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Type 2 diabetes and impaired glucose tolerance are associated with word memory source monitoring recollection deficits but not simple recognition familiarity deficits following water, low glycaemic load, and high glycaemic load breakfasts

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HIGHLIGHTS

- We examined the effects of type 2 diabetes and IGT on word retrieval processes.
- Type 2 DM and IGT were not associated with impairment in simple word familiarity.
- Type 2 DM and IGT were associated with complex word source monitoring deficits.
- Acute breakfast glycaemic load manipulations had no effect on retrieval processes.
- This enhances our understanding of specific memory impairment in type 2 diabetes.

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ABSTRACT

Background: It has been established that type 2 diabetes, and to some extent, impaired glucose tolerance (IGT), are associated with general neuropsychological impairments in episodic memory. However, the effect of abnormalities in glucose metabolism on specific retrieval processes such as source monitoring has not been investigated. The primary aim was to investigate the impact of type 2 diabetes and IGT on simple word recognition (familiarity) and complex source monitoring (recollection). A secondary aim was to examine the effect of acute breakfast glycaemic load manipulations on episodic memory.
Method: Data are presented from two separate studies; (i) 24 adults with type 2 diabetes and 12 controls aged 45–75 years, (ii) 18 females with IGT and 47 female controls aged 30–50 years. Controls were matched for age, IQ, BMI, waist circumference, and depression. Recognition of previously learned words and memory for specifically which list a previously learned word had appeared in (source monitoring) was examined at two test sessions during the morning after consumption of low glycaemic load, high glycaemic load and water breakfasts according to a counterbalanced, crossover design.
Results: Type 2 diabetes ($p < 0.05$) and IGT ($p < 0.01$) were associated with significant source monitoring recollection deficits but not impairments in familiarity. Impairments were only observed in the late postprandial stage at the second test session. These impairments were not attenuated by the breakfast glycaemic load manipulations.
Conclusions: Isolated source monitoring recollection deficits indicate that abnormalities in glucose metabolism are not detrimental for global episodic memory processes. This enhances our understanding of how metabolic disorders are associated with memory impairments.

1. Introduction

Findings consistently show that type 2 diabetes and impaired glucose tolerance (IGT) are detrimental for episodic memory [1–3]. However, the impact of such abnormalities on specific episodic memory retrieval processes remains relatively unexplored. Episodic memory can be separated into two separate processes of recollection and familiarity

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[4,5]. Recollection refers to the ability to recall vivid contextual details such as from where and how the information was learned. This contrasts with merely knowing that an item has been seen before (familiarity) but not being able identify where and how the item was learned [6]. Recollection and familiarity can be assessed using source monitoring tests. To accurately report the source of previously learned information requires recollection of specifics [7], whereas a simple judgement of occurrence can be solved with familiarity or simple recognition. Currently, the aetiology of episodic memory impairments in type 2 diabetes is unknown. Examining whether abnormalities in glucose metabolism are detrimental for one or both of the subtle but distinct processes of recollection and familiarity will enhance our understanding our the nature of episodic memory deficits in these populations. For example, it is thought that the hippocampus plays a critical role in the processes of recollection, whereas, anterior parahippocampal cortex activity is more strongly associated with familiarity [8,9]. Previous research indicates that type 2 diabetes is associated with hippocampal atrophy [10–14], therefore, we might expect to observe detriments in tasks heavily reliant on the hippocampus (such as source monitoring) in these populations. Therefore, the primary aim is to investigate the effect of type 2 diabetes and IGT on the retrieval processes of familiarity and recollection.

There is evidence that nutritional intake can enhance specific components of episodic memory. For example, oral glucose consumption in healthy young adults was associated with improvements in subjective source monitoring judgements whereas familiarity and simple recognition ratings were not affected [15]. Furthermore, foods which elicit lower glycaemic responses, such as low glycaemic index (GI) foods or low glycaemic load (GL) foods, have been shown to improve episodic memory in healthy adults relative to high GI/GL foods [16–19]. Acute nutritional interventions involving low GI/GL foods are of particular relevance to populations with abnormalities in glucose metabolism (such as type 2 diabetes and IGT) due to the ability of these diets to improve glycaemic control [20]. To date, one study has demonstrated that a low GI breakfast is associated with better memory function in adults with type 2 diabetes [21] and one study has reported similar memory benefits following a low GL breakfast [22]. Moreover, no studies have examined the effects of acute GI or GL manipulations on cognitive function in adults with IGT. Given the observed associations between GI/GL and cognition, and between abnormal glucose metabolism and cognitive impairments, there is potential for foods which deliver a favourable postprandial glycaemic profile to attenuate acute episodic memory deficits in populations with abnormal glucose metabolism. In contrast to GI, GL is a product of a food's glycaemic index and the amount of carbohydrate per serving, hence GL represents the glycaemic response of actual food portions [23,24] and is therefore more representative of everyday dietary intake. Therefore, in the present study we chose to manipulate GL rather than glycaemic index. With this in mind, the secondary aim was to investigate whether consumption of a low GL breakfast (a breakfast which produces a favourable postprandial glycaemic profile) can attenuate any observed episodic memory deficits in adults with type 2 diabetes or IGT, and more generally, to investigate whether source monitoring retrieval processes are affected by the consumption of low and high GL breakfasts relative to a water control.

2. Materials and methods

2.1. Participants

The present paper draws together data from two independent studies with identical methods; one study with an IGT population, and a second study with a type 2 diabetes population. Control participants were recruited independently for each study. All participants in both studies were non-smokers, had English as first language, and were White British or North American ethnicity.

2.1.1. The IGT study

Sixty five pre-menopausal females aged 30–50 years were recruited. Following an oral glucose tolerance test (OGTT) participants were categorised as having normal glucose tolerance (NGT, n = 47) or IGT (n = 18) according to World Health Organisation [25] criteria (2 hour plasma glucose ≥7.8 and <11.1 mol, and fasting plasma glucose <7 mmol/l). The smaller sample size for the IGT group compared to the NGT group represents the frequency of IGT in the general population. The NGT and IGT participants were free of all other disease or illness according to self reported data collected during screening.

2.1.2. The type 2 diabetes study

Twenty four adults (12 females) with type 2 diabetes diagnosed by a consultant diabetologist and 10 healthy adult controls (6 females) without diabetes were recruited from the local community. The non-diabetic partners or relatives of the type 2 diabetes participants were recruited as controls (NGT group) in order to match for lifestyle and socio-economic status. Not all type 2 diabetes participants had a suitable relative to act as a control, hence the sample size of the control group did not match the type 2 diabetes group. All participants were free of retinopathy and were not receiving or had not previously received insulin treatment. Average duration of diabetes was 5 years (sd 3.3). All the type 2 diabetes participants continued with their prescribed regime for diabetes medication (either metformin, sulfonylureas or a combination of both) and medication for cardiovascular disease and hypertension (n = 18, including statins, aspirin, beta blockers, calcium channel blockers, and angiotensin-converting enzymes). Exclusion criteria for both studies were dementia, neurological disorder, previous stroke, smoking in the last six months, and use of medication other than that prescribed for diabetes, cardiovascular diseases and hypertension. It is notable that only females were recruited for the IGT study whereas both genders were recruited for the type 2 diabetes study. The aim of this paper was not to directly compare episodic memory between type 2 diabetes and IGT populations, therefore, differences in age and gender between these populations was not problematic for the research objectives. Crucially, the respective control groups for the type 2 diabetes and IGT populations were matched on key demographic variables including age, IQ, BMI, waist circumference and depression (see Table 1).

Table 1
Baseline characteristics for the IGT study and the type 2 diabetes study, means (se).

IGT study (all female)	NGT (n = 47)	IGT (n = 18)	F(1,63)	p-Value
Age (years)	37 (0.81)	39.78 (1.35)	3.18	0.08
IQ (NART)[a]	40.15 (0.68)	39.44 (1.4)	0.26	0.62
BMI (kg/m^2)	25.85 (0.79)	26.22 (1.45)	0.06	0.81
Waist circumference (cm)	83.5 (2.1)	82.83 (3.1)	0.03	0.87
Type 2 DM study	**NGT (n = 10)**	**Type 2 DM (n = 24)**	**F(1,32)**	**p-Value**
Age (years)	56.2 (2.04)	60.96 (1.85)	2.27	0.14
Males	54.2 (2.7)	64.3 (2.2)		
Females	57.5 (3)	57.6 (2.8)		
IQ (NART)[a]	41.1 (1.99)	39.25 (1.4)	0.54	0.47
Males	40.8 (4.6)	39.7 (1.8)		
Females	41.3 (1.9)	38.8 (2.3)		
BMI (kg/m^2)	31.39 (2.55)	34.75 (1.31)	1.65	0.21
Males	32.3 (2.5)	33.6 (1.9)		
Females	30.9 (4.1)	35.8 (1.8)		
Waist circumference (cm)	98.78 (0.76)	109.54 (2.2)	3.76	0.18
Males	110.7 (3.8)	112.3 (2.8)		
Females	92.8 (9.8)	106.8 (3.4)		
Depression [BDI; Beck][b]	4 (0.65)	6.88 (1.14)	2.46	0.13
Males	4.5 (1.5)	5.4 (1.2)		
Females	3.7 (0.6)	8.3 (1.9)		

[a] Maximum score of 50. A higher score indicates higher IQ.
[b] Depression was not measured in IGT study. A higher score indicates higher levels of depression.