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Sweetened Blood Cools Hot Tempers: Physiological Self-Control and Aggression

C. Nathan DeWall[1,*], **Timothy Deckman**[1], **Matthew T. Gailliot**[2], and **Brad J. Bushman**[3]

[1]Department of Psychology, University of Kentucky, Kastle Hall, Lexington, Kentucky [2]SUNY, Albany, New York [3]The Ohio State University and VU University, Amsterdam, The Netherlands

Abstract

Aggressive and violent behaviors are restrained by self-control. Self-control consumes a lot of glucose in the brain, suggesting that low glucose and poor glucose metabolism are linked to aggression and violence. Four studies tested this hypothesis. Study 1 found that participants who consumed a glucose beverage behaved less aggressively than did participants who consumed a placebo beverage. Study 2 found an indirect relationship between diabetes (a disorder marked by low glucose levels and poor glucose metabolism) and aggressiveness through low self-control. Study 3 found that states with high diabetes rates also had high violent crime rates. Study 4 found that countries with high rates of glucose-6-phosphate dehydrogenase deficiency (a metabolic disorder related to low glucose levels) also had higher killings rates, both war related and non-war related. All four studies suggest that a spoonful of sugar helps aggressive and violent behaviors go down.

Keywords

aggression; self-control; self-regulation; glucose; metabolism

> "Educate your children to self-control, to the habit of holding passion and prejudice and evil tendencies subject to an upright and reasoning will, and you have done much to abolish misery from their future and crimes from society."
>
> — Benjamin Franklin, one of the Founding Fathers of the United States.

There are many causes of aggression and violence, including provocation, frustration, alcohol intoxication, violence in the media, weapons, hot temperatures, loud noises, pollution, crowding, and many other unpleasant events [for a review see Bushman and Huesmann, 2010]. This raises an important question: Why is there not more aggression and violence than there is? After all, who has not experienced provocation, frustration, anger, insult, alcohol, media violence, or hot weather in the past year? Yet most people do not hurt

*Correspondence to: C. Nathan DeWall, Department of Psychology, University of Kentucky, Kastle Hall, Lexington, KY 40506-0044. nathan.dewall@uky.edu.

or kill anyone. These factors may give rise to violent impulses, but people mostly restrain themselves.

Self-control refers to the ability to override urges, thoughts, and habitual tendencies in order to behave in accordance with personal or societal standards for appropriate behavior. Previous research has shown that poor self-control is perhaps the best predictor of criminal behavior [Gottfredson and Hirschi, 1990]. Unfortunately, self-control is a limited resource. When self-control energy is used it becomes depleted, an effect that has been dubbed ego depletion because the self's energy resources have been reduced [Baumeister et al., 1998]. Numerous studies have shown that when people engage in one act of self-control, they have less self-control for subsequent tasks [Finkel et al., 2006; Richeson and Trawalter, 2005; Schmeichel, 2007]. Of particular relevance to the current investigation is research showing that when people engage in an initial act of self-control they are less able to subsequently control their aggressive impulses [DeWall et al., 2007; Finkel et al., 2009]. Overriding aggressive impulses requires self-control energy, and when some of that energy is depleted people become more aggressive.

Self-control takes a lot of energy—energy that is provided in part by glucose. Glucose ($C_6H_{12}O_6$) is a chemical in the bloodstream made from nutritious intake that is converted into neurotransmitters that provide energy for brain processes. For glucose to become available in the bloodstream, it needs to be broken down from glycogen during a process known as glycogenolysis. Glucose is metabolized by the liver and kidneys, making those organs essential for brain processes to operate effectively. All brain activities require at least some glucose. Self-control processes, which involve the complex process of overriding a strong impulse, consume a relatively large amount of glucose [e.g. Benton et al., 1994, 1996; DeWall et al., 2008; Fairclough and Houston, 2004; Gailliot and Baumeister, 2007; Gailliot et al., 2009; Masicampo and Baumeister, 2008].

Self-control may therefore be considered a metabolically expensive process. Low glucose is linked to poor performance on numerous self-control tasks [Gailliot et al., 2007]. Furthermore, problems with the use of glucose (e.g. hypoglycemia, diabetes) have been linked to numerous signs of poor self-control, including eating fatty and sugary substances over a long period of time [e.g. Bolton, 1979; Eren et al., 2003; Pereira et al., 2005; Virkkunen and Huttunen, 1982]. Self-control is also impaired by inadequate levels of brain glycogen [Gailliot, 2008], a metabolite that provides energy for sustained effortful exertion. Thus, low glucose and problems metabolizing glucose into glycogen reduce self-control.

Because self-control allows people to refrain from engaging in aggressive behavior and also relies heavily on glucose, one would expect that low glucose levels should be linked to aggression. There is preliminary research showing a relationship between low glucose and both aggression and impulsivity [Donohoe and Benton, 1999; Lustman et al., 1991]. In addition, the Quolla Indians have a reputation for violence that dates back to the 16th century. Unpremeditated murder is common among them. The Quolla Indians experience chronic low blood glucose, with the most aggressive individuals having the lowest glucose levels [Bolton, 1973]. Studies have also shown that individuals rated by others as being highly aggressive had poorer glucose metabolism than did individuals rated as nonaggressive [Yaryura-Tobias and Neziroglu, 1975].

These findings suggest a potential direct link between glucose and aggression. Because glucose aids in self-control processes, raising glucose levels should decrease aggressive behavior when people are placed in an aggressive situation. Even if people do not experience provocation, self-control processes should aid them in overriding the temptation to behave aggressively for instrumental, proactive reasons. Metabolic problems that hamper efficient use of glucose should also relate to higher levels of aggression, but direct evidence is lacking. The current research aims to fill this gap.

OVERVIEW OF STUDIES

The current investigation tested the hypothesis that low levels of glucose are related to high levels of aggression and violence, using both experimental methods (Study 1) and correlational methods at the individual (Study 2), state (Study 3), and country (Study 4) level. Finding converging evidence across such varied methods and populations would offer converging evidence for a link between glucose metabolic problems and aggression.

STUDY 1

Although several studies have linked low glucose levels to high aggression levels, no experiments have shown that this link is causal. One previous study showed that consuming a glucose beverage compared with a placebo beverage caused participants to show fewer signs of frustration when playing an impossible computer task [Benton and Owens, 1993], but that study did not measure aggressive behavior. Study 1 sought to fill this gap in the literature. In Study 1, participants randomly received lemonade containing either sugar (glucose beverage) or a sugar substitute (placebo beverage). Afterwards, they were given a chance to blast an ostensible opponent with loud noise through headphones (aggression measure). We predicted that participants who had consumed a glucose beverage would behave less aggressively than participants who had consumed a placebo beverage.

Method

Participants—Participants were 62 college students (66% female; M_{age} = 19.45 years, SD = 0.97 years; age range 18–23 years; 76% White) who volunteered in exchange for course credit. To reduce glucose instability, students were told to fast 3 hr before participating. Only participants who reported fasting for 3 hr before their testing session were tested (100% actually fasted).

Procedure—Participants were tested individually in what was described as a “taste test study,” in which they would consume a beverage and would have their reaction-times tested in a computerized task against an opponent. After giving informed consent, participants were randomly assigned to receive 14 ounces of lemonade sweetened with either sugar (glucose beverage) or a sugar substitute (placebo beverage). Next they completed a filler task for about 8 min to allow the glucose to become absorbed in their bloodstream [Gailliot et al., 2007].

Participants then completed a competitive reaction time task [Taylor, 1967] against an ostensible partner of the same sex. This task is a well-established reliable and valid measure of aggressive behavior [e.g. Giancola and Zeichner, 1995]. Participants were told that they and their ostensible partner would have to press a button as fast as possible on each of 25 trials, and that whoever was slower would receive a blast of white noise (similar to radio static) through their headphones. At the beginning of each trial, participants set the level of noise their partner would receive if their partner lost the competition, from 60 dB (*Level 1*) to 105 dB (*Level 10*, about the same volume as a smoke alarm). A nonaggressive no-noise level (*Level 0*) was also provided. They could also control how long their partner heard the noise. Of the 25 trials, the participant won 12 (randomly determined). A computer recorded all events in the task. Basically, within the ethical limits of the laboratory, participants controlled a weapon that could be used to blast their partner with loud noise. Finally, participants were debriefed.

Results and Discussion

Noise intensity on trial 1 was used to measure aggression. The first trial provides a measure of unprovoked aggression because the partner has not delivered any noise to the participant yet [e.g. Bushman and Baumeister, 1998]. Therefore, using the first trial provides the simplest measure of aggression to analyze because provocation level need not be considered. We used the level of intensity selected by the participant as the measure of aggression, as in numerous other studies [Giancola, 2003, 2004]. After the first trial, aggression converged on what participants believed their partner had done (i.e. tit-for-tat responding). This is consistent with many findings that confirm the importance of reciprocation norms in determining levels of aggressive behavior [Axelrod, 1984].

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, M =4.80, SD =1.99 and M =6.06, SD = 2.21, respectively, $F(1, 60) = 5.55$, $P = .02$, $d = .60$. These findings offer the first evidence that boosting glucose levels causes a decrease in aggressive behavior.

STUDY 2

Study 2 replicates and extends the findings of Study 1 by testing why glucose is linked to aggression. Because glucose is a brain food that increases self-control, those who have difficulty metabolizing glucose should have less self-control. Low levels of self-control are linked to high levels of aggression [Gottfredson and Hirschi, 1990]. Diabetes is a disorder characterized by the inability to metabolize glucose. We therefore expected that diabetic status would be positively related to aggressiveness, but we expected this relationship to be indirect. Specifically, we predicted that individuals with diabetic symptoms (e.g. difficulty metabolizing glucose) would have difficulty exercising self-control. Difficulty exercising self-control, in turn, should be positively related to aggressiveness.

Method

Participants—Participants were 112 adult volunteers (80% female; M_{age} = 21.5 years, SD = 7.57 years; age range 18–54 years; 78.3% White) recruited via online advertisements placed in different US cities.

Procedure—After giving their consent, participants completed measures of diabetic status, self-control, and aggressiveness. Diabetic status was measured using the 34-item (e.g. “aching calves when walking,” “shortness of breath at night,” and “sleepiness or drowsiness”) Diabetic Symptoms Checklist-Revised [Grootenhuis et al., 1994], which assesses the number and severity of diabetic symptoms individuals had experienced within the past month. A diabetic symptom variable was created by averaging the number and severity of symptoms (Cronbach α = .87). Previous research has shown that lower glucose metabolism levels were associated with higher levels of diabetic symptom distress using this scale [Adriaanse et al., 2008]. Self-control was measured using the 16-item (e.g. “I am good at resisting temptation,” “I am able to work effectively toward long-term goals”) Brief Self-Control Scale [Tangney et al., 2004; Cronbach α = .87; M = 3.27, SD = 0.75], which measures how well people engage in activities that involve self-control. Aggressiveness was measured using the 29-item (e.g. “Some of my friends think I’m a hothead.”) Aggression Questionnaire [AQ; Buss and Perry, 1992; Cronbach α = .95; M = 2.82, SD = 1.20]. Finally, participants were debriefed.

Results and Discussion

As expected, diabetic status was positively correlated with aggressiveness (r = .49, P < .001). Glucose is brain food for self-control, and people who have difficulty metabolizing glucose also have difficulty controlling their aggressive impulses.

We expected that self-control would account for the relationship between diabetic status and aggression. To test this, we computed how much of the variance in the relationship between diabetic status and aggression was accounted for by self-control. We found that 4% of their relationship could be explained by an indirect path between them that went through self-control. The best estimate of the size of the indirect path was .015 with a 95% confidence interval ranging from .01 to .02 and did not include zero, indicating a significant path (Fig. 1). This confidence interval was computed using a nonparametric bootstrapping procedure [Preacher and Hayes, 2008]. We opted for this method because the traditional Sobel [1982] test assumes that the product of coefficients that constitute the indirect effect are normally distributed, when in fact they are usually skewed and leptokurtic. The bootstrapping method avoids these pitfalls.

Thus, the effect of diabetic status on aggressiveness was indirect. People with diabetic symptoms, as indicated by the DSC-R, have low self-control. Low self-control, in turn, is related to high levels of aggressiveness. Although these results are correlational, they suggest that aggression often starts when self-control stops.

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STUDY 3

Study 3 replicates and extends Study 2 using diabetic and violent crime rates from all 50 of the United States. We predicted that the diabetes rates from each state would correlate positively with violent crime rates from each state.

Method

The United States Federal Bureau of Investigation (FBI) classifies four crimes as violent: murder, assault, rape, and robbery. We combined these four crimes to obtain an overall measure of violent crime for the year 2001 [FBI Uniform Crime Reports, 2002]. The year 2001 was selected because we were able to obtain state diabetic rates for that year [Mokdad et al., 2003]. As a possible covariate, we also included 2001 median income [Statistical Abstracts of the United States, 2002], which accounted for more variance than race. Multicollinearity occurred when both race and median income were included in the model.

Results and Discussion

As expected, the prevalence of diabetes was positively linked to violent crime rates, $r = .38$, $P < .007$. After controlling for median income, the relationship between diabetes rate and violent crime rate was identical: $r = .38$, $P < .007$. This suggests that diabetes did not predict violent crime simply because poverty contributes to both diabetes and violent crime. These data are consistent with those obtained in Study 2 for individuals.

STUDY 4

Study 4 tested whether the prevalence of glucose- 6-phosphate dehydrogenase deficiency across the world would predict increased violence, in the form of violent (nonaccidental) killings not related and related to war. People with glucose-6-phosphate dehydrogenase deficiency lack an enzyme related to glucose metabolism. It is the most common enzyme deficiency in the world, afflicting more than 400 million people [Cappellini and Fiorelli, 2008]. It is especially common among individuals with diabetes [Gaskin et al., 2001]. In one study, school children with the disorder were rated by their teachers as more aggressive than other children [Meijer, 1984]. Given its links to impaired glucose metabolism and aggression, we predicted that glucose-6-phosphate dehydrogenase deficiency would predict increased violent killings both related and unrelated to war.

Method

Data from a collection of the most current prevalence rates of glucose-6-phosphate dehydrogenase deficiency in 122 countries across the world were obtained from the World Health Organization [WHO Working Group, 1989]. Glucose-6-phosphate dehydrogenase deficiency is hereditary and prevalence rates are stable from year to year across different geographical locations. Data showing violent killings related and not related to war by country across the world were taken from Associated Newspapers [2009] for the only year they were available, 2002.

Results and Discussion

The prevalence of glucose-6-phosphate dehydrogenase deficiency in countries throughout the world predicted non-war violent killings, $r(116) = .24$, $P = .01$ and war killings, $r(115) = 5.26$, $P = .005$. Countries with higher levels of the disorder had more violent killings, regardless of whether they were the result of war. However, because these data are correlational we cannot be sure that individuals with the disorder contributed to violent killings. The results for deaths in war would be particularly problematic because the number of war related deaths in one country may well be due to the aggression of another country. For example, during the Second World War, Poland experienced the death of about 16% if its population almost entirely as a result of being the victim of others aggression [Piotrowski, 1998]. This was a higher rate of death than experienced either by Germany or Japan. Additionally, it is much harder to make the case that war deaths are due to “lack of self-control.” Nevertheless, these worldwide data are, particularly for non-war killings, consistent with the data from Studies 1–3.

GENERAL DISCUSSION

Aggressive impulses arise frequently and with little effort [Finkel et al., 2002]. To act in accordance with societal standards, people must control their aggressive impulses. Unfortunately, people have a limited capacity to control their impulses, and much of this limited resource depends on the amount of glucose in the blood-stream that can provide energy for brain activities. Therefore, aggression may depend on individual differences in metabolic functioning and whether people have recently experienced a boost to their glucose levels that provides them with mental energy needed to override aggressive impulses.

The current studies provided consistent support for these hypotheses. Study 1 showed that participants who drank lemonade sweetened with a sugar substitute were significantly more aggressive against an ostensible partner (by administering louder noise through headphones) than were participants who drank lemonade sweetened with sugar. To our knowledge, this is the first study to find that boosting glucose levels can reduce actual aggressive behavior. Study 2 showed a positive correlation between diabetic status and aggressiveness that was partially accounted for by self-control. This is consistent with the idea that metabolic problems undermine self-control, and therefore increase aggression. Studies 3 and 4 linked the metabolic disorders of diabetes and glucose-6-phosphate dehydrogenase deficiency at a societal level, showing that the prevalence of diabetes predicted violent crime rates across the United States and that the prevalence of glucose-6-phosphate dehydrogenase deficiency predicted non-war killings and war victimization around the world. Taken together, these four studies offer converging evidence linking low glucose and other metabolic problems with aggression and violence.

Implications, Limitations, and Future Directions

These findings may have implications for acts of violence in which people reportedly “snap.” People who have chronic problems with their glucose functioning may not have sufficient mental energy to override their aggressive impulses, which may place them at risk for aggressing against others. People who have experienced minor metabolic demands might use up energy needed for restraining aggressive impulses, which increases the likelihood of aggression. To be sure, consuming sugar should not be considered a panacea for curbing aggression. The current results do suggest, however, that interventions designed to provide individuals with metabolic energy may foster harmonious social interactions. Interventions that increase brain glycogen, for instance, might help to provide additional metabolic energy that can be used for the self-controlled restraint of aggressive urges [see Gailliot, 2008].

Metabolic problems might increase aggression partly because individuals seek to be energized. Substances that provide metabolism can be highly sought out or can even become addictive. For example, the addictive drug caffeine is often sought out via energy drinks for its energy-providing properties [Reissig et al., 2009]. Engaging in physical aggression can energize a person by breaking down metabolites stored in fat and muscle. The metabolites then enter the bloodstream and can be used by other processes, an effect similar to that obtained from physical exercise. Low glucose and problems metabolizing glucose might predispose individuals to actions that increase their levels of arousal and energy (e.g. eating, ingesting caffeine), which may increase the likelihood of aggression [Zillman et al., 1972].

More broadly, processes that have especially enabled successful reproduction and evolution might tend to be more metabolically expensive [see Gailliot et al., 2010]. Evidence thus far supports the existence of three expensive psychological processes—reproduction (e.g. sperm production, ovarian activity during menstruation), immune defense (e.g. cancer is metabolically expensive and impairs executive functioning), and self-control or higher order executive functioning (e.g. aggressive restraint)—and all three confer relatively large contributions to evolved dispositions. Although aggressive restraint is metabolically expensive, its metabolic costs may have been outweighed by the benefit of passing along one's genes to the next generation. That is, the ability to inhibit aggressive behavior is beneficial to reproductive success above and beyond the metabolic costs of doing so.

Increasing glucose levels to adequate levels among aggressive-prone individuals could greatly reduce aggression in society. Police in the United Kingdom give lollipops to drunken club-goers late at night, which has been found to reduce the drunken aggression and mob violence common among them. Indeed, one report showed that the "sweet lollipop intervention" decreased the annual rate of physical assaults by 10% over a 1-year period [BBC News, 2007]. Thus, our findings may have practical significance in terms of reducing aggression and violence outside the laboratory.

One limitation from the current investigation is that self-control only partially accounted for the relationship between diabetic status and aggression, explaining only 4% of the variance. To be sure, multiple mediators likely exist. One possibility is that when people are placed in an aggressive situation, a boost of glucose increases activation in neural regions associated with conflict monitoring [e.g. dorsal anterior cingulate cortex; DeWall et al., 2010] and the downregulation of negative affect [e.g. right ventrolateral prefrontal cortex; Creswell et al., 2007]. This increased activation in the dACC and RVPFC may, in turn, be associated with lower levels of aggression. Another possibility is that the relationship between heightened glucose levels on aggression is due to an increase in positive mood. Although this is possible, our previous research has shown that the effect of glucose on behavior is not attributable to fluctuations in emotional states [e.g. DeWall et al., 2008; Gailliot et al., 2007]. Exploration of these potential mediators awaits future inquiry.

A second limitation relates to the effect of glucose- 6-phosphate dehydrogenase deficiency on war killings. It is possible that for war killings, the killing is carried out by one set of people with another set being killed. Therefore, higher levels of this metabolic disorder in one country may relate to more war killings in other countries instead of more killings in one's own country. Though possible, we believe that this is unlikely for at least two reasons. First, wars involve a violence escalation cycle in which one group of people kills members of another group, leading members of the second to kill members of the first group, and so on. Therefore, one's country amount of people killed in war depends in large part on how many people in that country are killing members of other countries. This reasoning meshes well with recent theoretical and empirical research showing that highly aggressive people create situations in which they both experience aggressive outbursts from others and perpetrate high levels of aggression toward others [Anderson et al., 2008; DeWall and Anderson, 2010]. Second, the results related to war killings are similar to results related to non-war killings, which suggests that how much people are killing in and out of war is related to how many people have a specific type of metabolic disorder. Thus, the findings related to war killings in Study 4 offer valid evidence regarding the relationship between deficiencies in glucose metabolism and aggression.

CONCLUSIONS

Aggression and violence often start when self-control stops. For society to function peacefully, people must control their aggressive impulses. Self-control requires a lot of brain food in the form of glucose. Thus, people who have difficulty metabolizing glucose (breaking it down into an useful form and keeping it at constant levels) are at a greater risk for aggressive and violent behavior. The inability to metabolize glucose is not only a risk factor for health problems in those afflicted with the disorder but also a risk factor for aggression and violence in all members of society. The healthy metabolism of glucose may contribute to a more peaceful society by providing individuals with a higher level of self-control energy.

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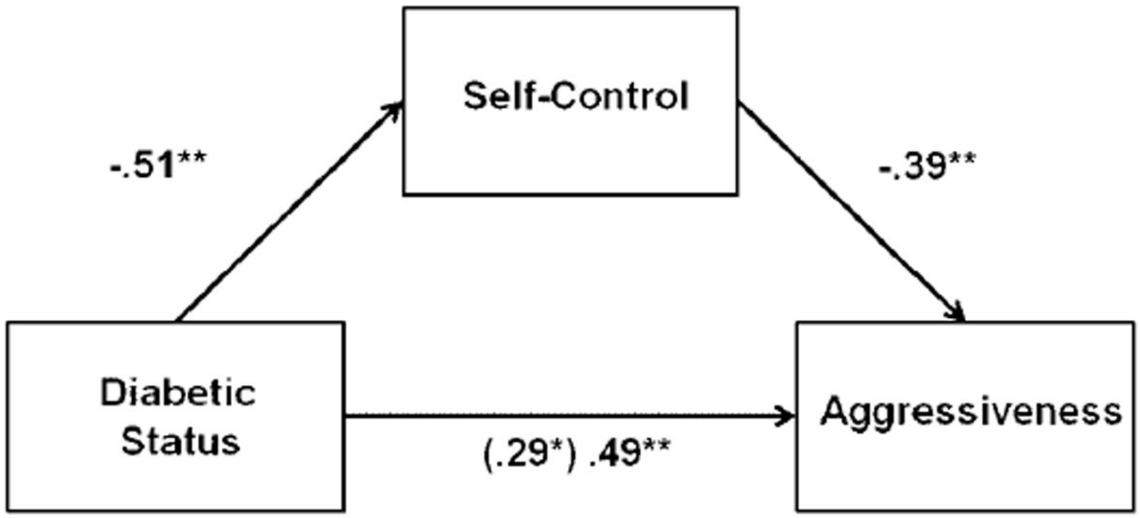

Fig. 1.
Relationship between diabetic status and aggressiveness is accounted for by self-control. Study 2. Values refer to standardized regression coefficients. $^{**}P<.001$; $^{*}P<.01$.