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The effect of glucose administration on the recollection and familiarity components of recognition memory

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Abstract

Previous research has demonstrated that glucose administration facilitates long-term memory performance. The aim of the present research was to evaluate the effect of glucose administration on different components of long-term recognition memory. Fifty-six healthy young individuals received (a) a drink containing 25 g of glucose or (b) an inert placebo drink. Recollection and familiarity components of recognition memory were measured using the 'remember-know' paradigm. The results revealed that glucose administration led to significantly increased proportion of recognition responses based on recollection, but had no effect on the proportion of recognition responses made through participants' detection of stimulus familiarity. Consequently, the data suggest that glucose administration appears to facilitate recognition memory that is accompanied by recollection of contextual details and episodic richness. The findings also suggest that memory tasks that result in high levels of hippocampal activity may be more likely to be enhanced by glucose administration than tasks that are less reliant on medial temporal lobe structures.

Keywords: Glucose; Aspartame; Recognition memory; Recollection; Familiarity; Healthy young adults

1. Introduction

The role of glucose in the modulation of cognitive processes in healthy young and aged animals and humans has been clearly demonstrated (see Messier, 2004 for a recent review). Previous studies have utilized a variety of procedures and paradigms, and benefits in cognitive performance have been found to occur in a range of cognitive tasks, including central processing speed and reaction times (Benton et al., 1994), working memory (Martin and Benton, 1999; Kennedy and Scholey, 2000; Sünram-Lea et al., 2001, 2002b) and attention (Messier et al., 1997). However, in general it appears that glucose administration and/or impairments in glucoregulatory mechanisms have a pronounced effect on declarative long-term memory performance associated with hippocampal function (e.g. Craft et al., 1994; Messier and Gagnon, 1996; Korol and Gold, 1998; Foster et al., 1998; Messier, 2004; Sünram-Lea et al., 2001, 2002a,b, 2004; Riby, 2004; Riby et al., 2006; Meikle et al., 2004, 2005) and smaller and/or less reliable effects on other aspects of cognitive functioning.

More specifically, robust glucose facilitation has been observed on memory tasks entailing intentional or conscious recollection of previous experiences, i.e. those tasks tapping explicit or declarative memory. For example, glucose administration has been shown to significantly improve delayed paragraph recall performance, but not procedural memory (Craft et al., 1994). Glucose ingestion significantly improved memory performance on explicit word recall tasks (Foster et al., 1998; Messier et al., 1999; Sünram-Lea et al., 2001; Sünram-Lea et al., 2002a,b; Meikle et al., 2004) and paired associate learning (Riby, 2004; Riby et al., 2006), whereas no facilitation of implicit memory performance was observed (Manning et al., 1997). Therefore, in healthy young people glucose seems to facilitate most reliably verbal long-term memory for complex associations. In addition, there is evidence that the glucose memory facilitation effect seems to be mediated by enhanced *retention* of information in the long-term memory store: the glucose memory facilitation effect observed in young people is

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typically maintained after controlling for both (a) participants' differential baseline blood glucose levels and (b) individual levels of immediate memory performance, and (c) retrograde glucose administration also significantly enhances memory performance (Foster et al., 1998; Sünram-Lea et al., 2001; Sünram-Lea et al., 2002a,b).

A recent influential theoretical position postulates that the 'extended hippocampal system' is primarily involved in the mediation of recall memory (that is spontaneous reproduction of material) rather than being involved in recognition memory (Aggleton and Brown, 1999). According to this framework, if the hippocampus is preferentially affected by glucose administration, significant facilitation effects on explicit memory performance should be noted on memory when this is tested by recall, but not by recognition. However, improved performance on verbal and facial recognition memory tasks under elevated blood glucose levels has previously been observed in some studies (Foster et al., 1998; Sünram-Lea et al., 2002a,b; Metzger, 2000; Metzger and Flint, 2003). This point notwithstanding, in our own laboratories facilitatory effects of glucose on recognition memory have proven to be more variable – compared to the more reliable glucose-mediated enhancement of long-term recall performance (Foster et al., 1998; Sünram-Lea et al., 2002a,b). This finding may be due to the application of simple 'yes'/'no' recognition paradigms in previous research. It has been suggested that the hippocampal-diencephalic system is not critical for efficient recognition, as recognition is considered to be composed of at least two independent processes, only one of which appears to be hippocampally dependent (Aggleton and Brown, 1999). More specifically, the proposition here is that item recognition occurs either through (i) recollection of the stimulus (a process which is hippocampally dependent) or (ii) detection of stimulus familiarity (which does not require the hippocampus) – or through some combination of these two processes. It has been further suggested that the familiarity process is mediated by the perirhinal cortex in the temporal lobes (Aggleton and Brown, 1999). These observations indicate that further research is merited in order to draw definitive conclusions about the possible fractionation of glucose enhancement effects on different long-term memory processes.

Recollection and familiarity are subjective memory experiences that refer to how we recognise a previously experienced event and/or a previously encountered individual (see Yonelinas, 2002, for a review). According to Tulving (1985), these subjective memory experiences can be based on the psychological experience of either 'remembering' or 'knowing'; by this framework, 'remembering' refers to an experience of recognition that is accompanied by recollection of contextual details, whereas 'knowing' lacks this episodic richness and is based on feelings of familiarity alone. Based on Tulving's theory, the 'Remember'-'Know' paradigm has been used to measure the different subjective experiences that can accompany recognition (for a review see Gardiner and Richardson-Klavehn, 2000). This paradigm is used widely in recognition memory testing: participants are shown a set of studied and unstudied items, and are required to decide whether each item was presented in the study phase (i.e. it should be judged to be 'old') or not (i.e. it should be judged 'new'). Following an 'old' decision, participants are then further required to make a 'remember', 'know' or 'guess' decision (the 'guess' response category is included so that the 'know' response category is not erroneously inflated by guesses; Gardiner et al., 1996).

Although there has been debate over the degree to which 'remember' and 'know' responses are process pure (Donaldson, 1996), there is ample evidence that 'remember' and 'know' responses can be dissociated experimentally (see Gardiner and Richardson-Klavehn, 2000). There is also evidence from psychopharmacological studies that 'remember' and 'know' responses can be dissociated by substances such as lorazepam (Curran et al., 1993) and alcohol (Curran and Hildebrandt, 1999). In addition, studies have shown that 'remember' and 'know' responses can be dissociated in terms of brain activity, both temporally and spatially (Henson et al., 1999; Eldridge et al., 2000; Mangels et al., 2001; Rugg et al., 1998; Düzel et al., 1997). Of particular relevance to the present study is previous evidence suggesting that 'remember' but not 'know' responses require hippocampal involvement (Henson et al., 1999; Eldridge et al., 2000). These findings demonstrate that recognition processes can be dissociated. Additionally, these findings buttress the notion that the 'remember-know' procedure will allow a more precise investigation of the effects of glucose administration on long-term recognition memory, thereby clarifying the somewhat inconsistent results observed when testing recognition memory in our previous studies.

The present experiment attempted to evaluate further the relationship between (i) glucose availability and (ii) different components of verbal long-term recognition memory. Our provisional working model specifies that the effects of glucose upon memory functioning may be mediated via the hippocampus. It has been suggested that the hippocampal-diencephalic system is vital for item recognition occurring through recollection of the stimuli, whereas item recognition mediated through detection of stimulus familiarity is independent of the 'extended hippocampal system' (Aggleton and Brown, 1999). Therefore, if glucose facilitation of long-term memory performance is indeed mediated predominantly via the hippocampus, we anticipated in this study that recognition based on recollection (as measured by 'remember' responses) will be improved by glucose administration, whereas familiarity-based recognition (as measured by 'know' responses) will be unaffected by glucose.

2. Materials and methods

2.1. Participants

Ffifty-six healthy young individuals with no history of neurological or psychiatric illness, or diabetes took part in this study. The age range was 18–25 years (mean age 20 years), with a mean BMI of 22.85 kg/m^2. Participants were recruited via an opportunity sample from the Lancaster University. Participants received £5 for taking part in the experiment. The study was approved by the Department of Psychology Ethics Committee at Lancaster University, and was