

**Accelerated forgetting and memory consolidation in
children with idiopathic generalised epilepsy**

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Accelerated forgetting and memory consolidation in children with idiopathic generalised epilepsy

Abstract

Long-term memory retention and learning of verbal and non-verbal material was investigated in children with idiopathic generalised epilepsy (IGE) and healthy controls. Ten children with IGE were compared to 12 control children for their initial learning ability and memory retention of verbal and non-verbal material at delays of 30-minutes and 1-week. A minimum learning criterion was used to control for initial learning. No significant group differences were found for the initial learning and recall of non-verbal material across delays. In the verbal test children with IGE did not differ significantly from controls in the number of learning trials they required to achieve criterion or in their recall at the 30-minute delay, however one week later they recalled significantly less than controls. There were no significant group differences for the recognition of verbal material across delays. These findings suggest that children with IGE have difficulty retrieving verbal material that has been successfully encoded and stored in long-term memory.

Introduction

Although patients with temporal lobe epilepsy (TLE) frequently complain of memory problems, their performance on standardised neuropsychological memory assessments is generally within the average range or is disproportionate to their complaints of memory difficulties (Piazzini, Canevini, Maggiori & Canger, 2001; Cocoran & Thompson, 1992; Gleissner, Helmstaedter, Quiske & Elger, 1998; Hall, Isaac & Harris, 2000; Hendriks, Aldenkamp, Van der Vlugt, Alpherts & Vermeulen, 2002). Standardised clinical memory assessments typically measure memory for learned materials after intervals of up to 30 minutes (e.g. Wechsler, 1987). A number of individual case and group studies have investigated rates of forgetting over longer time periods and have found that, despite normal initial learning and memory retention after delays of approximately 30-minutes, patients with epilepsy showed an accelerated rate of forgetting over 24-hours to 8-weeks in comparison to controls. (e.g. Blake, Wroe, Breen & McCarthy, 2000; Martin et al., 1991; O'Connor, Sieggreen, Ahern, Schomer & Mesulam, 1997).

Only one study has investigated accelerated forgetting (AF) in children with epilepsy to date (Davidson, Dorris, O'Regan, Zuberi, 2007). This study found AF for verbal material in a

sample of children with idiopathic generalized epilepsy (IGE). IGE encompasses a range of epilepsies (childhood absence epilepsy, juvenile absence epilepsy, juvenile myoclonic epilepsy) that occur in the absence of abnormal neurological symptoms or structural brain damage (Engle, 2001). Instead, it is believed to have a genetic basis (Engle, 2001). The term generalised refers to the fact that seizures occur in both brain hemispheres. Despite generally having intelligence (IQ) in the normal range and the majority following a normal developmental course, the educational attainment of children with IGE is often poorer than that of their healthy peers (Davison et al. 2007; Sturniolo & Galletti, 1994; Wirrell et al., 1997; Echenne, Cheminal, Roubertie & Rivier, 2001; Henkin et al., 2005). Research has also shown that, even after their seizures are well controlled, they have a risk of long-term learning impairment (Bailet & Turk, 2000) and poor psychosocial outcomes. In light of the detrimental effects of IGE on children's learning, further study into AF in this group is warranted and is the focus of the current study. It is hoped that another investigation of AF in children with IGE will throw light on the effects of generalised epileptiform activity on memory consolidation. The existence of AF in patients without underlying brain pathology may help clarify the role of seizures in producing AF. It will also be interesting to investigate AF in a group of patients who are generally less medicated than adults with TLE.

This paper reviews the following: AF in individuals and groups of adults with TLE; the possible mechanism underlying AF in patients with epilepsy; AF in depressed patients who have undergone ECT; theories and mechanisms of memory consolidation; verbal and non-verbal memory impairments at standard delays in children with epilepsy; and finally Davidson et al.'s (2007) study of AF in children with IGE.

Case Studies of AF in TLE Patients

The six case studies discussed here investigated AF in patients with temporal lobe epilepsy (Kapur et al., 1997, O'Connor et al., 1997; Lucchelli & Spinnler, 1998; Butler & Zeman, 2008a; Jansari, Davis, McGibbon, Firminger, Kapur, 2010; Mayes et al., 2003). In several of these studies the patients' epilepsy resulted from structural brain damage (Mayes et al., 2003; Kapur et al., 1997; O'Connor et al, 1997; Butler & Zeman, 2008a) whilst in others there was no visible brain pathology (Jansari et al., 2010; Lucchelli & Spinnler, 1998). The cases are summarised in Table 1.

All the case studies examined verbal memory retention over extended delays. To assess recall and recognition of verbal material, some studies required patients to learn word-lists (O'Connor et al., 1997; Butler & Zeman, 2008a), some required them to learn stories (Kapur et al., 1997; Jansari et al., 2010; Luchelli & Spinnler, 1998) and another required them to learn both (Mayes et al., 2003). All the patients demonstrated normal initial learning and memory retention after a 30-minute delay. However, compared to controls, they exhibited AF for both recall and recognition of verbal materials over extended delays ranging from 24-hours (O'Connor et al., 1997) to 6-weeks (Kapur et al., 1997).

AF for non-verbal material was investigated in four case studies using either visual designs or figures (Kapur et al., 1997; Luchelli & Spinnler, 1998; Mayes et al., 2003; Butler & Zeman, 2008a). All the patients showed normal initial learning and memory retention of the non-verbal material after a 30-minute delay. The findings for non-verbal recall performance over extended delays are mixed, with one patient demonstrating recall comparable to that of controls (Luchelli & Spinnler, 1998) and three exhibiting AF (Butler & Zeman, 2008a; Mayes et al., 2003; Kapur et al., 1997). The findings for recognition of non-verbal material over extended delays are also mixed. Of the three studies which examined recognition, one found AF (Mayes et al., 2003) and two did not (Kapur et al., 1997; Luchelli & Spinnler, 1998).

Group Studies

Six group studies have found evidence of AF in adult TLE patients in comparison to controls (Martin et al., 1991; Helmstaedter, Hauff & Elger, 1998; Blake et al., 2000; Manes, Graham, Zeman, de Lujan Calcagno & Hodges, 2001; Mameniskiene, Jatuzis, Kaubrys & Budrys, 2006; Butler et al., 2007). The group characteristics are described in Table 2.

All of the group studies examined verbal memory retention. In some studies participants had to learn word-lists (Martin et al., 1991; Butler et al., 2007; Helmstaedter et al., 1998); in others they had to learn stories (Manes et al., 2005; Blake et al., 2000); and in one study they had to learn both (Mameniskiene et al., 2006). Memory retention of the learnt material was tested after a 30-minute delay in all studies, however different studies examined rates of forgetting over different time intervals ranging from 24-hours (Martin et al., 1991) to 8-weeks (Blake et al., 2000). In some studies the patients demonstrated normal initial learning of verbal material (Martin et al., 1991; Blake et al., 2000; Manes et al., 2005; Butler et al., 2007)

whereas in others their learning was impaired (Helmstaedter et al., 1998; Mameniskiene et al., 2006).

Studies have found mixed results for the verbal memory retention of patients at the 30-minute delay. Some studies found that the patients performed comparably to controls (Martin et al., 1991; Blake et al., 2000; Manes et al., 2005) whereas others found that patients exhibited impaired verbal memory (Helmstaedter et al., 1998; Mameniskiene et al., 2006; Butler et al., 2007).

In all the studies TLE patients demonstrated AF for recall of verbal material over extended delays. Three studies also tested their participants' recognition memory for verbal materials over extended delays (Blake et al., 2000; Manes et al., 2005). Blake et al. (2000) and Manes et al. (2005) found that their patients demonstrated AF for story recognition. In contrast TLE patients in Martin et al.'s (1991) study exhibited impaired long-term recall in the context of normal recognition. The existence of AF for both recall and recognition in some patients implies memory consolidation failure (Blake et al., 2000; Manes et al., 2005). Whereas the existence of AF for recall but not recognition of verbal material suggests difficulties retrieving successfully stored memories (Bell & Giovagnoli, 2007).

Four studies examined non-verbal memory retention in patients and controls who were required to learn either visual designs (Manes et al., 2005; Butler et al., 2007) or figures (Maniensiene et al., 2006; Helmstaedter et al., 1998). TLE Patients exhibited normal initial learning in one study (Butler et al., 2007) and impaired learning in the other studies (Manes et al., 2005; Maniensiene et al., 2006; Helmstaedter et al., 1998). At the 30-minute delay, compared to controls, the non-verbal recall of TLE patients was normal in two studies (Helmstaedter et al., 1998; Butler et al., 2007) and impaired in two studies (Manes et al., 2005; Maniensiene et al., 2006). In Manes et al.'s (2005) study the patients' recall was at floor and the controls performed very poorly so they were not able to test non-verbal recall at the extended delay. All the other studies found that the patients had AF for recall of non-verbal material at extended delays. The only study which investigated recognition memory for non-verbal materials found that patients' recognition was comparable to that of controls at delays of 30-minutes and six-weeks (Manes et al., 2005). Because only one study investigated recognition memory it is not clear whether the TLE patients' impaired non-verbal recall is due to memory consolidation failure or to retrieval difficulties. The balance of the evidence

described above indicates that most patients who exhibit AF for recall of verbal material also exhibit AF for recall of non-verbal material.

Possible mechanisms of AF

Evidence for a correlation between AF and seizure frequency in patients with TLE who exhibit AF is mixed. O'Connor et al. (1997) found that their patient's memory retention decreased in conjunction with increased seizure activity. Furthermore, once his seizures had been controlled with anti-epileptic drugs (AEDs), his rate of forgetting was less severe. Mameniskiene et al. (2006) found a positive correlation between AF and the occurrence of both manifest and subclinical seizures during the experimental period. Jokeit et al. (2001) examined the interaction between AF, seizure laterality, and seizure occurrence across delays in patients with left and right TLE. They found that, while there was a significant correlation between AF and seizure occurrence, this was restricted to the patients with left TLE.

Other studies have failed to find a relationship between seizure activity and AF (Jansari et al., 2010; Blake, et al., 2000; Butler et al., 2007; Bergin, Thompson, Fish, & Shorvon., 1995). Bergin et al. (1995) investigated AF in patients undergoing video EEG monitoring of seizures. They found no significant difference in memory retention between patients who did and did not experience seizures across delays of 30-minutes and 48-hours. Blake et al. (2000) reported that there was no significant relationship between self-reported seizure frequency and their patients' rates of forgetting over an eight-week delay. AF has also been documented in patients whose overt seizures have been reduced or abolished with medication (Jansari et al., 2010; Butler et al., 2007). Although four studies did not find a relationship between overt seizure activity and AF, the authors stated that this did not necessarily rule out the negative influence of seizure activity upon memory across delays, as it is possible that the patients suffered from subclinical seizures or seizures that occurred during their sleep (Jansari et al., 2010; Blake, et al., 2000; Butler et al., 2007; Bergin et al., 1995; Butler, Mulhert & Zeman, 2010). To develop of clear understanding of the relationship between seizure activity and AF, patients with epilepsy should ideally be monitored for the presence of subclinical epileptiform activity during the experimental period as was done in the study by Mameniskiene et al. (2006).

There is substantial evidence showing that AEDs can have a negative affect upon cognition (Jokeit, Kramer & Ebner, 2005; Kwan & Brodie, 2001; Motamedi & Meador, 2004). The

most common side effects are psychomotor slowing and attentional difficulties (Aldenkamp De Krom & Reijns, 2003) especially when AEDs are given in high doses or as polytherapy (Jokeit et al., 2005). While the AF seen in some of patients may be due to treatment with AEDs, it is unlikely to be the only cause of AF (Butler & Zeman, 2008b), as many patients with transient epileptic amnesia (TEA, caused by underlying TLE) complain of AF prior to treatment with AEDs (Butler & Zeman, 2008a) and continue to exhibit AF after treatment is stopped (Cronel-Ohayon et al., 2006). Midorikawa and Kawamura (2007) found that following AED treatment, a TEA patient no longer exhibited AF. Furthermore TEA patients usually report improvements in their memory following treatment initiation (Zeman, Boniface, & Hodges, 1998; Butler et al., 2007).

Evidence for the role of structural brain pathology in causing AF is still unclear (Butler, Mulhert & Zeman, 2010). The presence of temporal lobe damage in four out of the six individual case studies of patients who demonstrated AF (Mayes et al., 2003; Kapur et al., 1997; O'Connor et al., 1997; Butler et al., 2008a) raises the possibility that structural damage alone can sometimes result in AF (Butler, Mulhert & Zeman, 2010). However, as Butler et al. (2010) point out, many of the patients included in the group studies which found AF did not have visible lesions on MRI. In a study of 70 patients who exhibited AF, only 11 had structural lesions (Mameniskiene et al., 2006), and none of the patients in two group studies had underlying brain pathology yet they still demonstrated AF (Butler et al., 2007; Manes et al., 2005). It seems therefore that while structural brain pathology may play a role in some cases of AF, the evidence for it playing a major role in causing AF in patients with TLE is weak (Butler et al., 2010).

AF in patients undergoing ECT

From the studies reviewed so far it is not clear what affect generalised seizures have on AF, as the majority of patients had lateralised seizures, and some had structural brain pathology. Investigations of the affects of ECT induced seizures on memory in patients with depression demonstrated that generalized epileptiform activity can cause AF in patients who do not have structural brain damage (Squire, 1981; Lewis & Kopelman, 1998). Squire (1981) investigated recognition memory for sentences and pictures in depressed patients undergoing ECT. They were tested on two occasions: two hours after receiving ECT and four months later, meaning that they acted as their own controls. On each occasion their memory retention for learnt material was tested after delays of 10-minutes, 30-minutes, two hours and 32-hours. Their

performance was compared to that of patients with Korsakoff's syndrome, healthy controls and a patient with diencephalic amnesia.

The depressed patients' initial learning level was matched to that of other healthy controls and to their own level of learning four months later. The performance of ECT patients was comparable to that of the other participants for picture recognition at 10 and 30-minutes, however their rate of forgetting was significantly faster after delays of two hours and 32-hours. The ECT patients' rate of picture forgetting was significantly faster post ECT than four months later. These findings were replicated by Lewis and Kopelman (1998), and additionally it was found that only patients who had received ECT demonstrated AF compared to untreated depressed patients. This shows that AF could not simply be attributed to depression. The finding that ECT induced generalised seizures can result in AF in patients without underlying structural brain pathology indicates that brain damage is not necessary for AF to occur and that generalized seizure activity alone can be sufficient (Butler et al., 2010).

Memory consolidation mechanisms and theory

The existence of AF in adults with TLE, and patients who have undergone ECT, challenges traditional models of memory which assumed that information that had been successfully retained in the brain for more than a few minutes reached long-term memory storage (Kapur et al., 1997). Research into AF suggests that memories have an extended period of vulnerability before being consolidated into long term memory (Blake et al., 2000). As such the process of memory consolidation could take days, weeks, months or even years (Blake et al., 2000; Squire, Cohen & Nadel, 1984). While the concept of memory consolidation has been of interest to researchers for over a century the exact time course and mechanisms of memory consolidation remain unclear (Meeter & Murre, 2004). It has been shown that damage to the medial temporal lobes (MTL) and particularly the hippocampus can result in the loss of recent memories or the inability to form new memories (Mayes et al., 2003; Meeter & Murre, 2004; Alvarez & Squire, 1994). There is general agreement that the medial temporal lobes and in particular the hippocampus are crucial in the initial stages of memory consolidation (Mayes et al., 2003).

Squire and colleagues (Alvarez & Squire, 1994; Squire, 1987; Squire, 1986) posited that once information has been learnt, there is a gradual reorganization of the neural substrates of

memory storage whereby memories become independent from the MTL, and come to reside long-term/permanently in the neocortex. This suggests that the hippocampal memory system enables us to learn information quickly and that the neocortical memory system takes time to store and consolidate this information (Meeter & Murre, 2004).

Although researchers still disagree about the exact mechanisms of memory consolidation, it seems apparent that interactions between the MTL and neocortex are involved in memory consolidation (Davidson et al., 2007). Accordingly it has been proposed that the phenomenon of accelerated forgetting in patients with epilepsy could be the results of structural damage to the neocortex as seen in many patients with TLE, or alternatively due to seizure activity which disrupts the interactions between the MTL and the neocortex (Mayes et al., 2003).

Verbal and non-verbal memory in children with epilepsy at standard delays

Research into verbal and non-verbal memory performance in children with epilepsy is limited, and has predominantly focused on assessing memory abilities at short delays (e.g. Joci-Jakubi & Jovic, 2007; Volk-Kernstock, Wilinger and Feucht, 2006; Henkin et al., 2005). The findings of verbal and non-verbal memory abilities have been mixed.

Jambaque et al. (Jambaque, Dellatolas, Dulac, Ponsot & Signoret, 1993) found that the memory performance of children with IGE was comparable to that of controls for most measures of verbal memory (e.g. story recall) apart from immediate and delayed word-list recall. Further evidence for impaired word-list learning and recall in children with epilepsy has also been found in other children with IGE (Henkin et al., 2005) as well as in children with TLE (Joci-Jakubi & Jovic, 2007).

The findings of non-verbal memory impairments in children with IGE have been mixed (Henkin et al., 2005; Jambaque et al., 1993). Jambaque et al. (1993) found that compared to controls their patients were impaired for every measure of visual memory (e.g. immediate and delayed geometric figure recall). In contrast to Jambaque et al. (1993), Henkin et al. (2005) found that the initial learning and recall of figures in their patients was comparable to that of controls.

Volk-Kernstock et al. (2006) examined non-verbal memory in children with benign childhood epilepsy with centro-temporal spikes (BCECTS) and healthy controls. They also investigated

the relationship between seizure laterality and memory performance. The children had to learn a visuo-spatial arrangement of blocks and to correctly estimate the distances between the blocks. After a 30-minute delay the performance of the children with BCECTS was impaired relative to that of controls. The findings of non-verbal memory impairments in children with epilepsy support those of Jambaque et al. (1993). Volk-Kernstock et al. (2005) found no relationship between seizure laterality and performance on this task.

AF in children with IGE

As mentioned previously, AF has only been investigated in children with epilepsy once (Davidson et al., 2007). Davidson et al. (2007) found evidence of AF for verbal material in children with IGE. Twenty-one children with IGE aged between eight and sixteen were matched on a pair-wise basis for age and intelligence (IQ) with healthy controls. To assess memory, Davidson et al. (2007) used the Dot-Locations (non-verbal memory) and Stories (verbal memory) subtests from the Children's Memory Scale (Cohen, 1997). Both tests were administered to the children, for a minimum of two learning trials, and up to a maximum of ten learning trials. The children were required to learn a pictorial array of dots to 83% accuracy over a minimum of two consecutive trials for the Dot-Locations test. In the Stories test the children had to learn two short stories to 90% accuracy. Children who did not achieve the learning criterion within the maximum of ten consecutive trials were excluded from the study. Following the last learning trial, the children's recall and recognition of the material was tested 30-minutes later and then again after a one week delay.

For the Stories test, children with IGE required significantly more learning trials to reach criterion than controls. The story recognition and recall of children with IGE was comparable to that of controls after 30-minutes. However, one week later the story recall of children with IGE was significantly poorer than that of controls, and there was a significant group by delay interaction. There was no significant group difference in story recognition at the one week delay.

Analysis of the Dot-Locations test results showed that children with IGE did not differ significantly from controls in the number of learning trials required to reach criterion, or in their recall at 30-minutes. Although the children with IGE did have slightly lower mean recall scores at the one week delay, the difference between groups was not statistically significant.

Further analysis revealed that the group differences in story recall at one week were due to the poorer learning efficiency of the children with IGE. The authors suggested that the lack of group difference at the 30-minute delay indicated that the poorer initial learning efficiency only impacts negatively on access to stored verbal information at the greater delay of one week. Davidson et al. (2007) posit that the lack of group difference for story recognition across delays indicates that the IGE group's poorer recall at one week was due to difficulties in retrieving successfully stored verbal information, rather than poor retention. The comparable group performance for story recognition indicates that failed memory consolidation could not be the cause of the poorer one week recall.

Davidson et al. (2007) state that it is possible that the 'force-choice' nature of the Dot-Locations test may underlie the lack of group difference in recall over delay. Children have to place all the counters on a grid to replicate the array of dots that they were shown in the learning trials. They are told to guess if they are not sure of the positions. The number of counters is equal to half the number of squares on the grid. This therefore limits the total possible variance in scores. Davidson et al. (2007) suggest that it is likely that some of the correct responses occurred through chance. Since this task does not include a recognition component, Davidson et al. (2007) state that it was not possible to determine whether the slightly lower mean scores in children with IGE resulted from poorer retrieval rather than retention. In their concluding comments Davidson et al. (2007) state that their findings challenge the prevailing interpretations of theories of memory consolidation which propose that failed long-term storage in the neocortex is due to a failure in memory consolidation.

The current study

The current study aims to further investigate AF for verbal and non-verbal material in children with IGE and to replicate the findings of Davidson et al.'s (2007) exploratory study. Davidson et al.'s (2007) measure of non-verbal memory was not completely satisfactory given its 'forced choice' response method. Furthermore their finding contrasts with previous studies which found non-verbal memory impairments in children with epilepsy at standard delays using 'non-forced choice' tasks (e.g. Volk-Kernstock et al, 2006; Jambaque et al., 1993).

In order to clarify whether children with IGE do or do not have a non-verbal memory impairment, or whether the 'forced-choice' nature of the task used by Davidson et al. (2007)

masked a deficit, an additional measure of non-verbal memory will be used. This additional measure is an experimental Object-Location task which requires the learning of a spatial array of objects, and does not use a 'forced-choice' response method (it will be described below). This task was piloted in a previous study with healthy children and has not yet been tested on children with epilepsy.

The following results are expected:

- Children with IGE will require more trials to achieve learning criterion for verbal material than healthy controls who are matched on a pair-wise basis for age and IQ.
- The number of trials required to achieve learning criterion for non-verbal material will not differ between groups.
- Recall and recognition of verbal material will not differ between groups 30-minutes after the last learning trial.
- Recall of non-verbal material will not differ between groups 30-minutes after the last learning trial.
- Compared to controls, children with IGE will demonstrate AF for verbal material but not for non-verbal material at an extended delay of one week.

Table 1. Individual case studies of AF in patients with epilepsy

<i>Authors (year)</i>	<i>Initials of patient</i>	<i>Age</i>	<i>Structural brain pathology</i>	<i>Seizure foci</i>	<i>Type of seizures</i>	<i>Non-memory impairment?</i>	<i>Type of material used</i>	<i>Type of memory tested</i>	<i>Memory impairment at 30-mins?</i>	<i>Memory performance at extended-delay</i>	<i>Delay at which AF first found</i>
Kapur et al. (1997)	JT	62	Left HC (subtle)	n/d	CPS	No	Verbal & non-verbal	Recall & recognition	No	Verbal & non-verbal recall	6 wks
O'Connor et al. (1997)	PA	42	MTL bilateral	Left	CPS	No	Verbal	Recall	No	Verbal recognition Verbal recall	24 hours
Lucchelli & spinnler (1998)	GB	65	No	Left	CPS	No	Verbal & non-verbal	Recall	No	Verbal recall	1 week
Mayes et al. (2003)	JL	46	TL bilateral	n/d	CPS	Yes	Verbal & non-verbal	Recall & recognition	No	Verbal & non-verbal recall & recognition	3 weeks
Butler & Zeman (2008a)	NR	54	Left HC (subtle)	Left	TEA	No	Verbal & non-verbal	recall	No	Verbal & non-verbal recall	1 week
Jansari et al. (2010)	RY	63	No	Right	TEA	No	Verbal	Recall & recognition	No	Verbal recall & recognition	24 hours

Key: AF=accelerated forgetting; HC= hippocampus; (M)TL = (medial) temporal lobe; n/d = not described; CPS=complex partial seizures; TEA = transient epileptic amnesia

Table 2: Group studies of AF in TLE patients

<i>Authors (year)</i>	<i>number of patients</i>	<i>Mean age</i>	<i>Structural brain pathology</i>	<i>Seizure foci</i>	<i>Type of seizures</i>	<i>Non-memory impairment?</i>	<i>Type of material used</i>	<i>Type of memory tested</i>	<i>Impaired learning?</i>	<i>Memory impairment at 30-mins?</i>	<i>Memory impairment found at extended-delay</i>	<i>Delay at which AF first found</i>
Martin et al. (1991)	21	31	Post operative	Left & right	TLE	IQ ↓	Verbal	recall	No	No	recall	24 hr
Helmstaedter et al. (1998)	55	27	45 TL lesion	Left & right	TLE	IQ ↓	Verbal & non-verbal	Recall Recognition	Verbal & non-verbal	Verbal recall & recognition	Verbal & non-verbal recall	1 wk
Blake et al. (2000).	21	34	5/14 HS	Left & right	14 TLE & 7 other	No	Verbal	Recall recognition	No	No	recall & recognition	8 wk
Manes et al. (2005)	7	57	No	n/d	TEA	No	Verbal & non-verbal	Recall Recognition	Non-verbal	Non-verbal recall	Verbal recall & recognition	6 wk
Mameniskiene et al. (2006)	70	33	11 TL	n/d	TLE	IQ ↓	Verbal & non-verbal	Recall	Verbal & non-verbal	Verbal & non-verbal recall	Non-verbal recall at floor Verbal & non-verbal recall	4 wk
Butler et al. (2007)	24	68	No	n/d	TEA	No	Verbal & non-verbal	Recall	No	Verbal recall	Verbal & non-verbal recall	1 wk

Key: AF= accelerated forgetting; TL = temporal lobe; HS= hippocampal sclerosis; TEA= transient epileptic amnesia

Method

Participants

All children aged between six and 16 who attended the epilepsy clinic at the Royal Hospital for Sick Children in Edinburgh and who had an established diagnosis of IGE were invited to participate. The diagnoses were confirmed by a consultant paediatric neurologist according to the International League Against Epilepsy criteria (ILAE, 2004).

Exclusion criteria for the IGE group were as follows: 1) history of psychiatric disorder, 2) history of neurological disorder other than epilepsy, 3) English not first language, 4) history of head injury, 5) global learning disability with a Full scale IQ less than 70, or 6) medically diagnosed developmental delay. The same exclusion criteria were also applied to the control group. Controls with a family history of epilepsy were excluded. These exclusion criteria were set to ensure that any findings of memory differences between the two groups were solely due to epilepsy and not influenced by other factors that might negatively affect memory functioning.

Twenty-one children with IGE consented to participate in the study, although four were subsequently excluded (three because they failed to reach the 90% learning criterion for the Stories subtest and one because of co-morbid attention deficit hyperactivity disorder). Three children were lost to follow-up (three failed to attend the final testing session). This left 14 children aged between 7 and 16 years in the IGE group.¹

Seventeen control group participants were recruited via one local primary and one local secondary school via letters to their parents. Two controls were subsequently excluded (one had had a head injury and one had a positive family history of epilepsy). This left 15 children aged between 9 and 15 years in the control group.²

The small sample size meant that it was not possible to match the controls and IGE participants for IQ and age on a pair-wise basis as originally intended. Independent sample *t*-tests revealed no significant age difference between children with IGE ($M= 12.1$, $SD=2.6$) and controls ($M= 11.6$, $SD=2.08$), $t(27) = 0.602$, $p= 0.488$. There was a significant IQ difference

¹ Two patients were tested by Katie Williams, 14 patients were tested by myself, and the remaining three were tested jointly.

² Two controls were tested by Katie Williams, 10 controls were tested by myself, and the remaining three were tested jointly.

between groups (IGE: $M=94.57$, $SD=13.52$; controls: $M=105.33$, $SD=13.29$; $t(27)=-2.16$, $p=0.04$) so in order to match the groups for IQ the data for controls and patients with IQ's 1.5 standard deviations below the control group's mean IQ was removed. This left 10 children remaining in the IGE group and 12 in the control group. Removing the data for these children meant that there was no longer a significant difference in IQ between groups (IGE: $M=100.9$, $SD=10.08$; controls: $M=103.3$ $SD=9.22$; $t(20)=-0.591$, $p=0.561$) and the lack of a significant age difference remained (IGE: $M=11.8$, $SD=2.54$; controls: $M=11.6$, $SD=1.99$); $t(20)=0.254$, $p=0.802$). The clinical characteristics of the IGE group are shown in Table 3.

Table 3
Clinical characteristics of IGE group (n=10)

Syndromal diagnosis	
Juvenile absence epilepsy	4 (40) ^a
General tonic-clonic seizure only	5 (20)
Unclassified IGE	1 (10)
Epilepsy status	
Active	8 (80)
Remitted	2 (20)
Current seizure frequency ^b	
None in last 2 years (remitted)	2 (20)
Daily	1 (10)
1 or 2 per week	1 (10)
Fewer than 1 per month	3 (30)
Current number of antiepileptic drugs	
0	3 (30)
1	7 (70)
Antiepileptic drug prescribed ^c	
Sodium valporate	1 (10)
Levetriacetam	2 (20)
Ethosuxamide	1 (10)
none	3 (30)

^a Results are expressed as n (%)

^b information missing for 3 participants

^c information missing for 3 participants

Procedure and measures

The following section describes the tests that participants were asked to complete. The tests were comprised of paper-and-pencil tasks. Participants completed the tests in three 1-hour sessions. Each session was separated by an interval of one week. Children with IGE were

tested either in their homes or in the Psychology Department at the University of Edinburgh. Controls were tested at their schools.

Assessment procedures: Standard

Wechsler Intelligence Scale for Children IV (WISC-IV, Weschler, 2004). The WISC-IV is a measure of intellectual ability which generates a Full Scale IQ (FSIQ) as well as composite scores of verbal comprehension, perceptual reasoning, processing speed and working memory. The ten core subtests from the WISC were administered to each participant (Block Design, Similarities, Digit Span, Picture Concepts, Coding, Vocabulary, Letter-Number Sequencing, Matrix Reasoning, Comprehension and Symbol Search). The tests were administered and scored according to the manual's instructions.

Information about epilepsy/seizure variables, medication, school progress and functional memory difficulties was collected from IGE participants and their parents/guardians.

Assessment of long-term memory retention

Children's Memory Scale (CMS, Cohen, 1997):

The Stories and Dot-Locations subtests of the CMS were used to assess verbal and non-verbal memory.

Stories

Participants were required to learn two short stories to a level of 90% accuracy (learning criterion). This learning criterion is the same as that set by Davidson et al. (2007). The stories were administered and scored according to the test manual instructions. There are three versions of this test, the one used depended on the age of the child (see Appendix 1). The test was administered to participants at least twice. The stories were read to the participant who then had to repeat them verbatim to the examiner. The stories were read in the same order to all participants. They had to achieve the learning criterion for each story within a maximum of 10 consecutive trials, those who failed to do so for one or both stories were excluded from the study.

Dot-Locations

Participants were required to learn one pictorial array of dots to a level of 83% accuracy (learning criterion). They had to successfully recall the array of dots over a minimum of two consecutive trials to achieve this. This learning criterion is the same as that set by Davidson et al. (2007). There are two versions of this test, the one administered depended on the age of the child (see Appendix 2). The learning criterion allowed for one error in each version of the test. For each trial the pictorial array of dots was presented to Participants for five seconds, following this it was hidden from view. Participants then had to place blue counters on a grid in exactly the same places that they had seen them in the pictorial array. They had to achieve the learning criterion within a maximum of 10 consecutive trials and those who failed to do so were excluded from the study.

Assessment of memory retention for Stories and Dot Location tests.

Delayed recall was measured for the Stories and Dot-Locations tests 30-minutes after the last learning trial, and then again one week later. Recognition memory was also measured following recall of the stories at both these time intervals. Each story was scored according to the test manual. The recall scores for both stories were combined as were the recognition scores to give an overall measurement of recall and recognition respectively. Because the age appropriate versions of the subtests give different maximum total scores, the delayed recall scores were converted into percentages to enable comparisons between the different versions.

Object-Locations test – an experimental measure

The Object-Locations task is an experimental measure that was piloted on 15 healthy children in a previous study by myself and a colleague (Williams, 2010). In the spatial object location task (see Figure. 1) participants were required to learn and memorise the positions of an array of 10 small toy objects (see Appendix 3 for list of objects). The toys were presented in a random spatial arrangement which had no discernable pattern on a white 60x60cm white board. Green dots marked the positions of each of the 10 objects on the board so the experimenter knew where to put them. The centre of each object (also marked by a green dot) was placed (positioned) on the corresponding green dot on the board.

Participants were asked to memorise the positions of the toy objects on the board. They were told that they would later have to recall the positions of these objects (see Appendix 4 for instructions). Participants were asked to name each object in order to encourage learning.

They were shown the board for 60 seconds and it was then removed from view. A white 60x60cm piece of paper was placed in front of the participants along with an identical set of toy objects. They were asked to place the objects in the positions where they had previously seen them. Following object location recall participants were again shown the original board complete with the objects in their original designated positions. This time and for all subsequent trials the board was shown for 30 seconds. Participants again had to recall the positions of the objects. The viewing durations were determined in the previous pilot study. While the participants were viewing the board the experimenter used a pencil to mark the recalled positions of objects on the sheet of paper where the participant had placed them.

To achieve the learning criterion for this task participants had to correctly recall the positions of seven out of the 10 objects. Participants had to successfully achieve learning criterion over a minimum of two consecutive trials. Participants were given a maximum of 10 consecutive trials to achieve the learning criterion and those who failed to do so were excluded from the study. The learning criterion and the maximum and minimum number of learning trials allowed to achieve criterion was determined based on the pilot study (Williams, 2010).

To determine accurate object placement recall a stencil was used where the centre of objects had to fall within a radius of 34mm from their original placement to be correct (see Figure. 2 for an image of the stencil). The stencil was designed in the pilot study (Williams, 2010). Delayed object location recall was tested 30-minutes after the last learning trial and then again 1-week later.

To determine the level of accuracy of participants' object placements, displacement scores were calculated. This was done by measuring the distance between the centre of each object recalled by the participant and that of its original position in millimetres.

Displacement scores were calculated for the last trial recall and recall after 30-minutes and 1-week. Overall mean displacement scores were also calculated for the array of recalled objects

Power calculation

Power for the Story and dot-locations tests was calculated using one-week recall data from the study by Davidson et al (2007) involving a sample of children with IGE and healthy controls. This study was chosen because the current study will be using an identical design. Assuming equal variance between, a normal distribution and a significance level of $p < 0.05$, we calculated that 21 children will be required for each group to achieve a power of 0.8. Power for the object-locations test was based on the data from the study by Volkl-Kernstock et al. (2006). Of the few published studies which have investigated the spatial abilities of children with epilepsy the task in their study bore the most resemblance to that of the object-locations task. Based on Volkl-Kernstock et al's (2006) data and assuming a normal distribution and equal variance between groups and a significance level of $p < 0.05$ we calculated that 8 participants were required for each group to achieve a power of 0.8.

Results

Table 3 summarizes the memory ratings and educational process variables for children with IGE. Parents reported a greater frequency of memory problems than children, with 60% stating that these problems caused some difficulties in their child's daily life. Four children felt that they had memory difficulties and one of these children felt that these problems were quite problematic in daily life. All children with IGE were attending mainstream schools, although two (20%) were receiving learning support. Six parents (60%) reported some concern about their child's school progress. None of the children had repeated a school year.

Table 3
Memory ratings and educational progress for the IGE group (n=10)

Child rating of memory problems	
No problems	6 (60) ^a
A little problematic	3 (30)
Quite problematic	1 (10)
Very problematic	0
Parent rating of child's memory problems	
No problems	4 (40)
A little problematic	4 (40)
Quite problematic	2 (20)
Very problematic	0
Repeated school year	0
Ever received learning support in school	2 (20)
Parent's rating of school progress	
No problems	6 (60)
Mildly concerned	2 (20)
Fairly concerned	2 (20)
Very concerned	0

^a Results are expressed as n (%)

All statistical analyses were conducted using SPSS for Windows. One-tailed tests were used for all analyses.

The Kolmogorov-Smirnov was used to examine the distributions of all experimental variables and revealed that none of them were normally distributed. To take into account the lack of a normal distribution logarithms of the raw scores were calculated.

The transformed data for Object recall at the 30-minute and 1-week delay were normally distributed so this data was analysed using a split-plot analysis of variance (ANOVA) with a between-participants factor of group (IGE vs. control) and a within-participants factor of delay (30-minutes vs 1-week). Following transformation the object trials data was still not normally distributed so the raw data was analysed using a Mann-Whitney U test. The α significance level was set at $p \leq 0.05$ for all the object-locations data.

None of the transformed data for the story or dot-locations variables was normally distributed so the raw data for these variables was analysed using Mann-Whitney U tests. Bonferroni corrected p -values were used for planned comparisons to account for multiple testing.

Stories test

Table 4: Descriptive statistics for performance of control and IGE groups on Stories subtest

	IGE group		Control group	
	Mean (SD)	Range	Mean (SD)	Range
Number of learning trials to criterion	4 (1.33)	2-6.5	3.66 (1.52)	2-6.5
Last learning trial (% recall)	93.75 (2.03)	91-97.5	93.2 (2.25)	90-98
30-Minute recall (% recall)	82.25 (10.28)	61.5-95	83.95 (6.94)	68-94
1-week recall (% recall)	67.95 (14.06)	47.5-90	82.29 (5.24)	73-88
% recall from 30-minutes to 1-week ^a	82.86 (15.33)	57-110	98.32 (6.11)	89-107
30-Minute recognition score (out of 30)	27.2 (2.57)	21-30	28.17 (0.93)	27-30
1-Week recognition score (out of 30)	26.5 (2.27)	22-29	28 (1.65)	25-30

^a Scores at 1-week as percentages of the corresponding scores for recall at 30-minutes

Descriptive statistics for performance on the Stories subtest are summarised in Table 4. Bonferroni corrected p -values were used for planned comparisons to account for multiple testing. An α significance level was set at $p \leq 0.008$ for the stories test (trials, 30-minute and 1-week recall, 30-minute and 1-week recognition, percentage recall difference). There were no significant group differences with respect to the number of learning trials required to reach

criterion, ($U = 50.5, p = 0.269$), 30-minute recognition ($U = 50.0, p = 0.269$), or 1-week recognition ($U = 37.0, p = 0.07$). For stories recall there was no significant group difference at the 30-minute delay ($U = 57.5, p = 0.436$) however the IGE group demonstrated significantly poorer recall at the 1-week delay ($U = 20.0, p = 0.003$).

The effect of group accounted for a large proportion of variance in 1-week recall scores ($r=0.56$) and a moderate proportion of the variance in the in the 1-week recognition scores ($r=0.33$). The effect of group was small for the number of learning trials to reach criterion ($r=0.13$), 30-minute recognition scores ($r=0.14$) and 30-minute recall scores ($r=0.035$). Story recall scores are illustrated graphically in Figure. 3.

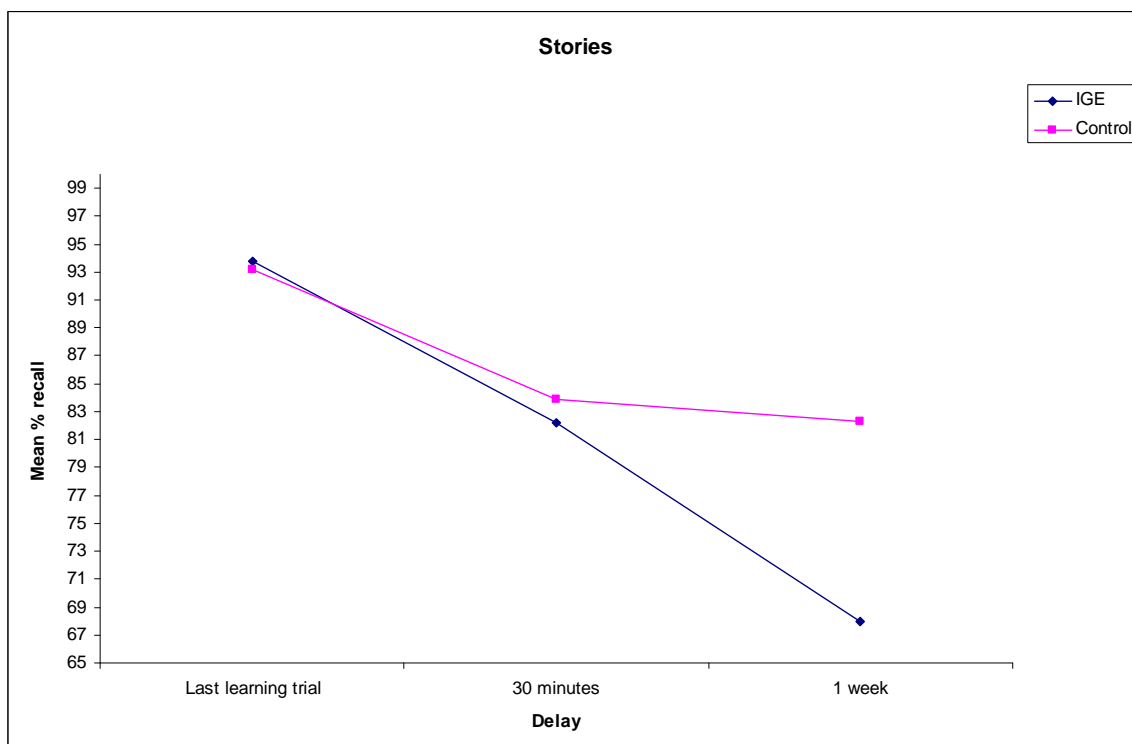


Fig. 3. Story recall scores for IGE and control groups across delays

To determine the rate of forgetting between the groups the difference in story recall between 30-minutes and 1-week was calculated for each participant using the following calculation:

$$= \frac{\text{1-week recall score}}{\text{30-minute recall score}} \times 100\%$$

This analysis revealed that the rate of forgetting was significantly faster for IGE group compared to controls ($U = 23.00, p = 0.007$). The effect of group accounted for a large proportion of variance in the percentage of story recalled between the 30-minute and 1-week delay ($r=0.52$).

Dot-Locations test

Table 5: Descriptive statistics for performance of control and IGE groups on Dot locations subtest

	IGE group		Control group	
	Mean (SD)	Range	Mean (SD)	Range
Number of learning trials to criterion	2.9 (1.92)	2-8	2.08 (0.28)	2-3
Last learning trial (% recall)	97.6 (5.06)	88-100	95.96 (5.97)	88-100
30-Minute recall (% recall)	90.05 (11.47)	75-100	95.92 (6.03)	88-100
1-week recall (% recall)	82.60 (20.54)	38-100	82.50 (19.38)	38-100

Descriptive statistics for performance on the Dot-locations subtest are summarized in Table 5. Bonferroni corrected p -values were used for planned comparisons to account for multiple testing. An α significance level was set at of $p \leq 0.016$ was set for the dot-locations test (trials, 30-minute and 1-week recall). The IGE group did not differ significantly controls with respect to the number of learning trials required to achieve criterion ($U = 46.0, p = 0.190$) 30-minute recall ($U = 44.0, p = 0.157$) or 1-week recall ($U = 59.0, p = 0.487$). Furthermore the effect of group only accounted for a small proportion of the variance in number of trials to achieve criterion ($r=0.29$), 30-minute recall ($r=0.25$) and 1-week recall. ($r=0.01$). Dot-location recall scores are illustrated graphically in Figure. 4.

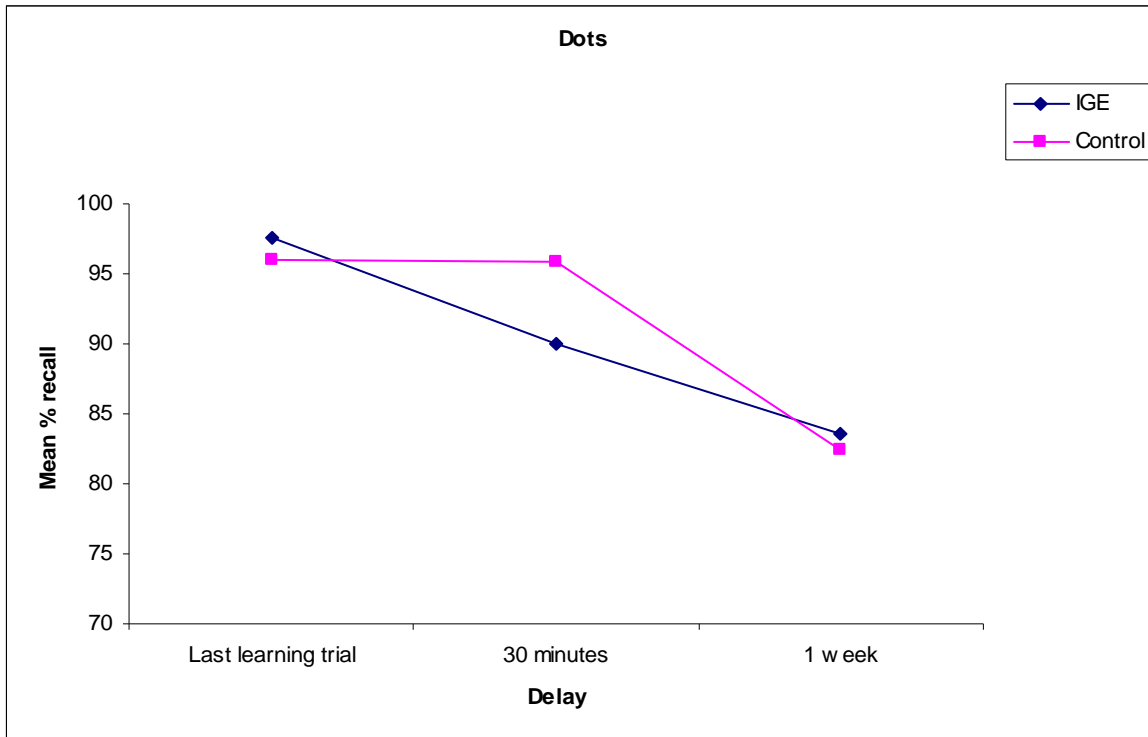


Fig. 4. Dot-location recall scores for IGE and control groups across delays

Object-Locations test

Table 6: Descriptive statistics for performance of control and IGE groups on Object locations subtest

	IGE group		Control group	
	Mean (SD)	Range	Mean (SD)	Range
Number of learning trials to criterion	3.10 (1.37)	2-6	2.83 (1.52)	2-7
Last learning trial (Displacement score in mm)	34.49 (8.52)	21-53	31.58 (9.01)	21-53
30-Minute recall (Displacement score in mm)	40.7 (14.46)	25-77	38.17 (12.23)	18-58
1-week recall (Displacement score in mm)	77.45 (59.28)	26-200	52.33 (27.65)	26-125

Descriptive statistics for performance on the Object-location test are summarized in Table 6.

Mann-Whitney U tests revealed no significant differences between children with IGE and controls for the number of learning trials required to achieve criterion

A split-plot ANOVA revealed that while there was a significant main effect of delay ($F(1, 20) = 9.01, p=0.007$) there was no significant main effect of group ($F(1, 20) = 0.885 p=0.358$) and no significant group x delay interaction ($F(1, 20) = 0.574, p=0.458$). Using η^2 as a measure of effect size 31% of the variance was attributable to the effect of delay, 2.8% to the effect of group, and 4.2% to the group x delay interaction. Object-location displacement scores are illustrated graphically in Figure.5.

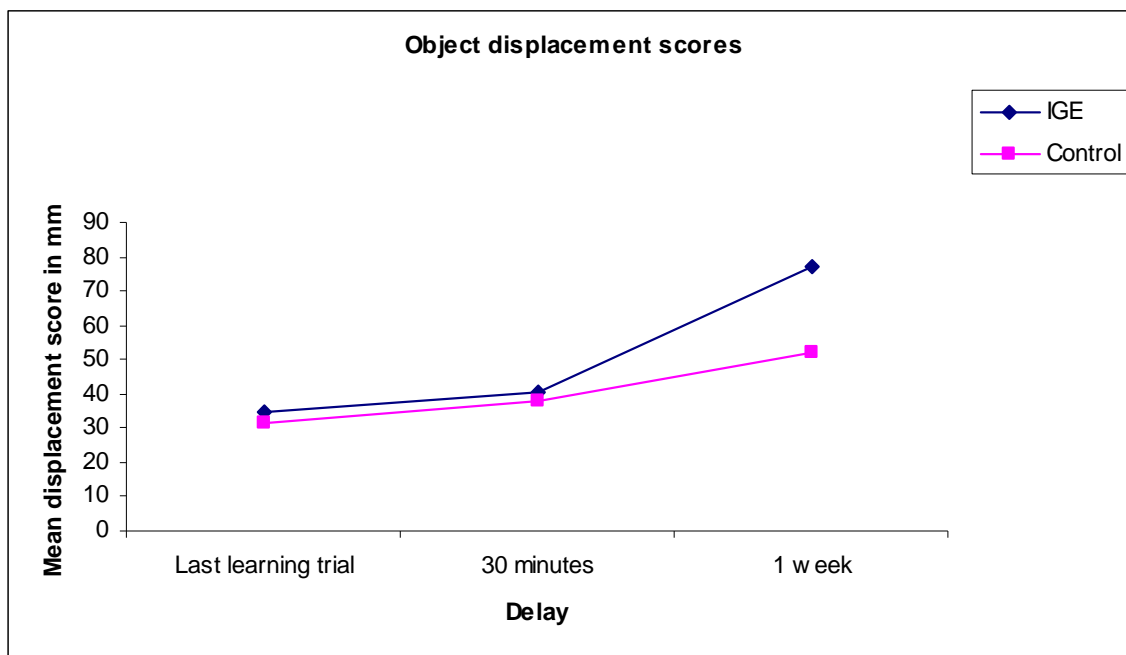


Fig. 5. Object-location displacement scores for IGE and control groups across delays.

Discussion

The aim of the current study was to investigate the memory retention of verbal and non-verbal material in children with IGE over a 1-week delay and to compare it with that of healthy controls. It was hypothesised that the IGE group's initial learning efficiency for verbal material would be impaired relative to controls, but that their level of initial learning of non-verbal materials would be comparable to controls. It was also hypothesised that children with IGE and controls would have comparable recall and recognition of verbal and non-verbal material at the 30-minute delay. At the 1-week delay it was hypothesised that, compared to controls, children with IGE would demonstrate AF for recall of verbal material. The recognition of verbal material, and the recall of non-verbal material, was hypothesised to be comparable for children with IGE and controls at the 1-week delay.

The results from the Dot-Locations test show that, as predicted, children with IGE did not differ significantly from controls in the number of learning trials they required to reach criterion, or in their recall at the 30-minute or 1-week delays. These findings, which replicate those of Davidson et al. (2007), show that children with IGE learn and forget non-verbal information at a comparable rate to healthy children and therefore indicate that children with IGE do not have AF for non-verbal material. It is important to note however that the 'forced-choice' response method of the Dot-Locations test makes it difficult to discriminate whether or not the recall ability of children with IGE differ from that of controls, as the total amount of possible variance in scores is limited (Davidson et al, 2007). Accordingly some of the results of this test may have been due to children guessing and not reflect whether or not children with IGE have a verbal memory impairment

The results from the Object-Locations test show that, as predicted, children with IGE did not differ significantly from controls in the number of learning trials they required to reach criterion, or in their recall of object-positions at the 30-minute or 1-week delays. The finding that both groups performed comparably across delays indicates that children with IGE do not have AF for non-verbal materials. The finding that the performance of children with IGE was not significantly different from that of controls for the Object-Locations test indicates that the lack of between group differences for the dot-locations task was not due to its 'forced-choice' response method.

The results from the Stories test showed that contrary to expectations children with IGE did not require significantly more trials than controls to reach learning criterion. This indicates that children with IGE did not exhibit poorer initial learning efficiency than controls. The smaller sample sizes in the current study, as well as the fact that it was not possible to match the groups on a pair-wise basis for age and IQ may account for this result. However, Jambaque et al. (2003) also found normal initial story learning in children with IGE. Furthermore several TLE studies have also found AF of verbal material in patients who learnt normally (Martin et al., 1991; Manes et al., 2005; Butler et al., 2007; Blake et al., 2000). Butler et al. (2008b) stated that AF is demonstrated most convincingly in patients with epilepsy who show normal learning and recall at a 30-minute delay but who are significantly impaired at extended delays.

As hypothesised, the story recall of both groups was comparable at the 30-minute delay, and the children with IGE recalled significantly less than controls after a 1-week delay. Because the story data was not normally distributed, it was not possible to examine the group by delay interaction. Analysis of the percentage difference in story recall from 30-minutes to 1-week revealed that, compared to controls, children with IGE demonstrated AF for story recall.

As expected the children with IGE did not differ significantly from controls in their story recognition at the 30-minute or 1-week delays. This finding indicates that difficulty in retrieving successfully stored verbal information was the cause of the IGE group's poorer story recall at one-week, rather than impaired retention. This suggests that the accelerated rate of forgetting found in the children with IGE was not due to a failure of memory consolidation.

The finding that children with IGE do not differ significantly from controls in their story recognition across delays replicates the results of Davidson et al. (2007). The verbal memory impairments found in children with IGE appear to be qualitatively different from those found in the majority of TLE studies, where the patients had both severe recall and recognition impairments (e.g. Blake et al., 2000; Manes et al., 2005, Helmstaedter et al., 1998). However several TLE studies have found normal verbal recognition performance in patients in the context of impaired delayed recall (Martin et al., 1991; Herman, Wyler, Richey & Rea, 1987). Herman et al. (1987) proposed that the normal recognition performance in the context of poor recall reflects impaired retrieval mechanisms. Davidson et al. (2007) suggested that children with IGE form poorer quality memory traces than healthy children, and that these poor quality

traces result in the threshold for retrieval failure being met sooner than for good quality memory traces. It is possible that retroactive interference from information which was encoded during the delay (Davidson et al., 2007; Wixted, 2004) and/or the disruptive effects of epileptiform activity, could have resulted in the threshold for retrieval failure being met sooner and account for the retrieval difficulties of children with IGE.

Martin et al. (1991) proposed that in patients with epilepsy, verbal material is stored in a degraded form rather than being lost from memory. If this is the case it explains why a recognition paradigm has a beneficial effect on performance (Martin et al., 1991). It is possible that the mechanisms underlying the AF of patients who have impaired recall and recognition may be different compared to those who only have impaired recall (Butler et al., 2008b).

The finding that children with IGE demonstrated AF for recall, but not recognition, of verbal material is not consistent with the prevailing interpretations of memory consolidation theory. These interpretations propose that failed consolidation leads to failed long-term memory storage in the neocortex (Dudai, 2004). Evidence from research with amnesic patients and with animals that have been given amnesic agents also poses problems for these interpretations of consolidation theory. Amnesic ‘consolidation blocking’ agents administered to animals shortly after learning of a conditioned response leads to retrograde amnesia (RA) for that response (Ricco, Millin & Gisquet_Verrier, 2003). However research has shown that this RA can be reversed by re-exposing the animals to the conditioned stimulus (Ricco et al., 2003). This suggests that, rather than preventing memory storage, these agents led to retrieval deficits (Dudai, 2004). Furthermore, amnesic patients who have been unable to recall learnt information are able to retrieve this information when given the appropriate retrieval cues (Warrington & Weiskrantz, 1970).

Ricco et al. (2003) propose that a broader view of consolidation is needed whereby it not only consists of the stabilization of memory traces, but also the maturation of these into a form that is suitable for future retrieval. The findings of the current study could be viewed as consistent with this broader view of memory consolidation (Davidson et al. 2007).

The mechanisms underlying the AF for verbal material found in children with IGE in the current study remain unclear. However the presumed absence of underlying brain pathology

in IGE means that the AF found in this group could not be attributed to brain damage. Furthermore their AF for story recall could not be attributed to encoding difficulties as their level of initial learning was comparable to that of controls. There was a low incidence of reported overt seizures in the IGE group during the delay interval. However the disruptive role of epileptiform activity on memory consolidation processes cannot be ruled out as the children may have had sub-clinical seizures or seizures while they slept.

AEDs were being taken by seven out of the 10 children with IGE. Research has shown that, while the AEDs taken by the children in this study (Sodium Valporate, Ethosuxamide, Levetiracetam) tend to have a favourable cognitive profile, as with all AEDs they do have some cognitive side effects and can result in mild psychomotor slowing (Aldenkamp et al., 2003; Siren et al., 2007; Gambardella, Labate, Colosimo, Ambrosio, Quattrone, 2008). As such, the possibility that the AEDs played a role in the children's retrieval difficulties at the one-week delay cannot be ruled out. Further research is needed to determine the impact of AEDs on memory consolidation in children with IGE. The best method to do this would be to assess the children's memory retention before and after starting treatment with AEDs.

Although both groups were matched for intellectual ability, two of the children with IGE were receiving learning support. Two-thirds of the IGE children's parents reported that their children had memory problems which caused difficulties in everyday life. Of these parents more than half expressed concern about their child's school progress. These reports are consistent with evidence showing that children with IGE may exhibit mild cognitive impairments which can potentially have a detrimental effect on their educational attainment and lead to poor psychosocial outcomes (e.g. Bailet & Turk., 2000; Sturniolo & Galletti, 1994; Davidson et al., 2007).

Evidence that children with IGE suffer from AF has now been found in two studies (including the current study). Given the small sample size in the current study, and that the findings for initial learning ability were not consistent with those of Davidson et al. (2007) a larger multi-site study is needed to determine whether or not children have encoding difficulties. The finding of AF for verbal material in children with IGE has important educational and clinical implications. At school children with IGE need to be given the appropriate help to enable them to retrieve successfully stored memories. As examinations form part of the assessment process at school, Williams et al. (2001) suggested that children with epilepsy should be given

assessments in a recognition format, for example through multiple-choice questions, in order to help them recall successfully consolidated information.

As standard clinical assessments typically test memory at a 30-minute delay, the finding that children with IGE perform normally at this delay yet later exhibit AF means that significant memory impairments in this group may fail to be detected. Future research should therefore aim to develop standardised assessments to assess memory over extended delays. To do so rigorous normative data for rates of forgetting needs to be collected. To determine the time-line of forgetting in children with IGE it would be interesting to test children over a range of delays, both shorter and longer than used in the current study. Other future research with children with IGE could investigate the relationship between AF and seizure frequency using video EEG monitoring, and the relationship between subjective complaints of AF by children with IGE and objective measurement of their memory retention at extended delays.

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Appendix 1: Age appropriate versions of the Stories test

Story A: Age 5 - 8 yrs

A mother cat had five brown and white kittens. One morning she took the kittens for a walk. The kittens looked for someone to play with. They found some butterflies in a field. A dog came and barked at them. The mother cat did not like the dog. The cat hissed at the dog and the dog ran away.

Story B: Age 5 - 8 yrs

On a sunny day in June, four boys built a clubhouse near a stream in the woods. The boys cut down dead trees and used scrap wood. They built a table and found some old chairs to sit on. When the boys were finished working, their parents took them for ice cream cones.

Story C: Age 9 - 12 yrs

Lisa and Melissa were walking past the grocery store on their way to school, when two men ran out with a money bag. The men jumped into a brown car and drove away very fast. When the police came, Lisa told them the colour of the car. Melissa told the police that one man was short and the other one was tall. Because the girls were in the right place at the right time, the men were caught one month later and the money was returned.

Story D: Age 9 - 12 yrs

Jessica had taken the lifeguard class at school. One Saturday morning in March, she was walking by Bear lake and saw two men fishing in a motorboat. The man steering the boat did not see a warning marker and hit a rock that was underwater. The boat began to sink. Jessica

jumped in and helped the men Swim to shore. After hearing the story, the park ranger offered Jessica a summer job as a lifeguard.

Story E: Age 13 - 16 yrs

Over two hundred years ago, the first hot air balloon was built in England. The balloon was made of paper covered with cloth to make it stronger. A large basket made of straw and weighing 20 pounds was attached to it with cables. A long rope anchored the balloon to the ground. On the first flight, the pilot was in the air for 15 minutes. Later he took a friend, and they stayed up for 1 hour. They travelled 100 miles before landing in a treetop on the side of a hill.

Story F: Age 13 - 16 yrs

In the 1700s, large herds of buffalo roamed the plains of America. Many Native American tribes, like the Sioux and the Blackfoot, followed the herds to survive. They hunted on horseback, killing the buffalo with bows and arrows. They used the meat for food, the bones for tools, and the skins for clothing. During the 1800s, the buffalo were killed in large numbers for sport and money by settlers from the East. Soon the buffalo had vanished, and the Native Americans lost their largest food source.

Appendix 2: Age appropriate versions of the Dot-Locations test

Age 5 – 8 yrs

●		●	
●			●
	●	●	

Age 9 – 16 years

●		●	●
	●	●	
●			●
		●	

Appendix 3: Toy objects used in Object-Locations test

- Frog
- Key
- Banana
- Strawberry
- Man
- Panda
- Car
- Duck
- Dice
- Watch

Appendix 4: Instructions for the Object-locations test (Williams, 2010)

Children are told:

“I am going to show you a board on which there are 10 toy objects. I would like you to look at each object and tell me what it is. Try to remember where each of the objects is placed because later on, I will ask you to put an identical set of objects onto a board in the same locations that you will have seen them before.”

After a minute the board is removed from view and a new board covered by a blank sheet of paper is placed in front of the children. They are given an identical set of toy objects. The children are then given the following instructions:

“Please put these objects in the same positions that you just saw them”

Once the child has finished placing the objects, they are again presented with the original board complete with the original objects and told:

“This is exactly the same board that you saw before. Have a good look at it and try to remember where each of the objects is placed”.

Each child is given a minimum of two learning trials and the procedure is repeated until the child reaches the required learning criterion. The maximum number of trials given is 10.