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Have we forgotten about forgetting? A critical review of ‘accelerated long-term forgetting’ in temporal lobe epilepsy.

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Abstract

~~The study of~~ Forgetting has been researched for over a century. This literature highlighted how forgetting rates can vary dependent on factors in the design and method. Recent interest in forgetting revived with evidence suggesting that seizures experienced almost immediately after matched learning could accelerate forgetting. This was followed by a growth in forgetting studies in patients with temporal lobe epilepsy, including a subset of those with transient epileptic amnesia. These patients have been described as expressing concerns about memory, yet often perform within ‘normal’ ranges on standard neuropsychological memory assessments. It was argued that such patients were experiencing a phenomenon termed ‘accelerated long-term forgetting’: apparently normal learning and initial retention with abnormal forgetting over days to weeks after learning. In this review, we critically evaluate aspects of this definition, namely whether learning and initial retention is, in fact, ‘normal’ at first, and further what this means in relation to ‘when’ abnormal forgetting starts. We propose a shift in the understanding of accelerated forgetting in temporal lobe epilepsy from an emphasis on late-onset forgetting to greater focus on early-onset, progressively greater forgetting. We argue that most evidence from studies to date could be conceptualized within the latter framework, with differences in forgetting patterns reflective of a continuum of severity and/or sensitivity.

Keywords: accelerated long-term forgetting; forgetting; temporal lobe epilepsy; transient epileptic amnesia; memory consolidation

1. Introduction

Forgetting (and its investigation) did not begin in the last decade. On the basis of somewhat obsessional self-experimentation, Ebbinghaus (1885) plotted forgetting curves of his own remembering over several days and found an inverse exponential rate of decline: the fastest forgetting occurred in the initial few minutes following learning. Subsequent research on forgetting, whether in healthy participants or patients, and whether looking over the ‘short-term’ or ‘long-term’, has generally confirmed a similar pattern (e.g. Baddeley & Warrington, 1970; Butters & Cermak, 1980, 1986; Kopelman & Stanhope, 1997).

Research in the 1970s and 1980s examined how the manipulation of exposure time and/or task difficulty affected the initial level of learning and the subsequent rate of forgetting. For example, Slamecka and McElree (1983) showed that the initial level of learning **in healthy participants** affected the intercept across a range of tasks (free recall, cued recall, category recall, etc.), but not the subsequent forgetting rate. Similarly, Huppert and Piercy (1977, 1978) demonstrated similar phenomena in amnesia. In both control participants and Korsakoff patients, incremental learning increased in proportion to the number of exposures to the learned material, and the Korsakoff patients showed a parallel learning curve, albeit from a lower baseline than the controls (compare: Kopelman & Morton, 2015). Likewise, when Huppert and Piercy (1977) increased the total exposure time of presented items, they found that there was an improved performance on Yes-No recognition testing in both healthy participants and Korsakoff patients, the latter performing at a lower level than the controls at each exposure duration. Moreover, when the rate of forgetting was compared over the course of a week, after matching performance at 10 minutes, Huppert and Piercy (1978) showed equivalent rates of forgetting between the two groups. In other words, it was initial learning, rather than forgetting rate, which was the primary problem in amnesia. Other authors replicated this finding when testing recognition memory, **finding no**

differences in forgetting rates across varying aetiologies or lesion sites (Kopelman, 1985; McKee & Squire, 1992).

An important, but relatively unexamined, finding from these studies was the intra-group variability in forgetting rates across individuals. Kopelman (1985) plotted correct recognition scores at 24 hours and seven days as a percentage of correct recognition at 10 minutes on the Huppert-Piercy task, finding considerable variability in Korsakoff patients. Some patients forgot relatively little over the course of a week, whereas others appeared to show excessive forgetting. Similar patterns were found in control participants and in Alzheimer patients. In the control and Korsakoff groups, some of this variability appeared attributable to age: forgetting rates at 24 hours appeared to correlate **inversely** with age, the oldest participants forgetting fastest.

Freed, Corkin, and Cohen (1987) examined intra-individual variability in forgetting rates. Huppert and Piercy (1979) had claimed that, whereas Korsakoff patients (with diencephalic pathology) had shown a normal rate of forgetting after matching 10-minute recognition memory scores, HM (with bilateral temporal lobe pathology) showed accelerated forgetting over one week, following a similar matching procedure. Freed et al. (1987) went on to compare HM with seven healthy controls on both Yes-No recognition memory and forced-choice recognition memory. On both tasks, HM was given four trials on equivalent sets of stimuli, and his performance was compared with the range of scores obtained by the seven control participants. On Yes-No recognition memory, HM performed better than any of the controls on two of the trials, and worse than the controls on the other two trials. Similarly, on forced-choice recognition memory, HM performed much better than the controls on one trial, within the range of control performances on a second trial, and as badly as the worst controls on the remaining two trials.

An important caveat needs to be made related to these findings: different patterns of forgetting occurred when retention was tested by recognition versus recall memory. In contrast to recognition memory findings (Kopelman, 1985; Kopelman & Stanhope, 1997), when tested on recall memory tasks, patients with **temporal lobe, diencephalic, and Alzheimer pathology** forgot faster than healthy participants, with most of the forgetting occurring between approximately 25 seconds and 20 minutes (Christensen, Kopelman, Stanhope, Lorentz, & Owen, 1998; Frisk & Milner, 1990; Isaac & Mayes, 1999a, 1999b; Kopelman & Stanhope, 1997). **When different aetiologies/lesion groups were compared, there were no significant differences between them (Green & Kopelman, 2002; Kopelman & Stanhope, 1997).** Various hypotheses exist as to why forgetting may be faster for recall memory tasks compared to recognition. One possibility is that this faster forgetting on recall memory tasks may reflect the more rapid decay of detail/contextual/relational information, compared with the familiarity responses underlying recognition memory (whether the latter is mediated by perirhinal structures, residual tissue in the hippocampi, or ‘extended hippocampal’ circuits) (Green & Kopelman, 2002; Sadeh, Ozubko, Winocur, & Moscovitch, 2014).¹ A second possibility is that recall and recognition memory could be differentially affected by decay versus interference of learned material dependent on their reliance on recollection versus familiarity respectively (Sadeh et al., 2014; Sadeh, Ozubko, Winocur, & Moscovitch, 2016). Thirdly, recognition tasks include target information presented as a cue to retrieval, whereas this is not the case in recall tasks. The differences in forgetting rates between these tasks might possibly be the result of differences in task difficulty.

¹ The Slamecka and McElree (1983) findings might argue against this but it should be noted they examined only healthy participants’ rates of forgetting

In summary, the forgetting literature has long highlighted the difficulty in measuring forgetting rates. Initial starting points need to be ‘matched’ across groups in order to measure subsequent forgetting (Huppert & Piercy, 1977, 1978). In doing this, it is essential to avoid initial ceiling effects and floor effects at the longest delays. Interpolated mental activity between learning and subsequent trials may be crucial, and there might be re-consolidation of material at retrieval (Isaac & Mayes, 1999a, 1999b; **Jansari, Davis, McGibbon, Firminger, & Kapur, 2010**; Kopelman & Stanhope, 1997). The literature has revealed that there can be differences in findings where testing is by recall or recognition (Christensen et al., 1998; Isaac & Mayes, 1999a, 1999b; Kopelman & Stanhope, 1997). Further, there is considerable variability in performance both within groups (Kopelman, 1985) and within individuals (Freed et al., 1987), which may be more important than (or disguise) differences between **patient** groups. All this makes forgetting a difficult topic to investigate, especially at very prolonged delays.

2. The rise of ‘accelerated long-term forgetting’

Evidence derived from studies of electro-convulsive therapy (Lewis & Kopelman, 1998; Squire, 1981) and from patients in post-traumatic amnesia following head injury (Levin, High, & Eisenberg, 1988), found that cerebral seizures or confusional states, occurring fairly immediately after learning, might disrupt consolidation processes and result in accelerated forgetting, even on tests of recognition memory. Subsequent case reports have suggested that epileptic seizures in temporal lobe epilepsy (TLE) might also result in accelerated forgetting (Kapur et al., 1997; Lucchelli & Spinnler, 1998; O'Connor, Sieggreen, Ahern, Schomer, & Mesulam, 1997).

Findings of accelerated forgetting in these case reports led the authors to hypothesise about possible mechanisms involved in disrupting memory retention. It was claimed that

these findings provided evidence for there being an extended timeframe over which newly encoded memories remained vulnerable to disruption (De Renzi & Lucchelli, 1993; Kapur et al., 1997; O'Connor et al., 1997), consistent with consolidation theory (Alvarez & Squire, 1994; Milner, 1967; Squire & Cohen, 1984). Implicit within versions of this hypothesis was the view that these patients were able to encode and retain new material during the initial stages of consolidation taking place within the medial temporal lobe, but that secondary stabilization of the memory engram was affected in some way, through disruption in pathways to, or storage in, the neocortex.

Since these case reports, there has been a rapid growth in group investigations of accelerated forgetting in TLE. Many investigations have focused upon the diagnosis of transient epileptic amnesia (TEA) (Kapur, 1990), a subtype of TLE, in part because these patients often complain of rapid forgetting (Butler & Zeman, 2008). Many have reported to find evidence that these patients experienced accelerated forgetting over delays of days to weeks, which were not detectable within the 'standard' delay of 30 minutes, often used in neuropsychological memory tests (e.g. Blake, Wroe, Breen, & McCarthy, 2000; Manes, Graham, Zeman, de Luján Calcagno, & Hodges, 2005; Martin et al., 1991). These findings have commonly been argued to support the notion that consolidation is disrupted during the later stages of processing, i.e. such forgetting is reflective of a "delayed onset amnesia" (Manes et al., 2005, p. 1390).

These conclusions were consistent with the suggestions made in earlier case reports (De Renzi & Lucchelli, 1993; Kapur et al., 1997): that late consolidation processes were disrupted in findings of accelerated forgetting. Although they themselves did not coin the term, Butler, Mulhert, and Zeman (2010) suggested that 'accelerated long-term forgetting' was perhaps the most suitable phrase to describe such findings. This was partly to distinguish such a pattern of forgetting from that seen in the amnesic syndrome, and also to recognise

that differing mechanisms might be contributing to this type of forgetting when compared with those implicated in rapid early forgetting.

Considering the mechanisms of consolidation, Dudai (2004) attempted to reconcile human and animal studies of the neurobiology of memory consolidation by distinguishing between synaptic and systems consolidation. Synaptic (early) processes were proposed as occurring minutes to hours after learning, whilst systems (late) consolidation occurred over a much longer timeframe, extending up to years after initial acquisition. Importantly, Dudai (2004) made the explicit qualification that the start point and/or the timeframe over which these different processes occurred was not clearly defined.

Over 40 papers have now used the phrase ‘accelerated long-term forgetting’, with 18 of them using it in their title. The term is now often shortened to the acronym ‘ALF’, and it has been defined as “a novel pattern of forgetting...in which information may apparently be learnt and remembered normally at first, but is forgotten at an accelerated rate over subsequent days to weeks” (Butler et al., 2010, p. 211). However, taking account of what we know about forgetting from the earlier lesion literature, there are several reasons to question the validity of this statement.

3. Challenging the ‘long-term’ of ‘accelerated long-term forgetting’

Many authorities accept the definition of ‘ALF’ given above. However, there are concerns with this definition, which involve (1) the supposition that this information is learnt and remembered ‘normally’ at first, following which (2) consolidation of the memory engram is disrupted (thereby quickening the rate of forgetting) only at a particular time-point thereafter. As already noted, this has led many to conclude that this pattern of forgetting is indicative of a disruption to late memory consolidation (e.g. Blake et al., 2000; Butler et al., 2010; Hoefelz, Dewar, Della Sala, Zeman, & Butler, 2013; Manes et al., 2005), thereby

neglecting the possible role of a subtle acquisition disorder and/or disruption of early consolidation in such forgetting.

3.1 Criticisms of design and method

To delineate the role of acquisition or early consolidation in later forgetting, well controlled experimental design is essential, as discussed in the Introduction. Despite this, forgetting studies in the epilepsy literature have not always considered those design factors known to influence forgetting. Elliott, Isaac, and Mulhert (2014) explored the extent to which investigations into forgetting in this population: (1) matched epilepsy and control groups for age and intellectual ability; (2) measured both verbal and visual memory; (3) measured both recall and recognition of material; (4) avoided ceiling and floor effects; (5) avoided rehearsal of material between time points; (6) tested immediate recall after a short delay filled with a distractor task; (7) attempted to match learning of material; and (8) equated initial learning of material.

Elliott et al. (2014) reported that the *only* epilepsy study, out of 33 examined, that met these criteria, was by Mulhert et al. (2011), and only when comparing the group of participants with TLE to a subset of the control participants who were age- and IQ-matched. Interestingly, Mulhert et al.'s (2011) patient group performed significantly worse on two standardized verbal memory tests. They also ~~showed~~ **reported** evidence of accelerated forgetting on three of their six experimental measures, two of which were visual recall tasks and one a verbal recognition task. The statistical outcomes of these findings were similar across measures: no significant group by delay interactions were observed between the first two time points (40 seconds to 30 minutes). **However,** ~~S~~significant interaction effects were observed between the two later time points (30 minutes to 3 weeks) on the three tasks, albeit with subtle differences. On the two visual recall measures, the patient group forgot the

material faster after the 30-minute delay, whereas, on story recognition, the patient group forgot the material progressively faster than the control group from learning onwards. **While Mulhert et al. (2011) did not directly compare recall versus recognition forgetting in their verbal and visual memory measures, they did find evidence of accelerated forgetting on both recall and recognition tasks.** This contrasts with the lesion ~~forgetting~~ studies **on forgetting**, described in the Introduction, which found accelerated forgetting was associated with recall measures as opposed to recognition. ~~Mulhert et al. (2011) did not find a recall/recognition distinction. The three tasks that found accelerated forgetting included both recall and recognition tasks. Whilst comparison between recall and recognition was not possible on the visual task due to ceiling effects on recognition, on the verbal task these authors found accelerated forgetting on story recognition but not recall.~~

This study raises doubt about the validity of the purported ‘phenomenon’ of ‘ALF’. Firstly, the patient group *did* exhibit poorer memory function than the matched control group on verbal measures at ‘standard’ delays. Secondly, their findings were variable across the different tasks. Mulhert et al. (2011) themselves noted that the timescale over which accelerated forgetting occurred remained unclear from their results, because of the long duration between 30 minutes and 3 weeks. Nevertheless, Elliott et al. (2014) concluded that ‘ALF’ could be considered a robust “memory disorder” (p. 30), because accelerated forgetting in these samples had been demonstrated across studies, *despite* their methodological limitations.

3.2 Timeframes of measurement

In addition, there needs to be consideration of the delay periods over which memory is assessed. Cassel, Morris, Koutroumanidis, and Kopelman (2016) noted that the timeframe

over which accelerated forgetting has been found to occur may reflect the time-points measured. This poses the risk of circular reasoning, whereby significant accelerated forgetting becomes statistically significant only after a ‘long-term’ delay, which happens to be the first ‘long-term’ delay (time-point) actually measured.

Hoefijzers, Dewar, Dalla Sala, Butler, and Zeman (2014) probed this issue in a group of patients with TEA. These patients had previously exhibited evidence of accelerated forgetting for verbal material after a week, when this was also the first ‘long-term’ delay interval measured. When shorter delays were studied, they found that forgetting was accelerating in the patient group, albeit non-significantly, from 30 minutes (the first time-point measured) to three hours after learning, and it became statistically significant after eight hours. This study raises interesting questions about the nature of accelerated forgetting findings across the literature. When findings of ‘ALF’ have been reported, to what degree have these been an artefact of the delay interval tested? When would the effect have first been observed, had ‘earlier’ delay intervals been used? With more frequent measurement, does forgetting become progressively more accelerated over time, or is forgetting ‘normal’ up until a certain time-point hours, days, or weeks after learning, and only *then* accelerates?

3.3 Implications of progressive vs. divergent forgetting

The last question is crucial for understanding the nature of forgetting, and whether forgetting is ‘normal’ at first before being disrupted at a longer delay. If this were the case, one would expect to see forgetting in a patient group progress at a rate similar to controls for a period of time, with the rate of forgetting only diverging and becoming faster than that of controls at a late delay, conceivably days to weeks after learning (illustrated in Figure 1a). Alternatively, the forgetting rate in the patient group might begin to diverge from that of controls soon after learning, albeit only subtly, and become increasingly divergent from the controls’ forgetting

rate over time (illustrated in Figure 1b). This would raise doubts as to how ‘normal’ the patients’ remembering really was initially. Certainly, forgetting might appear qualitatively ‘normal’ in such individuals, but a progressively faster rate of forgetting would imply different mechanisms of disruption from that in the previous scenario. Further, although the graphs in Figure 1 are purely hypothetical in relation to the timeframe of accelerated forgetting, the different forgetting curves illustrated additionally show how the nature of these contrasting hypotheses could be masked by infrequent delay measurement.

<< Insert Figure 1 about here >>

To explore this issue further, we searched PsycINFO and MedLine for articles investigating “accelerated long-term forgetting” and “epilepsy”, in addition to reviewing reference lists of journal articles and review papers on this topic. Thirty-six journal articles were found that had cumulatively employed over 100 measures of forgetting in adults with TLE and/or TEA. We were particularly interested to compare those studies with experimentally sound methods, i.e. those which: (1) matched initial learning and (2) avoided ceiling and/or floor effects. We only included studies which (3) measured (**and analysed**) memory performance soon after learning, at a delay of 10 to 30 minutes, and again at (at least) one ‘long-term’ delay beyond 30 minutes. Twenty-three measures of forgetting in 10 papers met such criteria and were included in Table 1 (Atherton, Nobre, Zeman, & Butler, 2014; Cassel et al., 2016; Evans, Elliott, Reynders, & Isaac, 2014; Hoefeijzers et al., 2013; Kemp, Illman, Moulin, & Baddeley, 2012; Mameniskiene, Jatuzis, Kaubrys, & Budrys, 2006; Martin et al., 1991; Mayes et al., 2003; Mulhert et al., 2011; Mulhert, Milton, Butler, Kapur, & Zeman, 2010). This Table includes 11 verbal and 12 visual measures. Three measures assessed recognition (two verbal, one visuospatial), with the one visuospatial task combining both cued recall and recognition (Cassel et al., 2016; Mayes et al., 2003; Mulhert et al., 2011). The remaining 20 tasks assessed various forms of recall, both free and cued.

<< Insert Table 1 about here >>

The nature of forgetting amongst these measures varied both between, and within, studies. Several patterns emerged:

(1), findings of comparable forgetting rates to controls, with non-significant group by delay interactions;

(2), very small or negligible forgetting within the first 30 minutes but with faster forgetting statistically evident by a ‘long-term’ time point;

(3), progressively faster forgetting following learning, only becoming statistically detectable at a ‘long-term’ time point;

(4), findings of accelerated forgetting that became significant within 30 minutes after learning, and which continued to deviate from controls over time; and

(5), significantly accelerated forgetting within 30 minutes with comparable forgetting thereafter.

Notably absent from these findings is a pattern of ‘normal’ forgetting until a ‘long-term’ delay *before* divergence is observed (as illustrated in Figure 1a). Such a pattern would provide the strongest evidence that late consolidation had been disrupted. Even amongst the six investigations that exhibited forgetting pattern (2), **the closest observed pattern that could implicate ‘late-onset’ disruption**, deviation invariably occurred between 30 minutes and the first ‘long-term’ probe following this. In these studies, this was *at least* one week later, **making it impossible to determine *when* ‘late’ disruption may have occurred** (Evans et al., 2014; Hoefjeijzers et al., 2013; Mayes et al., 2003; Mulhert et al., 2011). Seven of the findings showed forgetting pattern (3), with patient forgetting rates progressively deviating from controls **from learning onwards**. For most of the investigations, the deviation became statistically detectable at the first ‘long-term’ delay measured (Atherton et al., 2014; Mameniskiene et al., 2006; Martin et al., 1991; Mulhert et al., 2011; Mulhert et al., 2010). In

one study, it became evident at the second ‘long-term’ delay measured (Cassel et al., 2016), and in one study a progressively separating trend to significance was observed (Evans et al., 2014).

4. Is it time for a change in perspective?

The investigation of forgetting in TLE has grown rapidly over the past two decades. This has been driven, in part, by descriptions of ‘ALF’ as a novel memory disorder (e.g. Butler et al., 2010; Butler & Zeman, 2008; Fitzgerald, Mohamed, Ricci, Thayer, & Miller, 2013). Authors have argued that such findings provide evidence of late disruption to memory consolidation processes, i.e. that these individuals experience a “delayed onset amnesia” (Manes et al., 2005, p. 1390). Even in a critique of the forgetting literature, it was suggested that, as ALF was commonly observed in these studies *despite* their methodological confounds, the phenomenon was robust (Elliott et al., 2014). However, we question this viewpoint: it is *because of* their methodological confounds that doubts are raised about the nature of forgetting observed in the literature to date.

Comparing studies with experimentally sound design, we noted variability of forgetting curves. The different patterns ranged from (1) comparable, no faster, forgetting to rapid forgetting within minutes after learning, which then either continued at an accelerated rate (4) or became comparable thereafter (5). Forgetting patterns (2) and (3) reflected what has been typically described as ‘ALF’: accelerated forgetting that became statistically detectable only beyond a 30-minute delay. Within the first 30 minutes, changes in forgetting rates could be negligible, as in pattern (2), or could have started deviating from ‘normal’ forgetting, as in pattern (3). Neither pattern, however, necessarily implies that the *onset* of disruption to consolidation occurred only at a ‘late’ time-point. Even though accelerated forgetting was only *statistically detectable* a long time after learning, subtle disruption of

early retention may have initiated a graduated, progressively increasing, rate of forgetting in these studies ~~in these studies~~ (as illustrated in Figure 1b).

The patterns of forgetting found could conceivably lie along a continuum of severity (Blake et al., 2000; Cassel et al., 2016). Severe disruption to early consolidation could result in accelerated forgetting being detected soon after learning, whilst more subtle disruption to the same processes could mean deficits take longer to become apparent. **Incidence findings that over 40% of patients with TLE presented with memory deficits soon after learning, with a smaller but significant (33%) proportion showing evidence of accelerated forgetting by a week, suggests this continuum of severity may be evident in clinical practice (Miller, Mothakunnel, Flanagan, Nikpour, & Thayer, 2017). It should also be noted that some patients do not show any evidence of any memory impairment despite their diagnosis (Contador, Sánchez, Kopelman, & González de la Aleja, 2017; Miller et al., 2017).** As synaptic stabilization of newly encoded memories has been hypothesised to occur in the first minutes to hours after learning (Dudai, 2004), the forgetting patterns observed within the studies reviewed here could all be positioned along this continuum. Even when forgetting rates have been largely comparable within the first 30 minutes, this does not necessarily imply that early consolidation processes were not affected. **Consistent with this view, an intervention pilot in this Special Issue found that early rehearsal of material may hold the potential to alleviate accelerated rates of forgetting (Ricci, Wong, Nikpour, & Miller, 2017). The implications these findings have for the nature of consolidation disruption in accelerated forgetting warrants further investigation.**

Although we cannot rule out the possibility that late consolidation could also play a role in accelerating forgetting, these processes are thought to stabilize memories over weeks, months, or even years (Dudai, 2004). No study has found a pattern whereby forgetting rates

deviate unequivocally only at a time-point days or weeks after learning, suggesting there is little evidence implicating such processes in memory disruption to date.

Sadeh et al. (2014, 2016) have argued that memories based on recollection are forgotten faster in (**hippocampal**) patient groups than controls, but this is often not the case for memories based on familiarity. Recall memory is based **entirely prominently** on recollection memory, and recognition memory on a combination of familiarity and recollection (Mickes, Seale-Carlisle, & Wixted, 2013; Montaldi & Mayes, 2010; Sadeh, Maril, & Goshen-Gottstein, 2012; Wixted & Squire, 2010); and differences in forgetting rates have been found across recall and recognition in non-epileptic amnesic patients (Green & Kopelman, 2002; Isaac & Mayes, 1999a, 1999b; Kopelman & Stanhope, 1997). Few epilepsy studies have assessed forgetting using recognition procedures (Elliott et al., 2014), and using our criteria, only one study was included with both recall and recognition measures on the same task (Mulhert et al., 2011). There are, therefore, too few epilepsy studies to date to draw any definite conclusions about possible differences in forgetting patterns for recall versus recognition memory tasks as yet.

5. Conclusions

A renewed interest in forgetting research in TLE and TEA has propagated over the past decade. There are many reports of these patients performing within ‘normal’ ranges on standard neuropsychological memory assessments yet complaining of significant memory difficulties. It has been thought that these individuals might be forgetting newly learned declarative memories faster than expected over extended timeframes of days to weeks, thus making detection of deficits difficult (Blake et al., 2000; Butler & Zeman, 2008; Fitzgerald et al., 2013). Over 40 articles, to date, have used the phrase ‘accelerated long-term forgetting’ to describe this phenomenon, and there has been little challenge to its definition.

Despite this, the lessons learned from forgetting research in the 1970s and 80s have commonly been forgotten. The epilepsy literature is replete with faulty methods (Elliott et al., 2014), and many of the conclusions drawn about memory consolidation have been premature. Where abnormal forgetting is not statistically detectable until a ‘long-term’ delay, this has often been interpreted as evidence of late disruption to memory consolidation. Such interpretation assumes that ‘late’ detection of forgetting also implies ‘late’ onset of memory disruption.

In this paper, we have suggested an alternative interpretation of the findings in these studies. Later forgetting may reflect subtle acquisition deficits or problems in early consolidation. Such subtle differences in forgetting could be accentuated over time. There may also be a continuum across individuals, such that in some people retention deficits become detectable soon after learning, whereas in other individuals, these deficits may become detectable only after a considerable length of time. The degree of deficits may further vary dependent on factors related to recollection/familiarity, material specificity, and/or retrieval cues, but this will require further investigation. It would also have implications for clinical practice and remediation: efforts to support retention through rehearsal and other techniques may be better focused on the early stabilization of memories. These issues remain still to be resolved.

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Figure 1. Hypothetical accelerated forgetting rates illustrating curves indicative of: (a) forgetting that diverges at a 'late' delay interval; (b) forgetting that progressively accelerates from learning onwards

Table 1. Forgetting patterns observed in included measures

Table 1. Forgetting patterns observed in included measures

Paper	Type of Study	Sample	Measure	Learning		Delay Intervals			Forgetting Curve	Forgetting Pattern	
						‘Standard’	‘Long-term’				
Atherton et al. (2014)	GS	TEA	Word Pair: Cued Recall	Imm		30m	12h		Progressively separating, sig. LT	3	
Cassel et al. (2016)	GS	TLE	Story: Cued Recall		30s	10m	1d	1w	Progressively separating, sig. LT	3	
			Route: Cued Recall & Recognition		30s	10m	1d	1w	Sig. deviation in first 10m, comparable thereafter	5	
Evans et al. (2014)	GS	Pre-surgery TLE	Repeated Story: Recall	Imm		30m		1w	Progressively separating trend	3	
			Visual Scenes: Item Recall		45s	30m		1w	Comparable to CON	1	
			Visual Scenes: Spatial Recall		45s	30m		1w	Negligible to 30m becoming sig. greater by 1w	2	
			Visual Scenes: Descriptive Recall		45s	30m		1w	Negligible to 30m becoming sig. greater by 1w	2	
		Post-surgery TLE	Visual Scenes: Item Recall		45s	30m		1w	Comparable to CON	1	
			Visual Scenes: Spatial Recall		45s	30m		1w	Comparable to CON	1	
			Visual Scenes: Descriptive Recall		45s	30m		1w	Comparable to CON	1	
Hoefijzers et al. (2013)	GS	TEA	Word list: Recall	Imm		30m	1w	3w	Negligible to 30m becoming sig. greater by 1w, then comparable	2	
Kemp et al. (2012)	SC: SK	TEA	Story 1: Recall	Imm		20m	4d	11d	30d	Progressively separating (early sig.) up until 11d	4
			Family Pictures: Recall	Imm		20m	4d	11d	30d	Progressively separating, early sig.	4
	SC: EB		Word list: Recall	Imm		20m	4d	11d	30d	Comparable to CON	1
			Family Pictures: Recall	Imm		20m	4d	11d	30d	Comparable to CON	1
Mameniskiene et al. (2005)	GS	TLE	Rey Complex Figure: Recall	Imm		30m		4w	Progressively separating, sig. LT	3	
Martin et al. (1991)	GS	TLE	Word list: Recall	Imm		30m	1d		Progressively separating, sig. LT	3	
Mayes et al. (2003)	SC: JL	TLE	150 Word: Recognition		20s	30m		3w	Negligible to 30m becoming sig. greater by 3w	2	
Mulhert et al. (2010)	GS	TEA (GL)	Word list: Recall	Imm	40s	30m	1d	1w	3w	Progressively separating to 3w	3
Mulhert et al. (2011)	GS	TLE	Story: Recall		40s	30m			3w	Comparable to CON	1
			Story: Recognition		40s	30m		3w	Progressively separating, sig. LT	3	
			Visual Scenes: Item Recall		40s	30m		3w	Comparable to 30m with sig. divergence by 3w	2	
			Visual Scenes: Spatial Descriptive Recall		40s	30m		3w	Comparable to 30m with sig. divergence by 3w	2	

Key: time point in **bold** = when significant forgetting first detected

Index: **1** = comparable forgetting to CON, **2** = sig. LT forgetting with minimal deviation within 30m, **3** = sig. LT forgetting that progressively deviated from learning, **4** = sig. forgetting by 30m that progressively deviated, **5** = sig. forgetting by 30m that became comparable, CON = controls, d = day(s), GL = good learners, GS = group study, h = hours, Imm = immediate delay, LT = long-term, m = minutes, s = seconds, SC = single case, TEA = transient epileptic amnesia, TLE = temporal lobe epilepsy, w = week(s)