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Another Piece to the Puzzle: Accounting for the Reminiscence Bump

Review

The reminiscence bump comprises an increase in the recollection of memories from adolescence and early adulthood in older adults and can be elicited by the use of the Crovitz-Shiffman cue word method. Furthermore, the reminiscence bump also comprises less vivid, emotive and significant memories. Multiple accounts provide explanations of this phenomenon, one of which is Fitzgerald's life-story account. This account entails that the increase in recollected memories is due to the fact that more memories from this period are associated with one's identity, which starts to develop in adolescence and early adulthood. Secondly, the reminiscence bump can be explained by a life script, which postulates that most of the events that are expected to prevail in one's life occur during adolescence and early adulthood. Thirdly, an increase in memory encoding during adolescence and early adulthood could explain the increase of recollected memories from this period. Furthermore, based on observed age-related differences in the prefrontal regions and the hippocampus, a new suggestion is put forward to explain the reminiscence bump. To further clarify, advanced age is associated with less episodic memory recall, as reflected by diminished activity in the prefrontal regions. Additionally, a predominantly left-lateralized pattern of activity in the hippocampus with advanced age is associated with the recall of more remote, detailed and emotional memories. Finally, all three accounts and a new suggestion will be discussed in terms of their ability to explain the reminiscence bump. Limitations, implications and suggestions for future research are discussed.
Keywords: reminiscence bump, life story account, life script account, memory encoding, age-related differences.

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INTRODUCTION

Whittlesea and Price (2001) claimed that there is only one memory system that is used in the execution of all tasks, such as remembering a doctor's appointment and learning how to drive a car. However, patients with lesions to different parts of the brain, showing qualitatively different memory loss, contradicted the existence of merely one memory system (Scoville & Milner, 1957). The famous case of H.M. had parts of the bilateral temporal cortex, including large parts of the bilateral hippocampus, removed to reduce epilepsy (Scoville & Milner, 1957; Squire, 2004). After the surgery, patient H.M. was not capable of learning and remembering new information, but was still capable of remembering events long before the surgery took place (Scoville & Milner, 1957; Squire, 2004). Furthermore, patient H.M. was able to learn new motor skills, such as drawing a mirror image. The case of patient H.M. is a clear illustration of the existence of multiple memory systems. Therefore, current definitions of memory take multiple memory systems into account (Baddeley, 1997; Lieberman, 2012; Squire, 2004). For instance, Baddeley (1997) asserted that memory comprises a multitude of systems that vary in the amount and type of information that is stored and how long this information is stored.

Throughout the years, there have also been ample attempts to subdivide memory (Baddeley, 2004; Lieberman, 2012; Squire, 2004)**.** Examples include the division into short-term memory and long-term memory (Lieberman, 2012; Atkinson & Shiffrin, 1971). Short-term memory comprises the transient retention of data from different sensory modalities (Atkinson & Shiffrin, 1971; Lezak, 2004), while long-term memory entails the perpetual storage of data from which data loss is minimal (Atkinson & Shiffrin, 1971; Lieberman, 2012). For example, short-term memory is used to remember the items on a grocery list, while long-term memory is employed to remember the birth of your first child. Long-term memory can be further subdivided into semantic memory and episodic memory (Lieberman, 2012). Semantic memory equals the remembrance of facts and is used to, for instance, remember the capital of France (Lieberman, 2012; Squire, 2004). Episodic memory reflects the remembrance of personal experiences of bygone episodes (Lieberman, 2012; Roediger & Marsh, 2003; Squire, 2004), like remembering your partner proposing.

The term episodic memory is often interchangeably used with the term autobiographical memory, which overlaps with episodic memory but is distinguishable (Roediger & Marsh, 2003). Autobiographical memory comprises personal bygone episodes,

similar to episodic memory, but can additionally entail personal facts, like a birthdate (Conway, 2001; Roediger & Marsh, 2003). The retrieval of autobiographical episodes has led to a well-known and rather surprising phenomenon, named the reminiscence bump. This reminiscence bump entails an increase in the recollection of memories from adolescence and early adulthood in older adults (Berntsen & Rubin, 2002; Bohn, 2010; Rubin & Berntsen, 2003; Rubin & Schulkind, 1997, 1997a).

Many attempts have been postulated to explain the reminiscence bump (Berntsen & Rubin, 2002; Fitzgerald, 1988; Glück & Bluck, 2007; Rubin, 2002; Rubin, Rahhal, & Poon, 1998). Two accounts explain the reminiscence bump by referring to social and cultural aspects of a person's life. First of all, Fitzgerald (1988) explains the reminiscence bump by means of a life story, which states that memories from adolescence and young adulthood are related to the start of one's own identity. Secondly, according to the life script account more memories are retrieved from this period, since the most important events that are expected to happen during a person's life, occur during adolescence and young adulthood (Berntsen & Rubin, 2002; Bohn, 2010; Rubin & Berntsen, 2003). Besides, a postulated biological account- the cognitive account- comprises increased memory processes during the period of adolescence and young adulthood, causing more memories to be encoded for later retrieval. Finally, another biological suggestion- the retrieval account- will be presented based on theories that display age-related differences in retrieval-related structures, for example, the prefrontal regions and the hippocampus.

In conclusion, a multitude of theories have provided possible explanations for the reminiscence bump, which are either socially, culturally or biologically based. The present review will highlight these different accounts and, subsequently, a biological explanation will be postulated. This new suggestion could aid in elucidating the insights into the reminiscence bump and might also provide more insights into the working of memory functions and memory decline. Furthermore, it is important to emphasize that this suggestion is not meant to dismiss any of the already existing accounts, but rather to offer an additional explanation. The aim of this review it to provide an answer to the question: 'How is and can the reminiscence bump be explained?

A brief overview of this review will now be presented. First of all, the reminiscence bump will be discussed and explained. Secondly, two theories that are based on social and cultural assumptions will be presented. Thereafter, some criticism of these theories will be stated. Eventually a biological approach is taken to describe the reminiscence bump. This

biological approach includes a cognitive account to the reminiscence bump and a suggestion based on age-related differences in retrieval. Finally, some implications, limitations and suggestions for future research will be presented.

THE REMINISCENCE BUMP

Autobiographical memory is the kind of memory that is involved in the verbal recollection of detailed events from an individual's past and is supplemented by the conviction that these events were personally experienced (Fitzgerald, 1999; Rubin, 1996; Tulving, 1985). This type of memory has been studied by multiple researchers using the 'Crovitz-Shiffman cue word method' (Jansari & Parkin, 1996; Janssen, Chessa, & Murre, 2005; Janssen & Murre, 2008). This method entails asking participants to respond with their first personal memory that is elicited by the presentation of a number of cue words (Jansari & Parkin, 1996; Rubin, 1996). Afterwards, the recollected personal memories are dated to determine from what point in the individual's life they originate (Jansari & Parkin, 1996; Rubin, 1996). The results from studies using this method, in older adults, reveal a phenomenon called the reminiscence bump. This reminiscence bump entails an increase in the recollection of positive autobiographical memories from adolescence or early adulthood in older adults (Berntsen & Rubin, 2002; Bohn, 2010; Rubin & Berntsen, 2003; Rubin & Schulkind, 1997, 1997a). Similar findings were published by Rubin and Schulkind (1997) who suggested that more autobiographical memories were recollected from adolescence and early adulthood in older adults. Besides, it has been stated that this increase of recollected autobiographical memories only applies to positive events (Berntsen & Rubin, 2002; Rubin & Berntsen, 2003), but the memories from the reminiscence bump have also been characterized as being more vivid and significant in comparison with other life episodes (Rubin et al., 1998). For example, the memories from this reminiscence bump comprise the college years, the birth of a child, or marriage (Rubin, 1996). Negative events from this period do not display a reminiscence bump, but diminish in a monotonous manner when going further back in time (Berntsen & Rubin, 2002; Rubin & Berntsen, 2003). Contradictory, Janssen and Murre (2008) stated that the retrieved memories from the reminiscence bump do not only comprise significant, vivid and positive memories, but are also assisted by increased recall of less vivid, insignificant and less emotive events. In conclusion, the reminiscence bump reflects an increase in the recollection of memories from adolescence

and early adulthood in older adults and can be elicited by the use of the Crovitz-Shiffman cue word method.

SOCIAL AND CULTURAL ACCOUNTS ON THE REMINISCENCE BUMP

Throughout the years, there have been many attempts to explain the reminiscence bump (Berntsen & Rubin, 2002; Fitzgerald, 1988; Rubin & Berntsen, 2003). First of all, the life story or narrative account, postulated by Fitzgerald (1988), explains the reminiscence bump by referring to the formation of life stories out of memories. This account states that individuals form a continuously developing self-narrative about their own life to comprehend the world around them. In addition, this self-narrative aids in the understanding of the temporal order of events in a person's life (Rubin et al., 1998; Rubin, 1996, 2002) and in the expression of a personal identity (Rubin et al., 1998). This formation of an identity has been shown to begin during early adulthood and adolescence (Rubin et al., 1998; Rubin, 2002) and is fabricated by transforming memories into narratives to constitute an identity (Berntsen & Rubin, 2002). More memories are therefore recollected from this period since they are more associated to one's identity and are perceived as more self-defining (Cohen & Taylor, 1998; Fitzgerald, 1996). A similar statement was postulated by Rybash (1999), who claimed that the majority of the recollected vivid and significant memories from adolescence and early adulthood mark the beginning of people's life narrative and aid in their own identification.

A second account on the reminiscence bump is the life script account (Berntsen & Rubin, 2002; Bohn, 2010; Rubin & Berntsen, 2003). This life script account directs the recollection of one's life story, since it entails general guidelines about what an idyllic life should consist of (Berntsen & Rubin, 2002; Bohn, 2010; Rubin & Berntsen, 2003). For example, marriage and having children are examples of events that are expected to occur during a person's life within a certain culture (Rubin, 1996). According to the life script account, many of the above mentioned examples occur during adolescence and early adulthood (Glück & Bluck, 2007). Furthermore, this life script is comprised of mostly positive events (Bohn, 2010). Negative events would not occur in the reminiscence bump, since these events lack a life script (Rubin & Berntsen, 2003). The life script account thus explains the reminiscence bump, in that most positive events that are expected to occur in a person's life happen during adolescence and early adulthood. This claim was further supported by a study of Bohn (2010), in which

participants were asked to recollect the seven most significant memories from their own life. In addition, they were asked to state the most significant events that would happen in an imaginary person's life and additionally mention the anticipated date at which these events would occur. The results of this study revealed that there was a greater overlap between when the recollected memories and the stated important events, for an imaginary person's life, would occur in older adults. That is, older adults were more inclined than younger adults to use a cultural life script in the recollection of significant life events (Bohn, 2010).

Glück and Bluck (2007) extended this life script account by taking a developmental perspective. They suggested that the period of adolescence and early adulthood is characterized by an increase in exercised control with regard to making decisions that have lasting impacts on people's life. For example, going to college and having another child are two examples of these consequential decisions. Therefore, Glück and Bluck (2007) predicted that the reminiscence bump would not only comprise positive events, as is assumed in the life script account (Berntsen & Rubin, 2002; Rubin & Berntsen, 2003), but would also include memories characterized by high observed control. Glück and Bluck (2007) investigated this claim by asking participants to recall the most significant events in their life. Subsequently, these recalled events were rated, by the participants, on valence (positive or negative) and observed control. The results of this study reveal that the reminiscence bump did not only comprise more positive events, but that these recollections were also characterized as events on which they exerted more control. Furthermore, the recalled events in the reminiscence bump were shown to be perceived as highly significant to the participant's own development (Glück & Bluck, 2007).

The life script account differs from the life story account in that the former is focused on the expectations of how a typical life should look like according to norms within a certain culture, while the latter is solely focused on how an individual narrates about their own life by use of personal memories (Berntsen & Rubin, 2002). The life script focuses on the expected temporal order of certain goals, while life narratives often include reaching goals by overcoming challenges.

In sum, the life story account and the life script account provide an explanation for the presence of the multitude of significant, vivid and positive memories. In contrast, these theories also have some downsides. First of all, with regard to the life story account, Rubin and Schulkind (1997a) asserted that the memories from the reminiscence bump were not rated as more important and were not narrated about more than memories from other life episodes. Furthermore, the life story account does not provide an explanation for the diminished

recollection of negative events (Berntsen & Rubin, 2002). Finally, these theories do not agree with the findings from Janssen and Murre (2008), who stated that the reminiscence bump also comprises less emotive, less vivid and insignificant events.

BIOLOGICAL ACCOUNT ON THE REMINISCENCE BUMP

Autobiographical memory can be linked to different neural structures, reflecting activation necessary for the encoding and retrieval of memories (Maguire & Mummery, 1999; Nyberg, Habib, McIntosh, & Tulving, 2000; Schacter, Savage, Alpert, Rauch, & Albert, 1996). Cabeza et al. (1997) claimed that advanced age is characterized by alterations in the neural networks that are important for encoding and retrieval of memories. That is, both encoding and retrieval of events are associated with age-related differences. Therefore, two biological accounts are put forward, including the cognitive account and a new suggestion that is based on the age-related changes observed in the encoding and retrieval of information.

First of all, according to the cognitive account, early adulthood and adolescence are characterized by many new events that are recollected better due to enhanced memory processes (Rubin et al., 1998; Rubin, 2002). Increasing effort to comprehend a novel event and the uniqueness of the event are two examples of memory enhancing processes. This view is in accordance with Rubin, Rahhal and Poon (1998) who put forward a cognitive account to explain the reminiscence bump in three possible ways. First of all, according to the cognitive account, new and distinctive events are encoded better when followed by a "period of relative stability" (Rubin et al., 1998, p. 639). That is to say, these new and distinctive events are processed more thoroughly due to their distinctiveness and newness in comparison with preceding events. Secondly, because these events are so distinctive from preceding periods, there is less proactive interference. Proactive interference entails the failure to recall events due to the interference of previously learned material (Jonides & Nee, 2006). Finally, due to the long period of stability in adulthood, adolescence and early adulthood are often used as reference points at retrieval (Berntsen & Rubin, 2002). In sum, the elaborate encoding of new and distinctive events, the small amount of proactive interference and the long period of stability in adulthood render the events from the period of adolescence and early adulthood more accessible for recollection later in life.

Furthermore, the finding of Janssen and Murre (2008) can be explained by this peak in

memory encoding during adolescence and early adulthood, which not only causes more significant, vivid and positive events to be encoded, but also more insignificant, not so vivid and less emotive events (Janssen et al., 2005; Janssen & Murre, 2008). Hence, the increase in memory encoding during adolescence causes more events to be encoded in general, regardless of whether they are more emotive, vivid or significant. Besides, with increasing age, memory encoding declines and only the more remarkable events are being rehearsed, causing the older adult to be more inclined to recall the memories from adolescence at the expense of other lifetime episodes (Grady et al., 1995). Thus memory encoding peaks during adolescence and decreases throughout the rest of the life span. This also became evident in a positron emission tomography (PET) study conducted by Grady et al. (1995), who examined the regional cerebral blood flow (rCBF) while participants were encoding and recognizing faces. The results of their study revealed a heightened activation, during encoding, of the right hippocampal and left prefrontal cortices in the young participants. In contrast, older participants displayed a lack of activation in the hippocampus and the prefrontal cortex. This finding was interpreted by Grady et al. (1995) as a deficiency in the encoding of stimuli in old age. It follows that memory encoding is associated with age-related differences, since in old age there is a reduction in stimuli encoding (Grady et al., 1995).

In sum, the cognitive account provides a thorough explanation of the reminiscence bump, since enhanced encoding processes during adolescence and early adulthood cause more memories to be encoded in general, regardless of the significance or vividness of the memories. Since the peak in memory encoding declines with advanced age, older adults might recollect more memories from the period of adolescence and early adulthood, compared to other life time periods, reflecting the reminiscence bump.

Age-related differences in the prefrontal regions and hippocampus as an additional explanation to the reminiscence bump

Age-related differences have been observed, not only in autobiographical memory encoding, but also in autobiographical memory retrieval (Cabeza et al. 1997; Rybash, 1999), which has been associated with activation in different neural structures. Examples of these neural structures include the prefrontal regions and the hippocampus, among others (Maguire & Mummery, 1999; Nyberg et al., 2000; Schacter et al., 1996; Viard et al., 2007). Two theories have been put forward to explain memory consolidation and retrieval (Nadel, Samsonovich, Ryan, & Moscovitch, 2000; Piefke, Weiss, Zilles, Markowitsch, & Fink, 2003).

First of all, the standard consolidation theory emphasizes the momentary role of the

hippocampus during the processing and storage of memories (as cited in Nadel et al., 2000; Piefke et al., 2003). The hippocampus is important in the transferral of memories to the neocortex. Also, the hippocampus links different neocortical regions during the storage of memories (Nadel et al., 2000). Once the memories are integrated in the neocortical regions, they are no longer dependent upon the hippocampus (Rosenbaum, Winocur, & Moscovitch, 2001). That is, after the memories are consolidated, the neocortex is capable of memory recollection without the involvement or support of the hippocampus (Rosenbaum et al., 2001). The standard consolidation theory is in good accordance with the results of a study by Piefke, Weiss, Zilles, Markowitsch, and Fink (2003). Piefke et al. (2003) performed a functional MRI study to investigate the neural underpinnings of autobiographical memory retrieval. Participants were presented with visual stimuli and were asked to read them out loud. The stimuli consisted of the participant's own childhood memories that were collected during an interview prior to the study. Also, these stimuli comprised of either a recent or a remote memory. The results of this study revealed that recent memories were accompanied by activity in the retrosplenial and hippocampal region, which was not the case for remote memories (Piefke et al., 2003). This finding supports the standard theory of memory consolidation, as the hippocampus has a 'time-limited' part in memory processing (Piefke et al., 2003).

Further support for this standard theory is found in a phenomenon called retrograde amnesia (Bontempi, Laurent-Demir, Destrade, & Jaffard, 1999). Retrograde amnesia is characterized by damage to the hippocampus and relatively intact remote memory, while recent memories are damaged (Bontempi et al., 1999). This loss of only the recent memories indicates that the hippocampus does have a temporary role in the retrieval and storage of memories (Bontempi et al., 1999). In contrast, Rosenbaum et al. (2008) stated that participants with retrograde amnesia and damage to the hippocampus also display loss of remote autobiographical memories. In their study, they analysed the autobiographical retrieval of four patients with retrograde amnesia. It was concluded that the extent of remote memory loss was dependent upon the amount of damage to the hippocampus (Rosenbaum et al., 2008). To further clarify, one patient, with extensive lesions to the hippocampus in comparison with the other patients, displayed most severe loss of memories (Rosenbaum et al., 2008). This contrasting finding contributed to the development of a second theory that accounts for memory consolidation and retrieval, named the 'multiple trace theory' (as cited in Nadel et al., 2000).

The 'multiple trace theory' (as cited in Nadel et al., 2000) emphasizes the consistent role of the hippocampus in memory retrieval irrespective of the age of the memories (Nadel et

al., 2000; Piefke et al., 2003; Ryan et al., 2001). That is, the hippocampus is always rendered important in the storage and recollection of very remote and recent autobiographical memories (Nadel et al., 2000), since the connection between the neocortex and the hippocampus lasts for as long as the memory does (Rosenbaum et al., 2001). This consistent role of the hippocampus in memory retrieval only holds for episodic memory, since semantic memory is said to become independent of the hippocampus because of its lack of contextual aspects (Rosenbaum et al., 2001). Furthermore, according to the multiple trace theory, every retrieved memory is followed by the creation of a novel memory trace that is represented by neurons in the hippocampus and neocortex (Piefke et al., 2003; Rosenbaum et al., 2001; Ryan et al., 2001). Over time, this accumulation of memory traces, which are repeatedly activated by the recollection of memories, induces the creation of new memory traces, causing more remote memories to be represented by a multitude of traces compared to recent memories (Piefke et al., 2003; Rosenbaum et al., 2001; Ryan et al., 2001). Therefore, more remote memories are rendered less vulnerable to hippocampal damage in comparison with more recent memories (Piefke et al., 2003).

The multiple trace theory is further supported by the findings of Maguire and Frith (2003), who found that the hippocampus was related to age-related differences and involved in autobiographical memory retrieval. In their study, younger and older participants were asked to recollect real life episodes during a functional magnetic resonance imaging (fMRI) brain scan. The results of this study revealed activation in the left hippocampus for the younger participants, while the older participants displayed bilateral hippocampal activation during autobiographical memory retrieval. Furthermore, upon comparison of younger and older participants, it was shown that older participants displayed higher activation in the right hippocampus. In addition, the findings of the study by Nadel, Samsonovich, Ryan, and Moscovitch (2000) and Ryan et al. (2001) displayed similar activation in the hippocampus during recall of very recent and very remote memories. That is to say, the hippocampus is always involved in the recollection of autobiographical memory.

In sum, two theories have been postulated to explain memory consolidation and retrieval (Nadel et al., 2000; Piefke et al., 2003), which differ from each other in the emphasis they place upon the role of the hippocampus in the process of autobiographical memory retrieval. It follows from the above mentioned theories that the hippocampus and the prefrontal regions are important in autobiographical memory retrieval (Maguire & Mummery, 1999; Schacter et al., 1996). This became evident even more, in an fMRI study of Maguire, Vargha-Khadem and Mishkin (2001), in which a patient with damage to both sides of the

hippocampus displayed activation in the connectivity between the remaining hippocampus and the frontal cortex. That is, this patient displayed activation in the remainder of his hippocampi and medial frontal cortex when retrieving autobiographical episodes he clearly remembered. Both structures will briefly be discussed below.

Age-related differences in the prefrontal regions

First of all, the prefrontal regions are involved in autobiographical memory retrieval (Cabeza et al., 1997; Maguire & Mummery, 1999; Rybash, 1999; Schacter et al., 1996). This involvement of the prefrontal regions in autobiographical memory retrieval predominantly has to do with strategic retrieval (Burgess, Maguire, Spiers, & O'Keefe, 2001). This strategic retrieval reflects supplementary and extensive processing to resolve homogenous episodes from autobiographical memory (Grady & Craik, 2000), for example deciding whether a memorized event happened just recently or a couple of years ago (Grady & Craik, 2000).

Besides, the prefrontal regions are also associated with age-related differences with regard to the retrieval of autobiographical memories (Anderson et al., 2000; Cabeza et al., 1997; Grady et al., 1995). For example, the areas that are activated by younger adults display diminished activity in older adults, whereas more activity has been shown in other prefrontal regions (Anderson et al., 2000). Therefore, the specific role of episodic memory in the prefrontal regions deteriorates with age (Anderson et al., 2000), starting halfway the second decade of one's life (Werkle-Bergner, Müller, Li, & Lindenberger, 2006). This deterioration of episodic memory in old age is partly due to the diminution of recollected contextual particulars (Piolino, Desgranges, Benali, & Eustache, 2002; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002), which are said to render a memory as episodic (Piolino et al., 2002). An example of a contextual particular is recollecting who was present at your eight birthday or what they were wearing. Likewise, Levine, Svoboda, Hay, Winocur, and Moscovitch (2002) stated that autobiographical memory retrieval in old age was associated with less episodic details, while semantic particulars were still preserved. A study by Levine et al. (2002) offered further support for this statement. In this study, younger and older participants recollected episodes from five different periods of their life. The results of this study revealed that older adults were biased toward more semantic details during autobiographical memory retrieval. Semantic details, like having a relationship with someone for a couple of months, included factual information. In contrast, younger participants recollected episodic particulars, for example, beliefs and places that were associated with their memories. One explanation for this finding is compensation, by semantic memories, with advanced age (Piolino et al., 2002). That

is to say, deficiencies in episodic memory that are reflected by right prefrontal activation might be compensated for by semantic memory that is reflected by left prefrontal activation (Cabeza et al., 1997; Levine et al., 2004). Likewise, activation in the right inferior frontal gyrus was displayed during autobiographical retrieval, while activation in the left inferior frontal gyrus was apparent during semantic retrieval (Greenberg et al., 2005). According to Cabeza et al. (1997), this lateralization in prefrontal activation with advanced age reflects a shift in retrieval processes.

In a similar manner, age related changes have been documented in the study by Anderson et al. (2000), who stated that, among young adults, the prefrontal regions were bilaterally activated during retrieval, while the older adults displayed a left lateralized activation pattern. Finally, Cabeza et al. (1997) performed a PET study in which the rCBF was compared in young and old participants during the encoding, recognition and recollection of word pairs. This study revealed neural alterations with increasing age in the brain mechanisms responsible for recollection. For example, older adults displayed heightened bilateral activation in the prefrontal regions while recollecting memories.

In sum, the prefrontal regions are of importance to autobiographical memory retrieval. The deterioration of episodic memory recall with advanced age is reflected in a diminished activity in the right prefrontal regions. Due to semantic compensation, which is reflected by a predominantly left-lateralized pattern of activation in the prefrontal regions, the recollected memories of older adults comprise more semantic details than the memories of younger adults. Since semantic memory is less associated to the self than episodic memory (Conway, 2001; Roediger & Marsh, 2003), this finding is in accordance with the findings of Janssen and Murre (2008), who stated that the reminiscence bump also included less emotive, less vivid and less significant events.

Age-related differences in the hippocampus

A second important structure to autobiographical memory retrieval is the hippocampus (Maguire & Mummery, 1999; Maguire, Vargha-Khadem, & Mishkin, 2001; Viard et al., 2007). Heightened hippocampal activation is associated with the conscious retrieval of bygone episodes that are personally significant and time-specific (Maguire & Mummery, 1999; Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000), but is also involved in 'associative retrieval' of autobiographical memories (Rybash, 1999). Also, the hippocampus combines the qualities of a specific retrieved memory together to re-establish an episodic memory (Addis, Moscovitsch, Crawley, & McAndrews, 2004; Werkle-Bergner et al., 2006).

These qualities of retrieved memories include the emotional valence, specificity or detail, and the subjective significance (Addis et al., 2004; Werkle-Bergner et al., 2006).

A PET study by Fink et al. (1996) also confirmed the importance of the hippocampus in autobiographical memory. Participants were either presented with no stimulation or auditory stimulation in the form of sentences. These sentences contained autobiographical information from an unknown person or from their own past. Furthermore, participants were requested to imagine the content of these sentences. For example, one sentence described a swimming contest of a 15-year old person. Changes in rCBF were either measured in the absence of auditory stimuli or during the presentation of the above mentioned auditory stimuli., More activation was displayed in the right hemisphere when listening to autobiographic sentences of their own past than from other participants. This right hemispheric region comprises the hippocampus, temporo-parietal cortex and prefrontal cortex, among others. However, it should be emphasized that this study measured activation after participants listened to auditory sentences and imagined the contents of the displayed autobiographical information from their own or someone else's past. Thus, listening to auditory stimuli might not be equal to the recollection of autobiographical information.

Besides, the involvement of the hippocampus in autobiographical memory retrieval has also been shown to change with age (Piefke & Fink, 2005; Maguire & Frith, 2003; Werkle-Bergner et al., 2006), and starts deteriorating later than the prefrontal regions (Werkle-Bergner et al., 2006). A similar statement was postulated by Piefke and Fink (2005), who suggested that there is deterioration in autobiographical memory with increasing age that goes along with a deterioration of the retrosplenial circuits and the hippocampus. These age-related differences manifest themselves in different ways. Firstly, the phenomenal experience associated with the recollection of memories changes with the lapse of time, as was suggested by Piolino et al. (2004). Namely, the results of an fMRI study revealed heightened quality of the mental images for recent, in comparison with remote, memories (Piolino et al., 2004). A possible explanation is a change in the lateralization of hippocampal activation. Namely, an fMRI study showed that left hippocampal activation is associated with the recollection of more detailed memories and memories that are high in emotional valence (Addis et al., 2004. Furthermore, right hippocampal activation correlated with the recency component of the retrieved memories (Addis et al., 2004). It follows that changes in the lateralization of hippocampal activation might account for the changes in phenomenal experience. Furthermore, it was stated by Piefke and Fink (2005) that the hippocampal hemispheric lateralization was dependent upon the participant's age and that of the retrieved memories.

Secondly, age-related differences are observed among participants, as was shown in the study by Maguire and Frith (2003) who showed that the hippocampus was influenced by age of the participants and involved in autobiographical memory retrieval. In their study, younger and older participants were asked to recollect real life episodes during an fMRI brain scan. The results of this study revealed activation in the left hippocampus for the younger participants, while the older participants displayed bilateral hippocampal activation during autobiographical memory retrieval. Furthermore, upon comparison of younger and older participants, it was shown that older participants displayed heightened activation in the right hippocampus.

Thirdly, age-related differences are present with regard to the age of the memories. To further clarify, the hippocampus was shown to be asymmetrically involved in the retrieval of remote autobiographical memories (Maguire & Frith, 2003). Another, slightly different, fMRI study was conducted by Maguire and Frith (2003) to enlarge the insight in the neural underpinnings of remote memory. The participants in this study were interviewed prior to the experiment to collect personal and detailed memories. These memories formed the basis of assembled sentences that were presented auditorily to the participants. The participants were asked to attend to each sentence and indicate if the sentence was correct or untruthful. The results revealed that the hippocampi were active during the recollection of these autobiographical events. Furthermore, the left hippocampus displayed activity regardless of the age of the memories. In contrast, the right hippocampus displayed diminished activity as the memories became more remote (Maguire & Frith, 2003). For example, the right hippocampus was still active for memories extending back ten years, but decreased in activation with regard to memories from 30 years ago. Furthermore, the right hippocampus displayed no activity during the retrieval of memories from 40 years ago (Maguire & Frith, 2003). Viard et al. (2007) also investigated the neural underpinnings of autobiographical memory recollection in elderly. The results of their study revealed activity in the left hippocampus for the recollection of all episodes, while the right hippocampus displayed activity during the intermediate periods (Viard et al., 2007).

In sum, the hippocampus is important for autobiographical memory retrieval, since it binds together the particulars of a bygone episode that re-establishes the phenomenal experience of an episodic memory (Piolino et al., 2002). Also, age-related differences have been displayed with regard to hippocampal activation. First of all, the phenomenal experience changes and is reflected by a predominantly left-lateralized pattern of activation for the recall of remote, detailed and emotional memories (Piolino et al., 2004). Secondly, age-related

differences were observed in advanced age, since old age was characterized by a bilateral pattern of activation. Furthermore, left hippocampal activation reflected the retrieval of remote memories, while right hippocampal activation reflected intermediate and recent periods of recollection (Piolino et al., 2004). This change in hippocampal activation with advanced age therefore posits an explanation for the presence of the more significant, novel and positive emotions present in the reminiscence bump, since old age is characterized by a predominantly left-lateralized pattern of hippocampal activation reflecting the retrieval of detailed, emotional, and remote memories. In sum, differential activation in the prefrontal regions and the hippocampus represents less episodic memory recall, and recall of more remote, detailed and emotional memories, respectively. That is, older adults recollect memories that are less well characterized by time and place and more by factual or semantic information (Levine et al., 2002). The reminiscence bump comprises an increase in the recollection of positive, vivid and significant memories from adolescence and early adulthood in older adults, but also comprises less vivid, emotive and significant memories, as stated by Janssen and Murre (2008). This differential activation in the prefrontal regions and the hippocampus may therefore explain in part the findings as stated by Janssen and Murre (2008). It is unclear, however, if the change in hippocampal activation also reflects a compensatory function. Furthermore, this suggestion, regarding the retrieval-based structures, cannot explain the multitude of memories recollected during the period of adolescence and adulthood compared to other time periods or the presence of less emotive, insignificant and less vivid events. It remains unclear up to the present day, if left hippocampal activation also displays a compensatory function and could explain the presence of semantic particulars just as good as the prefrontal regions do.

DISCUSSION

This review set out to answer how the reminiscence bump is and can be explained. The reminiscence bump comprises an increase in the recollection of memories from adolescence and early adulthood in older adults (Berntsen & Rubin, 2002; Bohn, 2010; Janssen & Murre, 2008; Rubin, 1996; Rubin & Berntsen, 2003; Rubin & Schulkind, 1997, 1997a). The life story and life script account provide two possible explanations for this increase in recollection, based on the life stories of people and the implementation of life scripts (Cohen & Taylor, 1998;

Fitzgerald, 1988, 1996; Glück and Bluck, 2007; Rubin et al., 1998; Rubin, 2002; Rubin & Berntsen, 2003). Furthermore, two biological accounts provide explanations for the reminiscence bump. First of all, the cognitive account proposes increased memory enhancing processes during adolescence and early adulthood (Rubin et al., 1998; Rubin, 2002). Secondly, a new suggestion is put forward that is based on age-related differences in prefrontal and hippocampal regions (Anderson et al., 2000; Cabeza et al., 1997; Maguire & Frith, 2003; Maguire & Mummery, 1999; Piefke & Fink, 2005; Rybash, 1999; Schacter et al., 1996).

The above mentioned accounts are complementary and non-exclusive. Furthermore, they can be evaluated on the basis of three criteria. Certainly, other criteria might apply as well, but the focus will be on the following criteria. First of all, an important criterion is the competence of the account to explain why a multitude of memories are recollected from the period of adolescence and early adulthood compared to other lifetime periods (1). Another important criterion regards the capability of the account to explain the presence of mainly positive, vivid and significant events in the reminiscence bump (2). Furthermore, the theory should account for the presence of less emotive, less vivid and insignificant events in the reminiscence bump, to explain the findings of Janssen and Murre (2008) (3). All four accounts will be discussed according to these three criteria.

First of all, the life story account by Fitzgerald (1988) is competent in explaining the positive, vivid and significant memories from the reminiscence bump, but does not explain the less emotive, vivid and significant events nor the many recollected memories. For example, Rubin and Schulkind (1997a) have stated that the recollected memories from the period of adolescence and early adulthood were not narrated about more or rated as more important. Furthermore, the life script account does explain the presence of significant and vivid events in the reminiscence bump, by referring to this period as the start of a life story and identity. Also, the life script account does explain the multitude of recollected memories and the presence of positive, vivid and significant events. For instance, more positive and significant events are recollected during the period of adolescence and early adulthood because this period comprises many events expected to occur during a person's life. However, this life script account lacks an explanation for the presence of the not so emotive, significant and vivid events. In contrast, the cognitive account can satisfy all three criteria. That is to say, memory enhancing processes explain the multitude of the memories and the presence of memories in general, regardless of their emotional valence, vividness of significance. Finally, the retrieval account has been put forward in this review as a suggestion and additional explanation to the reminiscence bump, which may prove to be fruitful in the future. Based on the stated evidence

in this review, it can only be concluded that there is some evidence at present to indicate that the retrieval account is capable of explaining the presence of memories characterized as significant, novel and positive. It does not explain the multitude of the memories in the reminiscence bump or the presence of less emotive, less vivid and insignificant events, based solely on the observed age-related differences in prefrontal and hippocampal regions. This account can be used to complement already existing evidence and vice versa. For instance, the cognitive account might augment the retrieval account by explaining the multitude of the recollected memories. Also, the retrieval account could augment to the life story and life script account since it is based on observed neural activation patterns in the brain. Furthermore, even the cognitive account could be expanded to include the areas responsible for memory enhanced processing. In conclusion, considering the amount of evidence displaying a correlation between age-related retrieval differences at the cerebral level and differences in the reminiscence bump, it would be interesting to further explore this in the future. Eventually, the retrieval account is just another piece to the puzzle.

There are several limitations to this review. First of all, design limitations of studies cited hamper the interpretation of the reminiscence bump. That is, the majority of the above mentioned studies elicited the reminiscence bump by means of the Crovitz-Shiffman cue word method. Even though this is a well-known and widely used instrument to elicit the reminiscence bump, it is not regarded as representative of natural recollection (Cohen & Taylor, 1998). Additionally, the cue word method might facilitate the use of a strategy during autobiographical memory retrieval. For example, participants might choose a certain episode as a baseline to explore all other retrieved memories (Janssen et al., 2005). The use of such a strategy would then bias the autobiographical memory recollection, since the memories that are recollected are more associated to each other than would be the case during free recall. Secondly, the above mentioned accounts are not thorough explanations of the reminiscence bump. Interestingly, some deviations from the reminiscence bump have been reported. For example, Janssen, Chessa and Murre (2005) stated that the reminiscence bump was influenced by the nationality of the participants in their study. That is, American participants revealed a tendency to recall older memories than the Dutch participants. Another example of a deviation, with regard to the reminiscence bump, was a second reminiscence bump in older adults that reflected a national conflict in the life of the participants (Conway & Hague, 1999). Finally, the reminiscence bump has also been observed in younger participants. This finding became evident in a study by Jansari and Parkin (1996), in which the reminiscence bump was elicited by means of the Crovitz-Shiffman cue word method. Participants were allocated to a

recency or no-recency condition. In the no-recency condition the participants were asked not to recollect memories from the past two-and-a-half years, while this was not prohibited in the recency condition. Therefore, one should keep in mind that there are irregularities in the characterization of the reminiscence bump that prevent any account from providing a thorough explanation of the reminiscence bump. Furthermore, the hemispheric lateralization of the hippocampus with advanced age is not exclusive to the left and right parts of the hippocampus. That is, differences in relation to the recency component of autobiographical memories have been observed with regard to the anterior and posterior regions of the hippocampus (Gilboa, Winocur, Grady, Henevor, & Moscovitch, 2004; Lepage, Habib, Tulving, 1998). Also, autobiographical memory retrieval is not only limited to the involvement of the hippocampus and the prefrontal regions. Other neural structures have shown to be implicated in autobiographical memory retrieval, for example the parahippocampal gyrus (Tsukiura et al. 2002).

With regard to future research, it would be interesting to further examine the association of semantic compensation with the prefrontal regions and the hippocampus. This could be done by investigating if the recollected memories of older adults are indeed characterized by more semantic particulars in comparison with younger adults. Furthermore, the brain activity could be measured during the recollection of these memories. Also, lesions studies could provide insight in the workings of the right prefrontal and hippocampal regions. Finally, it might be interesting to explore the above mentioned suggestions by using methods other than the Crovitz-Shiffman cue word method. For example, Janssen et al. (2005) alternated the use of the cue word method with the dating of news events to prevent participants from using a certain episode as a starting point for the retrieval of subsequent memories. Additionally, it would be of interest to examine the specific conditions that elicit the variations in the reminiscence bump to see if these variations are mere exceptions to a general phenomenon. For instance, do all people who have experienced a national conflict display a second reminiscence bump? Also, it would be interesting to find out if the differences between nationalities can be explained by differences in gender or personality. Finally, research with regard to the different lateralization patterns and the surrounding brain structures might provide fruitful for further understanding in this phenomenon. For instance, the association of the parahippocampal gyrus might reveal more about the nature of the reminiscence bump than is known at present. Again, lesions studies might be beneficial to explore this suggestion. It is of great importance to further elucidate the above mentioned suggestions, since the reminiscence bump has not been explained thoroughly up to the present

day. Furthermore, gaining more insight into the reminiscence bump might provide more insight into the workings of memory retrieval and encoding. Overall, exploring the reminiscence bump, and memory retrieval and encoding, might give us more insight in healthy memory decline in older adults. Since there are currently no records to support these suggestions, future research is needed to further clarify them.

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