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Mild hypoglycaemia and educational performance

This article examines the implications of very small reductions in glucose level and the effects on learning.

Brain imaging techniques frequently use radioactively labelled carbon atoms that have been incorporated into glucose molecules (1). The carbon's path through the body can be traced by its radioactive emission. It is fortuitous, for research and diagnostic purposes, that glucose provides almost all of the 'fuel' used by the brain and that the brain is unable to store sufficient readily available glucose to maintain normal brain function for even a very brief time interval. This has three implications. First, this highlights the importance of glucose in maintaining brain function - very low levels of blood glucose in the brain may be rapidly fatal and small reductions can disrupt brain function. Secondly, it follows that since the brain cannot store enough glucose it must obtain it as a constant, not intermittent, supply from the blood stream and this implies that blood glucose levels in circulation are a very good measure of glucose levels in the brain. Thus a measure of blood glucose from a finger prick estimates with considerable precision the current blood glucose level in the brain. The distribution of glucose/blood supply within the brain is actually variable as more is allocated, at a given time, to areas of the brain that are particularly active in processing demanding tasks. Hence, brain imaging shows very active brain areas as 'lighting up' because of a larger radioactive emission from the labelled glucose being deployed compared to other areas with lesser metabolic demands at that time. Damaged tissue will thus show up as a contrast to active processing areas. The third implication follows from the above observances. If blood glucose is absolutely essential to brain metabolism then any reduction in supply will have deleterious effects on the integrity of the brain. Even very small reductions in glucose level, measurable from a drop of blood from a finger, may well produce cognitive impairments especially in terms of learning and memory. These latter effects are likely to be mild and reversible but they are very important in educational settings.

Previous studies

In previous studies (2, 3, 4) we have shown that low blood glucose levels impaired consolidation of learning, reduced comprehension of educational material and resulted in poorer memory retention for student induction material. These low blood glucose levels (hypoglycaemia) were very mild but were sufficient to impair performance on a wide range of educational activities. In each case we were able to increase performance with a soft drink containing 50g of glucose. This hypoglycaemia seems to arise because it is not uncommon for students to miss breakfast. An ongoing study at the University of Wolverhampton shows that our students usually consume breakfast.

However, we estimate, from data derived from a breakfast content questionnaire completed immediately before our studies commence, that it provides considerably less than 300kCals on average and we consistently find average blood glucose levels of ~ 4.5 mmol/L (5.0 mmol/L is the norm).

A substantial breakfast

The implications of this are that students should eat a substantial breakfast before attending classes and if they cannot do so on a particular morning then consuming the drink we used in our experiments should reverse the negative effects of mild hypoglycaemia although this is no substitute for a breakfast providing slower but more sustained carbohydrate release. Our glucose rich drink consisted of 50 grams of glucose in 250ml of water plus 40ml sugar free 'Robinsons' Whole Orange Quash and 10ml of lemon juice. This drink is very useful for experimental purposes since it closely approximates to a glycaemic index (GI) of 100. (G.I. - a measure of the release rate into the bloodstream of consumed glucose. 50g of glucose in 300 ml of water would have, by definition, a G.I. of 100, water would have a G.I. of 0). More formally, the G.I. measures how rapidly 50 grams of carbohydrate from a food item raises blood sugar levels compared to 50 grams of glucose [5]). Perusal of our University catering facilities shows that such a drink is unavailable but a range of sugar rich drinks that should be effective are available.

Current study

In the current study, we again use educationally meaningful materials rather than standard psychology measures of cognition, for example, memory span tests, so that the practical significance of the findings would be clear. This involved using video based documentary material on global warming as study material with a short test of retention after presentation. Previously we have used video presentations of biographical material [2] and health and safety material [4] in our studies. By modifying the task each time we are able to examine the extent to which the results can be generalised. Additionally, in the present study we have included a widely available soft drink condition to see if commercially available drinks, in this instance Coca Cola (Coke), with a somewhat lower G.I. would be as efficacious as our orange juice + glucose drink. There is also a 'placebo' condition employing sugar free orange juice sweetened with saccharine.

We hypothesise that the three groups should have very similar baseline blood glucose levels and that this would be elevated for the orange + glucose group and the Coke group shortly after consuming the drink but the placebo group would show little change. Similarly, we would expect similar levels of retention after the first DVD presentation but better performance by the orange + glucose and the Coke groups after the second, post-drink presentation. Again, the saccharine, placebo group should show no improvement.

Methods

81 undergraduates, aged 19 - 28, volunteered to actively participate in this study as part of coursework on "Brain and nutrition". Approximately 75% of the participants were female. Attendance was mandatory for course credit but students not wishing to actively participate were able to gain credit by observing the experiment. Individuals were excluded from active participation if they suffered from diabetes, haemophilia or any other serious metabolic disorder. All participants signed informed consent forms to indicate that they understood the experimental procedure and, in particular, the briefing on the Wolverhampton safe blood sampling protocol. Before signing they were aware that this study had been vetted by the

Wolverhampton University Science Ethics Committee.

The drinks

The students in the glucose condition received a drink consisting of 30 grams of glucose in 250ml of water plus 40ml sugar free 'Robinsons' Whole Orange Quash and 10ml of lemon juice. Note that this is the same as the drink used in earlier studies except that in the present study the glucose level was reduced from 50g to 30g to match it to the sugar content of a 'Coke'. The Coke condition employed 300ml of Coke which contains 30g of available sugars. However it should be noted that Coke also contains a significant amount of caffeine and this may temporarily improve attention. Those students who were assigned to the saccharine condition drank orange juice that was identical except that 2g of 'Sweetex' replaced the glucose. A pilot study at the University of Wolverhampton indicated that students could not distinguish between these two drinks. Using Universal Indicator strips we established that the drinks differed in acidity. The two orange drinks had pH ~ 2.5 and Coke had a pH ~ 2.0 showing that Coke was considerably more acidic than orange juice. The significance of this is that reducing pH slows glucose transfer to the bloodstream (in effect reducing the G.I. value). Clearly there are important differences between the orange + glucose and Coke conditions so similar results from these two drinks is not a forgone conclusion.

Blood glucose level was tested using BM-Test 1-44 blood glucose test strips with Prestige Medical Healthcare Ltd. HC1 digital Blood Glucometers. The average of two measures was recorded at each testing.

The sessions

The study was run over three days and each session commenced at 10 a.m. with a briefing on the study. Each student attended only one session. The briefing did not identify the drink to be consumed (beyond the obvious, that is, that orange juice was provided on two days and Coke on one day - students were not made aware that there was a placebo condition). Students in the 'orange juice' conditions were told that the study used both glucose and saccharine in the drinks and that they should abstain from drinking if they were likely to be adversely affected by any of the constituents. After the briefing informed consent forms were filled out and then students went to cubicles outside of the main laboratory area, at 10.20 am, where they were shown how to sample their own blood by trained demonstrators. In all cases, the student was the only person who came into contact with their blood and they were required to discard all disposable materials themselves (lancets, test strips, antiseptic swabs etc.) into sharps containers for later incineration. This results in a minimal biological hazard from body fluids. Any blood droplets not captured on test strips or swabs were covered in powdered bleach by the demonstrator. After applying their blood sample to two glucometers and recording the reading, participants returned to their seats. This procedure complies with the applicable risk assessment procedure.

Multiple-choice test

All participants then watched a 15 minute DVD presenting factual material with illustrative news footage and narration on global warming. Following this, students completed a multiple-choice test on the contents of the presentation. They were then requested to consume the drink provided before taking a break of 25 minutes during which they were not to eat anything or consume any drinks other than bottled water. This break allowed the absorption of glucose into the bloodstream. When they returned they had their blood sampled again and then they returned to their bench and watched a second 15 minute documentary on global warming. This was followed by another multiple choice test. A debriefing session was held one week after

the experiment was completed.

Results

The blood sugar data were analysed statistically using two-way analysis of variance. There was a significant statistical interaction ($F(2,78)=23.00$ $p<0.0001$) and Simple Effects analysis [6] showed that there was no significant change in the blood glucose level of the saccharine group ($p>0.05$) but the glucose drink and the Coke both resulted in a significant increase ($p<0.001$) in blood glucose. The three groups did not differ in blood glucose level at the baseline test, that is, before consumption of the drink ($p>0.05$). Analysis of variance on the memory data revealed that the three groups did not differ at first, baseline test ($p>0.05$) but at second test the orange + glucose group performed significantly better than the other two groups ($p<0.025$). The means and standard deviations, for blood glucose readings and multiple-choice test performance are shown in Table 1.

Table 1: Blood glucose levels in mmol/L before and after imbibing either an Orange + Glucose drink, Coca Cola, or an Orange + Saccharine drink and Multiple choice questionnaire (MCQ) scores

Drink	Orange + Glucose		Coca Cola		Orange + Saccharine	
	Before	After	Before	After	Before	After
Blood glucose level mmol/L.	4.82 ***0.86***	6.31 ***0.87***	4.63 ***0.86***	5.61 ***1.29***	4.24 ***0.73***	4.17 ***0.57***
MCQ score Max = 8.00	4.07 ***1.54***	5.15 ***1.54***	5.15 ***1.20***	5.07 ***1.54***	4.93 ***1.66***	5.04 ***1.74***

for each condition (Standard Deviation Scores in bold/italic).

Discussion

The results are largely as predicted except that there was no memory enhancement with Coke even though the Coke drink did increase blood glucose significantly.

Perusal of Table 1 shows that mild hypoglycaemia was present in all groups at the commencement of the experiment and that this was ameliorated by sugary drinks. Inspection of the MCQ scores shows that the improvement is modest and this is to be expected.

Large changes in performance do not occur when the baseline blood glucose is close to normal but the small changes that do occur could well be of sufficient magnitude to influence the grade attained (for example, on some tests one might get, say, a B instead of a C as a result of correcting blood glucose). When blood glucose level is considerably lower physiological distress (trembling, weakness, nausea etc.) occurs and this is rarely found in healthy individuals who simply miss breakfast.

This procedure is a 'gentle' corrective to a minor, transient problem, not a cognitive enhancer. It maybe that the blood sugar increase from Coke in this study is not sufficient (it is ~ 0.7 mol/L lower than the glucose condition) to 'fine tune' memory processors, especially as this particular group performed very well on the MCQ in the baseline condition. Nevertheless, the general results are consonant with our earlier findings and we will investigate the efficacy of Coke and other soft drinks further.

References.

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