

# An Assessment of Cognitive Impairment in Young Adults with Type 1 Diabetes Mellitus

by

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## **Abstract**

Emerging models of cognitive impairment in Type 1 Diabetes Mellitus (T1DM) implicate Hyperglycemia (high levels of blood glucose) and early onset of diabetes, as potential contributors to cognitive deficit in T1DM. This study assessed T1DM participants and controls across a variety of cognitive measures, in order to examine the impact of diabetes on cognitive function and the impact of illness duration on cognitive performance; controlling for depression, alcohol, drug use and other factors associated with cognitive function. 8 T1DM participants and 20 controls completed a range of comprehensive neuropsychological tasks. No significant relationship was found between diabetes and cognitive function. The impact of age of onset, duration of diabetes and HbA1c on cognitive function amongst T1DM participants were investigated, and avenues for future research suggested.

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## **Introduction**

This study assessed cognitive performance in an undergraduate sample of 8 adults with Type 1 Diabetes Mellitus (T1DM), aged between 18 and 26, and in 8 controls closely matched for age and gender; while controlling for factors known to impact on cognitive performance such as depression, alcohol consumption and drug use. The study additionally examined the sensitivity of a variety of neurocognitive measures to assess domains previously associated with deficits in T1DM; and measured the impact of age of onset, disease duration and glycemic level on cognitive function in participants with T1DM.

T1DM is an autoimmune disease, symptomised by the destruction of pancreatic islet beta cells normally responsible for the production of insulin (Middleton et al, 2006); and the direct destruction of endogenous insulin by insulin autoantibodies (Lambert, 2006). Typically, people with T1DM control glycemic (blood glucose) levels through regular intravenous insulin injection. Insulin treatment of T1DM, whilst reducing Retinopathy (retinal damage and attendant vision loss), Neuropathies (nerve damage), and Nephropathy (kidney disease); acts to increase levels of Hypoglycemia (low blood glucose) (Zinman, 1998), and severe Hypoglycemia (classified by convulsions or loss of consciousness) (Lachin, 1997).

Iatrogenic Hypoglycemia - a pathological reduction in blood glucose levels worsened by insulin therapy (Ferguson et al, 2003), can result in chronic illness and perpetuate the failure of counter-regulatory mechanisms which ordinarily correct insulin levels (Dagogo-Jack, 2004).

A variety of diabetes related illness processes are capable of creating neural damage. Ketoacidosis - a state of blood acidification potentiated by insulin deficiency, is frequently seen in untreated children and adolescents at first diagnosis of diabetes (Smith, 2006). Untreated, ketoacidosis can lead to cerebral oedema (a build up of water in the brain), with attendant oxidative stress and cell death (Fiordalisi, 2002) (Ying et al, 1999).

Periodic Hyperglycemia - characterised by excessive levels of blood glucose (BG) carbohydrate, can be considered the defining symptom of T1DM (Lambert, 2006), and often arises irrespective of treatment. Hyperglycemia results in a reduced

transmission of glucose across the blood brain barrier (McNay, 2005), and if chronically elevated, can potentially lead to structural and functional central nervous system damage (Ryan, 2006).

### *Incidence*

T1DM incidence is high and rising in Ireland. Roche et al (2002), assessed T1DM incidence in children under 15 in the Republic of Ireland, revealing a directly standardised (corrected for age and gender) incidence rate of 16.3 per 100,000 per year. This compares to a 1988 incidence rate of 6.8 (Metcalf & Baum, 1991), and a 1973 incidence rate of 4.47 (Bloom et al, 1975); putting Ireland in the high bracket of diabetes incidence (10 - 19.99 / 100,000 per year), as characterized by the WHO's Multinational Project for Childhood Diabetes (Karvonen et al, 2000).

### *Aetiology of Cognitive Impairment*

This study endeavoured to investigate cognitive performance in a sample of young adults with T1DM. A literature review was performed in order to identify areas in which deficit had previously been identified – these areas were used to select cognitive measures appropriate to detect a variety of the deficits which have been related to T1DM.

A wide range of cognitive impairments have been observed in T1DM, and no set methodology exists to test for the specific spectrum of cognitive impairment observed, making comparison across studies difficult (Liang, et al, 2006). The nature and suspected aetiology of cognitive deficits in T1DM relative to control varies widely across studies, as do the confounding variables controlled for. In the only recent metastudy of adult cognitive deficit in people with T1DM, Brands et al (2005), found that a variety of statistically significant, modest cognitive deficits were encountered across studies, specifically in intelligence, information processing speed, psychomotor efficiency, visual attention, sustained attention, cognitive flexibility, and visual perception, but not in learning and memory (Brands et al, 2005).

Brands et al (2005), did not replicate the findings of earlier studies relating impairment to disease duration, hypoglycemic episodes or glucose regulation (measured via HbA1c, an indicator of glycemic level over recent weeks). Methods and schedules of measuring hypoglycemia varied across studies, and this may account for the lack of consistency in reported effects (Brands et al, 2005). Brands study may have been insensitive to age of onset related differences due to its use of <15 years as a definition of early onset. Less than 7 yrs is often chosen to delimit early onset of diabetes, as it represents an early cut off point for attainment of adult brain volume (Ferguson et al, 2005).

A variety of cognitive deficits have been associated with T1DM (Table 1) - but neither severe nor moderate Hypoglycemia, nor Hyperglycemia acting alone, seem their sole pathogenesis. Induced Hypoglycemia in people with T1DM can create heightened distractibility, anxiety and reductions in mood and energy (McAulay, 2006). Traditionally, chronic Hypoglycemia has been implicated in multiple cognitive defects (Northam et al, 2001) (Kaufman et al, 1999). Cross sectional trials have evidenced a relationship between recurrent moderate Hypoglycemia and cognitive deficit (Brands et al, 2004); whilst longitudinal studies – which should be more able to assess intra-individual deficits - have recorded no such link (Lachin, 1997). In contrast, moderate Hypoglycemia may in fact to provide a protection or enhancement of euglycemic cognition (Kaufman et al, 1999).

Whilst Hypoglycemia can pose serious health risks during subcutaneous insulin therapy, and can reduce acute performance on a variety of cognitive tasks (McAulay et al, 2006), it rarely induces permanent neuronal damage and doubt has been cast over its long term cognitive effects (Ryan, 2006). Similarly a single episode of hypoglycemic coma does not usually result in permanent cognitive deficit in adult onset T1DM (Kramer et al, 1998).

A variety of potential explanations have been advanced to explain the puzzle of the enormous variety of subtle cognitive (memory, executive function, attention, processing speed, IQ etc) and neuronal deficits witnessed in T1DM - including interaction of early onset diabetes (EOD) and Hypoglycemia (Hershey, et al, 2005), interaction of EOD and Hyperglycemia (Ryan, 2006), and EOD and Hyperglycemic interaction creating a diathesis to Hypoglycemia (Ferguson et al, 2005).

**Table 1 – Diabetes Disease Factors and Related Cognitive impairments**  
(from Literature Review)

<b>Factor</b>	<b>Cognitive Impairment</b>	<b>Study</b>
<i>Diabetes</i>	IQ, Information processing speed, psychomotor efficiency, visual attention, sustained attention, cognitive flexibility, visual perception.	Brands et al (2005) - metastudy
	Intelligence, long term memory, processing speed, self monitoring, executive function	Northam et al (2001) - childhood study
<i>Early onset</i>	Spatial reasoning, psychomotor speed, information processing	Ferguson et al (2005)
	Visual perception, memory	Kaufman et al (1999) - childhood study
	Attention, Processing Speed, Executive Function	Northam et al (2001) - childhood study
<i>Disease duration</i>	Psychomotor speed, memory, processing speed, attention, working memory, verbal ability, general intelligence and executive function deficits	Brismar et al (2007)
<i>Retinopathy</i>	Performance IQ, spatial reasoning, psychomotor speed, sustained attention	Ferguson et al (2005)
<i>HbA1c Stability</i>	Memory, academic skills	Kaufman et al (1999) - childhood study
<i>Hypoglycemic Seizure</i>	Short term memory	Kaufman et al (1999) - childhood study

The wide variation in cognitive deficits reported in T1DM may be due to the subtle deficits experienced by T1DM patients, inadequate differentiation between patient subgroups, or lack of attendance to confounding factors such as idiopathic or fulminant diabetes - rare subtypes in Caucasian populations, which vary in incidence cross culturally (Balasubramanian et al, 2003). Age at onset (Ryan et al, 1985) (Northam et al, 2001), co-morbid conditions such as retinopathy (Ryan et al, 2003), duration of disease (Li et al, 2002), number and severity of hypoglycemic episodes (Hershey, 2005), glycemic regulation across illness history (Convit, 2005), co-morbid depression, autonomic neuropathy, and elevated blood pressure (Musen, 2006) may all potentially influence cognitive impairment.

### *Protective Factors*

Kaufman et al (1999), found a positive association between subtle Hypoglycemia for the preceding year (calculated by HbA1c) and a variety of cognitive improvements at euglycemia; memory, verbal comprehension, broad cognitive and academic ability. More incidents of subtle Hypoglycemia (>10 per month) actually acted as a protective factor, improving cognitive performance at normal glucose levels, on these measures (Kaufman et al, 1999).

### *The current study – an assessment of cognitive impairment in T1DM*

A need exists to develop and normalise a neurocognitive battery suitable for this population. Such a battery could more accurately measure the causes and specific nature of cognitive deficits in T1DM, and act to alleviate some aspects of Fear of Hypoglycemia (FOH), which can negatively affect the management of this disease.

The current study assessed young adults with diabetes, and matched controls, on a variety of cognitive measures targeted at domains identified as vulnerable to diabetes (Table 1) - executive function and metacognitive skills (Behavioural Assessment of Disexecutive Syndrome), Attention (DART task, a version of the Sustained Attention to Response Test, resistant to ceiling performance in subtle attentive deficit), Response Inhibition (XY Task), Working Memory (WAS-R - Figure Span test),

Hippocampal Memory (Face Name Pairs Test), Visospatial functioning (Rey-Osterrieth: Figure Reproduction Subtest), Premorbid IQ (National Adult Reading Test), and Psychomotor Speed (improvised Peg Board task); whilst controlling for a variety of demographic and disease factors associated with cognitive function (Table 2). Ultimately only 8 participants with T1DM were recruited, limiting the power of the sample to detect population differences in cognitive functioning.

T1DM participants were compared on a range of factors - reported glycemic history, seizure history, illness duration, diet, insulin regime, and current level of depression. Although effortful cognition (specifically recollection) may deplete glucose levels (McNay et al, 2000), and recall and attention can be mediated by pre-task infusion (Krebs & Parent, 2005) or ingestion of glucose (McNay & Gold, 2001), a variety of problems make glycemic testing in relation to cognitive performance impractical. A history of hyperglycemia is difficult to measure, as HbA1c levels are both infrequently recorded (Smellie, 2006), and subject to distortion by unrecorded nightly variations in glucose level (Matyka et al, 1999). Non-invasive in vivo glycemic tests are insensitive to glucose levels in the brains extracellular fluid - which may retain euglycemic levels of glucose uptake (for example in 'Hypoglycemia Unawareness Syndrome') (Boyle et al, 1995) - therefore such tests do not accurately represent pre or post task glucose levels in the brain. For this reason, and due to methodological practicalities, the current study did not attempt to record biomedical measures of acute glucose level, nor did it attempt to vary participant glucose intake, although participants did report their most recently recorded HbA1c level (Appendix 4).

<b>Table 2 – Covariate contributors to cognitive function</b>			
<i>Covariates of Cognitive Performance</i>	<i>Studies Evidencing Relationship</i>	<i>Measure</i>	<i>Reference</i>
<b>Fitness</b>	Kramer & Erickson (2007), Radak et al, 2001, Tomporowski, 2003	Allied Dunbar National Fitness Survey	Beck (1986)
<b>Diet</b>	Molteni et al (2002) Ying & Gomez-Pinilla (2004)	Medical and Biographical Survey	Created for this study.
<b>Gender</b>	Kimura (1996), Hausmann et al (2000)		
<b>Alcohol</b>	Wissenborn & Duka (2004)		
<b>Head Injury</b>	Killam et al (2005)		
<b>Education</b>	Farmer et al (1995), Gallacher et al (1999), Lee et al (2003)		
<b>Drugs</b>	Hoshi et al (2007), Dafters (2006)	Nutt Harmfulness Scale	Nutt et al (2007)
<b>Socio-economic Status</b>	Kaplana et al (2001)	Erikson-Goldthorpe Schema	Erikson & Goldthorpe (1992)
<b>Depression</b>	Austin et al (1992), Burt et al (1995)	Beck Depression Inventory	Activity and Health Research (1992)

Age at onset of diabetes may be a factor affecting the type and severity of cognitive deficit experienced by people with diabetes (Ferguson et al, 2005). Age of onset was recorded in the current study, as well as disease duration – calculated in months since the onset of diabetes.

The research questions to be addressed in this study were.

**Questions 1** – Does diabetes affect cognitive performance in the domains measured?

**Question 2** – In participants with diabetes, does age of onset significantly affect cognitive performance?

**Question 3** – In participants with diabetes, does disease duration significantly affect cognitive performance?

**Question 4** – In participants with diabetes, does an average of recent glycemic level (HbA1c) significantly relate to cognitive performance?

## **Methodology**

### **Participants**

Overall, 20 mixed gender control participants, and 8 mixed participants with T1DM were recruited. Non-diabetic participants were aged between 21 and 26, ( $M = 21.95$ ,  $SD = 2.064$ ); 11 were male and 9 female. Participants with diabetes were aged between 18 and 26 ( $M = 20.75$ ,  $SD = 2.435$ ); 5 were female and 3 male. All participants were undergraduate or postgraduate students of Trinity College or UCD. Significant difficulties were encountered recruiting participants with T1DM (Appendix 24).

### **Materials**

Table 3 details the tests used and capacities measured. A complete list of test materials is listed in Appendix 1, and copies of all written test materials are included in Appendices 2 – 19.

**Table 3 – Tests Used and Capacities Measured.**

Capacity Measured	Test	Reference
Working Memory	WAIS-R III – Digit Span Subtest	(Psychological Corporation, 1998)
Sustained Attention	Modified Dual-task Attention to Response computer task	(Dockree et al, 2006),
Response Inhibition	Modified X-Y GoNogo and NoGo computer tasks	(Garavan et al, 2002)
Hippocampal Memory	Face Name Pairs computer task	(Zeineh, Thompson, Bookheimer, 2003)
Premorbid IQ	Modified American National Adult Reading Test	(Nelson & Willison, 1991)
Mood / Depression	Beck Depression Inventory II	(Beck, Steer, Brown, 1986)
Psychomotor Speed	Improvised Grooved Peg Board	N/A
Visuospatial Reasoning	Rey-Osterrieth Figure Reproduction task	(Meyers & Meyers, 1995).
Physical Fitness	Modified Allied Dunbar National Fitness Survey	(Activity and health research, 1992)
Illness History	Improvised Medical and Biographical History	N/A
Executive Function	Behavioural Assessment of Dysexecutive Syndrome Battery – composed of rule shift, zoo map, action programme, key search, 6 elements, and temporal judgment tests; and DEX survey	(Wilson, Burgess, Emslie, Evans, 2003)

### *Hardware and Software*

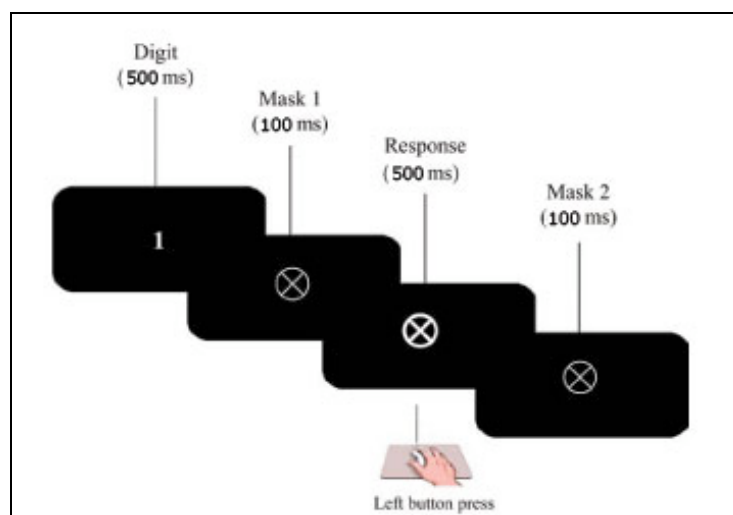
Computer based tasks were carried out in E-Prime Version 1.1.4.1 on Windows 98 SE, on an IBM Thinkpad A20m 2628-41G Pentium 3, 700Mhz Laptop, with 64MB of RAM, and a 14.1” TFT display running at 1024\*768 resolution. All tasks were modified in E-Studio to run at this resolution, and accept input via left and right click, rather than keyboard or response pad.

## Modified Tasks

### *DART Task*

The Dual-task Attention to Response (DART) Task (Dockree et al, 2006), detects disruptions in the alertness / sustained attention system. The task presents a monotonous serial series of numbers (1 – 9), to which participants respond by ‘left clicking’ on go-trials (black 1-9 digits, excluding 3), withholding a response on no-go targets (black ‘3’ digits) and ‘right clicking’ on grey digits. Task difficulty was increased in this implementation to increase sensitivity to subtler deficits. Stimuli were presented in two blocks. In block 1 17 stimuli were serially displayed for 500ms each, followed by a fixation mask (100ms), a response fixation (500ms), and a second fixation mask (100ms). Block two replicated this design, except that stimuli were displayed dynamically (out of sequential order). Both trials contained 92 go-trials, 13 no-go targets, and 12 greys. All participants completed both trials, in the order sequential => dynamic.

**Figure 1** – Dart Task (Adapted from Dockree, 2006)



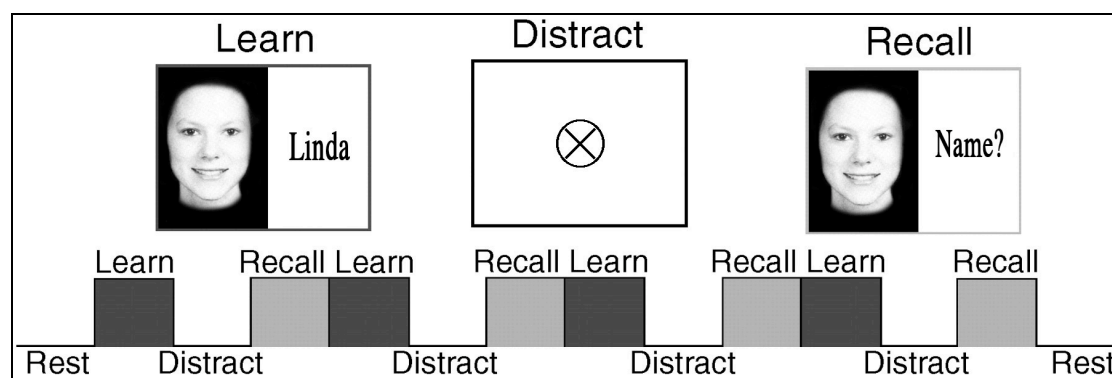
### *Go/Nogo Task*

An X-Y Go/Nogo task (Garavan et al, 2002) was used to detect deficits in response inhibition. The Go/NoGo paradigm presents the letters X, and Y in a serially alternating pattern, occasionally broken by a 'lure', a duplicated X or Y. In the version modified for this task, two blocks were created. Both blocks included 250 stimuli displayed for 600ms each, including 25 lures, distributed unpredictably. In the Nogo (on lure) block, participants were asked to withhold responses to lure stimuli, while in the Go (on lure) block, participants responded only to lure stimuli. Each participant completed both trials, and the order of trial presentation was varied in order to assess the impact of practise effects.

### *Face Name Task*

A Face / Name paradigm (Zeineh, Thompson, Bookheimer, 2003) (Figure 2) was used to assess hippocampal function / facial memory. Subjects were presented with FN Pairs 1 (eight female faces) over 5 blocks, each separated by a distractor reaction time task (which was not scored), and a recall condition. Participants were next presented with a new distracter set of face name pairs (FN Pairs 2), followed by a final distractor task, and immediately asked to recall both FN Pair 1 & 2. Each face name pair was displayed for 3500ms at both presentation and recall.

**Figure 2** – Face Name Task (adapted from Zeineh, Thompson, Bookheimer, 2003)



### *Grooved Peg Board*

A grooved peg board task (GPB) (Figure 3) was developed to test psychomotor speed. The task involved transporting a peg along a twisting path in as short a time as possible with closed eyes. The GPB was 210 mm width × 357 mm in length, while the peg groove was approximately 15 mm deep and 1950 mm in length. Participants were given two seconds to look over the path prior to the task (which was completed with eyes closed).

**Figure 3** – The Grooved Peg Board (and peg)



### *AM-NART*

The National Adult Reading Test Revised (NART-R) (Nelson & Willison, 1991) was modified through the addition of standard UK English pronunciations culled from the online OED (Oxford English Dictionary 2008b), (Oxford English Dictionary 2008a). Pronunciations were looked up for each word, and converted to phonetic spellings for ease of scoring. Additionally, in two cases commonly accepted Irish pronunciations were added; ‘Thyme’, pronounced Thy em’ and algae pronounced ‘Al gee’ or ‘Al gay’.

*ADNFS*

The Allied Dunbar National Fitness Survey was used to gather self-reports of participant physical activity. Participants were assigned a level on an activity level scale, compiled from the intensity and frequency of recent physical activity, where vigorous, moderate and light activities were assigned concrete values based on a table of the kilocaloric (kcal/min) expenditure of various activities.

**Figure 4** – Sample question from the Allied Dunbar National Fitness Survey

**1) Have you done any **HEAVY housework** in the past 4 weeks (DIY, vacuuming, cleaning, gardening...etc)?**                      **Yes / No** (please circle)

*If Yes:*

a) During the past four weeks on how many days have you done heavy housework?  
\_\_\_\_\_ **days**

b) During the last week, how many days, if any, have you done that kind of heavy housework? \_\_\_\_\_ **days**

c) On the day you most recently did some **heavy housework**, how long in total did you spend doing it? Please don't include any time you spent on lighter housework or any breaks you took. \_\_\_\_\_ **hours** \_\_\_\_\_ **minutes**

Heavy housework, long brisk walks, and demanding exercise over a four week period, were summed to provide a measure of vigorous and moderate activity. Participants were then assigned a level of fitness in accordance with the ADNFS's Activity Level Scale (Table 4).

Additionally two other scores of self reported participant activity in adolescence, degree of exercise participated in aged 14-19 (none – a lot) and comparative activeness aged 14-19 (not at all – very) were recorded.

<b>Table 4. Activity Level Scale (Reproduced from Allied Dunbar National Fitness Survey)</b>	
<b>Level 5</b>	twelve or more occasions of vigorous activity
<b>Level 4</b>	twelve or more occasions of a mix of moderate and vigorous activity
<b>Level 3</b>	twelve or more occasions of moderate activity
<b>Level 2</b>	five to eleven occasions of a mix of moderate and vigorous activity
<b>Level 1</b>	one to four occasions of a mix of moderate and vigorous activity
<b>Level 0</b>	none

### *BADS*

The BADS (Figure 5), a cognitive battery designed to identify Dysexecutive Syndrome, was utilised to assess executive function. The BADS test the monitoring and co-ordination of complex tasks (Wilson et al, 2003). As any deficits related to T1DM were expected to be moderate, additional timing information was retained for tasks where the amount of time taken was a factor in performance. Additionally the raw score of the action programme sub-task was retained (rather than the converted profile score used for calculation of an overall BADS score) to increase sensitivity. Another sub element of the BADS, the dysexecutive survey (DEX), usually filled out by both a participant and a close relative, was completed by participants alone.

**Figure 5 – The BADS Test Kit**



*MBH*

A 35 item Medical and Biographical History (MBH - Appendix 4) was devised. The MBH included demographic (date of birth, level of education, salary etc), dietary, fitness, medical, drug and alcohol consumption, and diabetes related variables.

**Figure 6** – Questions from the Medical / Biographical History

This is a survey of medical, biographical and mental health information which may be of relevance to cognitive differences experienced by those with Diabetes. Please answer these questions as honestly as possible. This information will be kept completely private and confidential. You are free to stop this experiment at any time, please ask the researcher present if you have any additional questions.

1. D.O.B: \_\_\_\_\_
2. Gender: M / F (delete as appropriate)
3. Approximate weight: \_\_\_\_\_
4. Daily servings of fruit consumed: \_\_\_\_\_
5. Daily servings of vegetables consumed: \_\_\_\_\_
6. Daily servings of high sugary foods / soft drinks consumed: \_\_\_\_\_
7. Estimate your level of fitness (circle as appropriate): Very Poor / Poor / Moderate / Good / Very Good

<b>Table 5. Shortened Nutt Drug Scale (Physical Harm)</b>		
	<b>Acute Harm</b>	<b>Chronic Harm</b>
Heroin	2.8	2.5
Cocaine	2.0	2.0
Alcohol	1.9	2.4
Ketamine	2.1	1.7
Amphetamine	1.3	1.8
Cannabis	0.9	2.1
Solvents	2.1	1.7
LSD	1.7	1.4
Methylphenidate	1.2	1.3
GHB	1.4	1.2
Ecstasy	1.6	1.6

As existing drug classifications measure in part government policy rather than physical harmfulness (Rand Corporation, 2006), a better measure was needed. Nutt et al (2007), produced a measure of the harmfulness of chronic and acute drug use across a variety of domains.

Using Nutt et al's (2006) estimation of physical harmfulness, drug use was scored and summed for each participant (Table 5). 10 uses or less of a substance per year was given the acute score, more frequent use was awarded the chronic score. Some drugs were missing from Nutt et al's (2006) original study - e.g.: Psilocybin - these were ignored. MDMA was coded as ecstasy.

The score produced was intended as an approximate comparative measure of chronic and acute drug use, rather than as a quantitative measure of harm experienced.

Alcohol use for each participant was recorded. 1 pint was equated with 2.4 units of alcohol, 1 spirit shot with 1 unit, and 1 glass of wine with 2.2 units (Drinkaware, 2007).

Social class was estimated for each participant, according to the 11 subclass occupationally organised Erikson-Goldthorpe scheme (Erikson & Goldthorpe, 1992) (Table 6).

<b>Table 6. Erikson-Goldthorpe Class Schema (Full Version)</b>	
<b>Class</b>	<b>Position</b>
<b>I</b>	Higher-grade professionals, administrators and officials; managers in large industrial establishments; large proprietors
<b>II</b>	Lower-grade professionals, administrators and officials; higher-grade technicians; managers in small industrial establishments; supervisors of non-manual employees
<b>IIIa</b>	Routine non-manual employees, higher grade (administration and commerce)
<b>IVa</b>	Routine non-manual employees, lower grade (sales and services)
<b>IVb</b>	Small proprietors, artisans, etc. with employees
<b>IVc</b>	Farmers: farmers and smallholders and other self-employed workers in primary
<b>V</b>	Supervisors of manual workers
<b>VI</b>	Skilled manual workers
<b>VIIa</b>	Semi-skilled and unskilled manual workers
<b>VIIb</b>	Agricultural workers workers

### **Procedure**

The test battery took approximately 100 minutes, and was completed by participants in experimental rooms at TCDINS and in the TCD Psychology Department. Verbal and written instructions provided to participants are included in test materials Appendix 2 - 19.

After providing consent to participate (Appendix 2), participants copied the Rey Osterrieth Figure (Appendix 6). Next, participants filled in the MBH (Appendix 4), taking between 5 and 8 minutes. The Rey was then drawn from memory. Participants

then completed the Face Name and DART computer tasks. After this, approximately 30 minutes into the test, participants completed the final Rey recall illustration. Participants next undertook the BADS executive function battery (Appendix 8). Participants then filled in the DEX Questionnaire (Appendix 8). Next participants completed the two block GoNogo task, in one of two orders (Go-Nogo, NoGo-Go). Participants were next scored reading AM-NART word list (Appendix 12). Then participants listened to the experimenter read the Forward and Back Digit Span subtest lists (Appendix 14), and repeated each item in turn. Finally, participants completed the Grooved Peg task, and filled out the ADNFS (Appendix 17) and the BDI (Appendix 16), before being debriefed (Appendix 18).

## Results

### *Coding*

Data was coded into SPSS 16 for Mac. Erikson-Goldthorpe class (Table 6), alcohol units consumed per month (Drink Aware, 2007) and summated drug use (Nutt, 2007) were calculated. DART, Go-NoGo and Nogo-Go test results were collected in E-Run, merged in e-merge, collated in E-data aid, summed in excel, and copied to SPSS. Variables with ceiling performance or an inadequate number of responses were removed.

Two computer based task results were missing (one participant each from Go-Nogo and Nogo-Go) – as computer files had failed to save for these subjects. Missing figures were substituted with sample means (Nogo  $M = 11$ , Go  $M = 20$ ). Two female participants ( $p = 23$  and  $p = 28$ ) provided no information on weight, and this information was substituted from the averaged weight (140 lb) of female participants.

### *Statistics*

Variables were tested for normality, and boxplots were created to detect outliers. In accordance with the recommendations of Tabachnick & Fidell (2001), a series of transformations were performed to correct for skew and kurtosis (Appendix 22). Health and Fitness related Variables were summated (and high sugar foods consumed subtracted) to create a Lifestyle variable.

An independent sample, two-tailed t-test, split for diabetes status, was conducted to ensure that the order of NoGo-Go / Go-Nogo test presentation had not affected scores. No significant effect of test order was found in control Go-NoGo Scores [ $t(19) = -1.494, p > .05$ ] or NoGo-Go Scores [ $t(18) = .646, p > .05$ ]. No significant effect of test order was found in T1DM Go-Nogo Scores [ $t(5) = -.932, p > .05$ ], or NoGo-Go Score [ $t(6) = -.853, p > .05$ ].

A multivariate general linear model analysis of covariance (MANCOVA) was performed to determine the contribution of T1DM status to a variety of measures of cognitive function; controlling for covariates (Table 8). Univariate normality does not guarantee multivariate normality (Fields, 2005), however equality of covariance could not be estimated as SPSS reported fewer than two nonsingular cell covariance matrices, hence Box's M could not be calculated in all tests. To offset this, the control group was reduced to a sample of equal size, matched as closely as possible for age and gender (Table 7).

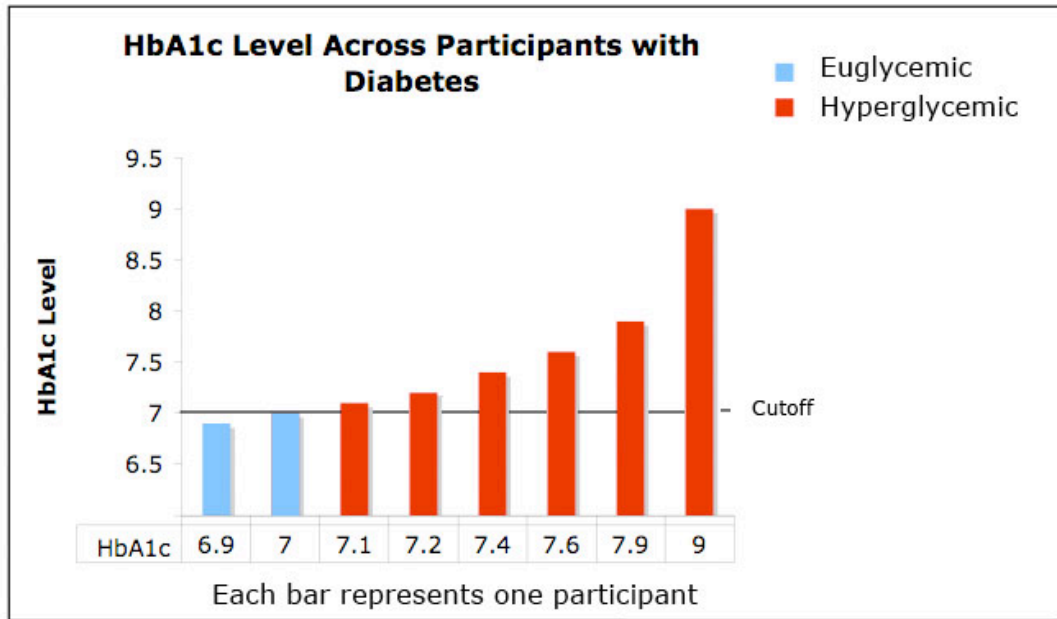
<b>Table 7 – Participants with Diabetes and Matched Controls</b>					
<b>Diabetic Group</b>			<b>Control Group</b>		
<i>Participant Code</i>	<i>Age</i>	<i>Gender</i>	<i>Participant Code</i>	<i>Age</i>	<i>Gender</i>
105	19	M	126	19	F
123	21	M	114	21	M
129	26	M	119	26	M
120	20	F	125	20	F
121	18	F	111	18	F
122	22	F	14	22	F
128	20	F	12	21	F
130	20	F	17	21	F

<b>Table 8 – Multivariate comparisons</b>		
<i>IVs (Fixed Factors)</i>	<i>Covariates</i>	<i>Dependent Variables</i>
DIABETES STATUS	AGE	ACTION PROGRAMME TIME
	GENDER	KEY SEARCH PROFILE SCORE
	LIFESTYLE	TEMPORAL JUDGEMENT SCORE
	YEARS IN EDUCATION	ZOO MAP TOTAL TIME 1
	SOCIO-ECONOMIC STATUS	ZOO MAP TOTAL TIME 2
	HEAD INJURIES	ZOO MAP PROFILE SCORE
	UNITS OF ALCOHOL PER MONTH	EXECUTIVE FUNCTION
	SUMMATED DRUGS SCORE	DYSEXECUTIVE SURVEY
	DEPRESSION	AM-NART WORD LIST
	WEIGHT	PREMOBID IQ
		DIGIT SPAN FORWARD
		DIGIT SPAN BACK
		REY-OSTERRIETH TOTAL
		PEG LATENCY
FACE NAME TOTAL		
NOGO X-Y SCORE		
GO X-Y SCORE		
DART SEQUENTIAL		
DART DYNAMIC		

As group differences were expected to differ across variates, and homogeneity of covariance was not certain, Pillai's trace was used. No covariates reached significance. Levines test was significant for Key Search Profile Score [ $F(1,14) = 8.459, p < .05$ ]; Zoo Map 2 Total Time [ $F(1,14) = 4.903, p < .05$ ], WAIS-R Digital Span Forward [ $F(1,14) = 5.469, p < .05$ ], WAIS-R Digit Span Back [ $F = 5.469, p < .05$ ], and Rey Osterrieth Total [ $F(1,14) = 16.262, p < .05$ ]; indicating that homogeneity of variance was violated. Diabetes status was not significantly predictive of multivariate variance, [ $F(6,1) = 5.196, p = .324, Pillai's Trace = .969$ ].

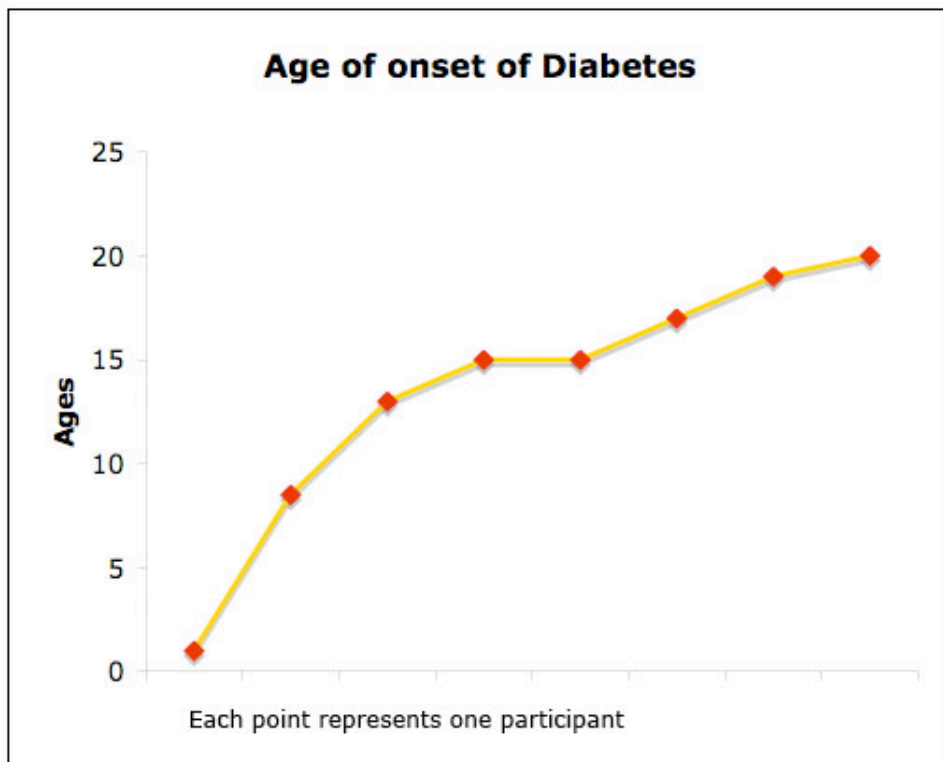
To test the impact of HbA1c level, Age of onset, and Duration in Months of Diabetes, a two-tailed bivariate spearman correlation was performed across all DV variables. Directionality of transformed variable correlations was adjusted via an additional correlation matrix of original untransformed variables.

**Figure 7 – HbA1c Level Across Participants with Diabetes**



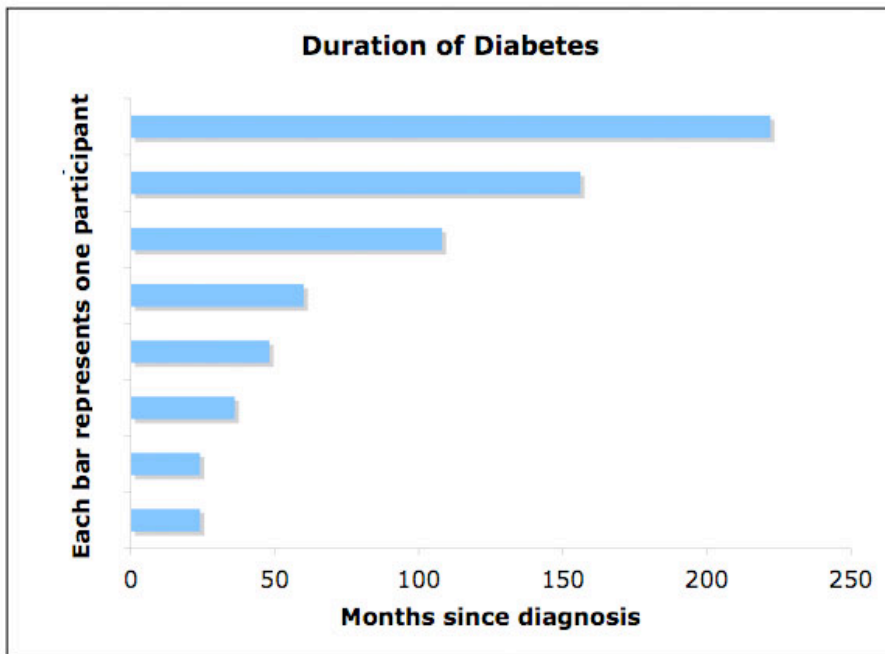
HbA1c level was significantly positively correlated with Dysexecutive Survey (DEX) Score [ $r(6) = .683, p < .05$ ], and significantly negatively correlated with NART estimated IQ [ $r(6) = -.690, p < .05$ ].

**Figure 8** - Age of onset of T1DM (in years)



Age of onset of Diabetes was significantly positively correlated Rey Osterrieth Total [ $r(6) = .768, p < .05$ ], and significantly negative correlated with Dart Dynamic Score (directionality corrected) [ $r(6) = -.934, p < .05$ ].

**Figure 9** – Duration of T1DM (in months)



Duration in Months of Diabetes was significantly positively correlated with Dart Dynamic Score (directionality corrected) [ $r(6) = .838, p < .05$ ], and significantly negatively correlated with Rey Osterrieth Total [ $r(6) = -.805, p < .05$ ], and close to significantly negatively correlated with Digit Span Back [ $r(6) = -.585, p > .05$ ].

## Discussion

No significant effect of Diabetes status was found. This is unsurprising as the sample size acquired did not match that necessary to detect a moderate effect size ( $r = .3$ ) over the number of dependent variables ( $DV = 19$ ) and groups ( $N = 2$ ) measured. An a priori preliminary MANOVA: Global effects analysis power calculation performed in G\*Power,  $r = 0.3$ ,  $\alpha = .05$ , indicated a sample size of 118 would be required to reach power ( $1 - \beta$  err prob) = .95. Given the sample size limitations ( $p = 27$ ) of this study, a Post Hoc, Pillai-Bertlett V, MANOVA: Global effects analysis, indicated that the actual power achieved was 0.11.

### *HbA1c Level*

Keeping in mind that correlation does not equal causation, and that any observed effect in a sample size of this magnitude may be a result of Type 2 error, an examination of the Spearman correlations produced for HbA1c level, Age of Onset and Duration of Diabetes could suggest directions for future investigation.

All T1DM participants reported HbA1c at or close to hyperglycemia ( $> 7$  mmol/L) (Genuth et al, 2003) (Figure 7). This limits generalisability, as hypoglycaemia is at least as symptomatic of insulin treated T1DM populations (Lambert, 2006). Higher HbA1c was significantly positively correlated with self-reported response score on the DEX, pointing to a self-perceived link between higher HbA1c and poorer executive function. A significant negative relationship between HbA1c and NART estimated (premorbid) IQ, suggests a link between higher recent glucose levels and lower generalised cognitive function. However, grey matter deficits in brain areas implicated in memory, language and attention, have been found in diabetes (Musen et al, 2006), reducing the reliability of NART as a measure of cognitive function in this population.

Strong, but not significant correlations (Appendix 23) linked higher HbA1c with slower problem solving (Action Programme Time, Zoo Map 2 Total Time), lower

psychomotor speed (Peg Latency), lower premorbid cognitive function (NART), and poorer visiospatial memory (Rey figure); and improved hippocampal memory (Face Name score), sustained attention (DART), and inhibition (NoGo)

### *Age at Onset*

Age of onset is a complex issue, as participants diagnosed earlier may be protected by insulin treatment from the developmental insult of hyperglycemia, but in turn may suffer glycemic fluctuation during earlier stages of brain development, especially prior to diagnosis. Ideally, research should compare early childhood onset (<7 yrs) with adolescent and adult onset. Due to the heterogeneity of onset in this small sample ( $M = 13.562$ ,  $SD = 6.22$ ), such a comparison could not be performed.

A significant relationship existed between an older age at first diagnosis of T1DM and improved visiospatial memory (Rey figure), but worsened sustained attention (DART Dynamic).

Stong, but non-significant correlations (Appendix 23) were found between older age at diagnosis and higher executive function (BADs Score), better short term memory (Digit Span Back), faster problem solving (Zoo Map 1 Time), higher psychomotor skill (Peg), worse hippocampal memory (Face Name), and worsened sustained attention (DART Sequential, and inhibition (Go) (Appendix 23).

Digit span back and forward should not be combined for clinical analysis, as they represent distinct sub-processes of working memory (Reynolds, 1998), so it is unsurprising to the find differences recorded here.

The greater significance of results for the Dynamic DART block in terms of both Age of Onset and HbA1c level, in addition to the close to significant correlation observed for Dart Sequential, implies a potentially greater sensitivity for this adaptation of the DART task.

### *Duration of Diabetes*

More months since diagnosis of diabetes had a significant relationship with better sustained attention (Dart Dynamic) and worsened visiospatial / hippocampal memory (Rey Figure).

Non-significant relationships existed between a greater duration of illness and worse psychomotor skill (Peg Latency), poorer problem solving (Key Search Score, Zoo Map 1 Time), poorer executive function (BADs), and poorer working memory (Digit Span) (Appendix 23).

Duration of disorder highly mirrored age of onset, indicating that in this young sample of later onset (with only 1 participant with onset < 7yrs), length of illness and age at onset measured similar contributors to deficit.

The small and homogenous nature of this sample suggests that in a wider more heterogeneous T1DM population, minus any potential neuroprotective factors enabling consistently higher functioning (and college attendance), these probabilities might reach significance.

### *Methodological Confounds*

A variety of methodological confounds emerged during the process of testing which may have affected the ability of these tests to estimate differences in performance between control and T1DM participants.

The BADs dysexecutive battery contains a number of methodological problems. The BADs Key search subtest asks participants to draw the path they would take to find keys lost in a field, and awards points based on aspects of the route taken. Points are deducted for entering the field map at the center of its base - despite the fact that a gate would likely be positioned here in a real field (verbally noted by several participants) - points are also deducted for failing to exit the field at its base, however

this instruction is not necessarily implicit in test instructions (Appendix 8). Time taken to search the field affects score, however this is also not made explicit in the instructions.

The BADS temporal judgement subtest asks participants to estimate time required to perform a variety of commonplace tasks. It is not made clear in the BADS test materials what function this test is designed to assess, and the questions – and answers included - seem arbitrary and culturally normative (e.g.: ‘how long does it take a window cleaner to clean the windows of an average size house’, correct answer – ‘15 – 25 minutes’).

The BADS 6 elements subtest contains 6 tasks which must be performed out of sequence. Points are awarded not for the amount of any one task completed, but for success in task switching. However as this marking scheme is not explicitly stated in task instructions, an implicit assumption of grading exists – participants frequently endeavoured to complete as many tasks as possible.

The BADS action programme subtest involves a logic puzzle, the correct solution to which requires moving water from one container to another to allow a cork to float, in order to retrieve it from the bottom of a tall tube. Practical difficulties drying this second container adequately between participants meant that water droplets and staining provided implicit cues to task solution.

Participants were given the BADS Dysexecutive Questionnaire (DEX) to fill out – this survey is intended as a measure of changes in personality, behavioural and other domains, and should also be completed by a close relative or carer – as this was not possible, answers may be unreliable.

Chamberlain (2003) is critical of the construct validity of the BADS, and emphasises that the only significant predictor of disorder in the test battery is the 6 Elements subtest.

Participants performed at ceiling on many of the BADS measures, and non-significantly even on timing measures (scored here, but not officially a part of the BADS battery), indicating the BADS may not be a suitable test of executive function in this population.

While participants with diabetes reported glycemic level over recent weeks (HbA1c), facilities were not available to test glucose levels across control and diabetes groups

prior to testing. Acute glucose level has been found to affect cognitive function across a range of domains, including attention (Korol & Gold, 1998), highly effortful cognition (Kennedy & Scholey, 2000), and word memory (Benton, 1993). At the same time effortful cognition can diminish glucose levels (Gailliot et al, 2007) and cognitive self regulation may depend on it (Shamosh, & Gray, 2007). Additionally, HbA1c levels are unreliable as a measure of mode glucose levels – due to extensive nightly glycaemic variation (Matyka et al, 1999). A record of glycaemic history over the duration of participant illness was not available.

The Grooved Peg board used as a measure of psychomotor skill in this battery was improvised, and as such may lack convergent validity.

A variety of domains found in previous studies to be affected by diabetes were not tested in this study – due to practical limitations in test duration, and availability of psychometric tests. Domains not specifically measured included visual attention (as distinct from sustained attention), cognitive flexibility, visual perception (as distinct from visual memory), spatial reasoning, self monitoring and other memory stores (everyday, working, autobiographical, verbal). Additionally, several confounding variables associated with cognitive function, including height, BMI, hypertension, and smoking, were not recorded.

On the Medical and Biographical History participants assumed that ‘Treatment Duration’ referred to duration of current treatment regime rather than longevity of insulin dependence, preventing duration of insulin from being assessed as a predictor.

A need exists for the development of a neurocognitive battery, tailored to the specific deficits and confounds found in T1DM, and normalised over a variety of disease populations, to uncover the genetic and environmental protective factors which may forestall T1DM, and to better elucidate its cognitive consequences. Future studies should endeavour to obtain samples differentiated by age of onset, collect acute glucose levels and glycemic histories, and record measures of executive function, visiospatial memory, and sustained attention - which may experience enhanced function at euglycaemia due to a history of moderate hypoglycemia.

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## Appendices

### Appendix 1 - Test Materials (1 of 2)

1. Stapler
2. Posters
3. Research Credits
4. Consumables Printout (1 for each participants 22pp \* 40)
  - a. Consent Form
  - b. Rey-Osterrieth drawing sheet \* 3
  - c. Medical Biographical History
  - d. Face Name score sheet
  - e. Rey-Osterrieth score sheet
  - f. 6 Elements answer sheet
  - g. BADs score sheet
  - h. AM-NART score sheet
  - i. Digit Span Instructions & Score / Grooved Peg Score
  - j. Allied Dunbar Modified Fitness Test
  - k. Debriefing form
  - l. Overall Score Sheet
5. Test Guide Printout
  - a. Materials list (2 sides)
  - b. Prep checklist
  - c. Test schedule
  - d. Rey-osterrieth / Face Name / Dart instructions
  - e. Bads instructions
  - f. X-Y / NART Instructions
  - g. AM-NART Word list
  - h. Grooved Peg Instructions
6. WAIS-R Digit Span
  - a. conversion sheet
7. NART
  - a. conversion booklet
  - b. Tape recorder
8. Grooved Peg Test
  - a. Grooved Peg Board
  - b. Grooved peg
9. Rey-Osterrieth
  - a. Marked Image
  - b. Unmarked Image
  - c. Pencil \* 1
  - d. Eraser \* 1
10. Beck Depression Inventory
  - a. Score sheet \* 45 (2 sides)
11. Computer Tasks
  - a. Laptop with plug - All tasks working
  - b. USB key

## Appendix 1 - Test Materials (2 of 2)

### 12. BADS Box

- a. BADs score sheet photocopy \* 45 (4 sides)
- b. Tape recorder
- c. Ipod touch (timer)
- d. Timer (stopwatch)
- e. Pen
- f. Pencil
- g. Eraser
- h. Coloured markers \* 7
- i. Rule shift cards booklet
- j. Rule shift rules laminate \* 2
- k. Beaker
- l. Beaker lid
- m. Base
- n. Tall Tube
- o. Cork
- p. Wire
- q. Small Tube
- r. Small Tube lid
- s. Water
- t. Key search Test laminate (photocopy) \* 45
- u. Zoo map 1 laminate (photocopy) \* 45
- v. Zoo map 2 laminate (photocopy) \* 45
- w. 6 coloured markers
- x. Test 6: Modified six elements instructions laminate
- y. 4 test pads
- z. Dex Questionnaire photocopy \* 45

## Appendix 2 – Consent Form

Participant No: \_\_\_\_\_

### **Letter of Consent to Participate in Experimental Research in the Department of Psychology, Trinity College Dublin.**

Dear Sir / Madam,

My name is Gareth Stack and I am an undergraduate student in the School of Psychology, Trinity College, Dublin. I am working under the supervision of Dr. Shane O'Mara. We are currently carrying out research on how memory and cognition are affected by diabetes. If you agree to participate in this experiment, you will be asked to complete several tasks related to memory and aspects of cognition, and to provide biographical information related to medical history, socioeconomic status, exercise, mood, depression, and mental health history.

In total the whole experiment will last no more than 2 hours, or 2 hours 15 minutes, including a 15 minute break.

Your scores will be averaged with those of other people, so nobody will know how you did on these tasks. Your data will be stored using a numbered code (e.g. Participant 101) to ensure confidentiality, and you are free to stop doing the experiment at any stage, and for any reason. Under the Freedom of Information Act, you have the right to see your scores after the test, if you wish.

Many Thanks,

Researcher

Supervisor

Gareth Stack

Prof. Shane O'Mara

Dept of Psychology  
Trinity College Dublin  
D2  
Dublin

Dept of Psychology  
Trinity College Dublin  
D2  
Dublin

Statement of Consent:

I, \_\_\_\_\_ (block capitals), have read this and give my informed consent to participant in the experiment.

Signed: \_\_\_\_\_

Date: \_\_\_\_\_

Appendix 4 – (1 of 4) Medical / Biographical History Participant No: \_\_\_\_\_

This is a survey of medical, biographical and mental health information which may be of relevance to cognitive differences experienced by those with Diabetes. Please answer these questions as honestly as possible. This information will be kept completely private and confidential. You are free to stop this experiment at any time, please ask the researcher present if you have any additional questions.

1. D.O.B: \_\_\_\_\_
2. Gender: M / F (delete as appropriate)
3. Approximate weight: \_\_\_\_\_
4. Daily servings of fruit consumed: \_\_\_\_\_
5. Daily servings of vegetables consumed: \_\_\_\_\_
6. Daily servings of high sugary foods / soft drinks consumed: \_\_\_\_\_
7. Estimate your level of fitness (circle as appropriate): Very Poor / Poor / Moderate / Good / Very Good
8. What sports / exercise do you engage in (if any), and how often? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
9. How many years in education \_\_\_\_\_
10. Current Employment: \_\_\_\_\_  
(if a student, please enter both parents jobs)
11. Current Salary: \_\_\_\_\_  
(if a dependant, please estimate combined parental salary)
12. Are you currently diabetic: Yes / No
13. Are you currently on any medications (if yes please list): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Appendix 4 – (2 of 4) Medical / Biographical History Participant No: \_\_\_\_\_

14. Have you ever been diagnosed with any of the following conditions (delete as appropriate):

Autism: Yes / No

Aspergers Syndrome: Yes / No

Dyslexia: Yes / No

ADD or ADHD: Yes / No

Tourettes Syndrome: Yes / No

Mild Cognitive Impairment: Yes / No

Schizophrenia: Yes / No

15. Are you currently being treated for any psychological / psychiatric disorder (if yes, please list):

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16. Have you in the past received treated for any psychological / psychiatric disorder (if yes, please list)

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17. Have you ever received a head injury? \_\_\_\_\_

18. If yes, please provide age at injury, seriousness and any treatment received:

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19. How often and how much alcohol do you estimate that you drink:

\_\_\_\_\_ pints per week / per month (circle as appropriate)

\_\_\_\_\_ spirits per week / per month (circle as appropriate)

\_\_\_\_\_ glasses of wine per week / per month (circle as appropriate)

20. Are you currently, or have you ever taken psychoactive drugs? \_\_\_\_\_

Appendix 4 – (3 of 4) Medical / Biographical History Participant No: \_\_\_\_\_

21. If yes, how often and how much of the following drugs do you estimate that you take

\_\_\_\_\_ marijuana per week / month / year (delete as appropriate)

\_\_\_\_\_ ecstasy per week / month / year (delete as appropriate)

\_\_\_\_\_ cocaine per week / month / year (delete as appropriate)

22. If you previously regularly took such drugs, please indicate how long ago this occurred

\_\_\_\_\_

23. Please list any other drugs recently or previously consumed, with approximate quantities

\_\_\_\_\_

\_\_\_\_\_

**Diabetes Patients Only**

24. What is your current HbA1c (glucose level) \_\_\_\_\_  
(Ignore this question if unsure).

25. Age at diagnosis: \_\_\_\_\_

26. What treatment, if any, do you take to control your diabetes? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

27. When was this treatment regime initiated: \_\_\_\_\_

28. Have you previously experienced a hypoglycemic fit or seizure? Yes / No (circle as appropriate)

29. If yes, please state the date and severity of your first seizure: \_\_\_\_\_

\_\_\_\_\_

30. If you answered yes to question 4, please estimate how often / many seizures you have experienced since then:

\_\_\_\_\_

\_\_\_\_\_

31. Have you experienced Ketoacidosis? Yes / No (circle as appropriate)

32. If yes please provide details of how often and how frequently

\_\_\_\_\_

Appendix 4 – (4 of 4) Medical / Biographical History    Participant No: \_\_\_\_\_

33. Have you experienced any of the following:

Heart Disease: Yes / No

Diabetes Related Visual Impairment: Yes / No

Nerve Damage: Yes / No

Kidney Damage: Yes / No

34. Do you have any disorders related to Diabetes (e.g.: celiac disease)? Yes / No (circle as appropriate)

35. If Yes, please list: \_\_\_\_\_

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## Appendix 15 - Test Instructions – Grooved Peg

Test Participant No: \_\_\_\_\_

### **18 – Grooved Peg Initial Setup**

Grooved Peg board + Peg should be out of sight (in laptop bag).

Grooved Peg Latency: \_\_\_\_\_

### **Instructions**

*I am going to give you a test of motor ability. I am going to ask you to close your eyes. With your eyes closed I will place the test in front of you. You will then be asked to open your eyes for two seconds to view the test. With your eyes closed again I will indicate start and end positions. Your task is to move the peg from the beginning the the end of the Grooved Peg board, without opening your eyes. Please try not to tilt the board as you carry out the test.*

Show where top is once. If necessary hold the board still.

Begin – Timing – and marking down any reversals.

## Appendix 18 - Debriefing Form (1 of 2)

**Research:** Cognitive Deficits associated with Type I Diabetes Mellitus in a young adult population

**Experimenter:** Gareth Stack, Final Year Undergraduate Student, Dept of Psychology.

Type I diabetes is a disorder usually arising in childhood or early adolescence. In Type 1 Diabetes the body's own antibodies attack the cells which normally produce insulin, a substance which normally allows the body use or store glucose. This makes it necessary for people with Type 1 Diabetes to regularly take insulin injections in order to control their glucose levels.

The purpose of this study is to compare a variety of specific mental skills, including elements of memory, attention, and reading ability, between a group of Type I diabetics and non-diabetics; in order to tell whether diabetes has altered these skills.

It is difficult to answer these types of questions, and your generosity and willingness to participate in this study are greatly appreciated. Your input will help contribute to the understanding of cognitive differences in diabetic patients.

### **Freedom of Information**

Under the Freedom of Information Act, you have the right to see your scores after the test, if you wish. Please bear in mind that this study does not represent a clinical diagnosis or determination of cognitive ability in any domain. Instead, it is designed to focus on average differences across groups of diabetic and non-diabetic people, in order to more specifically identify any potential effects of diabetes on the brain.

### **Diabetes**

If you would like further information on Type 1 or Type 2 diabetes, or the treatment of this condition, please contact 'The Diabetes Federation of Ireland', on Low Call - 1850 909 909. Their address is

Diabetes Federation of Ireland,  
76 Lower Gardiner Street,  
Dublin 1.

Further information is available from 'The American Diabetes Association', at <http://www.diabetes.org>.

## Appendix 18 - Debriefing Form (2 of 2)

### **Mental Health Issues**

As part of this research, a measure of depression was taken. This does not represent a clinical diagnosis. If you would like information related to depression please contact Aware, a voluntary organisation who provide information and help to those affected by depression.

1890 303 302

<http://www.aware.ie/contact.asp>

Information and help with mental health issues is also available from the Student Counseling Service.

The service can be contacted either by phone on 01 896 1407 (or ext 1407), or by dropping in to 199-200 Pearse Street (entrance located adjacent to Players Theatre, inside Trinity).

The Student Counseling Service also provide a confidential helpline, Niteline on 1800 793 793, available Monday to Thursday 9:00 pm to 2:30 am.

### **Further Queries**

You are of course free to contact myself with any future questions about this research (phone: 086 159 0262, email: [stackgm@tcd.ie](mailto:stackgm@tcd.ie)).

If you have questions or queries about this research, please contact my supervisor: Dr. Shane O' Mara (01 896 1175).

Thank you very much for participating!

Appendix 19 - Score Sheet

Participant no: \_\_\_\_\_

Diabetes Status: \_\_\_\_\_

Rule Shift Card Time 1: \_\_\_\_\_ Time 2: \_\_\_\_\_  
Profile Score: / 4

Action Programme Time: \_\_\_\_\_  
Raw Score: / 5

Key Search Time: \_\_\_\_\_  
Profile Score: / 4

Temporal Judgement Profile Score: / 4

Zoo Map Plan Time 1: \_\_\_\_\_ Total Time 1: \_\_\_\_\_

Plan Time 2: \_\_\_\_\_ Total Time 2: \_\_\_\_\_

Profile Score: / 4

6 Elements Profile Score: / 4

BADs Profile Total: / 24 Age corrected standardised score: / 139

Dex score: / 100

Allied Dunbar score: /

NART score: / 50

WAS-R digit span forward: / 14 back: / 14 combined: / 28

Rey-Osterrieth score:

Copy: / 18

Delay 1: / 18

Delay 2: / 18

Total: / 54

BDI Score: / 63

Gooved Peg Latency: \_\_\_\_\_

Face Name Task:

Recall 1: / 8

Recall 2: / 8

Recall 3: / 8

Recall 4: / 8

Recall 5: / 8

Recall 6 (new): / 8


Recall 7: / 8

Go/NoGo Order: \_\_\_\_\_

NoGo Errors: \_\_\_\_\_ Go Errors: \_\_\_\_\_

Dart Score Sequential: \_\_\_\_\_ Dynamic \_\_\_\_\_

## Appendix 20 - Advertising Posters



# EARN 4 RESEARCH CREDITS

Urgently seeking participants for final year project on cognitive impairment in Type 1 Diabetes.


Looking for:

- Participants with Type 1 Diabetes (usually childhood onset), aged 18 - 30 approx.
- Non Diabetics - aged 18 - 30.

My experiment is interesting, involving a wide variety of puzzles.

**If you know ANYONE with Type 1 diabetes (friend, sibling etc), please let them know about this experiment.**

Fmail Gareth at [STACKGM@TCD.IE](mailto:STACKGM@TCD.IE) or call on **086 159 0262**



# DIABETES EXPERIMENT

Urgently seeking participants for final year psychology project on cognitive impairment in Type 1 Diabetes.

Looking for:

- People with Type 1 Diabetes (usually childhood onset), aged 18 - 30 approx.

My experiment is interesting, involving a wide variety of puzzles.

**If you know ANYONE with Type 1 diabetes (friend, sibling etc), please let them know about this experiment.**

Fmail Gareth at [STACKGM@TCD.IE](mailto:STACKGM@TCD.IE) or call on **086 159 0262**

## **Appendix 22 – Kurtosis and Skewness Transformations**

An outlier in Action Programme Time ( $p = 28$ ,  $M = 136$ ) was substituted with overall sample mean ( $M = 58.925$ ). Key search profile score was squared. Zoo Map Profile score was squared. An outlier in AM-NART ( $p = 26$ ,  $M = 16$ ) was replaced with sample mean ( $M = 39.25$ ). A square root function was applied to BDI score. A log function was applied to Grooved Peg latency. An outlier in NoGo score ( $p = 24$ ,  $x = 196$ ) was replaced with sample mean ( $M = 230$ ), then the variable was reflected and square root function applied. Go score was reflected and the square root function applied. DART sequential score was reflected, and the log function applied. DART dynamic score was reflected and the log function applied. Weight was transformed, turning it from a measure to a score, via the log function. Fruit consumed had one outlier ( $p = 15$ ,  $M = 8.5$ ) replaced with sample mean ( $M = 2.5$ ). Veg consumed was transformed from a measure to a score, via the square root function.

### **Appendix 23 - Strong Non-Significant Correlations**

HbA1c level was strongly (but not significantly) positively correlated with Action Programme Time [ $r(6) = .5, p > .05$ ], Zoo Map 2 Total Time [ $r(6) = .310, p > .05$ ], Peg Latency [ $r(6) = .452, p > .05$ ], Face Name Total Score [ $r(6) = .527, p > .05$ ], DART Sequential (directionality corrected) [ $r(6) = .359, p > .05$ ] and NoGo Score (directionality corrected) [ $r(6) = .323, p > .05$ ]; and strongly but not significantly negatively correlated with NART [ $r(6) = -.587, p > .05$ ], Rey Osterrieth Total [ $r(6) = -.303, p > .05$ ].

Age of onset of Diabetes was strongly (but not significantly) positively correlated with BADS Score [ $r(6) = .404, p > .05$ ], Digit Span Back [ $r(6) = .451, p > .05$ ], and Zoo Map 1 Total Time [ $r(6) = .563, p > .05$ ]; and strongly (but not significantly) negatively correlated with Peg Latency [ $r(6) = -.359, p > .05$ ], Face Name Total [ $r(6) = -.319, p > .05$ ], and DART Sequential (directionality corrected) [ $r(6) = -.446, p > .05$ ], and Go Score (directionality corrected) [ $r(6) = -.359, p > .05$ ]

Duration in Months of Diabetes was strongly (but not significantly) positively correlated with Peg Latency [ $r(6) = .467, p > .05$ ]; strongly (but not significantly) negatively correlated with Key Search Profile Score [ $r(6) = -.448, p > .05$ ], Zoo Map 1 Total Time [ $r(6) = -.491, p > .05$ ], BADS Total [ $r(6) = -.512, p > .05$ ]

## **Appendix 24 - Recruitment Difficulties**

Initially, as per ethical approval from SPREC, participants were recruited via advertising within TCD (Appendix 20). With the help of Dr. David Heavey, Diabetes Ireland were approached in October 2007, and repeatedly contacted after that time, unfortunately in February 2008 Diabetes Ireland confirmed a disinterest in participating in this study. After consultation with Dr. Kevin Thomas, chair of SPREC, additional participants with Type 1 Diabetes were recruited from advertisements at UCD and online on Boards.ie, Tudiabetes.com, Buyandsell.ie, Dublin.craigslist.org and the TCD online noticeboard.. Trinity Student Disability Services (SDS) were approached by this researcher, and offered to contact registered Diabetic students. However this offer was later withdrawn pending a policy review. Finally, as per verbal approval from Dr. Kevin Thomas and in coordination with Prof. Shane O'Mara, and Dr. James Gibney of the Adelaide and Meath Hospital (AMNCH), and with Medical Guardianship approval from Dr. Kevin Moore (Appendix 19), participants were recruited in person from the Diabetes Day Clinic at AMNCH. Ultimately no participants were successfully obtained from the AMNCH.