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Research report

Specific role of medial prefrontal cortex in retrieving recent autobiographical memories: An fMRI study of young female subjects

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ABSTRACT

Episodic-autobiographical memory (AM) is characterized by self-conscious reflection, emotional connotation and mental time travel. Semantic memory (SM) contains context and emotion free general knowledge. The present study specifically aimed at exploring the effect of time on the neural substrates of autobiographical and semantic memory retrieval by studying memories from different life periods in young female participants using functional brain imaging. Recent compared to early childhood events activated retrosplenial cortex. More importantly, medial prefrontal cortex (MPFC) was specifically engaged in the retrieval of recent AMs. The data show time-modulated neural substrates during recent and remote memories in women and suggest that a specific MPFC activation underlies the autonoetic, emotional and self-related character of recent AMs.

1. Introduction

One of the most complex functions of our brain is the ability to reconstruct and re-experience our personal past. The episodic-autobiographical memory (AM) system allows mental time travel into our past and self-conscious reflection of our emotionally toned experiences. By contrast, the semantic memory (SM) system enables human beings to retrieve general

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knowledge without emotional context (Fink et al., 1996; Tulving and Markowitsch, 1998; Tulving, 2005). A complex neural network consisting of the medial prefrontal, temporal and retrosplenial cortices, as well as cerebellar regions is generally known to support AM retrieval (Maguire, 2001; Piefke and Fink, 2005) and constitutes the 'core' AM network (Svoboda et al., 2006). AM evolves around the age of 3 years, interacts with socio-cultural aspects and develops continuously during the course of life (Perner and Ruffman, 1995; Tulving, 2005). Developmental psychology suggests that the sense of self establishes itself between adolescence and young adulthood from the age of 18 years on and gains permanence in the growing young adult (Krampen and Reichle, 2002; Miller et al., 2001; Zeman, 2001). Therefore, it seems important to investigate the complex neurobiological basis of AMs in young adults, as they are in the course of their personal development and evolve a 'sense of self' about their past, especially about their emotional past which is a key aspect of AM.

Only a few imaging studies investigated AM in young adults (e.g., Rekkas et al., 2005; Piefke et al., 2003; Addis and Schacter, 2008), other mainly recruited middle-aged or elderly adults (Maguire and Frith, 2003; Ryan et al., 2001; Addis et al., 2004; Steinvorth et al., 2005). Even fewer of these imaging studies used recency or remoteness as a continuous variable to investigate younger adults (Maguire and Frith, 2003; Addis et al., 2004; Maguire et al., 2001; Piefke et al., 2003). The only imaging study, to our knowledge, which investigated subjects in their early 20s (Addis and Schacter, 2008) focused on hippocampal engagement. The current study concentrated on time-dependent (autobiographical and semantic) memory retrieval in 15 young women of 20–22 years of age and examined changes in neural activity in the whole brain using fMRI. We analyzed four different time periods with similar duration. Moreover, we adopted a matched, time-dependent control task, the retrieval of SMs, using public events of the same four time periods. Such a time-dependent semantic control task is especially important when investigating the specific effect of time on AM retrieval.

2. Materials and methods

2.1. Subjects

Fifteen healthy, right-handed female volunteers (aged 20–22, mean age 20.8 years) with no history of neurological or psychiatric illness were recruited at the University of Bielefeld. Only female participants were studied in order to obtain a homogeneous group. Since gender differences have been previously reported for AM processing (see, e.g., Piefke et al., 2005; Cahill et al., 2001), we decided to examine only women to not introduce another factor, i.e., gender, into our experimental design. This obviously limits the generalizability of the results to male subjects. Informed written consent and ethical approval were obtained.

2.2. Stimuli

By means of a semi-structured interview, individual autobiographical stimuli were acquired three months before scanning. Subjects were asked to recall spontaneously important personal positive and negative events from their early childhood to the day of their interview. Only personally remembered events were included; events which were only indirectly remembered (i.e., by report of others) were excluded. After the free recall, the events were classified into four life periods (constituting the lifeline of the person). *Period 1 (P1)*: memories from the age of 3 years until the beginning of school; *Period 2 (P2)*: memories from the beginning of school until the age of 15; *Period 3 (P3)*: memories from the age of 15 to 18 years; *Period 4 (P4)*: recent memories concerning only the last year before the interview.

After the initial interview, we asked our participants to indicate important personal events in the respective time categories. For that purpose, we proposed to them topics like ''the first day of school'', ''first kiss'', ''holidays'' etc. Subjects were required to provide detailed contextual information for each remembered event. The interviews were tape-recorded. Thereby, altogether 18 personal, detailed events were recollected for each life period in the interview (9 positive events and 9 negative events). To control for emotional tone, the number of positive and negative episodes was balanced. For the fMRI experiment, two different stimulus sentences were constructed for each autobiographical episode retrieved. Thus, 36 stimulus sentences per life period were created from the interviews resulting in a total of 144 spoken stimulus sentences (36×4 life periods) recorded with an audio program. (Example: *''During our ski holidays in Italy, I win the second price in a ski competition.''*).

To construct SM contents we created a large item pool with important past public events (covering the time span from early childhood until today). A questionnaire with the pool of items was given to an age-matched female control group of 15 healthy volunteers. The instruction was to indicate only those events they remembered at the time point of occurrence. Only events remembered by all 15 subjects were selected for the fMRI experiment. The public event stimuli also followed the same subdivision into the four life periods as the autobiographical stimuli. In total, we created 144 semantic stimuli from the questionnaires (36 per life period; example: *''Right after the start, an Air France Concorde plane crashes into a hotel.''*). As for the AMs, we carefully controlled for emotional tone by balancing the number of positive and negative public event stimuli.

2.3. Experimental set up and task

During the fMRI experiment all 288 stimuli were presented via headphones. We used a blocked 2×4 factorial design with two different memory types (*AM* and *SM*) and four life periods (*P1*, *P2*, *P3* and *P4*). The experiment comprised three experimental runs, lasting 15 min each.

Each of the three runs contained 96 stimuli divided into 16 blocks with 6 stimuli per block. Each stimulus sentence was displayed for a duration of 4.5 sec. The retrieval time was chosen referring to recent electrophysiological evidence which points at retrieval times for AMs ranging from 3 to 9 sec with a mean of 5 sec (Conway et al., 2003). The inter-stimulus interval between each stimulus sentence was 1 sec resulting in a block length of 33 sec. To prevent habituation effects, each stimulus sentence was presented only once. The order of