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DOSSIER

Mental time travel: Towards a computational account

Viagem mental no tempo: rumo a uma explicação computacional

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ABSTRACT

The paper aims to highlight similarities between computational routines of mentally traveling the present time, on the one hand, and routines of mentally traveling other times, on the other hand. The first and second sections, in which I lay out an eternalist view of the world and the massive modularity account of the architecture of the human mind, are intended to set the stage. Subsequently, I clarify the idea that we mentally travel the present. This explanation resorts to a cognitive mechanism I have proposed elsewhere. Finally, I submit that a similar computational routine takes place when we travel other times, be they earlier or later than the present moment.

Keywords: eternalism, modularity, episodic memory, four-dimensionalism.

RESUMO

Este artigo almeja destacar semelhanças entre as rotinas computacionais de viajar mentalmente no tempo presente e as rotinas de viajar mentalmente em outros tempos. As duas primeiras seções, nas quais apresento uma visão eternalista do mundo e também a posição segundo a qual a arquitetura da mente humana é massivamente modular, preparam o terreno. Em seguida, esclareço a ideia de que nós viajamos mentalmente no presente. Essa explicação recorre a um mecanismo cognitivo que propus em outro trabalho. Por fim, proponho que uma rotina computacional semelhante ocorre quando viajamos outros tempos, sejam eles anteriores ou posteriores ao presente.

Palavras-chave: eternalismo, modularidade, memória episódica, quadridimensionalismo.

A neurotypical human adult can easily leave the "now" (the present moment) and mentally travel to other times of her life. Right now, I am in my office writing this text. It does not take much to travel to a moment in the past and re-experience something, a kiss, for example. "I can travel forwards and somehow pre-experience something I believe is gonna happen", you may intervene. "That makes two of us", I would respond. When re-experiencing or pre-experiencing something, we transport ourselves into the past or into the future.

Mental time travel seems hugely significant for many aspects of everyday life. Consider that hard talk you had with your significant other. Don't you re-experience it over and over

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in your mind, in a very detailed and colorful way? Does your mind just replay the episode or does it also allow editions? While remembering, most people edit quite freely speeches, gestures, perceptions, feelings, both cutting and inserting stuff. So, remembering a past episode becomes also a constructive activity: we imagine/experience ourselves/others acting, reacting, perceiving, and feeling differently. Although much, this is only half the story: more or less the same goes on when we travel forwards. Just consider that job interview scheduled for next week and you will get what I mean. Don't you pre-experience it in your mind, simulating a number of situations?

Mental time travel turns out to be an interesting topic for several areas including philosophy, psychology, and neurosciences. Neuroscientists, for instance, have those wonderful tools and methodologies to identify neural correlates of pretty much everything, which allows them to come up with interesting hypotheses and inferences. The psychologists' broad agenda, in turn, covers the development and deterioration of the ability both in normal and pathological circumstances. The philosophers' agenda about the matter includes metaphysical issues (e.g. what is time, what is the mental, what is mental time), epistemological concerns (e.g. the reliability of remembering), and moral questions (e.g. the responsibility to remember, the right to forget), to name but a few.

In this paper I wish to highlight similarities between computational routines of mentally traveling the present time, on the one hand, and routines of mentally traveling other times, on the other hand. To make the case, I shall initially explain what I mean by "mentally traveling the present". Straight to the point: in the objective world, there is no such a thing as The Present. Contemporary Physics teaches us that "present", "past", and "future" are not referential terms. I will unfold this in the first section. Afterwards, in the second section, I shall assume a position in the philosophy of mind. I am going with what I consider one of the most progressive research programs of our time: evolutionary psychology, which proposes that the human mind is massively modularly organized. Elsewhere (Meurer, n.d.), I have reconciled eternalism and evolutionary psychology positing a cognitive mechanism dedicated to processing events and their temporal parts. In the third section, I will briefly recap computations and behavioral functions of that mechanism. Finally, in the last section, I submit that a similar computational routine takes place when the subject engages in mental time travel.

All times are equally real

Time is a dimension of reality, along with the dimensions of space. Indeed, after Einstein's theory of relativity, space and time no longer have independent significance. As Minkowski (1923, p. 75) states, "only a kind of union of the two will preserve an independent reality". This union, in turn, transforms the objective world into a four-dimensional manifold that simply is – "it does not happen" (Weyl, 1949, p. 116).

Minkowski takes space and time ontologically. They are not merely a representation of the world, but the world as such. "Let *x, y, z* be rectangular co-ordinates for space, and let *t* denote time. [...] A point of space at a point of time, that is, a system of values *x, y, z, t*, I will call a *world-point*. The multiplicity of all thinkable *x, y, z, t* systems we will christen the *world*" (Minkowski, 1923, p. 76). Meurer (n.d., p. 4) offers the following comments on this passage:

> *One conceivable world-point coincides with the occurrence of my birth. Another coincides with my typing of this sentence, and another coincides with the occasion on which you are reading it. What is at stake here? In short, if the world is the sum of all thinkable systems of values, as Minkowski put it, then it is bigger than the present world. The present (the "now", if you wish) turns out to be nothing but one among many slices for time. The totality of these temporal slices can be thought of as a four-dimensional manifold.*

From a slightly different perspective, four-dimensionalism can be described as a position regarding the ontological status of non-present objects. Four-dimensionalists hold "that there are past or future objects (or both); and in saying this, they mean to put such things ontologically on a par with present objects. [...] non-present objects are likely spatially distant objects: they exist, just not here where we are" (Rea, 2003, p. 246). Indeed, scholars committed to this view can be sorted into two broad groups: Eternalists, who hold that all world-points are equally real no matter how far they are, spatially and temporally, from any point you pick as reference, and Growing Block theorists, who consider the past as real as the present. For the former, what we call "past" and "future" is as real as what we regard "present". For the latter, the four-dimensional block is more like a block of history that grows as time passes. "At the present, which is located at the growing edge of the block, there is objective becoming; new reality constantly comes into existence as time passes. Thus, the location of the present moves along the time line as the block grows" (Prosser, 2016, p. 5).

Why should we endorse eternalism, i.e., the idea that the block is entirely given? Einstein's special theory of relativity leads us to the point: "Every reference-body (co-ordinate system) has its own particular time" (Einstein, 2001, p. 28). Consequently, two occurrences (e.g. two strikes of lightning A and B) may be simultaneous in one frame of reference but not in another one. So, if you define the present in terms of simultaneity (e.g. the lightning strikes A and B are both in the present if and only if both occur now, simultaneously), then you will face the fact that two observers in relative motion have different sets of simultaneous events in their presents. Were the world three-dimensional, this would never happen (Rietdijk, 1966; Putnam, 1967; Maxwell, 1985). Furthermore, it is easily explainable within a four-dimensional scenario: the two observers "have different three-dimensional cross-sections of the four-dimensional world, which they will regard as their presents" (Petkov, 2006, p. 214; see also Petkov, 2009).

Eternalists diverge among themselves when it comes to determine the present moment, the "now", if you prefer. For some, it is nothing but an indexical. The following statements exemplify this position: "my use of 'now' at any given time simply picks out the time at which it is used; consequently, my now is guaranteed to be present, since it is merely the time at which I am: *sum ergo sum nunc*" (Bourne, 2002, p. 359); "That some events are occurring *now* means only that those events are occurring contemporaneously with the utterance of that observation" (Arthur, 2006, p. 131). Other eternalists, however, take "present" as a referential term. Moving Spotlight theorists, for instance, hold that the present moment is metaphysically distinct due to a temporary property: *presentness*. This property is objective, and it moves from one moment to the next as time passes by. Thereby, "present" refers to the time-slice which instantiates that abstract monadic property (Cameron, 2015; Deasy, 2014, 2015). The computational routines I am going to propose later satisfy both sides of this contention.

Eternalism holds that the four-dimensional block is entirely given. The notion "temporal part" (Sider, 2008) comes in handy here: any temporally extended object has temporal parts, each of which is "now" only for a moment. Consider a teacup. The very first moment of this object – its first temporal part – coincides with the instant in which it came to existence, so to say. There are countless moments between *that* teacup there-earlier (in the factory where it was manufactured) and *this* teacup here-now (on my desk). Each of these moments was "now" once. The "now" keeps going from one to the next temporal part. According to the eternalist, old temporal parts – i.e., parts that have already been "now" – are as real as the part that is currently now. Forthcoming temporal parts – i.e., parts that will be "now" – are also real in the same sense. Figure 1 intendes to illustrate the idea of temporal parts.

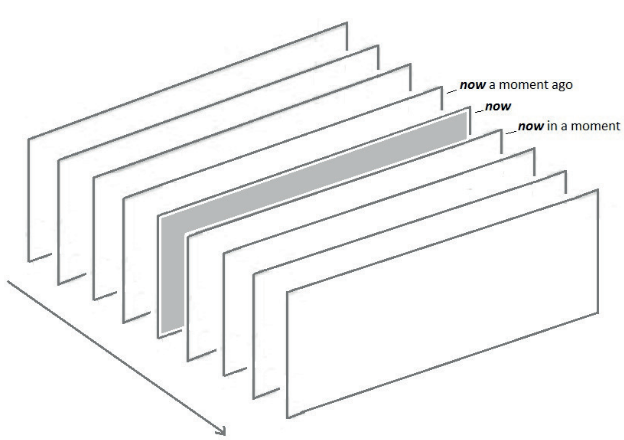

Figure 1. Temporal parts.

Sider (2008) makes the case for temporal parts within the Eternalist scenario: it is a "decent educated guess" (Sider, 2008, p. 244) that handles quite nicely the problem of change and temporary intrinsics, the puzzles known as the paradoxes of material constitution, and the argument from vagueness and anthropocentrism.

What about motion? As something dynamic, motion has significance only to our minds; it does not apply to the world as such. In the world, there are only differences between temporal parts. By analogy, think of a flipbook: it *is* a set of still pictures that vary gradually from one to the next. In a like manner, the world *is* a four-dimensional manifold. If you flip the book with the right speed, you will notice moving images, although the motion is not out there.

Human mind is massively modularly organized

In a relatively recent publication, Leda Cosmides states that the human brain's "evolved function is to extract information from the (internal and external) environment and use that information to generate behavior and regulate physiology" (Cosmides, 2006). She goes on suggesting that "to describe the brain's operation in a way that captures its evolved function, you need to think of it as composed of programs that process information" (Cosmides, 2006). To me, this is sound.

How many different information-processing programs are there? This is a question of the 80s, when Fodor (1983) took the lead by proposing an architecture comprised by a *central system* and some *input systems*, these understood as informationally encapsulated modules. A few years later, the hypothesis of a massively modular architecture got formulated in a meaningful way. Tooby (1985) was one of the first to suggest "an integrated architecture of different special-purpose mechanisms, "designed" to solve various adaptive problems". This architecture, he elaborates, "has been shaped by natural selection to structure interactions among different mechanisms so that they function particularly harmoniously when confronting commonly recurring (across generations) adaptive situations" (Tooby, 1985, p. 70-71).

Why should we endorse the massive modularity account? My three-step answer draws attention to computational reasons, evolutionary reasons and empirical evidence.

In the 90s, Cosmides and Tooby (1994) put forward some compelling computational reasons in favor of the thesis that evolution tends to favor specialized domain-specific modules rather than domain-general systems. First, "speed, reliability and efficiency can be engineered into specialized mechanisms because there is no need to engineer a compromise between different task demands" (Cosmides and Tooby, 1994, p. 89). Second, "there is no domain-independent criterion of success or failure [...] what counts as fit behavior differs markedly from domain to domain" (1994, p. 91). Third, "adaptive courses of action can be neither deduced nor learned by general criteria alone because they depend on statistical relationships between features of the environment, behavior, and fitness that emerge over many generations and are, therefore, often not observable during a single lifetime" (p. 93). Fourth, "combinatorial explosion paralyzes any system that is truly domain-general" (p. 94). Why? A truly domain-general system lacks domain-specific knowledge and domain specific procedures. Without any content that can guide the system towards fitness, the system is obliged to consider all the alternatives at stake. This would take forever, so to say, since alternatives easily increase exponentially. "By the time you analyze any biological problem of routine complexity, a mechanism that contains no domain-specific rules of relevance, procedural knowledge, or privileged hypotheses could not solve the problem in the amount of time the organism has to solve it" (Cosmides and Tooby, 1994, p. 94).

Carruthers (2006) elaborated what I call evolutionary reasons. First, given that "biological systems, when complex, need to have massively modular organization" and given that "the human mind is a biological system, and is complex", it follows that "the human mind will be massively modular in its organization" (Carruthers, 2006, p. 25). Second, assuming (as an inference to the best explanation) that "animal minds are massively organized" and that "in general almost all biological structures are preserved in the evolutionary transitions from one species into another", then "the human mind should at least be highly modular in character" (Carruthers, 2006, p. 34).

Finally, massive modularity meets the requirements of an empirically progressive research program (Lakatos, 1970). Since the 90s, the hard-core of the program – that our mind is massively made up of "specialized systems that can be described in computational terms and that have been shaped by natural selection to perform specific functions" (Eraña, 2012, p. 857) – has been consistently linked to empirical data. Researchers associated with this tradition have been proposing modules, and several predictions have found empirical corroboration: a module for cheating detection (Cosmides and Tooby, 1992); for sexual preference (Buss, 1992, 2008, 2016); for sexual disgust (Fessler and Navarrete, 2003; Tybur *et al.*, 2009); for ostracism prevention (Kurzban and Leary, 2001; Chester and De Wall, 2017), for kinship detection (Lieberman *et al.*, 2007; Park *et al.*, 2008), to assess others' ability to fight (Sell *et al.*, 2009; Sell *et al.*, 2010; Little *et al.*, 2015).

Let's sum up: the human mind is a complex system integrated by numerous mechanisms, each of which evolved to perform a specific task. These mechanisms (/modules) can be described in computational terms.

Mentally traveling the present

The human mind counts on a mechanism for event processing. Meurer (n.d.) defends this idea by means of a computational explanation of that system, which he calls *Event Processor*. Here, I am going to recap two key elements of that explanation: goals and behavioral functions. This accounts for what I call "traveling the present", and, on this basis, I will later suggest that similar routines take place when the subject engages in mental time travel.

Meurer's *Event Processor* has three goals: "*track* presentness, *link* temporal parts that already instantiated this property and, based on the sort of motion that this spacetime worm manifests, *predict* forthcoming temporal parts of the event (i.e., temporal parts that may instantiate presentness shortly)" (Meurer, n.d., p. 11). These goals are supposed to be meaningful not only for Moving Spotlight theorists, but also for Eternalists who take the present as an indexical. With a few vocabulary tweaks this becomes explicit: *track* the "present" or the "now"; *link* temporal parts that were present; predict temporal parts that may be present soon.

Some comments on these goals: first, not all human beings are able to *track* the present the same way neurotypicals do. The basic idea is this: in order to get the "now", a temporal parameter is needed. Meurer (n.d., p. 11) drives attention to empirical literature devoted to people with schizophrenia, whose sense of I-HERE-NOW is somehow compromised. On the one hand, fMRI shows that "the general neuropathology in schizophrenia alters the neural system configurations associated with self-representation" (Liu *et al.*, 2014, p. 169). On the other hand, people in this condition have low performance when it comes to integrating contours (Feigenson *et al.*, 2014), to integrating pieces of drawings (Sehatpour *et al.*, 2010), to grouping visual stimuli based on proximity and similarity (Kurylo *et al.*, 2007), to integrating moving stimuli (Tschacher *et al.*, 2008). For Meurer (n.d.) the now is not given; somehow, you need to organize it cognitively. In other words, the tracking of presentness involves something more than perception. So, in order to track the "now", a spatiotemporal reference is required. At the most basic level, a sense of I-HERE-NOW is needed. Take it as echoing a famous statement by Einstein: "unless we are told the reference body to which the statement of time refers, there is no meaning in a statement of the time of an event" (Einstein, 2001, p. 28-29).

Let's turn to the second goal: link temporal parts that already instantiated presentness [or: were present]. The mechanism is expected to accomplish this after having tracked a few temporal parts of the target event. The mechanism will link together just the temporal parts that the subject was able to track, and there are several situations in which one or more temporal parts are missing.

A set of temporal parts, once linked together, will manifest a pattern of motion (remember the flipbook I mentioned at the end of the section "All times are equally real"). Arguably, we get motion because we link temporal parts as economically as possible. The most economical mode – the one that spends less cognitive resources – compresses temporal parts of a four-dimensional object so as to transform it into a three-dimensional object that moves dynamically. Prosser (2016, p. 182-183) describes this operation and concludes that "it is more economical to represent a simple enduring identity through the employment of an object file rather than a perduring identity that consists in the unity of a series of parts".

Importantly, not all human beings are able to do this. Those who do not will possibly feel out of time. Based on 15 years of work, during which they treated more than 550 cases, Stanghellini and Rosfort (2013, p. 240) report that "schizophrenic persons often describe their sense of temporal reality as 'things to a standstill,' 'immobility, but not calm,' 'time going back to the same moment over and over,' 'people like statues,' 'frozen moment,' 'out of time,' 'marmoreal,' 'unreal stillness'".

Based on the pattern motion a sequence of linked temporal parts manifests, forthcoming temporal parts of that event are predicted. This is the third goal of the mechanism. Here are some examples:

> *Consider a neurotypical adult observing a small ball rolling along a flat surface. The Eternalist taught us that the ball is extended through time by having several different temporal parts (let's label them t1, t2, t3...), each of which instantiates presentness once. While the event unfolds, presentness moves from one to the next temporal part. It happens in such a way that the observer could truly say: now t1 is present, now t2... now t3... and so on. After a few moments, she is able to predict forthcoming temporal parts of that ball. Second example: the observer is watching her baby crawling in the living room. The same as with the previous case: this event – the baby – has temporal parts, one after another instantiating presentness, and soon the observer is able to predict forthcoming temporal parts of that event. Third example: she is observing a cup of tea on the table. Although common sense led us to believe that cups don't move on their own, this object also has temporal parts, none of them equal to the previous one. So, Event Processor does his job exactly the same way: based on the pattern of motion extracted from some temporal parts linked together, the mechanism predicts coming temporal parts (Meurer, n.d., p. 11).*

Meurer reinforces the case in favor of a mechanism dedicated to processing events and their temporal parts deriving a couple of behavioral functions. In his words, "*Event Processor* maximizes fitness by (i) assigning intentionality to events that present motion with biological timing; and (ii) processing events from the frame of a third person" (Meurer, n.d., p. 14).

Let's take a look at the first behavioral function. We already saw that motion requires a series of temporal parts and that our mind infers dynamicity by linking temporal parts together and inspecting the differences in search of a pattern. Eventually, this pattern gets classified as "biological". This impacts the prediction of forthcoming temporal parts: the event as such gets intentionality.

Empirical literature provides support for interesting inferences related to biological motion. Bidet-Ildei *et al.* (2014) suggest that humans are able to detect motion with biological timing from birth. Pyles *et al.* (2007, p. 2788) assert that "kinematics alone (without any explicit shape or social interaction) is sufficient to generate a percept of animacy". Saxe *et al.* (2004) found that a single region of the brain, in right posterior superior temporal sulcus (pSTS), shows a significantly higher BOLD response to biological motion and "that this region is involved in the representation of observed *intentional actions*" (Saxe *et al.*, 2004, p. 1435). According to Barrett *et al.* (2005, p. 317), six categories of biological motion – chasing, fighting, courting, following, guarding and playing – "seem to account for a great deal of natural animate motion, especially motion with significant adaptive costs, benefits, and risks". After a series of experiments with children and adults from different cultural backgrounds, Barrett and his team conclude that "motion schemas for chasing, fighting, following, and playing are not culturally contingent but may develop reliably as evolved adaptations for inferring intentions from physical motion trajectories" (Barrett *et al.*, 2005, p. 327).

The second behavioral function concerns the ability to process events from the frame of another agent. According to Meurer, this takes place when two people, let's call them A and B, are attentive to the same event but from different stances. Apparently, "A's module is able to do its job (*track* the present, *link* temporal parts that were present and *predict* forthcoming temporal parts of that event) from B's perspective. It is like an act of inhabiting someone else's mind" (Meurer, n.d., p. 15). Meurer clarifies this in terms of computing in first and in third person:

> *When I say "computing in first person", I mean Event Processor doing its job from its own world-point. In other words, I-HERE-NOW is functioning as parameter. On the other hand, computing in third person means the module doing its job from the current world-point of another agent (SHE-THERE-NOW) (Meurer, n.d., p. 16).*

In order to travel the present from someone else's perspective (i.e., computing in third person), the mind has to attribute perceptual states to that subject. This process somehow enables a different track, which eventually yields predictions that diverge from predictions achieved in first person. Empirical data produced by Kovács *et al.* (2010) show that humans perform quite well when it comes to encoding someone else's perspective in a shared scene. According to them, we sustain computations in third person even when the outcomes contradict our own, "possibly to be used for future predictions about the agent's behavior" (Kovács *et al.*, 2010, p. 1833). In this case, Meurer's two behavioral functions are deeply connected.

Mentally traveling other times

From a computational point of view, the routines of mentally traveling the present time are similar to the routines of mentally traveling other times. This claim rests both on the idea that the human mind counts on a mechanism for processing temporal parts of events and that the world is a four-dimensional manifold. In short: when traveling the present, *Event Processor* takes the *world-point* I-HERE-NOW as reference in order to carry out the job; when traveling other times, the system just operates on another spatiotemporal reference, like an I-THERE-EARLIER or an I-THERE-LATER. Throughout this section I speculate about the plausibility of this hypothesis.

During our mental travels, we transport ourselves from the HERE-NOW to another *world-point*. That other point may well be in the same time slice. In an ecological sense, I am here-now but I can mentally travel to a party that is happening now, 10 miles away. Doing this, a sense of I-*THERE*-NOW gets switched on. Although my current temporal part remains physically here, it is like I am there. To some extent, the "I" of the compound I-*THERE*-NOW has been detached from its ecological constituents. Would it be awkward to say that my mind works from *that* spatiotemporal reference, the I-*THERE*-NOW, while performing this travel? I do not think so.

Other world-points to which we switch when we mentally travel away from the HERE-NOW may well be in other time slices of the manifold, earlier or later than the current one. In my way of thinking, this means that usual tracking of the present gets temporarily suspended or lowered to the point of allowing the *Event Processor* to perform computations on another spatiotemporal reference. Basically, as soon as a sense of I-THERE-*EARLIER* is on, the mechanism uses *that* reference to track *that* present (and *links* temporal parts... and *predict*...). Here-now, the current temporal part of my body reenacts *that* experience in the fullest possible way. As a result, re-experiencing is intense and not at all boring. And pretty much the same happens when we mentally switch to a world-point that is later than the current one. Thanks to a sense of I-THERE-*LATER*, which becomes functional as a spatiotemporal reference, my future episodic thinking gets temporally organized *for me*. Indeed, we do pre-experience episodes in an organized way.

Our mental life seems to include more than one "now". Arguably, the most fundamental "now" is the I-HERE-NOW. It is the "now" that coincides with my current temporal part, which means the world-point that coincides with my sensorial awareness. Let's call it *ecological now*. Other nows are spatiotemporally earlier or later than the *ecological now*. Those that are earlier typically match up with an earlier temporal part of the subject. The I-THERE-EARLIER, no matter where in the four-dimensional manifold, has a "now" on its own. Let's call it *episodic now*. On the other hand, numerous nows are later than the *ecological now*. The I-THERE-LATER, no matter where in spacetime, also has its own "now". I will call it *prospective now*, due to the inherently speculative and constructive nature. Along these lines, when I mentally travel to an earlier region of spacetime and re-experience something there, this activity awakens an I-THERE-EARLIER and establishes the correspondent *episodic now*. Something similar happens when I mentally travel to a later world-point. The simulation of an I-THERE-LATER also enables a *prospective now*.

In its standard operations, *Event Processor* takes I-HERE-NOW as spatiotemporal reference. This reference sets the conditions to track the *ecological now*, then link temporal parts, then predict forthcoming temporal parts of any target event. Crucially, the tracking of present from the *ecological now* must slow down (get suspended or lowered) when it comes to activate a different now, be it episodic or prospective. This is quite interesting in light of Meurer's second behavioral function, mentioned above. On the one hand, *Event Processor* seems able to perform two processes in parallel, as long as they both track the ecological now. On the other hand, it seems impossible to process different nows in parallel. I cannot track any *episodic* or *prospective now* while my mind is actively tracking the *ecological now*.

The prevalence of the *ecological now* is explainable in terms of the importance of ecological awareness. Broadly speaking, we evolved to track mostly the *ecological now*, i.e., what is simultaneous to the I-HERE-NOW for reasons of survival. Only safely we switch to an *episodic* or to a *prospective now*. This safety, in turn, can be explained along the following line: when computations in the I-HERE-NOW frame are not predicting any situation that demands immediate action, then it is safe to switch and start computations in an I-THERE-EARLIER or in an I-THERE-LATER frame.

I submit that the ability to track the *ecological now* is required in order to set and track a different now, be it episodic or prospective. In other words, without an appropriate sense of I-HERE-NOW the subject is unable to mentally reach any I-THERE-EARLIER or -LATER. In representationalist terms: I-HERE-NOW is the basic internal representation of the self, from which the representations required for mental time travel are derived. On this basis, abnormalities associated with self-representation (I-HERE-NOW) preclude mental time travel.

For the time being, we know that the medial prefrontal cortex (mPFC) is strongly engaged in representation of self-knowledge (see Brunet *et al.*, 2000; Calarge *et al.*, 2003; D'Argembeau *et al.*, 2005). It is also known that abnormalities in mPFC correlate with deficits in episodic memories and future episodic thinking (Stawarzyck and D'Argembeau, 2015; Benoit and Schacter, 2015). Additionally, the hippocampus plays a critical constructive role, so to say: it is engaged in scene construction (Mullally and Maguire, 2014), creative thinking (Duff *et al.*, 2013), and binding of relational information across time (Duff *et al.*, 2007; Konkel *et al.*, 2008; Ranganath, 2010).

The empirical literature mentioned in the previous paragraph supports the following: it is not a matter of suspension but of lowering the track of the *ecological now* in order to voyage. Indeed, we do not completely turn off the traction of the ecological now when tracking a different now. First, we reenact here-now what is experienced in an I-THERE-EARLIER or -LATER frame. Via reenaction, the I-HERE-NOW turns out to be the ultimate recipient of all the voyages you undertake. Second, countless occurrences in ecological surroundings are able to quickly bring us back from a mental journey.

Concluding remarks

Humans mentally process the present time, and this ability can be computationally explained by positing a cognitive mechanism. In sum, when traveling the present we mentally take the stance I-HERE-NOW and track the so-called *ecological now* in a predictive way. This explanation, in turn, also sheds light on another ability: mental time travel. Indeed, in order to travel times other than the present, we have to lower the tracking of the *ecological now* to the point of establishing another traceable "now" in the world. Since the establishment of any such "now" requires a spatiotemporal reference, an I-THERE-EARLIER stance enables the tracking of an *episodic now*, and an I-THERE-LATER stance is mandatory to track a *prospective now*. The constructive nature of mental time travel, which has not been addressed in this study, may be a matter of interpolation of temporal parts.

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