Baumeister, 2009) have hypothesized that even self-control, aggression, and prejudice are all greatly impacted by the brain's glucose levels and, most important for the present argument, performance improvements in these domains occur after consuming sugar.

## Sugar Consumption Improves Self-Control

When blood and brain levels of glucose are high, self-control is more likely. When sugar levels are low, self-control suffers. For example, in a series of experiments with undergraduate student participants, Gailliot et al. (2007) found that blood glucose significantly decreased following tasks that required self-restraint or self-control (e.g., the Stroop task, emotional regulation, attention control). But on a second task, compared to participants who consumed Splenda-sweetened lemonade between tasks, participants who consumed sugar-sweetened lemonade between tasks made fewer errors on the Stroop task and were more persistent in solving word fragment problems. In the Stroop task, participants are shown words that are printed in a different color than the color that the word references (e.g., the word *red* may be printed in green ink). The participant's task is to state the color of the ink, not the word (e.g., "green," not "red"). Because people have a strong history of reinforcement for reading words rather than stating the color ink that the word is printed in, stating the color of the words rather than reading the words rapidly and without error is difficult and is said to require self-control. Galliot et al. found that participants who consumed sugar performed much better on the Stroop task than did participants who did not consume sugar. Improved performance on the Stroop task has also been observed in older adults following sugar consumption, as Gagnon et al. (2010) found that older adults who ingested sugar had significantly faster execution times during a modified version of this task relative to older adults who ingested a saccharin placebo.

Gailliot et al. (2007) hypothesized that sugar consumption may even increase helping behavior. When considering two hypothetical scenarios, undergraduate participants who consumed sugar were more likely to indicate that they were willing help strangers than were participants who did not consume sugar. Because helping behavior often requires effort, Galliot et al. contended that it necessitates some degree of self-control.

## Sugar Consumption May Reduce Aggression

Just as Bachorowski et al. (1990) observed improved behavior of juvenile delinquents after they consumed a sugar-filled breakfast, research suggests that sugar consumption may reduce aggressive behavior in adults, as well as in children. Benton and Owens (1993) found that, compared to undergraduate participants who consumed a placebo non-sugar beverage, participants who consumed a sugar beverage were less likely to show aggression, use profanity, or bang on the computer while playing a frustrating and intentionally impossible computer game. More recently, Denson, Von Hippel, Kemp, and Teo (2010) found that drinking a sugar-containing beverage 15 min prior to provocation reduced aggression (administering a blast of white noise to a fictitious participant). Among participants scoring high on a measure of "trait aggression," sugar consumption reduced aggressive behavior to a level comparable to those who scored low on trait aggression. Likewise, DeWall, Deckman, Gailliot, and Bushman (2011) conducted a study where

> Basically, within the ethical limits of the laboratory, participants [62 college students] controlled a weapon that could be used to blast their partner with loud noise. As expected, participants who drank the lemonade sweetened with sugar behaved less aggressively than did participants who drank the lemonade sweetened with a sugar substitute. (DeWall et al., 2011, p. 75)

## Breakfast, Snacks, Sugar, and Performance

The experimental studies convincingly show that consuming sugar improves performance across a wide spectrum of challenging tasks from the athletic to the academic. The performance-improving effects of sugar consumption are a likely reason why breakfast consumption is strongly related to school performance, and why school breakfast programs are one of the most effective interventions to improve school performance in impoverished areas. In the United States, the Child Nutrition Act of 1966 created the School Breakfast Program (SBP) to provide breakfast to children in poor areas. A review of the program found that participation in the SBP significantly improved school performance and reduced tardiness and absenteeism (Kennedy & Davis, 1998). Studies in Jamaica and Peru also found that providing poor children breakfast improved academic performance (see Pollitt, 1995). A review of 47 studies concluded that breakfast consumption improves cognitive function, test grades, and school performance in children and adolescents. Many of these breakfasts included ready-to-eat cereals that are high in sugar (Rampersaud, Pereira, Girard, Adams, & Metzl, 2005).

In addition to breakfast, sugar-filled afternoon snacks also improve performance in adults, as well as in children. Mahoney, Taylor, and Kanarek (2007) examined the effects of an afternoon confectionary (sugar) snack on a variety of cognitive processes essential for learning. The researchers found that "as a mid-day snack, dietary sugar intake appears to improve cognitive performance on measures of attention and spatial memory" (p. 350) of adults (Experiment 1) and children (Experiment 2).

## Rejoinder and Theoretical Overreach: Beyond Behavior and Brain to the Mystical Mind

While the brain consumes far more glucose than any other organ in the body, at present it is an overreach, if not an error, to assert that the performance-enhancing effects of sugar consumption are due to a "refueling" of the brain, much less due to some sort of recharging of hypothetical explanatory fictions, be they the "mind," "will," or "ego." However, this fantastical theorizing is exactly what many of the researchers who have investigated the effects of sugar consumption have done. "An accumulating body of research suggests that self-control relies on some sort of limited resource or energy, thus reviving the folk notion of willpower," noted Gailliot and Baumeister in the article "The Physiology of Willpower: Linking Blood Glucose to Self-Control" (Gailliot & Baumeister, 2007, p. 304). Terms and phrases such as "ego depletion … in homage to Freud" are offered to explain away experimental findings. In doing so, rather than increasing understanding of how sugar consumption affects human behavior, researchers have engaged in an exhausting digression.

It is scientifically implausible that a glucose recharging of the brain is solely responsible for performance improvements, but it is fantastical to claim that glucose is the fuel for mystical, nonphysical human inventions of "mind," "ego," and "will." It is theoretically burdensome and scientifically impossible that a natural physical substance—glucose—"recharges" a mystical, nonphysical entity—the "mind," "will," or "ego"—and that this nonphysical entity then goes on to power and control natural, physical activity, that is, behavior. But claims of the natural controlling the mystical and then the mystical controlling the natural are exactly the claims and theorizing that have occurred with regard to glucose and human behavior. Noting that "most interest in the mind-body interface has focused on the brain" in a study on the effects of a glucose drink on an experimental "impression-formation task," Masicampo and Baumeister (2008) "set out to elucidate the interplay of the mind and body in decision making" (p. 259). Masicampo and Baumeister claimed that their "results show one way in which the body (blood glucose) interacts with the mind" (p. 255), but no such thing was shown or occurred. What the results showed is that an independent variable, an environmental stimulus (sugar consumption), had a statistical on-average group effect on a dependent variable (behavior, a decision task). Group differences were observed. Never was an individual's brain or brain function observed or measured. There was no evidence for any mystical "mind," and certainly there was no measure of some mystical interaction between mind and body.

In their experimental work on the effects of glucose on human behavior, Galliot et al. (2007) proclaimed in the title that "Willpower Is More Than a Metaphor." But as Skinner accused cognitive scientists, the psychologists researching the effects of glucose consumption on human behavior but claiming to be investigating "willpower," "ego," and the "mind" *are guilty*

> of claiming to explore the depths of human behavior, of inventing explanatory systems that are admired for a profundity more properly called inaccessibility [and] of relaxing standards of definition and logical thinking and releasing a flood of speculation characteristic of metaphysics, literature, and daily intercourse, speculation perhaps suitable enough in such arenas but inimical to science (Skinner, 1987, p. 111)

Understanding the effects of energy (sugar) and nutrition intake on human behavior is complex enough on its own. It is counterproductive to make the task impossible by positing explanatory fictions to explain away observed effects. Organisms from slugs and jellyfish to bacteria all rely on glucose as their primary, if not sole, source of energy. Many of the organisms that rely on glucose do not have neurons, much less a brain. How, then, does the glucose interact with the minds, egos, and wills of these organisms? Perhaps a jellyfish does not have a mind, will, or ego. Perhaps glucose as a natural substance interacts with the physical and behavioral activity of a jellyfish in a natural way. If we are willing to grant jellyfish a place in the natural universe that functions in a natural way, why are psychologists denying the possibility that humans are natural organisms functioning in a natural way—with regard to glucose, physiology, behavior, and all other natural phenomena—in the natural universe, not dependent on some mystical, unnatural inventions that would take the study of human behavior and human physiology out of the realm of scientific inquiry?

As Skinner noted, given the natural impossibility of an unnatural, mystical mind somewhere inside the organism that controls human behavior, many in psychology have simply substituted “the brain” for “the mind” and continued on with metaphysical speculation to explain away human behavior:

> It has been possible to avoid the problems of dualism in substituting “brain” for “mind.” The brain is the place where thinking is said to take place. Both the mind and the brain are not far from the ancient notion of a homunculus—an inner person who behaves in precisely the ways necessary to explain the behavior of the outer person in whom he dwells. A much simpler solution is to identify the mind with the person. Human thought is human behavior. (Skinner, 1974, p. 117)

Instead of recognizing that thinking is behavior, modern psychology has invented a modern homunculus, “the central executive,” and reassigned thinking to “executive functions.” To the current point, rather than acknowledge that thinking is behavior and behavior is activity that uses energy (e.g., glucose, sugar), thinking or “willpower” is said to be an “executive function,” that requires glucose:

> At a theoretical level, we think the self’s executive function, also known as self as agent is generally expensive in terms of energy and thus glucose. The self is the controller of controlled processes, the self-regulator, the decision maker, and the initiator. (Gailliot & Baumeister, 2007, p. 304)

Fueling the brain per se, much less the “mind,” may not be what accounts for sugar’s performance-enhancing effects at all. The stimulating effects of glucose or the use of glucose by other physiological systems in the organism, such as glucose receptors in the liver, vagus nerve stimulation, hormonal activity, glucocorticoid secretion, pancreatic function, or any number of other biological systems, could also partially, or wholly, account for the performance-enhancing effects of sugar consumption. Many researchers have concluded that performance changes are unlikely to be due to increased brain glucose uptake (see Kurzban, 2010, for review and analysis). In short, a “recharging” of the brain is at most responsible for very little (possibly not any) of glucose’s performance-enhancing effects.

## Conclusion

Thinking, “cognitive performance,” acts of “self-control,” recognition and recall memory, and the like are popularly referred to as *cognitive activities* or *brain functions*, but ultimately they are behaviors, or worse, hypothetical constructs (e.g., explanatory fictions) that are only inferred from overt behaviors. Furthermore, while science can, with increasing specificity, inform us of how, when, and how much various organs utilize glucose, *sugar consumption* is an overt behavior, and the resulting increased glucose in the biological organism functions as an independent variable affecting a wide range of activities of the entire human organism. Glucose does not singularly affect the brain.

While it is difficult to identify the “natural line of fracture” between environment and organism with regard to sugar consumption (e.g., when does sugar go from being an environmental stimulus to being part of the organism? When it’s in the mouth? In the blood? When the glucose is finally converted to ATP molecules to be used as energy? Or at some other point?), the effects of sugar consumption on human behavior will not change with increased knowledge of the physiological effects and action of sugar in the human organism. As Skinner explained in *Science and Human Behavior*,

> The practice of looking inside the organism for an explanation of behavior has tended to obscure the variables which are immediately available for a scientific analysis. … In [any] case we have causal chain consisting of three links: (1) an operation performed upon the organism from without [for example, sugar consumption]; (2) an inner condition [for example, blood and brain glucose levels]; and (3) a kind of behavior [for example, performance on a Stroop task or on an academic assignment]. … The second link is useless in the *control* of behavior unless we can manipulate it. … The objection to inner states is not that they do not exist, but that they are not relevant to a functional analysis. We cannot account for the behavior of any system while staying wholly inside it. … If we must always go back beyond the second link for prediction and control, we may avoid many tiresome and exhausting digressions by examining the third link as a function of the first. *Valid information about the second link may throw light upon this relationship but in no way alter it*. (Skinner, 1953, pp. 31–35, first emphasis in original, second emphasis added)

To this point, what is *known* about the effects of sugar consumption on human behavior and performance is that sugar consumption, even in high amounts, does not contribute to hyperactivity, inattention, juvenile delinquency, reductions in cognitive performance, or other behavior problems in children or adults. Instead, a high level of glucose, or sugar, consumption actually improves athletic, academic, and cognitive performance, and may enhance self-control. Sugar consumption may reduce aggressive behavior, and sugar consumed during breakfast and in afternoon snacks improves performance during a wide range of activities. Of course, it is possible, but highly unlikely, that factors other than sugar consumption may have affected outcomes in the previously discussed studies. Across a variety of participants, settings, and tasks, all these studies found performance-enhancing effects of sugar consumption, thus providing evidence that sugar consumption improves behavioral and performance outcome measures independent of other variables.

As sugar consumption may improve behavior and performance, and as there is no empirical evidence that sugar consumption has detrimental effects on human behavior or performance, dietary restriction or elimination of sugar is not a scientifically valid focus of treatment or prevention efforts in the behavioral domains of childhood activity levels, aggression prevention, self-control, and academic or work performance. Behavioral treatments that directly address environmental and functional factors of problematic behavior (e.g., aggressive responses) or performance deficits (e.g., off-task behaviors during academic assignments) are most appropriate for such challenges and hold the most promise for lasting behavioral improvements (e.g., Flora, 2004). For instance, a functional analysis may reveal that a child's aggressive behavior is maintained at school by an escape from demands that results when his teacher removes him from the classroom, and this most likely has nothing to do with any sugar consumed prior to the aggressive act. Likewise, a college student may have difficulty completing assignments not because she frequently consumes sugar-containing beverages but because she has competing sources of reinforcement in her immediate environment (e.g., her laptop to check e-mail and chat online with friends) when she attempts to do her work.

Although it is safe and arguably best for one's health to consume sugar in moderation, erroneously attributing sugar as a cause of hyperactivity, inattention, and other behavioral or performance problems may be harmful by leading individuals to ignore the actual causal factors of performance deficits. As a result, scientifically proven behavioral treatments may be delayed or never implemented, thus potentially decreasing the likelihood that meaningful functional improvements will occur. Moreover, restriction or elimination of sugar from the diet may be unintentionally counterproductive, decreasing performance below what could have been obtained had sufficient glucose been consumed.

Furthermore, compared with children who are not on a restrictive diet, children with parental dietary restrictions may display excessive intake of restricted foods when given free access to these foods (Birch & Fisher, 2000), and restricting access to visible palatable foods may increase children's preference and intake of such foods (Fisher & Birch, 1999). Therefore, it is plausible that restriction of sugar-containing foods and beverages may paradoxically increase sugar consumption, resulting in an increased risk of obesity from excessive caloric consumption.

In addition to dispelling the myth that sugar ingestion causes behavioral and performance problems, it is important to consider the beneficial role that sugar may play in the human diet. As indicated by the experimental studies previously reviewed, sugar consumption may be essential for optimal brain function in both children and adults.

For individuals of all ages, research has demonstrated that sugar consumption has numerous beneficial effects on human behavior and performance. These effects may be most apparent when sugar is consumed shortly before engaging in athletic, academic, or cognitive activities. While future studies will further expand our knowledge of these performance benefits, the current literature suggests that sugar consumption can play an important role in the successful execution of a wide variety of effortful and demanding tasks.

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