

Motivational aspects of future thinking in the ventromedial prefrontal cortex

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A fascinating achievement of the human mind is the ability to momentarily disengage from the immediate environment in order to “travel mentally through time” and imagine events or states that might happen in the future (Atance & O'Neill, 2001; Buckner & Carroll, 2007; Schacter, Addis, & Buckner, 2008; Suddendorf & Corballis, 2007; Szpunar, 2010; Tulving, 2005). If you close your eyes for a moment and think about what you plan to do next weekend, for example, it is likely that in just a few seconds colorful images will appear in your mind's eye. You might “see” a totally different place than the one you are currently in, you might move around that place, grab objects, interact with people, and you might say things to yourself and feel emotions (D'Argembeau & Van der Linden, 2004, 2006). Such images, thoughts, and feelings about the future are frequently experienced in daily life and may serve a variety of important functions, such as action planning, decision-making, and emotion regulation (D'Argembeau, Renaud, & Van der Linden, 2011).

Recent studies in psychology and cognitive neuroscience have revealed that the imagination of future events (hereafter referred to as “episodic future thinking”) is a complex mental activity that recruits multiple cognitive processes and neural systems (for reviews, see Atance & O'Neill, 2001; Schacter, Addis, & Buckner, 2007; Schacter et al., 2008; Suddendorf & Corballis, 1997, 2007; Szpunar, 2010; Tulving, 2005). The focus of this chapter is on motivational aspects of episodic future thinking. When contemplating our personal future, we often envision events that are somehow important to ourselves, be they positive situations that we would like to attain or negative events that we would rather avoid (Berntsen & Jacobsen, 2008; D'Argembeau et al., 2011; D'Argembeau & Van der Linden, 2004; Gilbert & Wilson, 2007; Newby-Clark & Ross, 2003; Van Boven & Ashworth, 2007). The future events we imagine are thus often endowed with great motivational force, which influences our decisions and behavior (Johnson & Sherman, 1990; Karniol & Ross, 1996). We here review recent

functional neuroimaging findings that suggest that the ventromedial prefrontal cortex (vmPFC)¹ may play a key role in these motivational aspects of episodic future thinking. More specifically, it will be suggested that the vmPFC may be involved in appraising the personal relevance or value of the various future events we imagine, thereby promoting personal goal achievement.

Imagining emotional events in the near and distant future

A wealth of animal and human studies suggest that the vmPFC plays a key role in calculating the value of choice outcomes, which guides decision-making in diverse domains (for reviews, see e.g. Bechara & Damasio, 2005; Montague, King-Casas, & Cohen, 2006; Wallis, 2007). Bechara and Damasio (Bechara & Damasio, 2005; Bechara, Damasio, & Damasio, 2000; Damasio, 1994) have argued, in particular, that the vmPFC is a critical neural structure for attaching affective/emotional signals to mental representations of future outcomes. These affective/emotional signals would help individuals to know “what it feels like” to be in a given future situation, thus guiding their decisions in advantageous ways.² Patients with damage to the vmPFC indeed seem oblivious to the consequences of their actions, and accordingly present severe impairments of personal and social decision-making in their daily life (e.g., the choices they make often lead to loss of reputation, job, and family), in spite of otherwise largely preserved cognitive abilities (Bechara & Damasio, 2005; Damasio, 1994).

Bechara and Damasio (Bechara, 2005; Bechara & Damasio, 2005) have further suggested that anterior parts of the vmPFC may be particularly important for representing distant future outcomes. Cross-species comparisons indicate that major advancement in the size, complexity, and connectivity

¹ For the purposes of this chapter, we use the term “ventromedial prefrontal cortex” to refer to a broad area in the lower central portion of the prefrontal cortex, encompassing medial sections of Brodmann’s area (BA) 10, 11, 12, and lower BA 32.

² Note, however, that predictions of the affective consequences of future events are not always accurate and there is indeed evidence that people display a number of systematic biases in predicting future affective states (for a review, see Gilbert & Wilson, 2007).

of the frontal lobes in humans has occurred in relation to the frontal pole, suggesting that functions associated with this part of the cortex have become particularly important during hominid evolution (Semendeferi, Armstrong, Schleicher, Zilles, & Van Hoesen, 2001). Furthermore, there is evidence that during evolution, hominids have developed increased capacity to anticipate more distant future events, which allowed them to decide and act according to long-term goals rather than immediate circumstances (Leary & Buttermore, 2003; Sedikides, Skowronski, & Dunbar, 2006; Suddendorf & Corballis, 2007). On the basis of these findings, Bechara and Damasio suggested that more anterior parts of the vmPFC may play a key role in representing future outcomes that are more distant in time.

We have recently tested this hypothesis in a functional magnetic resonance imaging (fMRI) study, by directly comparing the brain regions recruited for imagining emotional events in the near and distant future (D'Argembeau, Xue, Lu, Van der Linden, & Bechara, 2008). Participants first took part in a pre-scan interview, in which they were asked to imagine positive and negative events that might happen to them in the near future (i.e., in the next few days or weeks), and positive and negative events that might happen to them in the distant future (i.e., in at least one year from now). They were free to imagine any event, provided that it was a personally meaningful event that could plausibly happen to them during the specified time period (e.g., "going to a friend's birthday party next Saturday" or "my graduation ceremony in two years from now"). Participants were also asked to think of some affectively neutral routine activities (e.g., showering), which were used as a control condition (imagining such routine activities involved the construction of multimodal representations of complex events but did not require projecting oneself into the future). For each future event and routine activity, a short cue summarizing the essence of the event was created.

The next day, participants were presented with each cue and were asked to mentally project themselves into the corresponding future event or routine activity and to imagine the situation in as much detail as possible (i.e., to consider the location where the event would occur, the persons

and/or objects that would be present, what they would do, how they would feel, and so forth) while their brain activity was measured with fMRI. In line with other studies of episodic future thinking (e.g., Addis, Wong, & Schacter, 2007; Botzung, Denkova, & Manning, 2008; Okuda et al., 2003; Spreng & Grady, 2010; Szpunar, Watson, & McDermott, 2007), we found that a network of brain regions that included the medial prefrontal cortex, medial posterior regions (posterior cingulate/retrosplenial cortex), the lateral temporal cortex, and the temporoparietal junction was more active during the imagination of future events compared to routine activities. More importantly, part of the neural circuit engaged when imagining future emotional events was modulated by temporal distance. Specifically, the anterior vmPFC was more active when imagining emotional events in the distant future than when imagining emotional events in the near future, thus supporting Bechara and Damasio's hypothesis (Bechara, 2005; Bechara & Damasio, 2005).

Episodic future thinking and personal goals

Extensive research has revealed that temporal distance changes the way people mentally represent future events (for a review, see Trope & Liberman, 2003). It has been demonstrated, in particular, that people use high-level goal-related knowledge to a greater extent for representing distant future events than for representing near future events. Consider, for example, a study by Liberman and Trope (1998), in which participants were instructed to imagine themselves in different situations either "tomorrow" or "next year" and then had to describe these situations. Liberman and Trope found that participants used more high-level goals to describe the situations in the distant future and more concrete details to describe the situations in the near future. For example, participants described the situation "moving to a new apartment" as "starting a new life" in the distant future condition, but as "packing and carrying boxes" in the near future condition.

Considering these differences in the way people represent near and distant future events, we speculated that the increased vmPFC activity observed when people imagine distant future events

might be related to the processing of personal goals (D'Argembeau, Xue et al., 2008). In order to test this hypothesis more directly, we conducted another fMRI study in which we explicitly manipulated the relevance of imagined future events with regard to personal goals (D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, Feyers et al., 2010). In a pre-scan interview, participants were asked to fill out an adaptation of the Personal Project Analysis Inventory (Little, 1983), which required them to list personal goals in various life domains (e.g., in relation to work, family, and material goods). Then, for each personal goal, participants were instructed to imagine a specific future event (i.e., something specifically located in place and time and lasting less than a day) related to that goal (e.g., for the personal goal “becoming a doctor,” a specific personal future event might be the imagination of one’s graduation ceremony; we hereafter refer to these events as “personal future events”). Participants were also asked to select “non-personal” future events, which were defined as events that can be vividly imagined and that could possibly happen in the future, although they are not part of personal projects and are not particularly self-relevant (e.g., taking one’s first golf lesson, handing out leaflets for an ecological organization). A future time period was then assigned to each selected event so as to match personal and non-personal future events with regard to temporal distance. Finally, a series of routine activities were also selected and used as a control condition.

During the fMRI session, participants were instructed to project themselves in each event and to imagine it in as much detail as possible in order to mentally experience the situation. In line with our previous study (D'Argembeau, Xue et al., 2008), we found that a network of brain regions that included the vmPFC, the posterior cingulate cortex, the inferior parietal lobe, and the lateral temporal lobe was more active when participants imagined future events compared to routine activities. Our main interest was then to directly contrast the imagination of personal and non-personal future events in order to isolate the brain regions that support personal goal processing during episodic future thinking. This comparison revealed greater activation in the vmPFC when imaging personal future events relative to non-personal future events. Importantly, the two types of

future events were matched for vividness and temporal distance, suggesting that differences in vmPFC activity cannot be accounted by these factors alone.

These findings suggest that the vmPFC may be involved in processing the relevance of future events to personal goals. To investigate this hypothesis further, we compared the brain activations observed during the imagination of personal future events with the brain activations associated with explicit judgments of personal relevance in another task. The neural activity associated with judgments of self-relevance was isolated using a task that has been extensively used in previous fMRI studies (e.g., D'Argembeau et al., 2007; Fossati et al., 2003; Heatherton et al., 2006; Kelley et al., 2002; Schmitz, Kawahara-Baccus, & Johnson, 2004). Participants were presented with a series of trait adjectives (e.g., polite, dependable, daring, talkative) and were asked to make different types of judgments on those traits. In the “self condition” they had to judge whether or not the adjectives described their own personal traits, and in the comparison condition they had to judge whether or not the adjectives referred to a positive trait. We found that explicit judgments of self-relevance in this task elicited activation in the vmPFC, which overlapped extensively with the vmPFC activation observed during the imagination of personal versus non-personal future events. This finding suggests that when we imagine future events, the vmPFC may be involved in appraising (explicitly or implicitly) the personal relevance or value of our mental constructions, such as their significance for personal goal pursuit.

Seeing one's personal future through rose-colored glasses

Personal goals can be distinguished along multiple dimensions (for a review of goal constructs in psychology, see Austin & Vancouver, 1996) and recent functional neuroimaging studies suggest that reflecting on different types of goals recruit distinct brain regions. Johnson et al. (2006) investigated two broad classes of goals—hopes and aspirations, and duties and obligations. Reflecting on these two types of personal goals was associated with greater activity in anterior and posterior medial

areas compared to thinking about concrete things such as polar bears fishing. Notably, an area of the vmPFC was more active when participants thought about hopes and aspirations compared to when they thought about duties and obligations. Furthermore, individual differences in chronic promotion orientation (i.e., a focus towards approach-related goals) were positively correlated with activity in the vmPFC when reflecting on hopes and aspirations.

Subsequent fMRI studies have detected similar activations in the vmPFC when reflecting on hopes and aspirations (Johnson, Nolen-Hoeksema, Mitchell, & Levin, 2009; Mitchell et al., 2009; Packer & Cunningham, 2009), suggesting that this brain area may be particularly important for representing future rewarding personal experiences. Note, however, that because a relatively unconstrained paradigm that did not explicitly require to imagine particular events was used in those studies, it is unclear whether participants engaged in episodic future thinking (i.e., whether they imagined specific future situations) or whether they reflected about their hopes and aspirations in a more abstract way. Yet other fMRI studies in which participants were explicitly asked to engage in episodic future thinking have also found that the vmPFC is particularly active when imagining rewarding experiences. For example, we asked participants to mentally project themselves into some specific future situations that could plausibly happen in their personal future and found that the vmPFC was more active when they imagined positive events (i.e., things they are looking forward to), relative to negative events (i.e., things they would prefer to avoid) (D'Argembeau, Xue et al., 2008). Sharot, Riccardi, Raio, and Phelps (2007) obtained similar results when participants imagined positive and negative events in response to descriptions of life episodes such as "winning an award" or "the end of a romantic relationship".

To the extent that the vmPFC is involved in processing self-relevance, these findings suggest that people may feel more personally involved when envisioning positive compared to negative future events, and there is indeed evidence that most people see their personal future through rose-colored glasses (Sedikides & Gregg, 2008; Taylor & Brown, 1988). In line with this interpretation, it

has been found that more optimistic people show greater activity in the vmPFC when imagining positive versus negative events (Sharot et al., 2007). Overall, then, the greater activation of the vmPFC when envisioning positive versus negative future events may reflect people's tendency to view their personal future in a positive light. Research suggests that this positive view of the personal future can increase one's motivation and performance (Ruvolo & Markus, 1992) and can provide benefits in terms of mental and physical health (MacLeod & Conway, 2007; Taylor, Kemeny, Reed, Bower, & Gruenewald, 2000).

Feeling connected to future selves and decision making

Besides the representation of specific life episodes, an important aspect of future thinking relates to people's views of themselves in the future (e.g., their representation of who they might become, would like to become, or are afraid of becoming; Markus & Nurius, 1986). Social psychological research indicates that people may feel more or less connected to imagined future selves, which affects their decisions, motivation, and behavior (e.g., Libby, Shaeffer, Eibach, & Slemmer, 2007; Peetz, Wilson, & Strahan, 2009; Pronin, Olivola, & Kennedy, 2008). Notably, there is evidence that people sometimes view their future selves as "other persons," such that their decisions for future selves differ from their decisions for present selves and instead more closely resemble decisions for other people. For example, Pronin et al. (2008) had participants make decisions involving drinking a disgusting liquid supposedly for the benefit of science. Depending on condition, participants were asked to choose how much liquid they will consume during the current experiment, how much they will consume during an experiment early next semester, or how much will be consumed by the next participant in the study. The results showed that participants chose to drink more disgusting liquid in the future than in the present and that their decisions for the future self resembled decisions for the other participant.

Recent fMRI studies have revealed that these differences concerning the way people view present versus temporally distant selves are mirrored in vmPFC activity. Specifically, we found that the vmPFC was more active when participants made trait judgments about their present self than when they made trait judgments about temporally distant selves (either in the past or in the future), whereas making judgments about distant selves and making judgments about others were associated with similar degrees of vmPFC activity (D'Argembeau, Feyers et al., 2008; D'Argembeau, Stawarczyk, Majerus, Collette, Van der Linden, & Salmon, 2010). Ersner-Hershfield, Wimmer, and Knutson (2009) have also observed higher activation in the vmPFC when making judgments about present versus future selves. Most interestingly, these authors found that individual differences in the degree of vmPFC activity when thinking about present versus future selves correlated with the degree to which people valued immediate gains over future gains in a temporal discounting task administered a week after scanning. In other words, individuals who showed fewer differences in vmPFC activity when reflecting on present versus future selves (presumably because they felt more connected to their future selves) showed less propensity to devalue future rewards. Another study indicates that individual differences in feelings of connectedness to future selves not only predict valuation of future rewards in laboratory tasks, but are also associated with real-world savings behavior (Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009). Altogether, these findings suggest that differences in degrees of vmPFC activity when thinking about present versus future selves may reflect the extent to which people feel connected to and value their future selves, which holds important implications for decision-making.

Conclusion

Human beings spend a lot of time imagining all sorts of situations and scenarios that might happen in their personal future, which can serve various functions in daily life, such as action planning, decision-making, and emotion regulation (D'Argembeau et al., 2011). This ability to mentally simulate

possible future events is a complex cognitive activity that depends on multiple brain systems (Atance & O'Neill, 2001; Schacter et al., 2007, 2008; Suddendorf & Corballis, 1997, 2007; Szpunar, in press; Tulving, 2005). The functional neuroimaging findings reviewed in this chapter suggest that the vmPFC is instrumental to motivational aspects of episodic future thinking. The vmPFC shows greater activation when people imagine future situations that are relevant to their personal goals, particularly situations that refer to possible rewarding experiences. Furthermore, degrees of vmPFC activity correlates with feelings of connectedness to imagined future selves, which influences important decisions. Considering these findings, we speculate that the vmPFC may be involved in appraising and/or coding the self-relevance or personal value of imagined future events. This process may not only increase our motivation and effort to achieve desired end-states, but may also prompt the mental simulation of the steps necessary for reaching these states (Karniol & Ross, 1996; Taylor, Pham, Rivkin, & Armor, 1998). Furthermore, valuing possible future outcomes may help us override momentary needs and impulsive behavior, in order to pursue courses of action that are more advantageous in the long-term (Bechara, 2005; Boyer, 2008). We thus suggest that a major function of the vmPFC during episodic future thinking is to assign a personal value to future event representations, thereby promoting personal goal achievement.

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