Pfundmair, M., Lermer, E., & Frey, D. (2017). Glucose increases risky behavior and attitudes in people low in self-control: A Pilot Study. *Social Psychology*, 48, 1, 47–53.

https://doi.org/10.1027/1864-9335/a000290

Glucose increases risky behavior and attitudes in people low in self-control: A Pilot Study

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Acknowledgment

The authors wish to thank Alexander Bauer and Helmut Küchenhoff for statistical consulting at STABLAB.

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The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Abstract

People low in self-control have a strong proclivity towards risk-taking. Risk-taking behavior provides an opportunity to obtain some form of reward. Glucose, on the other hand, seems to facilitate reward and goal-directed behavior. In a pilot study executed in the lab, we investigated whether consuming a glucose drink would increase risky behavior and attitudes in people low in self-control. Our findings revealed that a dose of glucose compared to placebo increased risk-taking on a behavioral and cognitive level in participants low in self-control but not in participants high in self-control. The findings may shed some light on the psychological underpinnings of glucose: By showing glucose's association with high-risk behavior, they support the assumption of glucose driving a goal-directed motivation. (119 words)

Keywords: risk-taking; self-control; glucose; reward

Glucose increases risky behavior and attitudes in people low in self-control: A Pilot Study

In decisions to buy shares, considerations about touring ski destinations, or even thinking about taking an umbrella when leaving the house, humans are constantly faced with risky decisions and behavior. Risk-taking behaviors involve some potential for danger or harm and, at the same time, provide an opportunity to receive some form of reward (Leigh, 1999). Risky behavior is also related to the psychological dimension of sensation seeking: High sensation seekers tend to estimate risks as lower (Zuckerman, 2007).

Some personality traits have shown to be more prone to risky behavior and attitudes than others, inter alia, self-control, the capacity to bring own responses into line with ideals, values, morals, social expectations, and long-term goals (Baumeister, Vohs, & Tice, 2007). Self-control empowers a person to restrain or override responses (Baumeister et al., 2007). Plausibly, people low in self-control – both when measured at trait level (Zuckerman & Kuhlman, 2000) and when state fluctuations are taken into account (Freeman & Muraven, 2010) – show increased risk-taking. This relationship can also be observed in everyday live: More impulsive (and thus less self-regulated) individuals show more drug and alcohol use (Wills, Sandy, & Yaeger, 2002), more dangerous driving (Vavrik, 1997), and a higher affinity for gambling (Martins, Tavares, da Silva Lobo, Galetti, & Gentil, 2004).

As risk itself, also glucose, a carbohydrate used as cellular source of energy, is associated with reward: Recent literature suggests that a dose of glucose increases activation in the ventral striatum and anterior cingulate cortex, regions that enhance reward and goal-directed behavior (Chambers, Bridge, & Jones, 2009). Consistently, glucose consumption has been observed to increase reward- and goal-related behaviors, for example, control in dogs (Miller, Pattison, DeWall, Rayburn-Reeves, & Zentall, 2010) and working memory in humans (Owen, Scholey, Finnegan, Hu, & Sünram-Lea, 2012). That is, brain regions responding to glucose, in particular the dopaminergic pathways within the striatum, seem to mediate emotional and behavioral reactions associated with rewarding stimuli (Berridge & Robinson, 1998; Kelley, Bakshi, Haber, Steininger, Will, & Zhang, 2002). It seems plausible that this glucose-induced reward motivation could also drive a preference for risks that per definition provide some form of reward (Leigh, 1999). A dose of glucose should therefore increase susceptibility to risk. Particularly people low in self-control who dispositionally have a strong proclivity towards risk-taking per se might be pushed by glucose to give in to their natural impulse.

Consequently, we predicted that consuming a glucose (versus placebo) drink would increase both behavioral and cognitive risk-taking in participants low in self-control. To investigate this hypothesis, participants drank lemonade sweetened with sugar or a substitute, filled out a measure of self-control, and completed a behavioral task as well as a cognitive measure of risk-taking.

Method

Participants and design

One-hundred-and-twelve German undergraduates (74 female, 37 male, and 1 who did not specify gender; M_{age}=25.05, SD_{age}=6.18) participated in this study. Participants were not allowed to take part if they reported to be diabetics.

Participants were randomly assigned to a 2 (beverage: glucose vs. placebo) between-subject design; self-control served as continuous moderator variable.

Procedure

Participants arrived at the laboratory for a study that ostensibly consisted of two independent experiments investigating a beverage’s appearance and taste, and responsiveness in playful situations. After completing informed consent, participants consumed either a glucose or placebo beverage without any information about the drink. Subsequently, they answered questions about mood, self-control, and liking for the beverage. After this, they completed the behavioral risk measure and filled out a questionnaire consisting of the cognitive risk measure and mood.

Materials

Beverage. Participants drank 14 ounces of Kool-Aid or Sprite lemonade sweetened with either sugar (glucose drink) or a sugar substitute (placebo condition). We used Kool-Aid lemonade and Kool-Aid lemonade sweetened with Stevia in the first half of data collection. However, as Kool-Aid, which is not sold in Germany, is experienced as particularly unusual by German drinkers, we changed the beverage into Sprite and Sprite Zero in the second half of data collection. Both glucose drinks contained approximately 140 calories, both placebo drinks approximately 0 calories.

Mood (pre-measure). Participants' implicit affect was assessed by the Implicit Positive and Negative Affect Test (IPANAT; Quirin, Kazén, & Kuhl, 2009). They were instructed to rate how well six artificial words (e.g., "VIKES"), purportedly from an artificial language, express six different mood adjectives on 1 = *does not fit at all* to 4 = *fits very well* response scales. We calculated the mean score of the positive (e.g., "pleased"; α=.66) and negative mood adjectives (e.g., "helpless"; α=.76).

Self-control. Participants filled out a measure of dispositional self-control capacity (SCS; Bertrams & Dickhäuser, 2009). The 13 items (e.g., "I am good at resisting temptation") answered on 1 = *not at all* to 5 = *very much* response scales were combined into a mean score (α=.81).

Liking for the beverage. Among filler measures intended to bolster the cover story on taste and appearance of the drink, participants completed two measures of liking for the drink ("How likely would you drink the beverage again?"; "How well does the beverage score compared to your favorite beverage?"; r=.76) and one sweetness evaluation ("How sweet did you experience the beverage?") on 1 = *not at all* to 5 = *very much* response scales.

Behavioral measure of risk. Participants' level of behavioral risk-taking was assessed using the Balloon Analogue Risk Task (BART; Lejuez et al., 2002). The BART is a computer program designed to simulate an actual risk-taking scenario. On a computer screen, participants are presented a simulated balloon, a button labeled *Press this button to pump up the balloon*, a button labeled *Press to collect $$$,* and a box labeled *Total earned.* Participants earned 5 virtual Cents for each time they pumped the balloon; as in previous studies (e.g., Hiemer & Abele, 2012), the total task contained 20 trials. Each trial started with a deflated balloon in the center of the screen. Participants could inflate the balloon by clicking on the according button. With each click, the balloon increased in size by approximately 0.3 centimeters. Participants could click on the *Press to collect $$$* button at any point in the trial which transferred the money earned during the current trial to their permanent bank (the box labeled *Total earned*). Participants were also informed that the balloon may explode at any point in the trial. With the increase of pumps, each subsequent pump risked more money. A trial ended either when the participant pressed the collect button or when the balloon exploded. If a balloon exploded, all money from the current trial was lost. The number of pumps required to burst each of the 20 balloons was random but constant across participants.

Following the recommendation of Lejuez et al. (2002), the number of pumps per balloon that did not burst was used as indicators of willingness to take risks (ICC = .61; M = 14.78, SD = 11.51). Seven participants did not complete the BART task because of technical difficulties.

Cognitive measure of risk. Participants' propensity for risk-taking was assessed using the Sensation Seeking Scale form V (SSS-V; Zuckerman, 1994). The SSS-V consists of 40 dichotomous forced-choice items, each belonging to one of four subscales: thrill and adventure seeking (e.g., "A sensible person avoids activities that are dangerous – I sometimes like to do things that are a little frightening"*;* α=.62), experience seeking (e.g., "I like to explore a strange city or section of town by myself, even if it means getting lost – I prefer a guide when I am in a place I don't know well"; α=.53), disinhibition (e.g., "I like 'wild' uninhibited parties – I prefer quiet parties with good conversation"; α=.67), and boredom susceptibility (e.g., "I get bored seeing the same old faces – I like the comfortable familiarity of everyday friends"; α=.53). The subscales were obtained by summing up the matching answers in terms of points. Due to their low reliabilities, we performed a factor analysis on the items of the sensation seeking scale which did not support four but 16 separate factors. At least, however, nine of 10 items of the disinhibition subscale loaded highly onto one single factor. Therefore, we decided to use only this subscale for the following analyses.

Mood (post-measure). Participants' affect was again assessed by the IPANAT. Reliabilities were acceptable for the mean score of the positive (α=.74) and negative mood adjectives (α=.83).

Results

Preliminary analyses. To ensure equality between the Kool-Aid and Sprite beverage, we first investigated differences in initial mood and beverage evaluations using *t*-tests. Participants who drank Kool-Aid neither differed from participants who drank Sprite in their positive, $t(110)=-1.24$, $p=.217$, or negative mood, $t(110)=-0.83$, $p=.410$, nor in liking for the drink, $t(110)=0.65$, $p=.517$, or the sweetness evaluation, $t(110)=0.43$, $p=.672$. Thus, we combined the two kinds of drinks together.

To moreover ensure equality between the glucose and placebo condition, we calculated some other *t*-tests. Participants who drank a glucose-laden drink neither differed from participants who drank the placebo in their initial positive, $t(110)=-0.99$, $p=.324$, or negative mood, $t(110)=-0.71$, $p=.482$, nor in liking for the drink, $t(110)=0.57$, $p=.567$, or the sweetness evaluation, $t(110)=-0.28$, $p=.784$. Furthermore, they did not differ in their level of self-control, $t(110)=0.66$, $p=.511$.

Behavioral risk-taking. To investigate the prediction that risky behavior would be increased in participants low in self-control when drinking a glucose-laden drink, we calculated a mixed-effects model (random intercept, no nested structure) entering beverage (effect coded as +1=glucose and -1=placebo), self-control (mean centered), the 20 BART trials (coded from 0 to 19) and their interaction terms as independent variables, and the number of balloon pumps (log transformed) as dependent variable; the procedural difference (change of beverage) was modeled as additional factor (effect coded as +1=Sprite and -1=Kool-Aid). There was a significant main effect of trial, see Table 1, and, notably, a significant interaction between beverage and self-control, see Table 2, tau-squared=.30, residual=.44. This interaction showed that participants low in self-control chose more pumps in the glucose than in the placebo condition whereas participants high in self-control did not differ in their number of pumps between the glucose and placebo condition, see Figure 1 (left panel). No other significant effects emerged.

Cognitive risk-taking. To investigate the predicted relationship between glucose and sensation seeking in participants low in self-control, we conducted a multiple moderation analysis: We entered beverage (effect coded as +1=glucose and -1=placebo) and self-control (mean centered) into a regression model using Hayes' (2013) Process tool; the procedural difference was modeled as additional factor (effect coded as +1=Sprite and -1=Kool-Aid). For disinhibition as dependent variable, there was a significant main effect of self-control which was qualified by a significant interaction between beverage and self-control, see Table 3. This interaction showed that participants low in self-control indicated more disinhibition in the glucose than in the placebo condition, whereas participants high in self-control did not differ in their disinhibition ratings between the glucose and placebo condition, see Figure 1 (right panel). No other significant effects emerged.[1] (See Electronic Supplementary Material 1 for analyses on the other sensation seeking subscales.)

Mood (post-measure). For positive mood, the same moderation analysis revealed neither a significant main effect of self-control, b=-0.02, SE=0.06, $t(103)$=-0.26, p=.795, beverage, b=-0.02, SE=0.04, $t(103)$=-0.61, p=.540, or the procedural difference, b=-0.01, *SE*=0.04, *t*(103)=-0.36, *p*=.718, nor a significant beverage × self-control, *b*=-0.02, *SE*=0.06, *t*(103)=-0.29, *p*=.771, beverage × procedural difference, *b*=0.02, *SE*=0.04, *t*(103)=0.42, *p*=.673, self-control × procedural difference, *b*=-0.04, *SE*=0.06, *t*(103)=-0.66, *p*=.510, or beverage × self-control × procedural difference interaction, *b*=0.05, *SE*=0.06, *t*(103)= 0.81, *p*=.419. Similarly, no main effects of self-control, *b*=-0.11, *SE*=0.07, *t*(103)=-1.53, *p*=.129, beverage, *b*=0.02, *SE*=0.04, *t*(103)=0.38, *p*=.703, or the procedural difference, *b*=-0.07, *SE*=0.04, *t*(103)=-1.48, *p*=.141, nor a significant beverage × self-control, *b*=-0.02, *SE*=0.07, *t*(103)=-0.26, *p*=.794, beverage × procedural difference, *b*=0.07, *SE*=0.04, *t*(103)=1.59, *p*=.116, self-control × procedural difference, *b*=0.05, *SE*=0.07, *t*(103)= 0.68, *p*=.498, or beverage × self-control × procedural difference interaction, *b*=0.03, *SE*=0.07, *t*(103)= 0.44, *p*=.662, emerged for negative mood.

The pilot study's script and datafile are accessible under Electronic Supplementary Material 2 and 3.

Discussion

Our findings revealed that glucose increases risk-taking in people low in self-control, not only on a cognitive but also behavioral level. This effect did not emerge in people high in self-control and could not be explained by mood.

The results may shed some light on the effect of glucose in human behavior. Previous research has reasoned that glucose may be the physical basis of self-control (Gailliot et al., 2007). A growing body of literature, however, is sceptical of links between glucose and self-control (e.g., Lange & Eggert, 2014; Kazén, Kuhl, & Leicht, 2015). Recent work has suggested that the role of glucose in self-control is one of allocation and not of depletion (Beedie & Lane, 2012). Other work has argued that glucose is an input to decision making systems (Kurzban, 2010). Empirical studies have supported this assumption: Specifically, glucose has shown to work through the activation of brain regions that are involved in reward (Chambers et al., 2009). It appears to increase a central drive or motivation (Carter, Jeukendrup, Mann, & Jones, 2004) by unconsciously suppressing fatigue signals (Pottier, Bouckaert, Gilis, Roels, & Derave, 2010). In our pilot study, the boosted susceptibility to reward-related behavior through a dose of glucose might have been reflected in increased risk-taking.

These effects only emerged among people low in self-control. According to the dual system perspective (Hofmann, Friese, & Strack, 2009), certain boundary conditions can shift the degree of potential activation in favor of an impulsive or reflective reaction. In our pilot study, glucose might have pushed people low in self-control who have a strong proclivity towards risk-taking per se (e.g., Zuckerman & Kuhlman, 2000) to give in to their natural impulse. However, the individual difference also allows for another interpretation: Recently, it has been proposed that socially oriented people conserve more energy as they construe relationships as opportunities to conserve resources (Beckes & Coan, 2011; see also Fitzsimons, Finkel, & vanDellen, 2015). Socially avoidant individuals, on the other hand, who normally have lower self-regulatory resources (e.g., Fuendeling, 1998) have been shown to devote higher levels of glucose to their bloodstream and consume more glucose with the expectation of increased personal effort (Ein-Dor et al., 2015). That is, highly attachment avoidant (and thus lower self-regulated) people are physiologically adapted to a relatively independent way of life. Accordingly, it is possible that people low in self-control in our study have chosen more extreme investments under glucose to manage the situation individually.

A large body of research, mainly stemming from research on prospect theory (Kahneman & Tversky, 1979), has shown the importance of considering gain vs. loss frames in risk taking. The increased susceptibility to risky behavior by consuming glucose has been observed in a gain frame in our pilot study: When playing the BART, participants were only able to win but not to lose. As glucose seems to enhance reward-directed behavior (Chambers et al., 2009), the increase of risky behavior in the gain-framed paradigm of BART was expectable. On the other hand, glucose should not increase but even decrease risk-taking in loss frames as those situations might not be able to provide any form of reward. Therefore, future research contrasting gain and loss frames by using different risk-taking paradigms would move us toward a better understanding of glucose's proposed mechanism.

Besides the behavioral measure of risk, we observed the predicted pattern on a cognitive risk-taking measure, namely the sensation seeking subscale of disinhibition. This preference for ignoring social constraints seems to be particularly associated with risk-taking: Disinhibition significantly contributes to patterns of risky behavior (Greene, Krcmar, Walter, Rubin, & Hale, 2000). It should, however, be noted that the other sensation seeking subscales were excluded from our main analyses as they yielded relatively low reliabilities and a factor analysis did not support the assumed factor structure. Thus, considering one of these subscales as "the" focal scale has to be treated with some caution.

In our interdisciplinary pilot study, we combined a well-validated behavioral measure with a self-report questionnaire and observed consistent effects. It should, however, be taken into account that our sample size was rather small for the present design. Thus, a replication of this effect in future research is crucial and could give more confidence in our conclusions.

Glucose's boosting role in risk-taking could explain behaviors from risky salary negotiations to dangerous driving after an intake of sugar. Moreover, it offers an important piece of the puzzle to understand the monosaccharide's psychological underpinnings.

Electronic Supplementary Material

ESM 1. Additional analyses (ESM1.doc). (= title and file name)

ESM2. Script (ESM2.doc). (= title and file name)

ESM3. Datafile (ESM3.xls). (= title and file name)

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Footnote

[1]We also investigated the predicted relationship between glucose and risk-taking in participants low in self-control using another statistical approach: For behavioral risk-taking, we entered beverage (effect coded as +1=glucose and -1=placebo), self-control (standardized) and their interaction term as independent variables into a linear regression; the mean number of balloon pumps served as dependent variable. As in the current analyses, we observed a significant interaction between beverage and self-control, p=.041. For cognitive risk-taking, we used the same linear regression, entering disinhibition as dependent variable. Again, a significant interaction between beverage and self-control emerged, p=.022. Although the current analyses differed from these in several aspects (treatment of the self-control and BART variables, inclusion of the procedural difference as additional factor), the result pattern remained stable.

Table 1

Means and standard deviations (in parenthesis) for balloon pumps on each trial, averaged across participants

Trial number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mean pumps	17.00 (16.65)	12.48 (9.44)	14.39 (11.44)	16.13 (13.86)	11.10 (6.06)	11.63 (7.42)	13.23 (9.69)	11.81 (8.15)	12.08 (9.25)	12.33 (6.93)	13.53 (13.58)	12.41 (8.57)	13.14 (8.61)	11.97 (6.93)	14.40 (9.84)	11.81 (6.36)	13.03 (9.61)	13.01 (7.32)	12.47 (8.44)	14.05 (9.21)

Table 2

Results for the mixed-effects model with beverage, self-control, trial, the procedural difference, and all interaction terms as predictors of behavioral risk-taking

	Estimate	*SE*	*df*	*t*	*p*
Beverage	0.22	.19	96	1.15	.251
Self-control	0.11	.20	96	0.54	.587
Trial	0.01	.004	1041	3.04	.002
Procedural difference	0.19	.17	96	1.11	.271
Beverage × self-control	-0.67	.33	96	-2.02	.047
Beverage × trial	-0.01	.01	1041	-1.10	.270
Beverage × procedural difference	-0.13	.26	96	-0.52	.605
Self-control × trial	-0.01	.01	1041	-0.72	.469
Self-control × procedural difference	-0.06	.27	96	-0.21	.838
Trial × procedural difference	-0.01	.01	1041	-1.26	.208
Beverage × self-control × trial	0.01	.01	1041	0.56	.574
Beverage × self-control × procedural difference	0.29	.42	96	0.69	.490
Beverage × trial × procedural difference	0.00	.01	1041	0.03	.974
Self-control × trial × procedural difference	0.00	.01	1041	0.44	.662
Beverage × self-control × trial × procedural difference	0.00	.02	1041	0.11	.911

Table 3

Results for the multiple regression analysis with beverage, self-control, the procedural difference, and all interaction terms as predictors of cognitive risk-taking

	Estimate	*SE*	*df*	*t*	*p*
Beverage	-0.32	.23	104	1.40	.165
Self-control	-1.20	.38	104	-3.18	.002
Procedural difference	-0.03	.23	104	-0.14	.893
Beverage × self-control	-0.90	.38	104	-2.36	.020
Beverage × procedural difference	-0.07	.23	104	-0.32	.746
Self-control × procedural difference	-0.57	.38	104	-1.50	.135
Beverage × self-control × procedural difference	0.53	.38	104	1.41	.161

Figure Caption

Figure 1. The interaction of beverage × self-control influences risky behavior (left panel) and attitudes (right panel).