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The effect of glucose administration on the emotional enhancement effect in recognition memory

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Abstract

Previous research has demonstrated that glucose administration improves memory performance. However few studies have addressed the effects of glucose on emotional material that by nature already enjoys a memory advantage. The aim of the present research was therefore to investigate whether the memory facilitation effect associated with glucose would emerge for emotional words. Experiment 1 demonstrated that negative words were better recognized and remembered than positive and neutral words. Experiment 2 further explored these effects under conditions of glucose administration and an aspartame control. The results revealed that both the aspartame and glucose groups replicated the results from Experiment 1. The present research therefore demonstrated that the glucose facilitation effect did not emerge for material that already benefits from a memory advantage. These results also raise the question of whether the dose response relationship previously associated with glucose administration is applicable when the information being processed is of an emotional nature.

Keywords: Glucose administration; Recognition memory; Emotional enhancement effect; Subjective experiences

1. Introduction

Research investigating the effects of glucose administration on cognitive performance has found beneficial effects in healthy young adults (see for example Benton et al., 1994; Kennedy and Scholey, 2000; Scholey et al., 2001; Sünram-Lea et al., 2002a); older adults (Craft et al., 1994; Gondor-Frederick et al., 1987) and even adults with severe cognitive pathologies such as Alzheimers disease (Craft et al., 1992; Manning et al., 1993). Although, the benefits in cognitive performance that have been found occur in a range of cognitive tasks, in general, it appears that glucose administration has a pronounced effect on tests of declarative long-term memory (for a recent review see Messier, 2004).

It has long been recognized that emotionally significant, stressful or arousing events can play an important role in the regulation of memory (for a recent review, see Packard and Cahill, 2001). Acute emotional arousal results in activation of two major endocrine systems, the hypothalamic-anterior pituitary-adrenocortical axis (HPA) and the sympatho-adreno-medullary axis (SAM axis). Activation of the HPA axis is associated with the release of glucocorticoids from the adrenal cortex and activation of the SAM axis leads to a release of adrenaline from the adrenal medulla. The hormone for which we have most evidence concerning the regulation of memory formation is adrenaline (for a detailed account see Gold, 1992). In considering the mechanisms by which adrenaline enhances memory, it is important to note that circulating adrenaline is largely excluded from the central nervous system (CNS); that is, adrenaline does not cross the blood–brain barrier (Weil-Malherbe et al., 1959). Since adrenaline does not appear to have direct actions on the CNS, it is most likely that the beneficial effect of adrenaline upon memory performance is closely related to its actions in the periphery (Gold, 1992). It has been suggested that the effects of adrenaline on memory may be mediated by activation of peripheral β-adrenergic receptors, located on vagal afferents projecting to the nucleus of the solitary tract in the brain stem (Cahill and McGaugh, 1998). However, another important peripheral action of adrenaline is to produce an increase in circulating blood glucose levels (Ellis et al., 1967; Gold, 1992). Increased plasma glucose levels subsequent to the release of adrenaline from the adrenal

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medulla appear to be an important contributor to the processes by which memory is normally regulated. Subsequent research indicated that it is this increase in glucose levels subsequent to peripheral adrenaline actions which contributes to enhancement of memory storage processing, rather than the liberation of adrenaline per se which benefits cognitive functions (Gold, 1991, 1992; Wenk, 1989; White, 1991).

In the context of memory modulation resulting from acute emotional arousal, it is important to investigate whether emotionally arousing stimuli are indeed associated with increases in (i) memory performance and (ii) blood glucose levels. Research on emotion and memory has shown the presence of an emotional enhancement effect such that emotional stimuli are more memorable than their more neutral counterparts (Hamann, 2001). This emotional enhancement effect has been demonstrated across a range of memory measures such as recognition memory (Kensinger and Corkin, 2003; Smith et al., 2004) and recall (Talmi and Moscovitch, 2004) and has also been found using a range of stimulus variables including both words (Dewhurst and Parry, 2000) and pictures (Ochsner, 2000). Moreover, research has shown that the emotional enhancement effect not only consists of a quantitative advantage (i.e., emotional stimuli are recognized more than neutral stimuli), but also consists of a qualitative advantage (i.e., emotional stimuli are more likely to be recognized on the basis of rich episodic 'remembering' in comparison to neutral stimuli, Dewhurst and Parry, 2000; Kensinger and Corkin, 2003).

Importantly, recent research has demonstrated that presentation of emotionally arousing material not only increases subsequent memory performance, but also raises plasma glucose levels (Blake et al., 2001; Parent et al., 1999; Scholey et al., 2006). Blake et al. (2001) presented participants either with emotional or neutral pictures and measured blood glucose levels both before and after the presentation phase, which was then followed by an incidental memory test (free recall). The results showed that recall was significantly greater for the emotional compared to the neutral pictures. Importantly though, the results also revealed that blood glucose levels had increased significantly for participants shown the emotional pictures but not for those shown the neutral pictures. This latter effect has also been found using narratives (Parent et al., 1999) and replicated with words lists (Scholey et al., 2006). These findings further support the notion that increases in circulating and (one may argue) central glucose levels in response to emotional arousal may reflect naturally occurring biological mechanisms regulating the formation of memory.

If increases in blood glucose levels are an important underlying mechanism for the emotion-induced memory enhancement effect, the question arises as to whether glucose administration, which has been shown to enhance memory performance, would increase memory for emotional material beyond the normal advantage this type of material benefits from, or whether administration of a memory enhancing dose of glucose would actually impair memory for emotionally arousing material. This question has recently been explored (Ford et al., 2002; Mohanty and Flint, 2001; Parent et al., 1999). Parent et al. (1999) found that glucose administration prevented the normal memory enhancing effects for an emotional narrative. In addition, Mohanty and Flint (2001) found that whilst glucose administration had no effect on the proportion of errors for neutral stimuli on a spatial memory task, it significantly increased the number of errors for the emotional material. The authors concluded that glucose might therefore attenuate the emotional enhancement effect. However, an effect of glucose on emotional material was not found in Ford et al. (2002) study in which more direct tests of memory were employed (as opposed to just measuring the proportion of errors). In this study, participants were either given a glucose or a placebo drink and then presented with 20 emotional and neutral words to memorise at study followed by tests of recall and recognition. The results demonstrated that across drink conditions emotional words were both recalled and recognized to a greater extent than the neutral words. However no effect of glucose on recall and recognition of the emotional (or indeed the neutral) words was observed. The authors argued that the lack of a glucose effect may have been due to glucose facilitation generally not being present using simple memory tests but only arising under conditions of increased cognitive demand such as dual task conditions (Foster et al., 1998; Sünram-Lea et al., 2001).

Given the mixed findings from previous studies, the aim of the present research was to provide a more comprehensive investigation of the possible effects of glucose administration on the emotional enhancement effect. Ford et al. (2002) argued that the lack of a glucose effect in their study was probably due to glucose facilitation effects only occurring under more difficult task conditions. In their study, they presented participants with 20 words to memorise and the results demonstrated scores averaging about 90% on the recognition memory test. These high recognition scores reflect the ease of the memory task and therefore, in order to make the task more difficult, in the present research participants were presented with 60 words at study (20 emotionally positive, 20 emotionally negative and 20 neutral).

The present research additionally included the use of emotionally positive as well as emotionally negative and neutral words. Past research exploring emotional enhancement effects in memory have mostly failed to make the distinction between emotionally positive and emotionally negative stimuli (e.g., Kensinger and Corkin, 2004; Talmi and Moscovitch, 2004) despite evidence showing that valence (how positive or negative an item is) affects recognition memory (Dewhurst and Parry, 2000; Ochsner, 2000). These studies have shown that both emotionally positive and negative material is more likely to be recognized than neutral items. Importantly though, emotionally negative stimuli are recognized to a greater extent than emotionally positive stimuli. Thus, type of valence differentially affects recognition memory and this finding contradicts the conclusions made by Blake et al. (2001) that the emotional enhancement effect is not related to the pleasantness of the stimulus material. Clearly, the size of the emotional enhancement effect depends on whether positive or negative stimuli are employed. A further aim of the present research was