Mental time travel and the shaping of the human mind

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Episodic memory, enabling conscious recollection of past episodes, can be distinguished from semantic memory, which stores enduring facts about the world. Episodic memory shares a core neural network with the simulation of future episodes, enabling mental time travel into both the past and the future. The notion that there might be something distinctly human about mental time travel has provoked ingenious attempts to demonstrate episodic memory or future simulation in non-human animals, but we argue that they have not yet established a capacity comparable to the human faculty. The evolution of the capacity to simulate possible future events, based on episodic memory, enhanced fitness by enabling action in preparation of different possible scenarios that increased present or future survival and reproduction chances. Human language may have evolved in the first instance for the sharing of past and planned future events, and, indeed, fictional ones, further enhancing fitness in social settings.

Keywords: mental time travel; foresight; language; evolution; episodic memory; amnesia

1. INTRODUCTION

Clive Wearing is an English musician. As an acknowledged expert on early music, he had built up a musical career with the BBC when he was infected at the age of 46 with the herpes simplex virus. This effectively destroyed his hippocampus and left him profoundly amnesic. The nature of his amnesia illustrates the distinction between semantic memory, which is memory for enduring facts about the world, and episodic memory, which is a personal record of the past (Tulving 1983). Wearing's semantic memory is largely intact, as is his procedural memory. He retains a normal vocabulary, recognizes his wife and family, and can still play the piano and conduct a choir. His episodic memory, though, is profoundly impaired. He has sufficient short-term memory to be able to converse but quickly forgets about topics he spoke about or experienced just moments earlier. He is continually under the impression that he has just woken up, or recovered from being dead. His conscious experience is entirely of the present, and is well captured in the book, *Forever today*, written by his wife Deborah (Wearing 2005).

Neuropsychological evidence reveals that deficits in episodic and semantic memory are doubly dissociated, implying distinct mechanisms. As with Clive Wearing, most cases of amnesia, especially those resulting from damage to the hippocampus, are characterized by severe deficits in episodic memory, while semantic memory remains largely intact (Scoville & Milner 1957; Tulving *et al.* 1988; VarghaKhadem *et al.* 1997; Aggleton & Brown 1999). Indeed, the very term

'memory' is usually taken to mean episodic memory, as when William James wrote 'Memory requires more than the mere dating of an event in the past. It must be dated in *my* past' (James 1890, p. 650). Yet in a degenerative condition known as semantic dementia, semantic memory is grossly impaired, leaving episodic memory surprisingly unaffected (Hodges & Graham 2001).

Retrieval of episodic memories involves the conscious reliving of past events, a sort of mental journey into the past (Tulving 1983). In recent years, evidence has accumulated that the episodic memory system is also involved in mental travel into the future, suggesting a general concept of mental time travel (Suddendorf & Corballis 1997, 2007). Conceiving of future events, of course, involves a process of active construction of events that have not yet occurred, but the more general process of mental time travel highlights the evidence that episodic memory, too, is better conceived as a conscious act of construction, rather than a faithful re-enactment of the past. Indeed, if the only function of episodic memory was to record the past, it might be expected to function in a reproductive manner, similar to a video recorder (Suddendorf & Corballis 1997). However, the slew of errors and distortions that episodic memory is vulnerable to shows us this is not the case (Schacter 1999; Schacter & Addis 2007). The primary role of episodic memory, then, may be to provide information from the past for the simulation of the future. Indeed, natural selection can only work on what memory can offer for present and future fitness rather than on the accuracy of the past record *per se* (Suddendorf & Corballis 1997; Suddendorf & Busby 2005).

In spite of the dissociation between semantic and episodic memory, there must be some links between them. The encoding of episodic memories must to some extent

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depend on semantic memories that are already in place (Tulving 2002); a remembered visit to a restaurant, for example, must depend in part on one's knowledge of what a restaurant is and what happens there. Indeed, descriptions of episodic memories and future simulations comprise both episodic and semantic details that are woven together into a narrative of the experience (e.g. Levine *et al.* 2002; Addis *et al.* 2008). Individual episodes, having drawn on semantic elements, are then related to the self in subjectively sensed time. This allows the experience of an event to be stored separately from the semantic system, and retrieved in what Tulving called 'episodic retrieval mode' (Tulving 2002). Just as they are during encoding, retrieved episodic memories are interwoven with elements of semantic memory. The episodic details of an event are not retrieved in isolation of the context that semantic information can provide (Levine *et al.* 2002). This would apply, we suggest, not only to the reconstruction of past events, but also to the construction of future ones, and even to story-telling—the construction of fictional episodes that permeate folklore, literature, stage drama, film and television (Hassabis *et al.* 2007*b*; Suddendorf & Corballis 2007).

In this paper, we review neuroscientific evidence for the continuity of mental time travel into the past and future, and consider what, if anything, might be uniquely human about mental time travel. We go on to suggest that human language may have evolved primarily for the communication of episodes, whether from the past or the imagined future, or indeed in the form of fiction. We conclude with some speculation as to when and why mental time travel evolved in hominin evolution.

2. NEUROPSYCHOLOGICAL AND NEUROIMAGING EVIDENCE

The title of Deborah Wearing's book, *Forever today*, also captures the fact that Clive Wearing is as unable to imagine future events as he is incapable of remembering past ones. It is becoming clear that this is true of other profoundly amnesic patients as well (Tulving 1985; Klein *et al.* 2002; Rosenbaum *et al.* 2005; Hassabis *et al.* 2007*b*). In one study, for example, patients with bilateral hippocampal damage and intact premorbid semantic memory were given cue words and short descriptions of scenarios, and asked to generate new experiences from them. Their scores for the detail and coherence of the imagined scenarios fell well below those of a control group (Hassabis *et al.* 2007*b*). Interestingly, this study suggests that the hippocampus may play a critical role, not only in terms of retrieving details from episodic memory to be used for an imagined scenario, but also the integration of such details into a coherent event. Moreover, it seems that such processes are not unique to imagining future events *per se*, but apply more generally to the construction of any fictitious scenario (Rosenbaum *et al.* 2005; Hassabis *et al.* 2007*b*).

Consistent with neuropsychological data, functional brain imaging also reveals a strong overlap in brain activity between backward and forward mental time travel. In one study, positron emission tomography revealed activity in the frontal poles and medial temporal lobes, including hippocampal and parahippocampal regions, to tasks involving both the remembered past and the imagined future episodes (Okuda *et al.* 2003). Although most areas showed equivalent activation to both the past and the future tasks, areas in the anteromedial pole showed greater activation to future than to past tasks, and greater activation to both tasks, the more distant the episode in time. A more recent study showed that hippocampal activity, too, was greatly increased for future events that were more distant from the present (Addis & Schacter 2008). These effects may reflect the degree of construction required, with higher levels of construction for more distant events.

Based on this, and on another work using functional magnetic resonance imaging (Addis *et al.* 2007; Szpunar *et al.* 2007), Schacter *et al.* (2007) identify a 'core network' that is used not just for remembering the past, but that functions adaptively and is even more actively recruited when integrating information from past experiences to construct mental simulations about possible future events. The prominent components of this network include regions of the medial prefrontal cortex, the lateral and medial parietal cortex (including precuneus and retrosplenial cortex), and the lateral and medial temporal lobes, including notably the hippocampus. Activity is intercorrelated across these regions and with activity in the hippocampal formation. While some recent studies challenge this finding, reporting more activity for past than future events (Hassabis *et al.* 2007*a*; Botzung *et al.* 2008; D'Argembeau *et al.* 2008), it is important to note that, in these studies, future events are not being imagined during the scan. Rather, they are constructed outside of the scanner and then recalled during the scan. Memories of imagined events are typically less detailed than memories of real experiences, and thus recruit fewer hippocampal resources during retrieval. This further supports the core network being more actively recruited when one must use episodic memory to construct and imagine a new event online.

Moreover, these findings challenge the traditional view that the role of the hippocampus is to hold episodic memories for a limited period of time until they are consolidated in other neocortical areas (Squire 1992; Squire *et al.* 2004). The alternative view, more consistent with these and other recent results, is that the hippocampus is always necessary for the retrieval of detailed episodic experiences, including remote ones (Moscovitch *et al.* 2005). By this account, the extent of hippocampal involvement probably depends on the vividness of the internal representation, whether of past episodes or imagined future ones (Hassabis *et al.* 2007*b*). Confirming this, Addis & Schacter (2008) also found more detailed representations to be associated with increased posterior hippocampal activity. This probably reflects the retrieval of information, necessary when remembering as well as imagining events. By contrast, future event detail was associated with greater activity in the anterior hippocampus, possibly reflecting the recombination of details into a coherent event.

The reported phenomenological richness of imagined events (D'Argembeau & Van der Linden 2004), as well as the number of imagined events reported (Spreng & Levine 2006), decreases with temporal distance into both the past and the future. There are

further parallels in the development of mental time travel into past and future across the lifespan, both in terms of initial emergence (Busby & Suddendorf 2005) and eventual decline (Addis *et al.* 2008). The neural and cognitive evidence linking episodic memory to imagining the future is increasingly recognized (e.g. Hassabis & Maguire 2009; Schacter & Addis 2009).

3. UNIQUELY HUMAN?

In a detailed account of the nature of episodic memory, Tulving (1983) proposed that it was uniquely human. It was later proposed more generally that mental time travel was unique to our species and that the main adaptive advantage must lie with foresight (Suddendorf & Corballis 1997, 2007). This does not mean that non-human animals do not behave in a manner oriented to the future. The futures of animals and their offspring often depend on instinctive behaviours, such as food caching, migrations and nest building, as well as on learned behaviours and semantic memory (Suddendorf & Corballis 2007). Semantic knowledge can be important for prospection, but must be distinguished from episodic future thinking. For example, knowledge of where Paris is located, what language is spoken there and how to get there will clearly enhance the prospects of making a trip to that city. Episodic memories of experiences in Paris, though, allow conscious construction of imagined future events there, including, perhaps, friends that one might meet there, places one might revisit, specific restaurants and, perhaps, specific dishes, and so forth. More generally, episodic memory provides a vocabulary from which to construct possible scenarios, and compare them off-line in order to optimize future behaviour. This ability to act with specific, individually anticipated future events in mind may account for why human behaviour is so immensely flexible and, as we shall argue further below, why humans have evolved open-ended communication systems.

The claim that only humans are capable of episodic memory and episodic foresight has posed a challenge to animal researchers. One of the difficulties has been to demonstrate memory that is truly episodic, and not merely semantic or procedural. For example, does the dog that returns to where a bone is buried remember actually burying it, or does it simply know where it is buried? One suggestion is that episodic memory in non-human animals might be defined in terms of *what* happened, *where* it happened and *when* it happened—the so-called *www* criteria. It has been proposed that scrub jays (*Aphelcoma coerulescens*) meet these criteria, because of experimental evidence that they can select the locations of food they have previously cached not only according to the type of food that is stored there, but also according to how long it has been stored, implying that they remember when it was stored. For example, they will recover recently cached worms in preference to nuts, since fresh worms are more palatable, but if the worms have been cached for too long they will retrieve nuts, because the worms will have decayed and become unpalatable (Clayton & Dickinson 1998). Furthermore, if another jay observes them caching food, they will later re-cache it,

presumably to prevent the observer stealing the food. They will only do this, however, if they have themselves stolen food in the past (Emery & Clayton 2001). Clayton and colleagues (Clayton *et al.* 2003) concluded that scrub jays can not only remember the what, where and when of past events, but also anticipate the future by taking steps to avoid future theft.

A recent study suggests that meadow voles (*Microtus pennsylvanicus*), too, have a similar capacity (Ferkin *et al.* 2008). Male voles were first allowed to explore two chambers, one containing a pregnant female 24 hours pre-partum, and the other containing a female that was neither lactating nor pregnant. Twenty-four hours later, they were again given access to the chambers, now empty and clean, and spent more time exploring the chamber that had contained the previously pregnant female than the one that had housed the other female. This suggests that they had remembered the pregnant female and her location, and understood that she would now be in post-partum oestrus, a state of heightened sexual receptivity. In another condition, they first explored a chamber containing a female in post-partum oestrus and another containing a female that was neither lactating nor pregnant, and was not in oestrus. Twenty-four hours later, they were again allowed to explore the now-empty cages, and showed no preference for the chamber that had housed the female in oestrus. This suggests that they realized the female would no longer be in a state of heightened receptivity.

Several other recent experiments have documented that various species of mammals and birds may pass the www criteria (for reviews, see Dere *et al.* 2005; Zentall 2006; Suddendorf & Corballis 2007). If this entails that these species can travel mentally in time, then we are in need of a fundamental reconsideration of animal welfare and ethics (Lea 2001; Suddendorf & Corballis 2007). The extent to which animals live in the present has a major impact on their capacity for suffering—if they can mentally revisit a past traumatic event or anticipate future pain, as humans do, then considerations for their welfare would need to take this into account when attempting to minimize their suffering (see Mendl & Paul 2008 for a detailed discussion).

It remains possible, though, that these ingenious studies do not prove that the animals actually remember or anticipate episodes. For example, associative memory might be sufficient to link an object with a location, and a time tag or 'use-by' date might then be attached to the representation of the object to update information about it (Suddendorf & Corballis 2007). Moreover, 'how long ago' can be empirically distinguished from 'when', so the ability of scrub jays to recover food depending on how long ago it was cached need not actually imply that they remember when it was cached. As evidence for this, a recent study suggests that rats can learn to retrieve food in a radial maze on the basis of how long ago it was stored, but not on when it was stored, suggesting that 'episodic-like memory in rats is qualitatively different from episodic memory in humans' (Roberts *et al.* 2008).

More generally, the www criteria may not be sufficient to demonstrate true episodic memory. Most of us know where we were born, when we

were born and, indeed, what was born, but this is semantic memory, not episodic memory (Suddendorf & Busby 2003). Conversely, one can imagine past and future events and be factually wrong about what, where and when details (in fact, we are often mistaken). This double dissociation, then, strongly suggests that we should not equate mental time travel with www memory.

Non-human animals and very young children may be limited in their foresight in a number of different ways (Suddendorf & Corballis 2007). One variant on the claim to human uniqueness is the so-called Bischof-Köhler hypothesis, which states that only humans can flexibly anticipate their own future mental states of need and act in the present to secure them (Bischof 1978; Bischof-Köhler 1985; Suddendorf & Corballis 1997). Again, an experiment with scrub jays has been claimed as a counterexample. The birds were prefed with one type of food for three hours and then allowed to cache the prefed and an alternative food. They were subsequently prefed with the alternative food before being allowed to recover what they had cached. On the second and third trials, the birds cached more of the food on which they were satiated, on the apparent understanding that they would be hungry for this food at later recovery, thus challenging the Bischof-Köhler hypothesis (Correia *et al.* 2007). Closer analysis of the data, however, suggests that this interpretation is misleading. Although the birds cached a greater proportion of food for which they would later be hungry, the absolute number of items stored did not change in any meaningful way. The six birds in the critical condition cached an average of 0.7 items of the prefed food on the first trial, and 1.2 items and 0.8 items on the second and third trials, respectively. Thus, they did not increasingly store the food that was more desirable in the future (Suddendorf & Corballis 2008).

The most promising challenge to the Bischof-Köhler hypothesis so far comes from the great apes. In one study, orang-utans (*Pongo abelii*) and bonobos (*Pan paniscus*) learned to use a tool to extract grapes from an apparatus in a test room. They were later given a choice of tools, some appropriate and others inappropriate for extracting grapes, and significantly chose appropriate ones for later access to the test room (Mulcahy & Call 2006). In a similar experiment, two chimpanzees (*Pan troglodytes*) and an orang-utan were shown, on a single trial, how to use a plastic hose as a straw to obtain juice from an apparatus, and on subsequent trials, prior to access to the test room an hour later, chose this tool in preference to others. In one critical condition, the animals were offered grapes, their favourite food, along with the other tools, and chose the hose more often than the grapes, suggesting that obtaining a large amount of fruit juice in the future may have been valued more than a small instant grape reward (Osvath & Osvath 2008). In both the studies, the experimenters took pains to rule out alternative explanations, such as simple association between tool and later reward, but there continue to be some methodological concerns (see Suddendorf 2006 and Suddendorf *et al.* in press for critical analyses).

So far, examples of putative mental time travel in non-human species appear limited to situations with a strong instinctive component. They do suggest ways in which animals might adapt their behaviour to maximize future reward, but, so far, they have little of the flexibility and generality of mental time travel in humans. Humans can simulate virtually any event and evaluate it in terms of likelihood and desirability. It has been argued that this human faculty may be likened to a theatre production in that we employ mental analogues to a stage, a playwright, actors, a set, a director, an executive producer and a broadcaster (Suddendorf & Corballis 2007). These sophisticated mental roles may be employed to simulate future events, just as readily as to imagine the minds of others (theory of mind) and entirely fictional stories (Suddendorf & Corballis 1997; Buckner & Carroll 2007; Hassabis *et al.* 2007b). Animals may be restricted in their capacity to travel mentally in time by limits in any of these domains. For example, just as a playwright is responsible for creating new stories, mental simulations of novel future events require open-ended generativity—our ability to combine and recombine a limited set of items into virtually unlimited ways (something not evident in any of the animal studies). Our memories for episodes are made up of combinations of people, actions, objects and places, along with qualities such as time of day, season, emotional states, and so forth. Imagined future events are similarly constructed, and we may, in fact, compose different scenarios depending on various contingencies, such as the weather, or who is likely to show up. Indeed, it may be the generative component that most clearly distinguishes mental time travel in humans from future-directed capacities in other species. This generativity is also characteristic of other human faculties such as navigation, number, theory of mind and language (Corballis 2003). Language is often regarded as the most distinct of human faculties (e.g. Hauser *et al.* 2002), and much of what humans talk about (or broadcast) are the mental simulations of past events and future possibilities (Szagun 1978).

4. LANGUAGE

Testing for episodic memory in humans is normally reliant on language, which is why it is difficult to devise ways of testing for it in non-human animals. This raises the possibility that the evolution of language itself is intimately connected with the evolution of mental time travel. Language is exquisitely designed to express 'who did what to whom, what is true of what, where, when and why', as Pinker (2003) put it—a combination of *w*'s that goes well beyond the www criteria—and these are precisely the qualities needed to recount episodic memories. The same applies to the expression of future events—who will do what to whom, or what will happen to what, where, when and why, and what are we going to do about it. When considering the future, the conditional may also be important—if it rains, then X will happen; if it does not we may enjoy Y. To a large extent, then, the stuff of mental time travel is also the stuff of language (Corballis & Suddendorf 2007).

Language allows personal episodes and plans to be shared, enhancing the ability to plan and construct viable futures. To do so, though, requires ways of representing the elements of episodes: people;

objects; actions; qualities; times of occurrence; and so forth. Language may well have begun as pantomime, with the use of bodily gestures to mimic events (Donald 1991), with gestures becoming conventionalized, and thus more arbitrary and less representational, in the interests of greater economy and efficiency. According to this scenario, vocal gestures gradually replaced manual ones as the dominant mode (Corballis 2003; Rizzolatti & Sinigalglia 2007), although most people still gesture manually as they speak.

The recounting of mental time travel places a considerable and, perhaps, uniquely human burden on communication, since there must be ways of referring to different points in time—past, present and future—and to locations other than that of the present. Different cultures have solved these problems in different ways. Many languages use tense as a way of modifying verbs to indicate the time of an episode, and to make other temporal distinctions, such as that between continuous action and completed action. Some languages, such as Chinese, have no tenses, but indicate time through other means, such as adverbs or aspect markers (Lin 2005). The language spoken by the Pirahã, a tribe of some 200 people in Brazil, has only a very primitive way of talking about relative time, in the form of two tense-like morphemes, which seem to indicate simply whether an event is in the present or not, and Pirahã are said to live largely in the present (Everett 2005).

Reference to space may have a basis in hippocampal function; as noted earlier, current theories suggest that the hippocampus provides the mechanism for the retrieval of memories based on spatial cues. It has also been suggested that, in humans, the hippocampus may encompass temporal coding, perhaps through analogy with space; thus, most prepositions referring to time are borrowed from those referring to space. In English, for example, words such as *at*, *about*, *around*, *between*, *among*, *along*, *across*, *opposite*, *against*, *from*, *to* and *through* are fundamentally spatial, but are also employed to refer to time, although a few, such as *since* or *until*, apply only to the time dimension (O'Keefe 1996). It has been suggested that the hippocampus may have undergone modification in human evolution, such that the right hippocampus is responsible for the retrieval of spatial information, and the left for temporal (episodic or autobiographical) information (Burgess *et al*. 2002). It remains unclear whether the left hippocampal specialization is a consequence of left hemispheric specialization for language, or of the incorporation of time into human consciousness of past and future, but either way it reinforces the link between language and mental time travel.

The most striking parallel between language and mental time travel has to do with generativity. We generate episodes from basic vocabularies of events, just as we generate sentences to describe them. It is the properties of generativity and recursiveness that, perhaps, most clearly single out language as a uniquely human capacity (Hauser *et al*. 2002). The rules governing the generation of sentences about episodes must depend partly on the way in which the episodes themselves are constructed, but added rules are required by the constraints of the communication

medium itself. Speech, for example, requires that the account of an event that is structured in space–time be linearized, or reduced to a temporal sequence of events. Sign languages allow more freedom to incorporate spatial as well as temporal structure, but still require conventions. For example, in American sign language, the time at which an event occurred is indicated spatially, with the continuum of past to future running from behind the body to the front of the body.

Of course, language is not wholly dependent on mental time travel. We can talk freely about semantic knowledge without reference to events in time, as typically required by the education industry—and, indeed, this very paper. However, it is mental time travel that forced communication to incorporate the time dimension, and to deal with reference to elements of the world, and combinations of those elements, that are not immediately available to the senses. It is these factors, we suggest, that were in large part responsible for the development of grammars. Given the variety of ways in which grammars are constructed, such as the different ways in which time is marked in different languages, we suspect that grammar is not so much a product of some innately determined universal grammar (Chomsky 1988; O'Keefe 1996) as it is a product of culture and human ingenuity, constrained by brain structure (Christiansen & Chater 2008). Through language, then, we see not just language itself, but also the structure of human thought, and how it is composed of basic elements including 'events, states, things, substances, places and goals' (Pinker 2007)— and times. Moreover, the generativity of language reflects the generativity of the underlying thought processes themselves.

5. EVOLUTIONARY CONSIDERATIONS

Instinct, learning and memory are adaptations that enhance the fitness of animals, and shape their futures. Episodic memory is a form of memory, possibly unique to humans, that further allows the fine-tuning of behaviour, based on specific episodes in the past. It allows us to imagine future episodes, make specific plans and compare different scenarios. Language, we suspect, coevolved with mental time travel to allow the sharing of episodic information, sometimes to the point that we confuse events that have actually happened in our lives with those told to us by others, or even with those gleaned from fictional accounts.

Mental time travel and grammatical language probably evolved during the Pleistocene (Suddendorf & Corballis 1997, 2007; Corballis 2003). Survival pressures brought about by changes in climate and the replacement of a forested environment by the more exposed savannah necessitated greater social cohesion, more detailed future planning and more effective communication. Brain size increased dramatically in the genus *Homo* during the Pleistocene, reaching a peak with the large-brained Neanderthals and precursors to modern humans perhaps 500 000 years ago. It has been suggested that the emergence of the genus *Homo* was also accompanied by a prolongation of the period of development from infancy to adulthood, and that an extra stage, known as childhood, was inserted into the

sequence of developmental stages (Locke & Bogin 2006). Childhood lasts from age 2.5 to approximately age 7, roughly the period during which both mental time travel and grammatical language develop.

There can be little doubt that flexible foresight became a key human survival strategy (Suddendorf 2006) and that humans have taken the quest for securing future survival to a new level. Consider, for example, Norway's construction of a 'doomsday' seed bank designed to withstand global catastrophes to protect all known varieties of the world's crop. Yet, in spite of our strong reliance on foresight, humans are notoriously fallible with our predictions. For example, we display systematic errors in predicting the affective consequences of future action. Gilbert & Wilson (2007) recently reviewed these biases and concluded that several characteristics of mental simulation are the main contributors to these pervasive errors. Simulations tend to be unrepresentative, since they are often based on the most recent or most salient aspects of episodic memory, rather than on the most representative sampling. They often tend to reflect the gist of an event but fail to represent many details, and they often fail to take into account different future contexts in which events occur. The systematic biases in misapprehending how we will feel when a future event becomes the here and now is an essential problem for anyone in pursuit of happiness, and Gilbert (2006) offered the following simple solution to the dilemma: ask someone else who is or has been where we project ourselves as going. Their advice, on average, will be a far better guide to what it will be like than one's own biased simulations. This resonates with our proposal that one adaptive function of language may be to allow us to improve our mental time travel by drawing on the descriptions others can offer of what the future may hold. Undoubtedly, language allows us to learn from other individuals' experiences as no other animal can.

Whether this also leads to greater happiness remains debatable. Unlike, perhaps, psychologists, evolution does not care for our happiness and errors in affective forecasting are only errors if they negatively affect survival and reproduction. As with reconstruction of past events, it is not accuracy *per se* but the fitness consequences of foresight that matter. Systematic biases and errors may thus, in fact, serve adaptive purposes. For example, humans generally tend to expect more positive events than is rational to expect, and this optimism bias has specific neural correlates (Sharot *et al.* 2007). Although we may often be wrong with our optimism, this positive mental stance may have profound selective advantages over a more realistic (and possibly bleak) perspective. Foresight, fallible and biased as it often may be, must have made a net positive contribution to fitness. Indeed, it is arguably our most formidable weapon. The price we might have had to pay for this are unique psychological stresses and disorders (e.g. Brune 2006 makes the case for obsessive–compulsive disorder).

In this review, we proposed that human language evolved in the first instance for the sharing of mental time travel. After reviewing the growing neuroscientific evidence linking episodic memory and episodic foresight, we discussed data from non-human animals.

On current evidence, mental time travel, as with language, appears to reflect something uniquely human. This is not to say, however, that language and mental time travel are drawing on the same neurocognitive machinery. Language and mental time travel are clearly dissociable in modern humans. The total collapse of our faculty for mental time travel leaves a linguistically sophisticated person such as Clive Wearing trapped in the present and unable to conduct his life without the extensive support of others who can look ahead.

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