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Shifting visual perspective during retrieval shapes autobiographical memories

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ABSTRACT

The dynamic and flexible nature of memories is evident in our ability to adopt multiple visual perspectives. Although autobiographical memories are typically encoded from the visual perspective of our own eyes they can be retrieved from the perspective of an observer looking at our self. Here, we examined the neural mechanisms of shifting visual perspective during long-term memory retrieval and its influence on online and subsequent memories using functional magnetic resonance imaging (fMRI). Participants generated specific autobiographical memories from the last five years and rated their visual perspective. In a separate fMRI session, they were asked to retrieve the memories across three repetitions while maintaining the same visual perspective as their initial rating or by shifting to an alternative perspective. Visual perspective shifting during autobiographical memory retrieval was supported by a linear decrease in neural recruitment across repetitions in the posterior parietal cortices. Additional analyses revealed that the precuneus, in particular, contributed to both online and subsequent changes in the phenomenology of memories. Our findings show that flexibly shifting egocentric perspective during autobiographical memory retrieval is supported by the precuneus, and suggest that this manipulation of mental imagery during retrieval has consequences for how memories are retrieved and later remembered.

1. Introduction

Memories from our personal past are not static, but can be retrieved and thought about in multiple ways. This adaptive and flexible characteristic of memories enables us to construct alternative visual perspectives from which to view the past, in which we shift our first person viewpoint from inside the body to outside the body—seeing ourselves within the memory rather than re-experiencing it directly (Nigro and Neisser, 1983). Moreover, retrieving the past from alternative visual perspectives is not merely epiphenomenal, but impacts our sense of self (Sutin and Robins, 2008), affects our current mood and future behavior (Holmes et al., 2008; Libby et al., 2007), influences our causal attributions (Frank and Gilovich, 1989), and is affected in several mental disorders (Kenny et al., 2009). Thus, understanding the mechanisms by which we can adopt alternative visual perspectives during memory retrieval has important implications for many domains. Here we examine how neural mechanisms that enable the construction of alternative versions of the personal past when adopting different visual perspectives during memory retrieval shape remembering and subsequent memories.

Visual perspective is a necessary feature in order to retrieve memories as remembered events rather than self-knowledge (Rubin and Umanath, 2015). Moreover, the particular egocentric perspective adopted during memory retrieval may also provide insight regarding the constructive nature of memories (also see McDermott et al. (2016)). Memories can be retrieved from the visual perspective of our own eyes, as most events are initially experienced, as well as from the visual perspective of an observer, as if we were seeing ourselves in the memory. If remembering was like pressing play on a movie, the observer perspective would be like watching the star in the movie as a member of the audience, whereas the own eyes perspective would be like experiencing the movie as the main star. Recent autobiographical memories are more frequently associated with spontaneously adopting an own eyes perspective, whereas remote memories are associated with an observer perspective (e.g., Nigro and Neisser, 1983; Rice and Rubin, 2009). This consistent pattern of results is thought to reflect the natural transformation of memories overtime (Butler et al., 2016), because memories are not usually formed from an observer perspective (but see

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Bergouignan et al. (2014), Cardena and Spiegel, 1993; Ozer and Weiss, 2004). Actively shifting visual perspective from an own eyes to an observer perspective during memory retrieval has also been shown to affect the content and phenomenological characteristics of retrieval. For example, adopting an observer visual perspective during retrieval reduces the emotional intensity of memories (Berntsen and Rubin, 2006; Robinson and Swanson, 1993), possibly due to increased detachment or distance from the remembered event (but see Libby and Eibach (2011)). Moreover, these changes in memories as the result of shifting visual perspective during retrieval at one point in time can also contribute to persistent changes in subsequent memories (Sekiguchi and Nonaka, 2014). A number of functional neuroimaging studies have demonstrated that memory retrieval is an active process that can modify memories (Bridge and Paller, 2012; Gershman et al., 2013; St Jacques et al., 2013b), which supports memory theories that emphasize the critical role of reactivation in shaping the brain networks that contribute to long-term memory representations (Mcclelland et al., 1995; Winocur and Moscovitch, 2011). Manipulating visual perspective during memory retrieval could provide an experimentally tractable way to investigate constructive neural mechanisms that potentially shape autobiographical memories in both the short and long-term.

Adopting a particular visual perspective critically depends upon egocentric representations in the posterior parietal cortex (Aguirre and D'Esposito, 1999; Ciaramelli et al., 2010; Wilson et al., 2005), and has been linked in particular to the precuneus (for reviews see Byrne et al., 2007; Cavanna and Trimble, 2006). As the so-called “mind's eye” (Fletcher et al., 1995), the precuneus has long been associated with mental imagery processes during memory retrieval, as well as visuospatial imagery and self-referential processes (for review see Cavanna and Trimble (2006)). A rich literature has demonstrated that the precuneus also supports the ability to imagine alternative visual perspectives (Jackson et al., 2006; Vogeley et al., 2004; for review see Van Overwalle and Baetens (2009)) and to navigate in space (Ghaem et al., 1997; Spiers and Maguire, 2006; for review see Boccia et al. (2014)), perhaps reflecting a more general ability to orient the internal representation of the self with the external world (Peer et al., 2015). According to a prominent neural model of spatial memory and imagery, egocentric frameworks generated during retrieval from long-term memory within the precuneus can be manipulated and updated when people imagine the possible movements they can make within the remembered scene (Byrne et al., 2007). Supporting this model, a number of recent studies have shown that the precuneus contributes to the ability to update internal representations of the world when imagining changes in self-location in space (Dhindsa et al., 2014; Lambrey et al., 2012; Sulpizio et al., 2016; Wolbers et al., 2008).

Much less is known about how visual perspective influences the neural mechanisms of long-term episodic memory retrieval, including autobiographical memories. Autobiographical memory retrieval is supported by a network of brain regions that encompasses lateral and medial parietal cortices, including the precuneus (Cabeza and St Jacques, 2007; Fuentemilla et al., 2014; Spreng et al., 2008; Svoboda et al., 2006). Generating and elaborating upon vivid mental images during autobiographical memory retrieval has been linked to the precuneus (Daselaar et al., 2008; Fuentemilla et al., 2014; Gardini et al., 2006; Söderlund et al., 2012), and recruitment of this region also contributes to the ability to construct a complex and realistic scene of the personal past (Hassabis et al., 2007; Summerfield et al., 2009). In a structural MRI study, Freton et al. (2014) found that the volume of grey matter in the precuneus was positively related to the spontaneous retrieval of autobiographical memories from an own eyes perspective, but the rating scale they used precluded examining whether a similar relationship held for memories spontaneously retrieved from an observer perspective (e.g., Rice and Rubin, 2009). The couple of neuroimaging studies that directly examined how adopting an own eyes or observer visual perspective influences memory retrieval have also found inconsistent results concerning the involvement of the precuneus. In a recent fMRI study, Grol, Vingerhoets and De Raedt (2017) found that neural recruitment of the precuneus was greater when adopting an observer compared to an own eyes perspective during autobiographical memory retrieval. In contrast, Eich et al. (2009) found that the precuneus was similarly involved when retrieving memories for complex lab-based events from own eyes and observer perspectives. These inconsistent findings with respect to the precuneus involvement, when adopting a particular egocentric perspective during memory retrieval, could reflect different demands on perspective shifting processes (Wolbers et al., 2008). Here we hypothesize that during autobiographical memory retrieval shifting visual perspective involves the manipulation of egocentric mental images in the precuneus.

Using functional magnetic resonance imaging (fMRI) we examined the neural mechanisms that support the ability to retrieve alternative versions of the personal past and to shape online and subsequent memories by manipulating whether participants adopted a dominant or alternative visual perspective during memory retrieval. In an initial session, participants generated a large number of autobiographical memories and provided subjective ratings on the degree to which memories were spontaneously retrieved from own eyes and observer perspectives (see Fig. 1). We then selected a subset of memories that were strongly associated with a spontaneous own eyes perspective, which allowed us to control for the initial perspective of memories in order to more effectively manipulate visual perspective shifting during fMRI scanning. We manipulated the degree of visual perspective shifting during fMRI scanning by asking participants to retrieve memories either from the alternative (i.e., observer perspective) or the same (i.e., own eyes) visual perspective as originally reported, thus requiring a shift in perspective or no shift, respectively across study sessions. A repetition suppression approach was employed here to compare the linear decrease in the blood oxygen level dependent (BOLD) response across the two perspective conditions (Grill-Spector et al., 2006). Participants were asked to retrieve memories across three identical repetitions and we examined repetition suppression, or the decrease in the BOLD response, from the first to the third repetition. We predicted that in both egocentric conditions repeated retrieval of memories would result in reductions in neural recruitment across the memory retrieval network in line with repetition suppression effects observed in similar tasks (Szpunar et al., 2014; van Mulukom et al., 2013). However, we hypothesized that shifting visual perspective during memory retrieval likely requires additional processes that enable egocentric perspectives to be updated during long-term memory retrieval (e.g., Byrne et al., 2007). In particular, we predicted that precuneus would show a linear decrease with repetitions when shifting visual perspective during retrieval, reflecting decreased engagement of egocentric updating mechanisms with successive repetitions of memories from an alternative visual perspective. We then examined how this neural signature of egocentric updating during memory retrieval contributed to online and subsequent changes in the phenomenology of memories, where we predicted greater subsequent changes due to shifting perspective compared to maintaining the same perspective.

2. Material and methods

2.1. Participants

Participants were aged 18–30 years. All participants were right-handed, reported no history of neurological or psychiatric episodes or current use of medication known to affect cognitive function. Participants gave written consent for a protocol approved by the Harvard University Intuitional Review Board. In total, 37 participants (24 women; Mean Age in Years=22.3, *SD*=3.3) gave written informed consent. Three participants were excluded due to an inability to retrieve a sufficient number of strong own eyes memories (for further