WHEN EINSTEIN'S RELATIVITY MEETS NEUROSCIENCE

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ABSTRACT

When perceived by the human mind, an object might encompass diverse content according to different observers. Further, subjectively experienced time is encoded in the later entorhinal cortex. Starting from these two observations concerning mental perception of space and time, and considering Einstein's accounts, we show how, in terms of special relativity, imagination's content is not stationary and fixed, rather depends on the observer's standpoint. We elucidate how the subjective phenomenon of time (perceived by our mind as static) might give rise to changes in quantifiable content between the real and the imagined object. We describe how to correlate the quantifiable content of the sensed object embedded in the environment with the corresponding internal thought (subjective percept). In particular, based on recent neuroscientific literature, we show how changes in our mental time windows are able to squeeze the information content of the subjective percepts, compared with their matching environmental objects. Further, we elucidate how this novel framework could be able to confirm or reject a recently raised hypothesis, which suggests that the brain activity takes place in functional dimensions higher than our usual four-dimensional spacetime.

Keywords: Brain; nervous system; timescale; Einstein; relativity; Hakwing entropy

INTRODUCTION

In our daily phenomenal experience, our conscious states' contents occur "now" and "here" (Droege, 2009; Fingelkurts and Fingelkurts, 2014). It has been recently demonstrated that the encoding of time and its binding to events occurs in rats within the lateral entorhinal cortex (Tsao et al., 2018), suggesting that the latter area represents episodic time through the encoding of subjective experience. Further, it has been suggested that conscious awareness necessarily demands mental content being held "fixed", "frozen" within a discrete but continuous progressive present moment that stands for a phenomenal unity (James, 1890; Lynds, 2003; Revonsuo, 2003, Fingelkurts and Fingelkurts, 2014). Estimates of the mean duration of the specious present's frame suggest that it varies from ~100 ms to several seconds, depending on circumstances (Pöppel, 1988). In this paper, we try to extend the subjective perception of time to an objective reference frame outside the phenomenal realm. We will discuss the relationships between two different observer's standpoints: a) the standpoint of an observer while he watches an object embedded in his external environment, and b) the standpoint of an observer while he thinks about the same object, thus having the subjective thought presenting the object.

Here we ask: are we allowed to use Einstein's special relativity, in order to assess mental ideas? How many quantifiable features does an observed object (say, an ambulance that you watch in the street) encompass? Are such quantifiable features invariant quantities? Is it feasible to quantify also the "concept" of ambulance my brain is thinking about? Can we assess the content of a thought, i.e., the mental process of imagining the same ambulance? If the content encompassed in our ambulance is a fully describable, measurable quantity, is an observer able to collect from the environment an accurate amount of features related to it, in this case coming from the ambulance he is looking at. If the quantifiable content of the ambulance surface is constant, how does our brain process such input? Is it feasible to assess the quantifiable features encompassed in the subjective image/thought and concept of the ambulance reminded or imagined by our brain?

Here we show how, by joining concepts from far-flung scientific disciplines, a novel and suitable framework can be drawn, able to throw a bridge between the quantifiable features encompassed in the environmental objects and the ones endowed in their corresponding mental presentations. We show also how this novel approach could be experimentally used in order to confirm or reject a recently raised claim, e.g., that the brain activity lies in functional dimensions higher than the four-dimensional spacetime environment surrounding us (Tozzi and Peters, 2016a, 2016b; Peters et al., 2017a).

EINSTEIN'S SPECIAL RELATIVITY COMES INTO PLAY

In order to try to answer to our questions, we need to project ourselves into the field of the special relativity (Einstein, 1905). By the standpoint of an observer in uniform traslatory motion, an object seems to modify when its own speed increases. In particular, in an inertial frame, when the object approaches the light speed, its time slows down compared with the time detected by the observer at rest.

The Einstein's formula of time dilation at increasing speeds is the following:

$$\Delta t = t_0 / \sqrt{1 - v^2/c^2}$$

where Δt stands for the time interval between two events, and t_0 for the minimum duration of the time length.

Another detectable change predicted by Einstein equation occurs: modifications in object length along one of its spatial dimensions. Indeed, when a body approaches the light speed, one of its length shortens, according to the formula:

$$L = L_0 \sqrt{1 - v^2/c^2}$$

where L stands for the length of a moving body and L_0 for the maximum length of a body at rest. In Einstein's words, the length of a regulus (in this case, our object) is not invariant, because its dimension X shortens together with increases in its speed.

Therefore, in the inertial frame of special relativity, one of the three spatial dimensions changes, depending both on the observer's standpoint and the observed object's speed. In terms of object length, this means that, if the inertial observer changes his relative position and speed compared with the object, he detects changes in the length, and therefore in the surface, of the observed object.

Δt and L are correlated through the formula:

$$\frac{\Delta t}{\Delta t_0} = \frac{L_0}{L}$$

In other words, in a *gedankenexperiment*, a spherical object at rest appears more or less squeezed by the standpoint of two hypothetical observers, one at rest, and another traveling at the speed light. Therefore, according to the different observer's motion and speed, the spherical surface is more or less deformed. In special relativity, the Minkowski norm of 4-vectors makes sense; such quantities (such as the object length in our case), constructed out of non-invariant quantities, can be shown to exist.

It can be demonstrated that such apparently non-invariant quantities display different quantifiable content. According to the different observer's standpoints, the object's features change at relativistic speeds, e.g., close to the speed of light. Therefore, when the observer moves in an inertial system, the quantifiable features he detects about the analyzed object modify. Indeed, in an inertial system, the object's quantifiable content must change when the observer's speed varies, because also the object's surface modifies. When an observer analyzes an object, he detects different features, according to his relative speed. This means that the quantifiable features endowed in an object are not invariant, static, stationary and fixed physical quantities as currently believed, but fully depend on the observer. Consequently, the amount of quantifiable features encompassed in an object depends on the observer's speed. The faster the observer, the more features he gains about the object at rest being analyzed.

ASSESSING THOUGHTS, VIA THE MENTAL TIME

The above-mentioned Einstein's framework stands, of course, for "relativistic" inertial frames, e.g., when the objects or the observers move close to the light speed. Is it feasible to use the same framework in order to assess and quantify also mental operations which take place at very low nonrelativistic speeds? In other words, is it possible to describe the changes in information experienced by our mind, compared with the stationary physical information embedded in the objects we observe? Brain operations, of course, cannot reach the lightspeed, therefore the parameter speed must be kept invariant and fixed. However, there is a parameter in Einstein equations that deeply modifies during our brain activity: *time*. Indeed, our mind is able to subjectively dilate the time as a progressive present moment (Fingelkurts and Fingelkurts, 2014). Therefore, in order to build a relativistic theory of human mind functions, we have to leave apart the case of an inertial frame in which the observer (or the object) moves at light speed, because this is not feasible neither in our brain, nor in our biological niches. We do not need to take into account what happens at light speed, rather what happens when time dilates in an inertial mental frame. By the standpoint of special relativity, a massive time dilation resembles the case in which an inertial observer at rest watches an object moving close to the light speed. In our case, based on time lengths, the observer watches an object which physical features (in particular, the length on one of its

dimensions) modify. In other words, in the dilated time achievable by our conscious mind, an object's perception modifies.

By using simple calculations, our theoretical approach allows us to formulate empirically testable previsions related to brain function. We provide an example, in order to elucidate how to build the proper experimental setting. Take a cube at rest, 1-meter sided. In this case, L_0 stands for 1 meter. The cube is sensed by us for one second, through direct observation. In this case, t_0 stands for 1 second. The cube's objective information content (expressed in bits) can be calculated, through the Bekenstein-Hakwing formulas. After the object has been removed from the visual sight of the subject, he/she continues to observe it mentally in a thought for, e.g., 3 seconds. Now the cube's length in the mind should be calculated. In other words, we need to calculate the object's deformation that occurs in the subject's mind, when his/her mental time is subjectively dilated. The calculation is the following. The time, from the observer's standpoint (in this case, the subject's standpoint), is t_0 , while the cube length is L_0 . Therefore, the Einstein equation for time dilation is:

$$\Delta t = 1/\sqrt{1-0} = 1 \text{ second}$$

where t_0 stands for one second of direct observation of the cube at rest, and therefore with speed = 0. In this case, the time detected by the observer is unchanged, i.e., is one second.

Now we want to examine what happens to the cube length when the subject mentally sees the cube for three seconds.

Starting from the above-mentioned relationship:

$$\frac{\Delta t}{\Delta t_0} = \frac{L_0}{L}$$

We achieve the following results:

$$\frac{3 \text{ seconds}}{1 \text{ second}} = \frac{1 \text{ meter}}{x}$$

Where x stands for the unknown value of the L of the cube that the subject imagined for three seconds. Solving by x , we easily find that the required length is 0.3333. Therefore, in the case of 3 seconds of thought, the cube detected by the subject's mind has the following side measures: $1 \times 1 \times 0.333$.

Figure 1 grossly describes what happens when our mental time dilates. In sum, our theory predicts that, when a person thinks for three seconds to a one-meter-sided cube, he/she would mentally detect a decrease of one of its sides until the value of 0.3 meters. The imagined object displays a surface lower than the real observed one, therefore encompasses a lower amount of entropy. This means that the amount of information of the cube's subjective image/though is modified, compared with the objective values detected from the real cube's surface. As an example, **Figure 2a** illustrates the case of an observer rushing at light speed into a town street. This picture, according to our theory, corresponds to our subjective mental representation of an imagined object (**Figure 2b**). Note that he/she detects shapes and images that display entropy degrees very different from the real ones.

Recent findings provide strong clues confirming our hypothesis of mental shape distortion occurring during imagination and memory recall. Indeed, Costa and Bonetti (2018) assessed geometrical distortions in those large-scale cognitive geographical maps that our mind uses in order to represent space. They found that oblique geographical units tend to be rotated toward the orthogonal axes in cognitive maps, so that alignment leads to the misattribution of correct latitude and longitude (**Figure 3**). Overall, their data showed remarkable effects of rotation, alignment, shape compactness, regression toward the mean in large-scale geographical cognitive maps.

Furthermore, in touch with our framework, Howard (2018) reported behavioral evidence for a compressed representation of time in memory. Indeed, he found that the time to scan a point is a decelerating function of objective distance and that different forms of memory may rely on a compressed representation of time.

Figure 1. The brain is able to detect, through his sensory channels, the naïve quantifiable content endowed in an object in the environment (**upper Figure**). When the brain slows his mental time, the object (in this case, the thought of the object) is squeezed. Therefore, an imagined or reminded object encompasses a lower amount of quantifiable features (**lower Figure**).

A **B**

Figure 2A: appearance of a town street with respect to a viewer moving at speed light. **Figure 2B.** Our testable hypothesis suggests that our mind subjectively imagine objects and landscapes in the same way. Modified from: Chang et al., 1996.

Figure 3. Polygonal area connecting some European capitals in the metric map (left) and in the sketch map provided by observers' distance estimation (right). Note that, in touch with our previsions, the irregular polygonal shape that connects the capitals is transformed in a squeezed, polygonal shape in cognitive maps. Modified from Costa and Bonetti (2018).

CONCLUSION

Einstein's special relativity is based on invariant and non-invariant quantities (time and the axis parallel to the moving object), the latter being quantities that may change according to the subjective standpoint of the observer. While physics prefer not to consider the non-invariant quantities and to focus their accurate calculations on the "hard" data coming from the invariant frame, it turns out that it could be the opposite for mental functions. Indeed, our theory depicts the individual's brain as able to assess the non-invariant quantities of a relativistic-like inertial frame, giving rise to the astonishing variances in mental activity experienced by different people. Indeed, our claims suggest that an observer thinking of an object in a dilated mental time will detect a subjective mental deformation in one of object's sides. It might be argued that such phenomenon could not be noticed by the observer. One explanation could be that this is so simply because people usually are used not to pay attention to this parameter (but see the next paragraphs for the alternative explanation). Further, our calculations predict that the longer one thinks about the object, the more the object squeezes, until it disappears from the consciousness. This might explain why our thoughts seem to fade away with seconds passing.

In order to further operationalize our theory, we could at first calculate the objective amount of entropy (information) of an object embedded in our external environment. Then, we could calculate (e.g., through fMRI or EEG) the amount of entropy that occurs in a subject's brain when he/she is thinking about (mentally visualizing) the same object for a given number of seconds. Our framework is able to predict exactly the expected amount of entropy. The process can be also studied in the special cases in which the mental time is peculiarly dilated. For example, it is well known that certain psychoactive agents create subjective time distortions when administered. Particularly, opioids intake can lead to a prolongation of the subjectively perceived duration of thought. Neurophysiologically, as measured by EEG, this subjective experience is accompanied by an increased duration of operations produced by the neuronal assemblies with simultaneous decrease of synchronization between these operations (Fingelkurts et al., 2006). In touch with our framework, one may expect that the amount of entropy and information will be smaller under opioids administration than in an ordinary state, when the thoughts have normal duration. Another experimental model that allows easy manipulation of the subjective experience of time is hypnosis. For example, a neutral hypnotic state does not need any suggestion, but allows a subject to experience an altered background state of consciousness radically different from the normal baseline one. In such state, that is characterized by "emptiness" or "absorption", the subjective sensation of time

passing is modified, so that internal events are subjectively slowed (Fingelkurts et al., 2007). Neurophysiologically, this type of subjective experience is reflected in the extremely low level of the number and strength of synchronized operations produced by different local neuronal assemblies (as measured by EEG), thus leading to a limited possibility for any larger constellation of such neuronal assemblies to emerge (Fingelkurts et al., 2007). Again, one would predict that the amount of entropy and information should be smaller during such a neutral hypnosis state when compared with ordinary wakefulness state, when the thoughts have normal duration. Another feasible experimental model is sleep dreams. The nature of dreams in REM (rapid eyes movement) and non-REM sleep is different. During REM the dreams are complex, organized, temporally evolving, multimodal and often bizarre, while during non-REM the dreams are characterized by simple, static or isolated image(s) or thought(s), usually of one modality. One would expect that the non-REM static dreams should be accompanied by short-lived small neuronal assemblies and long-lived large neuronal assemblies, as well by the noticeable increase of synchrony combinations (but with a weak strength) between the operations produced by such neuronal assemblies (as measured by EEG). Empirical evidence fully confirms such hypothesis (see p. 34-35 in Fingelkurts and Fingelkurts, 2015). In this example, one would predict that the amount of entropy and information should be smaller in non-REM dreams, when compared with REM ones, or with wakefulness imagery. Furthermore, it is noteworthy that the pattern described in **Figure 2B** resembles the “tunnel experience”, or moving through a passageway, described in near death experiences, where, presumably, the subjective time is temporarily frozen (van Lommel et al., 2001).

In the previous section, we have proposed to quantify the value of entropy detected by our mind when thinking about the object, and we concluded that our brain machinery uses for mental thoughts a lower amount of content, compared with the real object’s perception. If brain multidimensionality’s claims were true (Tozzi and Peters, 2016b), we need to expect, during object’s imagination and thinking, an INCREASE in information content, rather than a DECREASE. There is a possible solution for this objection. According to the recently tested framework involving the Borsuk-Ulam theorem, every brain surface projects to two matching surfaces on one dimension higher (Peters et al., 2017b; Tozzi and Peters, 2017). This means that, when evaluating the quantitative content of a thought, we need to assess it in terms of higher dimensions. Therefore, coming back to our example of the 1-meter sided cube, the information encompassed in the thought of this cube is not anymore correlated with the squeezed object “surface”, but with its squeezed “volume”. If we, during the experiment suggested above, will detect an increase of mental object’s features, compared with the real object’s one, and if such an increase would equal to the predicted one, we would be able validate the fascinating hypothesis of the multidimensional brain.

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