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No effects of ingesting or rinsing sucrose on depleted self-control performance

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HIGHLIGHTS

- Carbohydrate metabolism proposed to be energetic source of self-control.
- Non-metabolic effects of oral glucose rinsing on ego depletion contradicts this.
- We report no specific effect of carbohydrate metabolism or rinsing on self-control.
- Suggests role of carbohydrate as the physical mediator of self-control overstated.

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ABSTRACT

Self-control tasks appear to deplete a limited resource resulting in reduced subsequent self-control performance; a state of *ego depletion*. Evidence of reduced peripheral glucose by exertion of self-control, and attenuation of ego depletion by carbohydrate metabolism underpins the proposition that this macronutrient provides the energetic source of self-control. However, the demonstration of positive, non-metabolic effects on ego depletion when merely sensing carbohydrates orally contradicts this hypothesis. Recent studies have also failed to support both metabolic and non-metabolic accounts. The effects of ingesting or rinsing a carbohydrate (sucrose) and an artificially sweetened (sucralose) solution on capillary blood and interstitial glucose, and depleted self-control performance were examined in older adults. Forty, healthy, adults (50–65 years) ingested and rinsed sucrose and sucralose solutions in a 2 (method) × 2 (source), fully counterbalanced, repeated measures, crossover design. Capillary blood and interstitial glucose responses were assayed. Depleted self-control performance (induced by the Bakan visual processing task) on an attention switch task was assessed under each study condition. Ego depletion had no consistent effects on peripheral glucose levels and no significant effects of ingesting or rinsing sucrose on self-control were observed. The act of rinsing the solutions, independent of energetic content, resulted in a small, non-significant enhancement of performance on the attention switch task relative to ingesting the same solutions (RT: $p = .05$; accuracy: $p = .09$). In conclusion, a metabolic account of self-control was not supported. Whilst a positive effect of rinsing on depleted self-control performance was demonstrated, this was independent of energetic content. Findings suggest glucose is an unlikely physiological analogue for self-control resources.

1. The effect of ingesting and rinsing sucrose and sucralose on depleted self-control performance

Acts of self-control require the effortful inhibition of predominant responses, emotions, thoughts, and impulses, permitting behaviour to vary adaptively moment to moment [1,2]. Exertion of self-control is considered to be a key process in the human personality structure as flexibility in behavioural response permits the attainment of goals, and facilitates adherence to rules, laws, and social norms and standards [3]. Indeed, self-control capacity has been positively associated with an impressive array of behaviours of personal and societal significance (e.g., reduced aggression [4]; scholistic achievement [5]; interpersonal success [6]; criminality [7]).

The capacity to exert self-control appears to be limited [8]. The resource strength model maintains that acts of self-control consume and temporarily deplete a common, and crucially limited, resource; ultimately resulting in 'ego depletion' [9,10]. Self-control performance is therefore determined by the current strength or level of depletion of this common resource. Indeed, initial expenditure of self-control has been repeatedly demonstrated to result in reduced subsequent performance on self-control tasks independent of differing task modalities

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[11]. This would fit with the claim that the resource involved in inhibition and self-control reflects a form of executive function [12,13].

Gailliot and Baumeister [14] extended the strength model from the metaphorical to the physical by proposing that glucose is the central energy source of self-control. This proposition was founded on evidence of (*i*) reduced blood glucose levels after initial exertion of self-control; (*ii*) an association between subsequent, post-depletion, self-control performance and blood glucose decline, and (*iii*) attenuation of the detrimental ego depletion effect on self-control performance after ingestion of glucose, but not artificial sweetener (sucralose) [14]. Subsequent attempts to replicate the moderation of peripheral blood glucose by exertion of self-control have not supported this original finding [15]. The amount of glucose required for acts of self-control is likely to be negligible in absolute brain energy cost terms. Furthermore, reduced peripheral glucose is unlikely considering the efficiency of homeostatic systems in maintaining brain energy levels [16].

The capacity of glucose ingestion to counteract the impairing effect of ego depletion has however been replicated [17–20]. Nevertheless, the precise role of glucose in self-control performance remains indistinct. Firstly, a number of studies have demonstrated that glucose can influence performance on self-control tasks in a non-energetic manner. Merely sensing carbohydrates in the oral cavity can confer a restorative benefit on cognitive self-control performance under conditions of ego depletion [15,21,22]. The positive effect of carbohydrate oral rinsing has also been demonstrated in physical endurance performance [23,24], conferring greater performance benefits than ingestion [25]. Such findings suggest a potential motivational rather than metabolic effect of carbohydrates on performance, underpinned by activation of motivational neural reward pathways [15,24,26]. Ego depletion effects can also be moderated by manipulation of subjective states such as motivation [27], expectation of self-control capacity [28], and self-affirmation [29]. Evidence of moderation of self-control performance by subjective state casts further doubts on the specific role of glucose.

The existing evidence for metabolic accounts of self-control (e.g., [11,14]) has also received criticism on the statistical grounds of potentially inflated effect sizes and methodological shortcomings [(16,30–32)]. Further, failed attempts to replicate the effects of carbohydrate ingestion and oral sensing suggest the effect of carbohydrate on self-control performance may not be as robust as the literature suggests [30,31]. In sum, whilst the ingestion and rinsing of carbohydrate-containing solutions have previously been shown to attenuate the ego depletion effect, critiques of the existing evidence, and recent failures to replicate the effect, necessitate further independent examination of the relationship between carbohydrate and self-control.

The present study examined the effect of ingesting and rinsing a sucrose and sucralose solution on a self-control task under conditions of ego depletion. The potential depletion of glucose by the exertion of self-control, and moderation of self-control by the metabolism of glucose, were rigorously assessed using formal laboratory standard capillary blood glucose analysis techniques and continuous interstitial glucose monitoring. Previous studies examining the effects of glucose ingesting and rinsing on self-control have recruited young, predominantly student samples. The facilitative effects of carbohydrate intake on cognitive performance may be more potent in individuals with disrupted metabolic or cognitive functioning [33–37] rather than young, high functioning students. Indeed, glucose administration has been shown to selectively enhance cognitive performance in elderly, but not the young [33,34] and was additionally mediated by glucoregulatory control in older but not younger adults [33]. Ageing is associated with cognitive decline and disturbed regulation of primary hormones and neurotransmitters mediating glucose regulation and cognitive function (e.g., acetylcholine, adrenaline [37]). Therefore, older adults were considered a highly relevant population in which to study the effects of ingesting and rinsing carbohydrate solutions on self-control performance, due to commonly observed age-related decline in cognitive control [38] and an age-associated deterioration in glucose regulation [37].

2. Methods

2.1. Design

A 2 (method: rinse or ingest) × 2 (source: sucrose or sucralose) fully counterbalanced (William's Latin Square), within subjects, crossover design was employed to expose participants to each experimental condition. Participants were required to ingest or orally rinse sucrose and sucralose solutions (sucrose/ingest; sucrose/rinse; sucralose/ingest; sucralose/rinse) over four study visits separated by one week. At each visit, self-control was depleted prior to solution intake and performance on a different task requiring self-control was assessed post-intake. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the University of Leeds' School of Psychology Research Ethics Committee. The study was registered on Clinicaltrials.gov on February 26, 2014, registration identification number: NCT02075333 (available at https://www.clinicaltrials.gov/ct2/show/NCT02075333) Written informed consent was obtained from all participants. An honorarium of £140 was paid upon completion of the study.

2.2. Participants

Forty (16 males; 24 females), non-smoking, non-obese (x =25.20, SD = 2.53 kg/m^2; BMI < 30 kg/m^2; WHO, 2013), older adults (x = 57.75, SD = 5.79 years) were recruited from the University campus and local community. Participants self-reported to be free from symptoms of dementia, depression, Type II diabetes, phenylketonuria or other conditions that precluded the ingestion of sucralose, and were not taking medication likely to influence glucose metabolism or cognitive function. Volunteers with impaired glucose tolerance (2 h postprandial capillary blood glucose ≥7.8 mmol/L) were excluded at screening. Fifteen female participants reported themselves as postmenopausal. After eligibility screening, participants were randomly assigned to a counterbalanced experimental condition order.

2.3. Glucose measures

Capillary blood glucose was obtained via finger prick measures at −40, −24, −2, +5, +19, +33, +37, and +44 min relative to solution intake across study visits. Blood glucose was analysed using a YSI 2700 Glucose/Lactate Analyser (Yellow Springs Instruments, Yellow Springs, OH). Interstitial glucose was also measured in a subgroup of the total sample (5 male; 5 female) using a subcutaneous continuous glucose monitoring system (CGMS iPRO, Medtronic MiniMed, CA, USA). The CGMS was fitted the day prior to each study visit and continuously measured interstitial glucose every 5 min until the end of the test day. The time of solution ingestion/rinse was recorded and used to centre the response profile (0 min). Consequently, measures taken −50 min pre- and +40 min post-solution intake are reported. A finger prick measure collected upon waking on the study visit morning and measures collected by the experimenter at −40, +5, and +33 min at each visit were used to calibrate the CGMS. Capillary blood and interstitial glucose levels are reported in millimols per litre (mmol/L).

2.4. Self-control tasks

All cognitive tests were presented using E prime software (Psychology Software Tools, Inc., PA, USA) on a Dell Optiplex 760 desktop computer with a 17″ monitor (screen resolution 1280 × 800 pixels). Responses for both tasks were made on a keyboard spacebar.