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Oral Consumption of D-Glucose Increases Blood Glucose Levels but does not Alter the False Memory Effect using the Deese-Roediger-McDermott task in a Non-Diabetic Sample

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Glucose, a well-known memory modulator and physiological component of acute arousal, was examined for its influence on the false memory effect in two experiments. A baseline blood glucose (BG) measure was followed by the consumption of d-glucose or saccharin and a 15-minute post-consumption BG test in Experiment 1. Participants were then asked to listen to either a false memory lure wordlist or a control wordlist. Subsequently, participants completed recall and recognition tests. In Experiment 2, participants consumed either glucose or saccharin prior to listening to ten lure wordlists, each followed by a recall and recognition test. Results of Experiment 1 revealed significant elevations in BG following d-glucose consumption and greater recall for lure lists than control lists regardless of drink type. The lure was also recalled significantly more often from the lure list, replicating the false memory effect for words using a single wordlist. D-glucose had no effect on word recall, but decreased wordlist recognition performance, and had no effect on false memory or 'remember'/'know' judgments. Results of Experiment 2 indicated that d-glucose significantly enhanced word recall and recognition of old words, but as in Experiment 1, it did not alter recall of the lure, thus failing to influence the false memory effect. The failure of glucose to alter the false memory effect suggests that this neurobiological product of the stress cascade may not likely alter real world occurrences of false memory.

Real world occurrences of false memory are often associated with high levels of emotional arousal, although the impact of arousal and its physiological manifestations have received little attention in the false memory literature. The potential impact of such biological changes on false memory are important from both empirical and applied perspectives, as the false memory phenomena is frequently an issue of legal debate. The goal of these experiments was to examine the effects of d-glucose, commonly elevated under acute emotional stress (Flint, 2002), on the false memory effect using the Deese-Roediger-McDermott (DRM) task (Deese, 1959; Roediger & McDermott, 1995). In the context of the present study, false memory is defined as the remembrance of a word that was not presented during training. The false memory effect has been reproduced numerous times using the DRM task in an attempt to elaborate on the characteristics of this phenomenon (Dewhurst, 2001; Gallo, Roberts, & Seamon, 1997; Kellogg, 2001; McDermott, 1996; McDermott & Roediger, 1998; McDermott & Watson, 2001; Neuschatz, Payne, Lampinen, & Toglia, 2001; Newstead & Newstead, 1998; Schacter, Verfaellie, & Pradere, 1996), and as such, has become a well-documented means through which to examine false memory in a laboratory setting.

Research investigating the effects of d-glucose on cognition has demonstrated memory-enhancing effects on a range of tasks and with a variety of different populations (Benton & Owens, 1993; Craft, Zallen, & Baker, 1992; Messier, Pierre, Desrochers, & Gravel, 1998; Mohanty & Flint, 2001; Parsons & Gold, 1992; see Flint, 2002 for review). D-glucose is a major product of the stress cascade, and is known to play an important role in the memory modulation associated with arousing stimuli, especially those linked to emotional and stressful situations (Mohanty & Flint, 2001; Flint, 2004).

The relationship between d-glucose and false memory is important, as many real-world accounts of false memory involve emotional arousal and/or stress which likely result in increasing plasma glucose levels through the hypothalamic-pituitary-adrenal axis and the sympatho-adrenal-medullary axis (Blake, Varnhagen, & Parent, 2001). Although there are important differences between laboratory-based experiments of false memory and real-world occurrences, relatively little study has been undertaken to elucidate the role of neurochemicals associated with physiological arousal in modulating the false memory effect.

The interaction between the memory modulating effects of glucose and emotional arousal has been demonstrated using a spatial memory task (Mohanty & Flint, 2001). In this study participants received d-glucose or saccharin and were asked to learn and remember the arrangement of 16 emotional or non-emotional pictures arranged on a 4x4 grid. Results indicated that memory was enhanced for emotionally arousing pictures in the saccharin condition and for neutral pictures in the glucose condition. However, memory for the emotional pictures in the glucose condition was significantly worse. These results demonstrate an interaction between the memory enhancing effects of glucose and emotional arousal, suggesting that glucose may play an important role for memories formed under emotional arousal.

The impact of emotionality on false memory has been examined by studying arousing lures and arousing study list words using the DRM false memory paradigm (Pesta, Murphy, & Sanders, 2001). In a series of experiments it was found that false memory for an emotionally arousing lure could be demonstrated when the study list was devoid of emotional items and that this effect increased drastically with the addition of emotionally arousing items to the study list. While these results (Pesta et al., 2001) clearly demonstrated the impact of emotional lures and study list items on false memory, it is not clear that these stimuli prompted activation of the neurobiological components of the stress cascade.

Participants with high measures of imagery reportedly have a higher rate of false memory when stressed, than not stressed, and individuals scoring low on trait anxiety reportedly designated false memories as remembered more when they were stressed (Roberts, 2002). Other labs have created highly positive, highly negative, and neutral scenes, which for some participants, were accompanied by a false suggestion (Porter, Spencer, & Birt, 2003). Results indicated that negative emotion increased false memory under these circumstances. These few studies helped exemplify the importance of assessing the impact of emotional arousal on false memory, but differed substantially, so it is difficult to discern any common pattern of results. Furthermore, the previous studies have taken a more behavioral or cognitive approach to emotional arousal and have not accounted for the physiological changes associated with arousal.

In Experiment 1, d-glucose or saccharin was administered to participants shortly prior to hearing a wordlist (Roediger & McDermott, 1995). Participants completed a word recall test and a recognition test making 'old'/'new' and 'remember'/'know' judgments (Tulving, 1985).

Experiment 1
Method

Participants

Seventy four undergraduate psychology students (7 male, 67 female) between the ages of 18 and 24 (M = 18.62, SD = 1.13) served as participants in this study. Eighty-nine percent of the participants were Caucasian/white. Of the remaining participants, 3 were Hispanic/Latino, 2 were Asian/Pacific Islander, 1 was American Indian/Alaskan Native, and 2 indicated other for race/ethnicity. All participants received credit in their Introductory Psychology course in the form of experimental points for a course requirement, or extra credit. Alternative means of earning credit were made available for those students who did not wish to or were unable to participate for any reason. All data collection took place between 8:30 and 11:00 AM in a fasting state (i.e., participants were required to refrain from consuming any food or beverage except water after midnight prior to participation). Participants with hypoglycemia, diabetes, phenylketonuria, or a family history of any of these disorders were excluded from participating in the experiment for health/safety reasons. Participants whose fasting blood glucose levels did not fall between 60 and 130 mg/dl were also excluded from the study. One participant was excluded for failing to meet one of these inclusion criteria.

Apparatus & Materials

All research took place in a small office equipped with a desk, two chairs, a file cabinet, and a computer. The office was located on a reserved floor of the library, minimizing the likelihood of any extraneous disturbances during testing.

D-glucose (50 g Dextrose, ADM Corn Processing, Inc.) or saccharin (23.7 mg, Sweet 10) was administered by combining it with 8 oz of an unsweetened lemon-flavored beverage

(Kool-Aid). Blood glucose levels were assessed using a One Touch Basic Glucometer, enzyme strips, and lancets (LifeScan, Inc., Milpitas, CA).

The wordlists, both lure activating and control (non-lure activating), were selected from those used by Roediger and McDermott (1995). The lure-activating wordlist for the critical lure 'chair' consisted of fifteen associative words: table, sit, legs, seat, couch, desk, recliner, sofa, wood, cushion, swivel, stool, sitting, rocking, and bench. This wordlist has been established as one of the most effective wordlists for examining false memory for the critical lure (Stadler, Roediger, & McDermott, 1999). The control wordlist was comprised of fifteen unassociated words; emotion, gray, toast, frost, cure, mouth, cocktail, sister, elevate, rule, old, ski, rhythm, knitting, and winding. All wordlists were presented via audiotape using a Lenox Sound Cassette Recorder (Model CD-102).

Procedure

Participants from the human subject pool for students enrolled in Introductory Psychology signed up to participate in this experiment at regular intervals throughout the semester and received information about participant restrictions and fasting instructions at this time. Data was collected from one participant at a time. Upon arrival for the experiment, all participants completed an informed consent form, indicating the importance of the participant restrictions and fasting procedure, and were assigned to one of four groups varying with respect to drug treatment (saccharin or d-glucose) and wordlist type (lure or control). Following completion of this form, a baseline blood glucose measure was obtained using a finger prick and standard diabetic glucometer. Participants were then asked to consume an 8 oz lemon-flavored beverage sweetened with either d-glucose (50 g) or saccharin (23.7 mg) within a 2-min period. Immediately following consumption, all participants were asked to complete a brief demographic questionnaire. Fifteen minutes following consumption, each participant was given another blood glucose test, immediately prior to the onset of the false memory training/testing procedure.

For the wordlist task (lure and control), participants were told that they would be listening to a list of words read by a male and presented via audiotape at a rate of approximately 1 word every 2-sec (Roediger & McDermott, 1995). Participants were instructed to pay close attention to the words as they would be required to remember them later. Immediately following the wordlist presentation, all participants were required to read aloud from a passage taken from the introduction of a journal article for 1-min as a distracter task to prevent rehearsal of the wordlist. Participants were then given a wordlist recall form and were given 2.5 min to write down as many words as they could recall from the wordlist. Immediately following completion of the recall test, participants were administered a recognition test in which they were asked to identify whether the word was 'old' (from the previous wordlist they heard) or 'new' (not heard on the previous wordlist). If the word was identified as 'old', subjects were then asked to circle 'remember' (indicating that there was a vivid memory of the presentation of the word) or 'know' (indicating certainty that the word was presented but no recollection of the actual occurrence). The recognition memory task was comprised of 31 words (all 15 from each of the wordlists plus the lure). Words were pseudorandomly arranged on the data sheet so that no more than 3 new or old words were presented in a sequence. Participants were given an unlimited amount of time to complete the recognition memory task.

Results

Parametric and descriptive statistics were used to examine these data. Comparisons were considered statistically significant when generated p values were less than or equal to .05. Effect sizes for omnibus analyses were calculated using partial eta squared (η_p^2).

Blood Glucose Levels. A 2 by 2 mixed Analysis of Variance (ANOVA) for drug (glucose/saccharin) and time of blood test (pre- or post-consumption) revealed a significant main effect of drug ($\eta_p^2 = .31$; $F(1,71) = 32.15$, $p < .001$), time of blood test ($\eta_p^2 = .45$; $F(1,71) = 44.41$, $p < .001$), and a significant interaction ($\eta_p^2 = .39$; $F(1,71) = 58.86$, $p < .001$). These results indicate that glucose significantly elevated blood sugar levels in those participants that consumed 50 g of d-glucose (Figure 1).

Wordlist Data Analysis. Two by two ANOVAs (drug x wordlist type) were conducted for the total number of words recalled and recognized correctly. Results of the recall data (Figure 2) revealed a significant main effect of wordlist type ($\eta_p^2 = .50$; $F(1,69) = 70.14$, $p < .001$), but no effect of drug ($\eta_p^2 = .02$; $F(1,69) = 1.11$, $p > .05$; power = 1.0) or wordlist by drug interaction ($\eta_p^2 = .00$; $F(1,69) = .01$, $p > .05$; power = 1.0). The data from the recognition task revealed significant main effects for both wordlist type ($\eta_p^2 = .29$; $F(1,69) = 28.54$, $p < .001$) and drug ($\eta_p^2 = .09$; $F(1,69) = 6.54$, $p < 0.05$), but no interaction ($\eta_p^2 = .01$; $F(1,69) = .62$, $p > .05$; power = .12) (Figures 3 and 4). These results indicate that more words were recalled and correctly recognized by participants who heard the lure-activating wordlist, and that participants who received saccharin performed significantly better on the recognition test than those who received glucose, regardless of the type of wordlist.

Figure 1: Blood Glucose

Mean baseline and 15-minute post-consumption blood glucose levels (mmol/l) for the saccharine control and 50 g glucose groups.

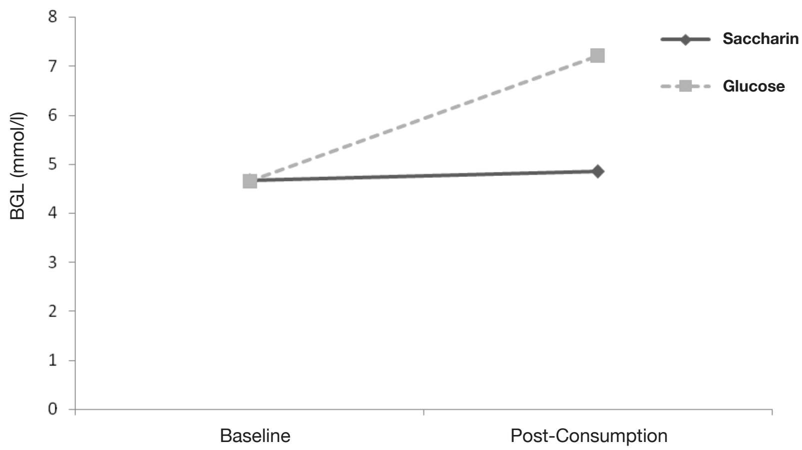
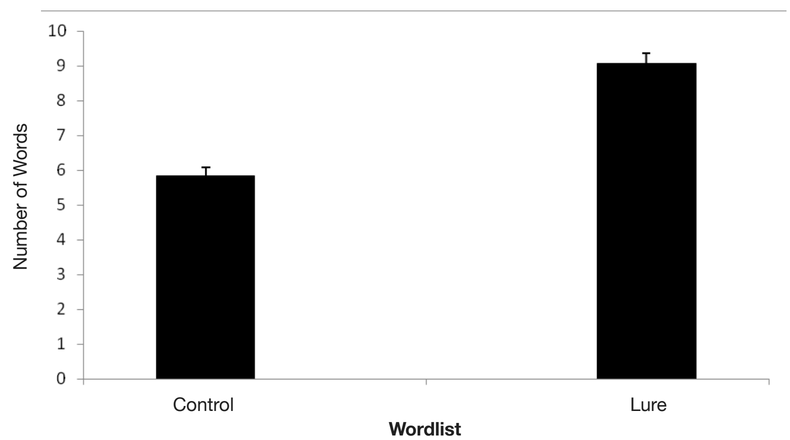


Figure 2: Experiment 1 Word Recall Data

Mean number of words recalled for the lure and control groups. Note: Error bars represent the standard error of the mean.



The mean proportions for recall and recognition of the lure word 'chair' for the glucose and control groups are displayed in Table 1. An ANOVA (drug by wordlist type) of the recall test data for the lure word revealed a significant effect of wordlist ($\eta_p^2 = .76$; $F(1,69) = 219.04$, $p < .001$), but no effect of drug ($\eta_p^2 = .00$; $F(1,69) = .16$, $p > .05$; power = .09) or interaction ($\eta_p^2 = .00$; $F(1,69) = .16$, $p > .05$; power = 1.0). The same pattern

Figure 3: Experiment 1 Word Recognition Data for List Type

Mean number of words recognized for the lure and control groups. Note: Error bars represent the standard error of the mean.

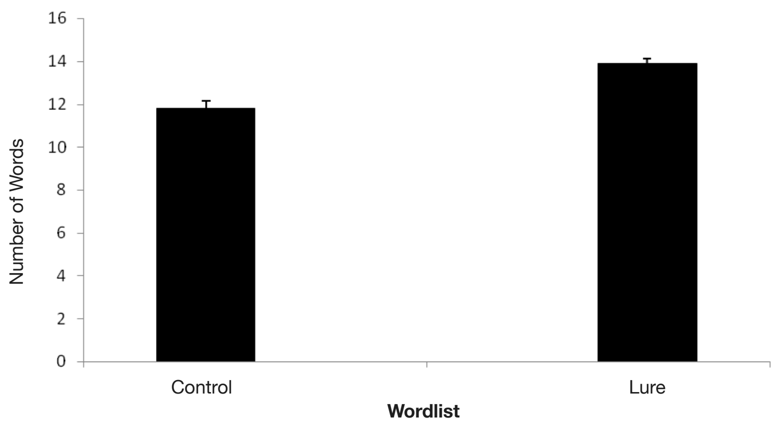
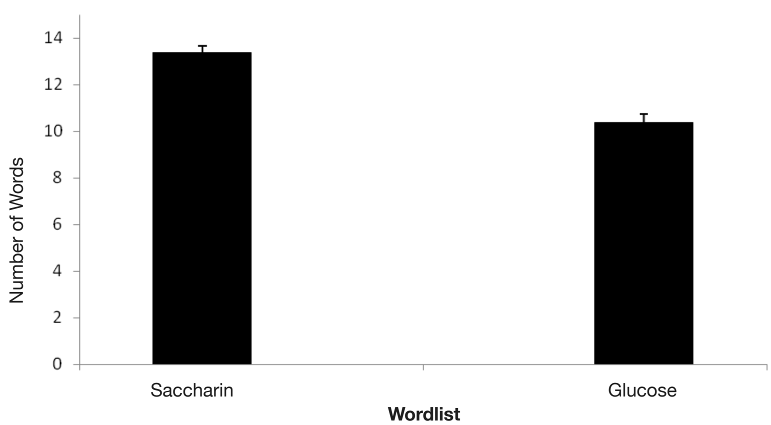


Figure 4: Experiment 1 Word Recognition Data for Drug Group

Mean number of words recognized for the saccharin and glucose groups. Note: Error bars represent the standard error of the mean.



of results was revealed for performance on the recognition test, a significant main effect of wordlist ($\eta_p^2 = .71$; $F(1,69) = 167.36, p < .001$), but no effect of drug ($\eta_p^2 = .01$; $F(1,69) = .74$, $p > .05$; power = .14) or interaction ($\eta_p^2 = .00$; $F(1,69) = .00$, $p > .05$; power = .05). These results support the false memory effect by illustrating that participants were significantly more likely to report the presence of the lure word 'chair' on both the recall and recognition tests if they had heard the lure activating wordlist as opposed to the non-lure activating wordlist.

Data from one participant in group 2 was excluded from the remember/know analyses for failing to complete the recognition task properly. Analysis of the remember and know judgments were conducted using 2 by 2 (drug by wordlist type) ANOVAs. A significant effect of wordlist was revealed for words judged as remembered ($\eta_p^2 = 0.12$; $F(1,68) = 9.28, p < 0.01$), but there was no drug effect ($\eta_p^2 = 0.03$; $F(1,68) = 1.96$, $p > 0.05$; power = .28) or interaction ($\eta_p^2 = 0.02$; $F(1,68) = 1.46$, $p > 0.05$; power = .22). Analysis of the know judgments did not reveal any main effect of wordlist ($\eta_p^2 = 0.01$; $F(1,68) = 0.38$, $p > 0.05$; power = .08), drug ($\eta_p^2 = 0.00$; $F(1,68) = 0.23$, $p > 0.05$; power = .09), or interaction ($\eta_p^2 = 0.04$; $F(1,68) = 3.01, p > 0.05$; power = .40).

Experiment 2

The results of Experiment 1 support the false memory effect using only a single wordlist, but do not provide any evidence that elevations in plasma glucose levels alter this effect. However, d-glucose did significantly elevate post-consumption glucose levels and produced an interesting decline in performance on the recognition memory test, but not the recall test. One major difference between Experiment 1 and other studies using the Deese-Roediger-McDermott task is in the number of wordlists used to demonstrate the effect. Other studies

Table 1. *Proportion of False Word Recall and Recognition for Experiment 1*

	Control	Lure
Recall		
Glucose	.00	.89
Saccharin	.00	.84
Recognition		
Glucose	.11	.94
Saccharin	.17	1.00

have commonly utilized many wordlists, thus increasing the power in the study. To this end, Experiment 2 was designed to examine the potential effects of glucose on the false memory effect using multiple lure wordlists.

Methods

Participants

Fifty-three undergraduate students (9 male, 44 female) between the ages of 17 and 22 (M = 18.75, SD = 1.21) with a mean bodyweight of 145.36 (SD = 35.59) lbs served as participants in this study. Ninety-four percent of the participants were Caucasian/white. Of the remaining participants, 2 were Black/African American and 1 indicated 'other' for race/ethnicity. Most participants were freshman (36) or sophomore (10), although some were of junior (3) and senior (4) status. Opportunities for credit through participation or alternative means were the same as reported in Experiment 1. All data collection took place between 8:30 and 11:00 AM under fasting conditions with the same participation restrictions as previously described. Research was approved by the Institutional Research Board for research with human participants prior to any data collection.

Apparatus & Materials

Research protocols were conducted in groups in a standard academic classroom setting. D-glucose (50 g Dextrose, ADM Corn Processing, Inc.) or saccharin (23.7 mg, Sweet 10) was administered by combining it with 8 oz of an unsweetened lemon-flavored beverage (Kool-Aid). Beverages were placed into coded cups and randomly distributed to participants.

Ten lure-activating wordlists were selected from those used by Roediger and McDermott (Roediger & McDermott, 1995). Wordlists were presented in the same manner as described in Experiment 1, and free recall tests were completed on blank sheets of paper during a 2 minute period of time immediately following each wordlist presentation. The recognition memory test involved the distribution of a packet containing the first, eighth, and tenth items from each wordlist (30 words), the lure from each wordlist (10 words), the first, eighth, and tenth items from 10 wordlists from Roediger/ McDermott that were not presented to the participants (30 Words), and the corresponding lures for each of these lists (10 words). Participants designated each of these 80 words as either 'old' (was presented on the audiotape) or 'new' (was not presented on the audiotape). Instructions at the top of each page of the recognition memory test also asked participants to indicate whether or not the words judged as 'old' were either 'remembered' ("You have a vivid memory for hearing the word when it was presented on the audiotape") or 'know' ("You are sure the word was presented but you lack the feeling of remembering the actual occurrence of the word").

Procedure

Announcements were made in classes prior to the day of data collection instructing potential participants to refrain from consuming anything but water after midnight on the scheduled day of the study. Data was collected in groups. Upon arrival for the experiment, all participants completed an informed consent form, indicating the importance of the participant restrictions, and were assigned to one of two groups, depending on the type of sweetener to be consumed (saccharin n = 28, d-glucose n = 25). Following completion of this form, participants were asked to consume an 8 oz lemon-flavored beverage sweetened with either d-glucose (50 g) or saccharin (23.7 mg) within a 2-min period. Following consumption, all participants were asked to complete a brief demographic questionnaire. The false memory task began fifteen minutes following consumption.

Participants were instructed to pay close attention to the words, as they would be required to remember them later. Immediately following the first wordlist presentation, participants completed a free recall test for 2 min. Immediately following the recall test, participants listened to the second wordlist followed by its recall test. This procedure continued until all 10 wordlists had been completed. Immediately following completion of the last recall test, participants were administered a recognition test in which they were asked to identify whether the word was 'old' or 'new'. If the word was identified as 'old', subjects were then asked to circle 'remember' or 'know'. Participants were given an unlimited amount of time to complete the recognition memory task, but all completed the task within 10 min. Participants were debriefed following the completion of the word recognition task.

Results

Four participants were removed from the analyses for failing to complete all of the recall tests. Parametric and descriptive statistics were used to examine these data and comparisons were considered statistically significant when generated p values were less than or equal to .05, unless otherwise indicated. Cohen's d has been reported as a measure of effect size for pairwise comparisons.

An independent samples t-test for the mean number of words correctly recalled from the 10 wordlists (see Figure 5) indicated that the d-glucose group performed significantly better than the saccharin group ($d = .60$; $t(47) = 2.10$, $p < .05$), but had no effect on false memory, as indicated by recall of the lure words ($d = .15$; $t(47) = .31$, $p > .05$).

Analyses of the recognition test data indicated that d-glucose significantly enhanced the total number of words correctly recognized (old words identified as old combined with new words identified as new) ($d = .95$; $t(47) = 3.32$, $p < .01$). Upon closer examination, it was found that this effect was specific for 'old' words ($d = .81$; $t(47) = 2.79$, $p < .01$), but not for 'new' words ($d = .25$; $t(47) = .88$, $p > .05$) (see Figure 6).

Figure 5: *Mean number of words recalled for the saccharin and glucose groups. Note: Error bars represent the standard error of the mean.*

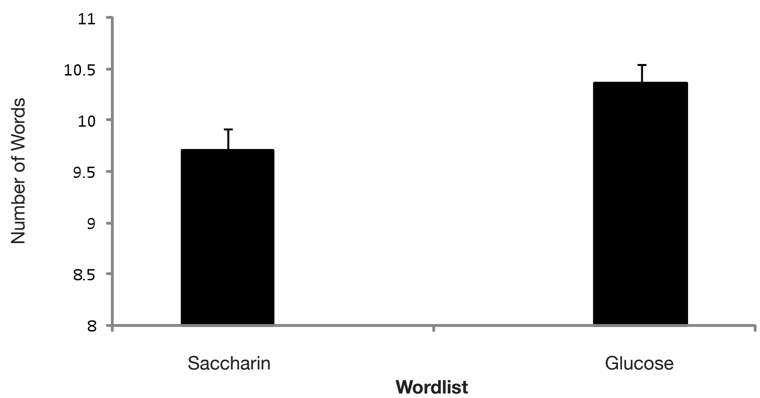
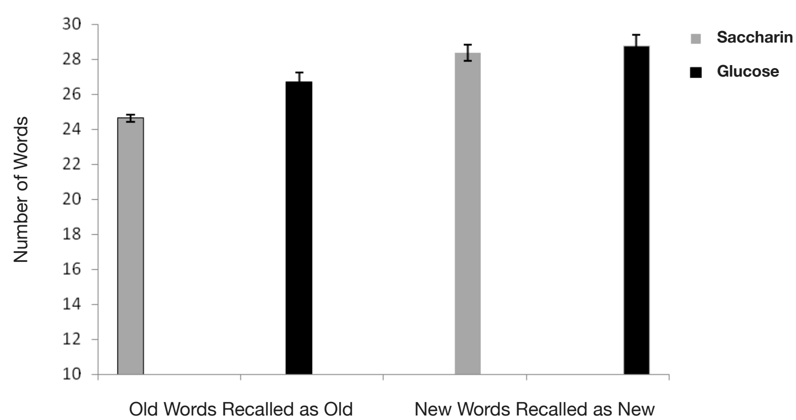


Figure 6: *Mean number of old words recognized as old and new words recognized as new for the saccharin and glucose groups. Note: Error bars represent the standard error of the mean.*



Discussion

The results of Experiment 1 indicate that 50 g of d-glucose significantly elevates plasma BG levels in comparison to saccharin controls. Word recall and recognition was significantly higher for participants who had heard the lure list in comparison to those who heard the control list, an effect commonly reported due to the high degree of association among lure list words. Participants who heard the lure list also had greater recall of the lure word 'chair' in comparison to participants who heard the control list. Together, these results replicate what has been reported in other studies using 50 g of d-glucose (Flint & Turek, 2003; Mohanty & Flint, 2001) and the DRM task (Roediger & McDermott, 1995). However, d-glucose also appeared to selectively impair performance on the recognition test, but had no effect during the recall test. This finding is in contrast to the many studies demonstrating the memory enhancing effects of d-glucose. Given that only a single wordlist was used to examine the effects of d-glucose on cognition, it is possible that this finding reflects a type 1 error.

Experiment 2 was conducted in order to examine the d-glucose effect on recognition more closely and to increase the power for examining potential d-glucose effects on false memory. Replicating Experiment 1, we found no effect of d-glucose on false memory across the 10 wordlists. We also found that glucose significantly enhanced word recall and recognition, findings contrary to those in Experiment 1, but consistent with other published reports of the memory enhancing effects of d-glucose.

The manifestation of a false memory in real world situations is often associated with an emotionally arousing or stressful event and one goal of this study was to evaluate the role of glucose on the false memory effect using the laboratory based DRM style task. The lack of any effect of glucose on false memory suggests that this component of the neurobiological stress response does not alter the false memory effect.

One complication in the present studies may be differential glucoregulatory responses in our participants. Prior research in human and non-human animals has revealed that the memory modulating effects of glucose are often more evident in those animals with poor glucose regulation (Awad, Gagnon, Desrochers, Tsiakas, & Messier, 2002; Craft, Murphy, & Wemstrom, 1994; Messier, 1998; Messier, Desrochers, & Gagnon, 1999; Messier, Gagnon, & Knott, 1997; Messier, Tsiakas, Gagnon, Desrochers, & Awad, 2003; Stone, Rudd, Parsons, & Gold, 1997; Stone, Wenk, Olton, & Gold, 1990), thus organisms with poor glucoregulation would benefit more from added plasma glucose. Unfortunately, the results of Experiment 1, where blood glucose levels were obtained, do not maintain sufficient power to examine glucoregulatory response.

The relationships between emotion-/stress-induced arousal and false memory may have important implications for applied areas of psychology and forensic investigation. However, some have articulated the importance of such research relevant to the current recovered/false memory controversy in the context of cautioning readers of the limitations of laboratory research to applied fields (Freyd & Gleaves, 1996). The present study is meant to illuminate the relationship between glucose and false memory as defined as incorrectly remembering a word that was not previously presented in a wordlist. We view this line of laboratory research as important to understanding the potential relationship between physiological arousal and false memory as studied using the DRM style task, but caution readers not to generalize these results to the recovered/false memory controversy in accordance with the arguments presented by Freyd and Gleaves.

References

Awad, N., Gagnon, M., Desrochers, A., Tsiakas, M., & Messier, C. (2002). Impact of peripheral glucoregulation on memory. *Behavioral Neuroscience, 116,* 691-702.

Benton, D. & Owens, D. S. (1993). Blood glucose and human memory. *Psychopharmacology, 113,* 83-88.

Blake, T. M., Varnhagen, C. K., & Parent, M. B. (2001). Emotionally arousing pictures increase blood glucose levels and enhance recall. *Neurobiology of Learning and Memory, 75,* 262-273.

Craft, S., Murphy, C., & Wemstrom, J. (1994). Glucose effects on complex memory and nonmemory tasks: The influence of age, sex, and glucoregulatory response. *Psychobiology, 22*(2), 95-105.

Craft, S., Zallen, G., & Baker, L. D. (1992). Glucose and memory in mild senile dementia of the Alzheimer type. *Journal of Clinical and Experimental Neuropsychology, 14*, 253-267.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58,* 17-22.

Dewhurst, S. A. (2001). Category repetition and false recognition: Effects of instance frequency and category size. *Journal of Memory and Language, 44,* 153-167.

Flint, R. W. Jr. (Ed.)(2002). Glucose-induced memory modulation. In: Flint, R.W. Jr. (Ed.). *Forget It? Sources, Theories, & Mechanisms of Alterations in Mnemonic Function* (pp. 197-216). North Chelmsford, MA: Courier Custom Publishing, Inc.

Flint, R. W., Jr. (2004). Emotional arousal, blood glucose levels, and memory modulation: Three laboratory exercises in cognitive neuroscience. *The Journal of Undergraduate Neuroscience Education, 3*(1), A16-A23.

Flint, R. W. Jr., & Turek, C. (2003). Glucose effects on a continuous performance test of attention in adults. *Behavioural Brain Research, 142,* 217-228.

Freyd, J. J. & Gleaves, D. H. (1996). "Remembering" words not presented in lists: Relevance to the current recovered/false memory controversy. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 811-813.

Gallo, D. A., Roberts, M. J., & Seamon, J. G. (1997). Remembering words not presented in lists: Can we avoid creating false memories? *Psychological Bulletin and Review, 4,* 271-276.

Kellogg, R. T. (2001). Presentation modality and mode of recall in verbal false memory. Journal of Experimental Psychology: *Learning, Memory, and Cognition, 27,* 913-919.

McDermott, K. B. (1996). The persistence of false memories in list recall. *Journal of Memory and Language, 35*, 212-230.

McDermott, K. B. & Roediger, H. L., III. (1998). Attempting to avoid illusory memories: Robust false recognition of associates persists under conditions of explicit warnings and immediate testing. *Journal of Memory and Language, 39,* 508-520.

McDermott, K. B. & Watson, J. M. (2001). The rise and fall of false recall: The impact of presentation duration. *Journal of Memory and Language, 45,* 160-176.

Messier, C. (1998). The absence of effect of glucose on memory is associated with low susceptibility to the amnesic effects of scopolamine in a strain of mice. *Behavioural Brain Research, 96*(1-2), 47-57.

Messier, C., Desrochers, A., & Gagnon, M. (1999). Effect of glucose, glucose regulation, and word imagery value on human memory. *Behavioral Neuroscience, 113*(3), 431-438.

Messier, C., Gagnon, M., & Knott, V. (1997). Effect of glucose and peripheral glucose regulation on memory in the elderly. *Neurobiology of Aging, 18*(3), 297-304.

Messier, C., Pierre, J., Desrochers, A., & Gravel, M. (1998). Dose-dependent action of glucose on memory processes in women: Effect on serial position and recall priority. *Cognitive Brain Research, 7*(2), 221-233.

Messier, C., Tsiakas, M., Gagnon, M., Desrochers, A., & Awad, N. (2003). Effect of age and glucoregulation on cognitive performance. *Neurobiology of Aging, 24,* 985-1003.

Mohanty, A. & Flint, R. W., Jr. (2001). Differential effects of glucose on modulation of emotional and nonemotional spatial memory tasks. *Cognitive, Affective, & Behavioral Neuroscience, 1,* 90-95.

Neuschatz, J. S., Payne, D. G., Lampinen, J. M., & Toglia, M. P. (2001). Assessing the effectiveness of warning and the phenomenological characteristics of false memories. *Memory, 9,* 53-71.

Newstead, B. A. & Newstead, S. E. (1998). False recall and false memory: The effects of instructions on memory errors. *Applied Cognitive Psychology, 12,* 67-79.

Parsons, M. W. & Gold, P. E. (1992). Glucose enhancement of memory in elderly humans: An inverted-U dose-response curve. *Neurobiology of Aging, 13,* 401-404.

Pesta, B. J., Murphy, M. D., & Sanders, R. E. (2001). Are emotionally charged lures immune to false memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 328-338.

Porter, S., Spencer, L., & Birt, A. R. (2003). Blinded by emotion? Effects of the emotionality of a scene on susceptibility to false memories. *Canadian Journal of Behavioral Science, 35*(3), 165-175.

Roberts, P. (2002). Vulnerability to false memory: The effects of stress, imagery, trait anxiety, and depression. *Current Psychology: Developmental, Learning, Personality, Social, 21*(3), 240-252.

Roediger, H. L., III, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 803-814.

Schacter, D. L., Verfaellie, M., & Pradere, D. (1996). The neuropsychology of memory illusions: False recall and recognition in amnesic patients. *Journal of Memory and Language, 35*, 319-334.

Stadler, D. L., Roediger, H. L., III, & McDermott, K. B. (1999). Norms for wordlists that create false memories. *Memory & Cognition, 27,* 494-500.

Stone, W. S., Rudd, R. J., Parsons, M. W., & Gold, P. E. (1997). Memory scores in middle-aged rats predict later deficits in memory, paradoxical sleep and blood glucose regulation in old age. *Experimental Aging Research, 23,* 287-300.

Stone, W. S., Wenk, G. L., Olton, D. S., & Gold, P. E. (1990). Poor glucose regulation predicts sleep and memory deficits in normal aged rats. *Journal of Gerontology Series A Biological Scientific and Medical Science, 45,* B169-B173.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26,* 1-12.

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