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Research Report

Autobiographical memory loss in Alzheimer's disease: The role of the reminiscence bump

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ABSTRACT

Research on autobiographical memory loss in Alzheimer's disease (AD) is characterized by conflicting findings concerning a possible sparing of older memories. The literature shows evidence for both a negative temporal gradient, a flat gradient and a reminiscence bump – that is, a disproportionately high frequency of memories from early adulthood relative to surrounding periods. Here, we expanded the number of lifetime periods of the Autobiographical Memory Interview (AMI; Kopelman, Wilson & Baddeley, 1989, 1990) from the standard three to seven in order to increase the sensitivity of the test to variations in the temporal distribution of autobiographical memories across the life span. Twenty-five older adults diagnosed with AD (MMSE = 21.16, SD = 5.08) and a matched sample of 30 healthy, older adults were assessed. The temporal distribution for personal semantic information in AD showed a temporal gradient steadily decreasing from middle childhood to present life, consistent with predictions derived from consolidation theories. In comparison, the temporal distribution of incidents/episodic memories produced by AD patients in response to the expanded AMI showed a predominance of autobiographical memories from age 6 to 30, followed by a steep drop in memory referring to events that had occurred after age 30. This distribution challenges standard theories of retrograde amnesia in AD by showing neither a temporal gradient, decreasing progressively from early to later life, nor a flat gradient. In contrast, the distribution is consistent with the reminiscence bump identified in autobiographical memory research. Schematization and retrieval support provided by cultural life scripts are discussed.

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1. Introduction

One of the first and foremost cognitive deficits in Alzheimer's disease (AD) is an impairment of *autobiographical memory*—that is, memory for the personal past (e.g., El Haj, Antoine, Nandrino, & Kapogiannis, 2015; Greene, Hodges, & Baddeley, 1995; Kopelman, 1989, 2019). However, not all components of autobiographical memory are equally compromised in AD. There is some evidence that memories for the earlier parts of life are relatively spared compared with memories for the more recent past (Kirk & Berntsen, 2018, for a review). Nevertheless, findings are mixed and the exact nature of the retrograde amnesia in AD is still debated.

According to the standard consolidation model (Alvarez & Squire, 1994; Squire & Alvarez, 1995), retrograde amnesia following damage to the medial temporal lobe (MTL) structures shows a negative temporal gradient, sparing older relative to recent memories. This negative gradient reflects episodic memories being only temporarily dependent on the MTL structures. After a period of years, a gradual reorganization (systems consolidation) takes place, with the consequence that memories that originally were dependent on the MTL structures instead are stored elsewhere in the brain, such as in the neocortex (Alvarez & Squire, 1994).

In contrast, the original version of Multiple Trace Theory (MTT; Nadel & Moscovitch, 1997) predicted that memories for autobiographical events show persistent dependency on the MTL structures, for which reason damage to these structures in AD would produce a uniform impairment of autobiographical memory retrieval without any sparing of older memories, that is, a 'flat' gradient. Winocur and Moscovitch (2011) later embedded MTT within their 'Trace Transformation Theory' (TTT), arguing that with repeated rehearsal, memories are transformed from an episodic to a gist-like (more semantic) form (compare Cermak, 1984). This, and later revisions of MTT, limit the involvement of the MTL structures to detailed, perceptually rich and context specific episodic memories (Gilboa & Moscovitch, 2021, p. 2240, also see; Moscovitch & Gilboa, 2021). The most recent theoretical development of the MTT/TTT framework – called the Neuro-Psychological Representation Correspondence (NPRC; Gilboa & Moscovitch, 2021) – specifies that memories for events encompass different types of cognitive representations that are supported by differing neural structures. The revised theory distinguishes between full-blown episodic, gist-like, and semantic memory representations of the same remembered event, which coexist, and may be expressed at different times. As already mentioned, only the expression of detailed, perceptually-rich episodic memories requires the involvement of MTL structures, according to this theory. Thus, the shape of the temporal gradient in retrograde amnesia in patients with hippocampal damage, such as AD, will depend on which memory variant is examined. Only tasks requiring full-blown episodic memories would be expected to show a flat gradient (Gilboa & Moscovitch, 2021; Moscovitch & Gilboa, 2021; Sekeres, Moscovitch, & Winocur, 2017; for reviews, see Kopelman, 1989, for alternative findings).

A less frequently considered possibility (Kopelman, 2008, 2019) is that retrograde amnesia might be influenced by the

temporal distribution of memories typically seen in healthy middle-aged and older adults. Accordingly, the memory loss in AD would not follow a linear decline from early to later life, nor show a flat gradient. Instead, the distribution of memories would show a reminiscence bump, that is, an increase in memories from the second and third decades of life, relative to the surrounding life-periods (Rubin, Rahhal, & Poon, 1998; Rubin, Wetzler, & Nebes, 1986). Currently, it is possible to find empirical support in the literature for all these positions. The present study was undertaken to elucidate this issue.

1.1. Assessments of retrograde amnesia in Alzheimer's disease

Retrograde amnesia for episodic and personal semantic memories in AD is typically examined using either the Autobiographical Memory Interview (AMI; Kopelman, Wilson & Baddeley, 1989, 1990) or the Autobiographical Interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). In the standard AMI, participants are asked to retrieve memories in response to specific probes for three specific lifetime periods; childhood, early adult life, and recent adult life (in modified versions, up to five periods; see Barnabe, Whitehead, Pilon, Arsenaault-Lapierre, & Chertkow, 2012; Rensen et al., 2017). Some of the questions concern memories for specific episodic events, related to each period (i.e., the autobiographical incident schedule), and other questions probe semantic facts related to each time-period (i.e., the personal semantic schedule). The incident schedule requests three memories of specific events for each time-period, whereas the personal semantic schedule requests 12 to 15 autobiographical facts for each period. In contrast, the standard AI probes for memories pertaining to five time-periods (early childhood, adolescent–teenage years, early adulthood, middle age, and the previous year), and participants are typically requested to report just one memory for each period. Each reported memory is then coded for the amount of episodic and semantic details generated.

The majority of studies employing the AMI in AD patients have found indications of a temporal gradient for autobiographical incidents with relative sparing of early memories in terms of the frequency of memories retrieved and their episodic specificity. Thus, more numerous and elaborate memories are produced from childhood and young adulthood than from the recent past (e.g., Barnabe et al., 2012; De Simone et al., 2016; Graham & Hodges, 1997; Greene et al., 1995; Irish, Lawlor et al., 2011; Kirk & Berntsen, 2018; Kopelman, 1989; Leyhe, Muller, Milian, Eschweiler, & Saur, 2009; Müller, Mychajliw, Reichert, Melcher, & Leyhe, 2016). Some studies have reported non-significant numerical differences in the same direction (Gilboa et al., 2005; Hou, Miller, & Kramer, 2005; Meeter, Eijsackers, & Mulder, 2006; Nestor, Graham, Bozeat, Simons, & Hodges, 2002), or a gradient only for personal semantic memory (Addis & Tippett, 2004).

In contrast, studies using the AI have often reported a flat temporal gradient for episodic memories in AD (Addis, Sacchetti, Ally, & Schacter, 2009; Irish, Hornberger et al., 2011). These conflicting findings may reflect differences in methods. There is evidence that the temporal gradient varies as a function of how many time-periods are included in the

assessment, as well as the number of memories requested at each time-period (Barnabe et al., 2012; Rensen et al., 2017). The autobiographical incident schedule of the AMI measures both the number of memories generated for each of three epochs as well as their descriptive richness and specificity in time and place, whereas the standard AI is concerned with the amount of episodic and semantic details generated for only one specific memory for each of five time-periods. We use the AMI here because it is sensitive to variations in memory frequency between time-periods, which is important for detecting a reminiscence bump.

1.2. Negative gradient or reminiscence bump?

At face value, the predominance of older memories identified, when assessing the life distribution of memories in AD with the AMI, would seem to support the standard consolidation model (Alvarez & Squire, 1994; Squire & Alvarez, 1995). However, matters do not appear to be quite so simple. Studies that have increased the number of time-periods in the AMI from three to five, thereby allowing more variation to be identified in the life span distribution of memories, have not always found a simple temporal gradient in AD patients, as would be expected according to the standard consolidation model. Some of these studies have shown indications of a memory peak in early adulthood relative to the surrounding time-periods (e.g., Irish, Lawlor et al., 2011; Piolino et al., 2003; see Kopelman, 2019, for a review). A similar distribution is found in studies in which AD patients were asked to freely recall memories across the life span in response to word cues (Kirk & Berntsen, 2018) or to freely tell their life story (Fromholt & Larsen, 1991; Fromholt et al., 2003). Such a peak in memories from the second and third decades of life, relative to the surrounding periods, is known as the ‘reminiscence bump’ in the broader autobiographical memory literature (Koppel & Berntsen, 2015; Koppel & Rubin, 2016; Rubin et al., 1986, 1998). It is, therefore, possible that the temporal gradient identified in earlier research, using the AMI with three time-periods in AD patients, in fact reflects a reminiscence bump; and that this requires more fine-grained analyses to become visible (Kirk & Berntsen, 2018; Kopelman, 2008, 2019).

In healthy middle-aged and older adults, the life span distribution of autobiographical memories retrieved in response to word cues shows three distinct characteristics: (i) a predominance of memories from the recent past, corresponding to normal forgetting, (ii) an absence of memories from the first years of life, corresponding to childhood amnesia, and (iii) an increase in memories from late childhood to early adulthood, relative to the surrounding periods, known as the reminiscence bump (Rubin et al., 1986, 1998). The distribution of memories from the recent past varies with cueing technique (Koppel & Berntsen, 2015; Rubin & Schulkind, 1997), whereas a reminiscence bump has been found for many different types of memories. These include word-cued autobiographical memories, and important, emotionally positive, or life-story autobiographical memories, although the exact location and size of the bump varies across these cueing methods (see Koppel & Berntsen, 2015; Koppel & Rubin, 2016; Rubin et al., 1998, for reviews). The ‘bump’ has also been found in memories for semantic information, such

as memories for public events or memorable books (Koppel & Berntsen, 2016; Rubin et al., 1998, for reviews). In contrast, the bump is rarely found for measures of vividness or other characteristics associated with individual memories, which typically show a uniform distribution across life (Rubin & Schulkind, 1997). The latter can be seen as consistent with a ‘flat’ temporal gradient in studies measuring the degree of memory detail using the AI with just one memory per life period (Addis et al., 2009; Irish, Hornberger et al., 2011).

If the temporal gradient identified in dementia with the standard AMI (see Kirk & Berntsen, 2018; Kopelman, 2019, for reviews) in fact reflects a reminiscence bump, then the life span distribution of autobiographical memories in AD would show a distribution similar to the one in healthy middle-aged and older adults, albeit with no increase in memories of recent events. The aim of the present study was to examine this possibility.

1.3. The present study

We developed a revised version of the AMI, which segmented the life span into seven time periods: 0–5, 6–11, 12–19, 20–30, 31–45, 46+, and the most recent year. Although a few studies (e.g., Barnabe et al., 2012; Irish, Lawlor et al., 2011; Piolino et al., 2003; Rensen et al., 2017) have expanded the number of AMI life-periods/epochs from the original three, they have used only up to five epochs, and have not employed a subdivision of childhood and middle-aged adulthood. In other words, the way previous work has broken the life span into epochs has not allowed a clear detection of any reminiscence bump. In contrast, our division of adult life into four epochs allowed us to observe whether a steep drop in memory frequency after age 30 is present, as predicted by the bump literature (Rubin et al., 1998) but counter to the idea of a progressively decreasing temporal gradient. Also, by dividing the period of childhood into 0–5 and 6–11 years of life, the test was potentially capable of identifying childhood amnesia.

Using the expanded AMI with seven time epochs allowed us to examine hypotheses derived from existing (conflicting) theories concerning the nature of retrograde amnesia in AD. According to the standard consolidation model (Alvarez & Squire, 1994), we would expect a negative gradient, decreasing from the remote to recent past for both episodic and semantic autobiographical memory. In contrast, according to the MTT (Nadel & Moscovitch, 1997) and its later revisions (e.g., Gilboa & Moscovitch, 2021; Moscovitch & Gilboa, 2021), the retrieval of full-blown episodic memories continues to depend on the MTL structures, and damage to these structures in AD would not show sparing of older episodic memories, and thus a flat gradient. Only personal semantic memory information would show a temporal gradient due to increased semantization with the passage of time (see Kopelman, 2019; Moscovitch & Gilboa, 2021 for overviews of these theoretical positions). Importantly, research on the reminiscence bump in healthy populations (e.g., Rubin et al., 1998) suggests that the distribution of autobiographical memories in AD might show the same autobiographical memory distribution as controls, but at a generally lower level of performance and without a peak for recent memories. Thus, childhood amnesia and a reminiscence bump should be

clearly observable, followed by a marked drop in memory frequency after age 30. The autobiographical memory literature on the bump would hold no specific predictions regarding personal semantic memory, such as personal facts as examined by the personal semantic schedule of the AMI. However, the fact that the bump is found for favorite books, music and movies as well as factual knowledge about public events (Koppel & Rubin, 2016; Rubin et al., 1998; for reviews) suggests that personal semantic knowledge, as probed by the AMI, might also show a reminiscence bump in AD.

2. Materials and method

We report how we determined our sample size, all data exclusions (if any), all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

2.1. Participants

Of the sixty-one participants recruited to the study (25 AD patients, 36 Healthy Controls), fifty-five participants were included in the final analyzes: 25 AD patients (11 female, 14 male) and 30 HCs (16 female, 14 male). Six HC participants were excluded as they scored <88 (see inclusion/exclusion criteria below) on the Addenbrooke's Cognitive Examination (ACE; Mathuranath, Nestor, Berrios, Rakowicz, & Hodges, 2000). This sample size was deemed appropriate to detect life period \times group interaction, based on previous findings (Kirk & Berntsen, 2018) and using Gpower 3.1.9.2. software (with the following parameters: alpha = .05, power = .80, effect size $f = .25$; Faul, Erdfelder, Lang, & Buchner, 2007).

All AD patients had been diagnosed at a hospital-based memory clinic in Denmark. They met the clinical criteria for 'probable AD' according to the National Institute on Aging and Alzheimer's Association (NIAA) (McKhann et al., 2011); and Danish national guidelines are consistent with the NIAA requirements, involving (1) a thorough medical history of the patient, (2) a physical/somatic examination (including neurological), (3) assessment of the mental state and behavior, (4) cognitive assessment, (5) assessment of activities of daily living, (6) appropriate blood screen, (7) structural brain imaging, and (8) an informant/caregiver history. If there were any uncertainty about the diagnosis, this basic examination was supplemented by an examination of the cerebrospinal fluid (CSF) for biomarkers, and/or Positron Emission Tomography (PET scan), and/or amyloid-binding tracing (e.g., 11C-PiB-PET) (Sundhedsstyrelsen, 2018).

AD patients and control participants were matched for age, gender and years of education, see Table 1. For the AD patients, the range of scores on the ACE was 43–83, and the range on the MMSE was 12–28, with the exception of one highly educated AD patient who scored 96 and 30, respectively, on these measures. The corresponding scores for the control participants were ACE: 88–99, and MMSE: 27–30.

With the assistance of regional dementia workers in the public care sector, AD patients were recruited from patient organizations (Demenshjørnet, Aarhus, Denmark) and local residential homes. Control participants were recruited from

local seniors' organizations, and from the research center's participant database. All participants were tested in their own homes by trained psychological staff.

Participants were included in the study if they were native Danish speakers and had no history of substance abuse, severe head injury, or any other major neurological or psychiatric disorders. Participants were required to demonstrate normal or corrected-to-normal visual acuity and hearing ability. Use of antidepressants, and/or medication to ameliorate AD itself, was not exclusion criteria. Additional inclusion criteria for the control participants were a score of ≥ 88 on the Addenbrooke's Cognitive Examination (ACE; Mathuranath et al., 2000), as a score below 88 on this measure may indicate cognitive dysfunction. The study was approved by the Central Denmark Region Committees on Health Research Ethics, and all participants gave informed consent to participate in the study.

2.2. Materials

2.2.1. Neuropsychological assessment

Overall cognitive ability was assessed via the Addenbrooke's Cognitive Examination (ACE; Mathuranath et al., 2000), which includes the Mini-Mental State Examination; MMSE (Folstein, Folstein, & McHugh, 1975). Maximum scores on both measures index optimal cognitive ability. As part of the ACE, participants were also assessed on verbal fluency (i.e., phonemic, letter S) and semantic fluency (animal category; Lezak, Howieson, Bigler, & Tranel, 2012). Participants were screened for depressive symptoms with the Geriatric Depression Scale (GDS-15; Djernes, Kvist, Olesen, Munk-Jørgensen, & Gulmann, 2004; Brink et al., 1982). This self-report scale consists of 15 items that can be answered with a Yes or No in reference to how the respondent felt over the past week. Scores ≥ 6 have been shown to be indicative of depression in a Danish validation study with frail elderly participants (Djernes et al., 2004). None of the participants in the present study scored 6 or more; two AD participants scored 5. All the other AD patients scored 0–4.

2.2.2. The Autobiographical Memory Interview-expanded

The AMI (Kopelman, Wilson, & Baddeley, 1990) tests recall for two components of autobiographical memory, that is, autobiographical incidents/episodes and personal semantic information. The original version of the AMI (Kopelman et al., 1989, 1990) examined autobiographical memory recall across three lifetime periods (childhood, early adult life, recent life). For each of the three lifetime periods, participants were required to recall three episodic events per life-period (i.e., a total of 9 events) and a total of 43 personal semantic questions (i.e., 12 questions related to childhood, 16 questions related to early adult life, 15 questions related to recent life, which gave a score of 21 points for each life-period) (See also Table 2).

We expanded the original AMI from three to seven life-periods to increase its sensitivity to more fine-grained variations in the temporal distribution of the memories. Like the original version of the AMI, the expanded AMI (AMI-Expanded) comprised of two sections, which independently tested recall for the two components of autobiographical memory (autobiographical incidents/episodes and personal

Table 1 – Descriptive Statistics and Independent t-test Results for Age, Education, Cognitive Ability and Executive Functioning.

	Alzheimer (n = 25)		Control (n = 30)		t(df)	CI
	M	SD	M	SD		
Age (years)	81.12	6.82	79.87	6.31	t(53) = .707, p = .483	[-2.30, 4.81]
Education (years)	10.56	3.89	11.93	3.40	t(53) = -1.397, p = .168	[-3.35, .60]
Geriatric Depression Scale/15	2.00	1.57	1.17	1.29	t(51) = 2.124, p = .039	[.46, 1.62]
MMSE/30	21.16	5.08	29.43	.94	t(53) = -8.760, p < .001	[-10.17, -6.38]
ACE/100	64.50	14.66	93.50	3.32	t(50) = -10.511, p < .001	[-34.54, -23.46]
Semantic Fluency	11.50	5.60	21.00	4.09	t(50) = -7.077, p < .001	[-12.20, -6.80]
Phonemic Fluency	6.18	2.81	15.50	4.46	t(50) = -8.613, p < .001	[-11.49, -7.15]

Note. MMSE = Mini Mental State Assessment; ACE = Addenbrooke's Cognitive Examination; CI = Confidence Intervals. The MMSE is included in the ACE. Fluency scores are presented as total number of items recalled. Ns for Geriatric Depression Scale = 23, ACE (including fluency) = 22.

Table 2 – Overview of life time periods and questions in the original AMI and the Expanded AMI.

AMI original (Kopelman et al., 1990)	Autobiographical incidents	Personal semantic information
1. Childhood (0–18 years of age)	3 questions	12 questions
2. Early adult life (approx. 18–30 years of age)	3 questions	16 questions
3. Recent life (recent year)	3 questions	15 questions
Total	9 questions	43 questions
AMI-Expanded	Autobiographical incidents	Personal semantic information
1. 0–5 years of age	2 questions	4 questions
2. 6–11 years of age	2 questions	5 questions
3. 12–19 years of age	2 questions	5 questions
4. 20–30 years of age	2 questions	4 questions
5. 31–45 years of age	2 questions	5 questions
6. 46 years of age up to one year ago	2 questions	4 questions
7. Recent last year	2 questions	5 questions
Total	14 questions	32 questions

semantic facts). However, the AMI-Expanded consisted of seven different lifetime periods (1 = 0–5 years of age, 2 = 6–11 years of age, 3 = 12–19 years of age, 4 = 20–30 years of age, 5 = 31–45 years of age, 6 = 46 years of age until to one year ago, 7 = recent/last year), rather than the three lifetime periods of the original AMI (see Table 2).

For each of the seven lifetime periods, participants were required to recall two autobiographical incidents (giving a total of 14 autobiographical incidents for the full interview). If the person was unable to retrieve an autobiographical incident/episode, prompts were used to facilitate memory. We made efforts to ensure uniformity of the probes used for the different lifetime periods with regard to their level of specificity and emotionality. For example, the probes used for age 12 to 18 were: 'Involving a friend or class mate', 'Involving a teacher', 'Involving a girlfriend or boyfriend or falling in love', 'Involving passing or failing an exam', 'Involving a major achievement', and 'Involving leaving home'. In comparison, the probes used for age 46 and above until the most recent year were: 'Involving children leaving home', 'Involving having grandchildren, nieces, nephews', 'Involving going on a holiday', 'Involving some sort of celebration (e.g., wedding- or work anniversary at work)', 'Involving an incident related to retiring from work', and 'Involving a major achievement'.

For the personal semantic component of the interview, participants were presented with a total of 32 questions (with a uniform maximum score of 8 points for each time-period). The questions addressed personally relevant information (e.g., the name of the school attended as a child, year of graduation, or alternative options in cases of a different life path, such as year of leaving school if the person had not been to college).

2.2.3. Scoring of autobiographical incidents

Autobiographical incidents were coded according to the (1) AMI protocol (Kopelman et al., 1990), and (2) a rating scale developed by Piolino, Desgranges, Benali, and Eustache (2002).

2.2.3.1. AMI SCORING PROTOCOL (KOPELMAN ET AL., 1990). Scores range between 0 and 3, where the different scores range from an absence of an answer or purely semantic response to providing a purely episodic event; 0 = No response, or response based on semantic memory, 1 = Vague personal memory, 2 = either a personal but non-specific event, or a specific event but time and place not recalled, 3 = episodic memory, specific in time and place. Higher scores on both the autobiographical incident schedule and the personal semantic scale index better memory performance. The new version of the questionnaire originally

included a phenomenological question, where participants were required to rate the vividness of the memory on a scale from 0 to 5 (i.e., 1 = not at all, 5 = very vivid). However, after testing six AD participants, it was clear that AD participants found the question confusing, and it was omitted.

2.2.3.2. EXPANDED SCORING PROTOCOL (PIOLINO ET AL., 2002). The rating scale developed by Piolino et al. (2002) extended the episodic memory score from the AMI by further specifying the degree of detail and time/place specificity of the recalled events. The scale consists of seven different scores that range from an absence of an answer to providing a specific event with a high degree of detail; 0 = Absence of an answer or general information, .5 = Vague personal impression, 1 = Vague event/repeated or continuous with little details of time and space, 1.5 = Generic event (repeated or continuous situated in time and space), 2 = Detailed generic event (repeated or continuous, situated in time and space), 2.5 = Specific event (isolated, situated in time and space) without details, and 3 = Specific event (isolated in time and space) with details (thoughts, emotions, images etc.). Thus, lower scores are indicative of semanticised and decontextualized information, whereas higher scores reflect more episodic and autobiographical recall with a high degree of episodic content, that is, specificity and a high degree of details, such as emotions, thoughts and images.

2.3. Procedure and coding

All participants were interviewed at their home by trained psychological staff. Before the interview, participants were assessed on global cognitive ability and depressive symptoms. The interviews were audio recorded in order to allow for subsequent verbatim transcription and coding. The personal semantic information provided by the participants was scored by the interviewer during the interview. The autobiographical incidents were coded according to the AMI protocol (Kopelman et al., 1990) and the Piolino scoring protocol (Piolino et al., 2002) by two raters blind to group allocation. In cases of disagreement between the two raters and, in accordance with the AMI guidelines, the mean score was taken when they disagreed by less than one point. When they disagreed by more than one point, they would discuss the response together before coming to an agreement. Inter-rater reliability statistics (intraclass correlations) demonstrated satisfactory consensus between raters on the AMI coding protocol (.99) and Piolino et al. (2002) coding scheme (.99).

3. Results

3.1. Neuropsychological assessments

Table 1 shows that the AD and Control group were comparable in terms of age and education. The AD group was significantly impaired regarding general cognitive functioning as measured by the MMSE and the ACE. These patients also showed impaired executive function as measured by the phonemic and semantic fluency tasks. In addition, the AD group showed significantly higher levels of depressive symptoms as measured by the Geriatric Depression Scale (Brink et al., 1982),

but their scores were still within the normal range (Djernes et al., 2004).

3.2. The Autobiographical Memory Interview

The findings regarding the expanded AMI are illustrated in Figs. 1–3 and detailed in Table 3. In the following, we describe these findings in greater detail with respect to the autobiographical incident schedule, the personal semantic schedule, and correlations with other neuropsychological assessments.

3.2.1. The autobiographical incident schedule

Figs. 1 and 2 illustrate the distribution of memories deriving from the autobiographical incident schedule. Fig. 1 shows findings when coded according to the original AMI protocol by Kopelman et al. (1990), and Fig. 2 shows the results using the expanded coding scheme by Piolino et al. (2002). As evidenced by both coding protocols, there is an elevated recall performance, relative to other time-periods, in the AD group between the ages of 6–30, corresponding to a reminiscence bump. After the age of 30, the performance drops dramatically in the AD group and stays low over the remaining time-span up to the most recent year. Data from the control group shows a scarcity of incidents/episodic memories from the first five years of life, corresponding to the ‘childhood amnesia’ period, followed by a substantial rise in memory retrieval that stays uniformly high across the intermediate and recent time-periods. The distributions are largely identical across the two coding systems (Kopelman et al., 1990; Piolino et al., 2002). We therefore conducted the following statistical analyses on the distributions based on the original coding protocol, and values for Piolino’s (2002) coding scheme are placed in parentheses for comparison.

Statistically, the data shown in Fig. 1 revealed a significant main effect of group, $F(1, 53) = 53.624, p < .0001, \eta^2 = .50$, a significant main effect of lifetime period, $F(1, 53) = 14.78, p < .0001, \eta^2 = .22$, and a significant Group x Life-period interaction effect, $F(1, 53) = 9.06, p < .0001, \eta^2 = .15$. [The corresponding values for the data shown in Fig. 2 were Group, $F(1, 53) = 69.38, p < .0001, \eta^2 = .57$; Lifetime period, $F(1, 53) = 15.12, p < .0001, \eta^2 = .22$, and interaction, $F(1, 53) = 9.51, p < .0001, \eta^2 = .15$].

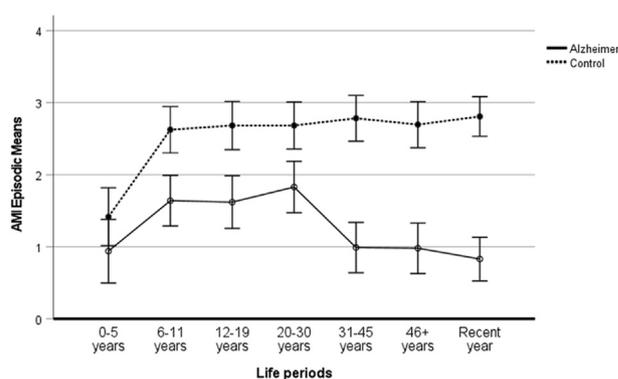


Fig. 1 – Mean scores on the episodic incident schedule from the Autobiographical Memory Interview. Note: The codings were conducted according to the original AMI protocol (Kopelman et al., 1990). Error bars ± 2 SE.

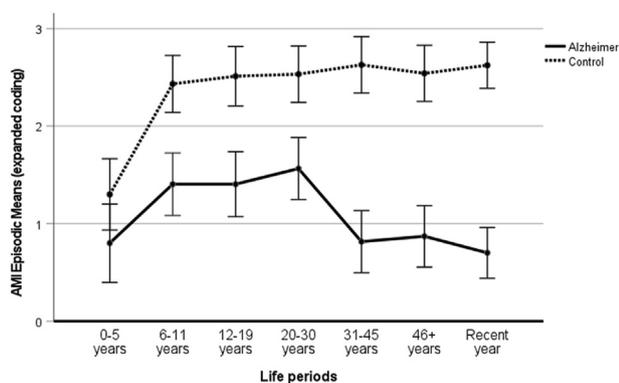


Fig. 2 – Mean scores on the episodic incident schedule from the Autobiographical Memory Interview (expanded coding). Note: The codings were conducted according to an expanded protocol for coding episodic details (Piolino et al., 2002). Error bars \pm 2 SE.

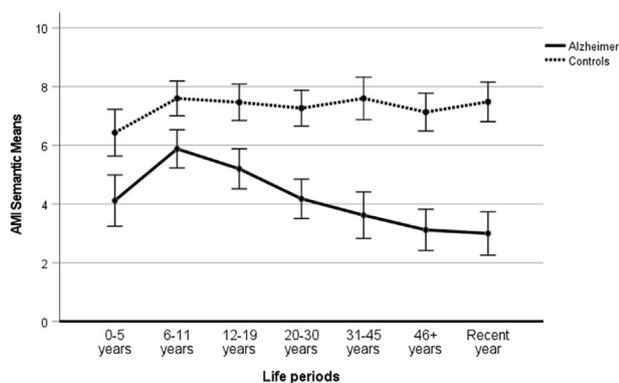


Fig. 3 – Mean scores on the personal semantic schedule from the Autobiographical Memory Interview. Note: The codings were conducted according to the to the original AMI protocol (Kopelman et al., 1990). Error bars \pm 2 SE.

More detailed statistical analyses, based on values shown in Fig. 1, showed a significant increase from 0 to 5 to 6–11 years of age in both the AD group, $t(24) = 3.43$, $p < .01$, $d = 1.02$, and the control group, $t(29) = 5.21$, $p < .001$, $d = 1.27$. There was a significant decrease from 20 to 30 to 31–45 years of age in the AD group, $t(24) = 4.04$, $p < .001$, $d = 1.04$, but not in the control group, $t < 1$. Similar statistical results were obtained based on data from the Piolino scoring system (Fig. 2).

3.2.2. The personal semantic schedule

Fig. 3 illustrates the results from the personal semantic schedule. There was an (expected) scarcity of memory retrieval from the first five years of life due to ‘childhood amnesia’, following which the AD group showed a steadily decreasing distribution of memories from the period 6–11 years of life across the remaining parts of the life span, whereas the controls displayed a flat gradient at ‘ceiling’ (Fig. 3). Statistical analyses identified a significant main effect of Group, $F(1, 53) = 62.65$, $p < .0001$, $\eta^2 = .54$; a significant main effect of lifetime period, $F(1, 53) = 13.95$, $p < .0001$, $\eta^2 = .21$; and a Group \times Life-period interaction effect, $F(1, 53) = 10.65$, $p < .0001$, $\eta^2 = .17$.

Statistical tests of within-subjects contrasts showed a linear decrease from 6 to 11 years of life to the most recent year in the AD group, $F(1, 24) = 63.39$, $p < .0001$, $\eta^2 = .72$, but not in the control group, $F(1, 29) < 1$.

3.2.3. Correlations with neuropsychological assessments

Measures of memory performance correlated meaningfully with overall cognitive performance within the AD group, as evidenced by Spearman rank-order correlations. For the MMSE, correlations were .58 (incident schedule standard coding), .59 (incident schedule expanded coding), and .83 (personal semantics). For the ACE, the corresponding correlation coefficients were .64; .64 and .82, all $ps < .01$. Thus, in the AD group, performance on the AMI showed strong associations with level of cognitive deficits. In the control group, such associations were not present. For the MMSE, correlations in the control group were .16 (incident schedule standard coding), .08 (incident schedule expanded coding), and .12 (personal semantics). For the ACE, the corresponding correlation coefficients were .27; .20 and $-.14$, all $ps > .15$. Furthermore, performance on the incident- and semantic schedule correlated strongly in the AD group ($R = .73$, $p < .001$) and moderately in the control group ($R = .38$, $p < .05$). Not surprisingly, a substantial part of this association in the AD group was explained by shared variance with the degree of cognitive impairment. A linear regression analysis with performance on the incident schedule as the dependent variable showed that when controlling for MMSE score in step one ($\Delta R^2 = .40$), semantic memory performance entered in Step 2 accounted for an additional 30% of the variance ($\Delta R^2 = .30$).

4. Discussion

Several studies have suggested that retrograde amnesia in AD to some extent spares memory for the earlier parts of life. However, the temporal distribution of memories across the life span in AD remains unclear. Most previous studies have used the AMI (Kopelman, 1989; Kopelman et al., 1990), probing episodic and personal semantic memory across three time-periods (childhood, early adult life and recent life) or the AI (Levine et al., 2002) addressing the level of episodic and semantic detail for a single memory retrieved from each of five life-periods. In their standard forms, neither of these methods allows sufficiently fine-grained analyses to detect a reminiscence bump, that is, a preponderance of memories from the second and third decade of life relative to the surrounding periods. The bump has been consistently observed in autobiographical memories of healthy middle-aged and older adults (Rubin et al., 1986; for reviews see Koppel & Berntsen, 2015; Koppel & Rubin, 2016; Rubin et al., 1998), and was also identified in a few studies using open-ended autobiographical memory tasks in dementia (Fromholt & Larsen, 1991; Kirk & Berntsen, 2018). However, it has not been examined systematically using a structured clinical interview. The present study was undertaken to fill this gap in the literature.

We developed an expanded version of the AMI, which segmented the life span into seven time-periods (age 0–5, 6–11, 12–19, 20–30, 31–45, 46+, most recent year). Unlike earlier investigations, this fine-grained segmentation of the

Table 3 – Descriptive Statistics and Independent t-test Results for the Autobiographical Memory Interview.

	Alzheimer		Control		t(53)	CI
	M	SD	M	SD		
AMI Episodic Part (original coding)						
Total Score/42	17.66	12.55	35.39	3.98	-7.32, $p = .000$	[-22.59, -12.87]
1. 0–5 years of age/6	.94	1.09	1.42	1.12	-1.60, $p = .116$	[-1.08, .12]
2. 6–11 years of age/6	1.64	1.08	2.63	.68	-4.14, $p = .000$	[-1.46, -.51]
3. 12–19 years of age/6	1.62	1.23	2.68	.54	-4.29, $p = .000$	[-1.56, -.57]
4. 20–30 years of age/6	1.83	1.14	2.68	.62	-3.52, $p = .001$	[-1.34, -.37]
5. 31–45 years of age/6	.99	1.19	2.78	.46	-7.61, $p = .000$	[-2.27, -1.32]
6. 46 years of age up to one year ago/6	.98	1.15	2.70	.55	-7.24, $p = .000$	[-2.19, -1.24]
7. Recent last year/6	.83	1.01	2.81	.44	-9.68, $p = .000$	[-2.39, -1.57]
AMI Episodic Part (expanded coding)						
Total Score/42	15.12	11.13	33.15	3.79	-8.33, $p = .000$	[-22.37, -13.69]
1. 0–5 years of age/6	.80	.98	1.30	1.02	-1.84, $p = .071$	[-1.04, .04]
2. 6–11 years of age/6	1.41	.95	2.43	.65	-4.73, $p = .000$	[-1.46, -.59]
3. 12–19 years of age/6	1.41	1.10	2.51	.53	-4.89, $p = .000$	[-1.56, -.65]
4. 20–30 years of age/6	1.57	.98	2.53	.59	-4.50, $p = .000$	[-1.40, -.54]
5. 31–45 years of age/6	.82	1.04	2.63	.50	-8.44, $p = .000$	[-2.25, -1.38]
6. 46 years of age up to one year ago/6	.87	1.01	2.54	.53	-7.83, $p = .000$	[-2.10, -1.24]
7. Recent last year/6	.70	.84	2.63	.43	-10.95, $p = .000$	[-2.28, -1.57]
AMI Semantic Part						
Total Score/56	29.12	14.73	50.98	3.22	-7.49, $p = .000$	[-27.40, -16.32]
1. 0–5 years of age/8	4.12	2.57	6.43	1.79	-3.92, $p = .000$	[-3.50, -1.13]
2. 6–11 years of age/8	5.88	2.28	7.60	.71	-3.92, $p = .000$	[-2.60, -.84]
3. 12–19 years of age/8	5.20	2.35	7.47	.84	-4.92, $p = .000$	[-3.19, -1.34]
4. 20–30 years of age/8	4.18	2.26	7.27	.95	-6.80, $p = .000$	[-4.00, -2.18]
5. 31–45 years of age/8	3.62	2.88	7.60	.53	-7.43, $p = .000$	[-5.05, -2.91]
6. 46 years of age up to one year ago/8	3.12	2.42	7.13	.90	-8.44, $p = .000$	[-4.97, -3.06]
7. Recent last year/8	3.00	2.63	7.48	.70	-8.98, $p = .000$	[-5.48, -3.48]

Note. AMI = The Autobiographical Memory Interview; CI = Confidence Intervals.

life span allowed us to identify whether there would be an increase in memories from pre-school to later childhood, consistent with childhood amnesia (e.g., [Howe & Courage, 1993](#); [Rubin, 2000](#)), together with a fall in memory for events occurring after the age of 30, consistent with a reminiscence bump ([Rubin et al., 1986, 1998](#)).

The temporal distribution of memories produced by AD patients in response to the expanded autobiographical incidents schedule showed a clear deviation from a progressively decreasing temporal gradient from early to later life, challenging a pure consolidation model of retrograde amnesia ([Alvarez & Squire, 1994](#); [Dudai, 2012](#); [Squire & Alvarez, 1995](#)). In addition to the expected scarcity of memories from the first five years of life, corresponding to childhood amnesia, there was a dominance of autobiographical memories from age 6 to 30 in AD, followed by a steep drop in the retrieval of memories for events that had happened after age 30. In contrast, the distribution of memories for personal semantic information showed a temporal gradient in AD, decreasing steadily from middle childhood to present life. The healthy control group performed close to ceiling on both the autobiographical incident and the personal semantic schedules, except for the first period of life, referring to the childhood amnesia period.

Findings on the personal semantic schedule in the AD group are consistent with both standard consolidation theory ([Alvarez & Squire, 1994](#); [Squire & Alvarez, 1995](#)) and with MTT/TTT ([Nadel & Moscovitch, 1997](#); [Winocur & Moscovitch, 2011](#)),

showing the temporal gradient which both theories would predict (for reviews, see [Kopelman, 2019](#); [Moscovitch & Gilboa, 2021](#)). However, neither of these two theories predicted the distribution of episodic memories in the AD group. Consolidation theory would predict a steadily decreasing negative gradient, and the MTT (at least in its original form) would predict a flat gradient for episodic information, neither of which is consistent with our findings. Instead, the data suggested that the lifespan distribution of autobiographical memories in AD patients resembled the one generally seen in healthy middle-aged and older adults, but with an absence of memories for the recent past. Thus, the lifespan distribution of memories retrieved in response to the autobiographical incident schedule was consistent with a reminiscence bump ([Rubin et al., 1986, 1998](#)), as suggested by [Kopelman \(2008, 2019\)](#) and [Kirk and Berntsen \(2018\)](#).

Although this distribution was not predicted by standard theories, one often cited explanation of the reminiscence bump appears compatible with the NPRC ([Gilboa & Moscovitch, 2021](#)), by suggesting a central role for schematized event knowledge in terms of cultural life scripts ([Berntsen & Rubin, 2004](#)). Cultural life scripts are semantic knowledge as to how individuals, born into a particular culture, are supposed to go through life and transit from one social role to another (e.g., from unmarried to married). A life script represents the most important transitional events in a certain culture, and stipulate the time slots in the life course when they are expected to happen consistent with cultural

norms (e.g., when to begin school, when to graduate and when to retire) (Berntsen & Rubin, 2004). Previous work has shown that the temporal distribution of freely generated, cultural life-script events mirrors that of ‘important’ autobiographical memories by showing a predominance of positive events expected to happen in young adult life (e.g., Berntsen & Rubin, 2004; Tungjitharoen & Berntsen, 2022; Zaragoza Scherman, Salgado, Shao, & Berntsen, 2017). Thus, the earlier parts of the lifespan are more saliently represented in cultural life scripts than later epochs. Because this over-representation of events in adolescence and young adulthood in the life script parallels the reminiscence bump for remembered personal events, Berntsen and Rubin (2004) suggested that the reminiscence bump may partly reflect the influence of cultural life scripts, structuring retrieval from autobiographical memory and favoring events from young adult life (also see Rubin & Berntsen, 2003; Berntsen & Rubin, 2002). Several studies have provided support for this idea (e.g., Berntsen, Rubin, & Siegler, 2011; Dickson, Pillemer, & Bruehl, 2011; Özdemir, Leichtman, Kreinices, & Pillemer, 2021).

Following this explanation, people with dementia may retain a reminiscence bump, because the retrieval of events from the ‘bump’ life-period is less demanding as a result of the retrieval support provided by the cultural life script. In addition, events consistent with cultural life scripts (e.g., beginning school, getting married, first child) may be better encoded and more rehearsed, due to their personal and collective importance as well as schema-consistent nature. This enhancement will make them more accessible and less vulnerable to forgetting. These considerations agree with recent findings that knowledge of cultural life scripts is relatively well-preserved in AD (Rasmussen & Berntsen, 2021), and is represented in the life stories of people with dementia to the same extent as in the life stories of healthy controls (Tippett, Prebble, & Addis, 2018, also see; Fromholt & Larsen, 1991).

The bump covers a formative period in people’s lives, central to self and identity (Conway & Pleydell-Pearce, 2000) and strongly influenced by the cultural life script (Berntsen & Rubin, 2004), which together raises the possibility that memories from the bump might be more gist-like and semantic in nature than memories from other periods. According to MTT, such memories would not require MTL involvement (e.g., Gilboa & Moscovitch, 2021; Nadel, Winocur, Ryan, & Moscovitch, 2007), possibly explaining why memories from the period of the bump are better preserved in people with AD. However, retrieval support from cultural life scripts could also facilitate the recovery of genuinely episodic memories. For example, thinking of typical life script events, such as ‘getting married’, may bring back specific memories of one’s own wedding with episodic details, such as the color of the wedding dress, the weather during the photographing in the garden, the thunder in the evening etc. In order to examine whether bump-memories were as episodically rich as memories from surrounding periods, we examined memories that attained a score of ‘3’ on the AMI incident schedule (compare Kopelman & Morton, 2015). These were descriptively rich, episodic memories, specific in time and space (Kopelman et al., 1989, 1990). As expected, such memories were overall substantially less frequent in the AD group than in the control group. But for the AD group, more than two-thirds of these memories derived from life before age

30, whereas the control group showed a more even distribution of such memories across time-periods, half referring to incidents up to age 30 and the other half to events occurring after age 30. Thus, ‘bump memories’ in AD did not show a relative lack of spatio-temporal specificity. On the contrary, the AD group retrieved more memories from the bump period that were descriptively rich and specific in time and place, than from subsequent periods.

Although the exact mechanisms underlying the bump remain to be clarified (see Koppel & Berntsen, 2016, for a discussion of different theoretical positions), identifying a reminiscence bump in AD is important for understanding the nature of the retrograde amnesia in this population. The present finding is consistent with a few previous studies identifying a bump in dementia by cue-word methods and/or free life story tasks (Fromholt & Larsen, 1991; Kirk & Berntsen, 2018; see also Kopelman, 2019). Although the cue word method is widely used for sampling autobiographical memories, it has some limitations in the present context by confounding a person’s predisposition or preference to remember events from a certain life period with his or her cognitive ability to do so (e.g., Rensen et al., 2017). This is because the cue-word method typically allows the person to sample freely across the entire life span (Crovitz & Schiffman, 1974)¹. The same limitation applies to the life narrative task, which also allows free sampling of memories from across the whole lifespan (Fromholt & Larsen, 1991). The expanded AMI used in the present study overcomes these limitations by structuring retrieval so that memories are assessed across the full life span. At the same time, it distinguishes systematically between episodic and semantic memory information, in contrast to more open-ended methods.

4.1. Limitations and future directions

The present study leaves several questions open for future clarification. First, it is well-established that the neural degeneration and cell loss that characterize AD begin in the hippocampi (e.g., Vyas, Montgomery, & Cheyne, 2020), and we have no reason to doubt that our AD participants have hippocampal damage. However, it was beyond the aim of the present study to include direct measures of hippocampal volume or function, in part because the extent of damage to the hippocampus is not closely related to the severity and extent of retrograde amnesia (Gilboa & Moscovitch, 2021; Kopelman et al., 2003). Nonetheless, it may be desirable to incorporate measures of hippocampal functioning in future studies on the present topic. As a proxy, we here examined memories that had attained a score of 3 on the AMI incident schedule, indicating descriptively rich episodic memories that were specific in time and place, that is, memories assumed to require hippocampal-dependent binding. As mentioned earlier, these memories more frequently derived from the first three decades of life in the AD group.¹

Second, future research should clarify the neural basis for cultural life script knowledge and the retrieval of

¹ The AMI was part of a test battery including other autobiographical memory measures (i.e., word-cueing and flashbulb memory), which will be reported elsewhere.

autobiographical memories supported by such knowledge in people with AD and healthy controls. The ventromedial prefrontal cortex has been found to play a role in schema-based encoding (Ghosh, Moscovitch, Colella, & Gilboa, 2014), but it remains to be investigated whether this brain region also is involved in the neural underpinning of cultural life script knowledge and its interaction with autobiographical memory.

Third, the control group did not show a reminiscence bump. Instead, they scored close to ceiling at all life periods, except for the earliest one coinciding with the period of ‘childhood amnesia’. However, a reminiscence bump has been demonstrated numerous times in healthy individuals and across a variety of cueing methods (e.g., Koppel & Berntsen, 2015, for review), including studies where participants have been asked to retrieve memories from within specific lifetime periods (as in the AMI) rather than freely across the entire lifespan. For example, Conway and Holmes (2004) identified a reminiscence bump in healthy older adults (62–89 years of age), when asked to retrieve three autobiographical memories from each of seven lifetime periods and allowed only 5 min to retrieve from each time-period before proceeding to the next epoch (for similar findings, see Demiray, Gülgöz, & Bluck, 2009; Elnick, Margrett, Fitzgerald, & Labovie-Vief, 1999). Because these temporally constrained cueing methods can be seen as similar to the technique used in the AMI, albeit more demanding, and because the reminiscence bump is a robust finding in healthy older adults, we do not view the ceiling effect in the control group in the present study as problematic. What the present study adds is that such bump is also observable in AD patients when probed by methods that are sufficiently sensitive to detect it in this particular population. Future studies, using the AMI in this context, might consider manipulating task difficulty to avoid ceiling effects in controls, for example by varying the response time or expanding the number of episodic memories required of the control group. However, such manipulation likely would increase the risk of floor effects in the AD group.

Fourth, it might be suggested that the dramatic drop in performance on the incident schedule after age 30 in the AD group reflects the onset of early disease, beginning there is hamper encoding already at this early age. Although there is evidence that AD has a long preclinical phase (e.g., Mufson, 2015), we nonetheless consider this explanation unlikely as, logically, this would imply a much more gradual decline than the one observed (especially when averaging across differently aged participants). The same would apply to any putative effects of increasing fatigue during the AMI interview.

5. Conclusion

Previous research has identified a temporally graded amnesia in AD for past events and personal semantic knowledge, when assessed on the AMI using only three lifetime periods. In contrast, the present findings indicate that the gradients for the two types of memory follow somewhat different distributions when more time-periods are included. Memory for autobiographical events follows a

distribution equivalent to a reminiscence bump, whereas memory for personal semantic facts shows a temporal gradient decreasing progressively from childhood to the recent past. Thus, the temporal gradients shown for episodic and semantic information in previous studies, although apparently similar when measured across only a few time-periods, may not reflect the same underlying mechanisms. Future research should examine whether a reminiscence bump is present in other neurological disorders, and whether, more generally, it provides an account of the temporal gradient in retrograde amnesia.

CRediT author statement

Dorthe Berntsen: Conceptualization, Methodology, Project management, Supervision, Formal analysis, Writing original draft, Funding acquisition.

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Data availability statement

Given patients' sensitive information, and General Data Protection Regulations (GDPR), the conditions of our ethics approval as well as Aarhus University GDPR policy do not permit public archiving of the anonymized data and codes generated during the current study. However, access to anonymized materials will be granted from the corresponding author upon request, but will require the completion of a formal data sharing agreement, in compliance with GDPR and Aarhus University rules. Legal copyright restrictions prevent public archiving of the various assessment instruments and tests used in this study, which can be obtained from the copyright holders in the cited references in section 2.2.

Pre-registration statement

No part of the study procedures nor analyses was pre-registered prior to the research being conducted.

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