TOWARDS THE PHYSICAL DESCRIPTION OF AN IMAGINED OBJECT

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ABSTRACT

Visual imagery (VI) is the mental experience of objects in the absence of their corresponding visual stimuli. Asking whether mental images can be physically quantified, we seek for relationships between visual imagery and special relativity. The Einstein's account states that, by an observer's standpoint, an object traveling at light speed is subjected to time dilation and length contraction. We hypothesize that objects are contracted both in the physical framework of Einstein's relativity due to the light speed, and in the mental framework of VI due to the dilated perception of time. Since the duration of thoughts can be experienced as progressively prolonged, we conjecture, in touch with Einstein's account, that the VI content must consist of objects undergoing length contraction. In the VI dilated mental time, the object might be experienced as more squeezed than the real object. Our calculations based on Einstein's equations predict that the longer an object is imagined, the more it is experienced as contracted until it disappears from consciousness. In touch with our hypothesis, review of published data provides evidence that distance estimates are shortened during VI. We suggest to evaluate VI in experimental settings where time is perceived as dilated, such as dreams, hypnosis and opioids intake. While the physical account of Einstein's special relativity is framed on invariant quantities such as the light speed, the mental experience of VI could be framed on non-invariant quantities, namely, quantities that change according to the subjective standpoint of the observer.

KEYWORDS

Brain; nervous system; visual imagery, Einstein; relativity; spacetime.

INTRODUCTION

In daily mental experience, the contents of conscious states occur "now" and "here" (Droege, 2009). It has been suggested that conscious awareness demands mental images being held "fixed" and "frozen" within a continuous progressive present moment (James 1890; Lynds 2003; Revonsuo 2003, Fingelkurts and Fingelkurts, 2014). Estimates of the mean duration of the present mental frame suggest variations from∼100 ms to several seconds, depending on circumstances (Pöppel 1988). Here we provide an effort to describe the subjective perception of time through an objective reference frame built upon physical constraints. We analyze the individual's standpoint during the mental experience of visual imagery, namely a type of sensory imagination occurring in the absence of the corresponding external stimulus (Fulford et al., 2018). Visual imagery is correlated with memory retrieval and is characterized by subjective experiences like perception, or at least by the mental representations that underlie these experiences (D'Angiulli et al., 2013; Butler et al., 2016).

It is still unclear whether the mental representations mediating visual imagery are:

a) Depictive, i.e., arising from activity in a visual buffer with crucial spatial properties (Kosslyn, 2005), or

b) Propositional, i.e., standing for one product amongst many of a syntactically structured system (Pylyshyn, 2003).

To assess the functional contributions of specific brain areas to visual imagery, Winlove et al. (2018) examined 180 parcellated cortical regions through neuroimaging studies. Consistent with the above-mentioned depictive theories, the visual area V1 was typically activated during visual imagery, even when participants had their eyes closed. Here we ask whether it is feasible to assess and quantify the physical features of the images recalled during the mental experience of visual imagery. Emphasizing the scientific importance of joining concepts from far-flung scientific disciplines to achieve experimentally testable hypotheses, we show how clues from Einstein's special relativity point towards the possibility to quantify the mental content of visual imagery. We will support the hypothesis that an object is contracted both in the physical framework of Einstein's relativity and in the mental framework of visual imagery. In the first case, the object's contraction is due to the light speed, in the second case to the dilated perception of time.

MATERIALS AND METHODS

We provide a brief description of the inertial frame in Einstein's special relativity. When a body approaches the light speed, two modifications occur by the standpoint of an observer in uniform translatory motion, namely time dilation and length contraction (Einstein, 1905). Compared with the time detected by the observer at rest, the time at the location of the object seems to slow down. Further, when a body approaches the light speed, its length seems to shorten by the standpoint of the observer at rest. The more the reference frame goes faster, the more the object shortens in the direction of the motion relative to the stationary observer. That's why an astronaut on a rocket traveling at light speed would be younger than his brother on the Earth.

In Einstein's words, the length of an object like a regulus is not invariant by the observer's standpoint. One of the object's' three spatial dimensions shortens together with the object's increases in speed and changing of relative position (**Figure 1A**). The time interval between two events Δt and the length of a moving body L are correlated through the equation:

$$\frac{\Delta t}{\Delta t0} = \frac{L0}{L}$$

Where t_0 stands for the minimum duration of the time length and L_0 for the maximum length of a body at rest.

To provide an example with a *gedankenexperiment*, the perception of a spherical object would be different by the standpoint of two hypothetical observers, one at rest, and another traveling at light speed. According to the different motion and speed of the observers, the spherical surface would appear more or less squeezed. In technical terms, we may state that in special relativity the Minkowski norm of 4-vectors makes sense, so that quantities (such as, in our case, the object length) constructed out of non-invariant quantities can be shown to exist. It is worth mentioning that length contraction and time dilation only become significant when the observer or the object are traveling at relativistic speeds, i.e., close to the light speed.

In conclusion, apparently non-invariant quantities like a traveling body might display different quantifiable content, so that an observer watching an object in a relativistic frame detects physical features that vary with the object's speed.

A mental counterpart for special relativity. We stated that the Einstein's framework turns out to be valid for "relativistic" inertial frames, e.g., when the object or the observer moves close to the light speed. Yet, the brain is clearly not a relativistic system since nerve conduction velocities are too slow (Rastmanesh and Pitkänen, 2021). Even though the brain activity takes place at non-relativistic speeds, it is nevertheless possible to build a relativistic theory of the brain activity to assess and quantify the mental experience of visual imagery. To build a neuroscientific theory based on Einstein's account, the case of an inertial frame in which the observer (or the object) moves at light speed must be left apart. Ever though the parameter *speed* of Einstein's equation must be kept fixed (Le Bihan, 2019), another parameter can be modified, namely, *time*. Like an observer at relativistic speeds perceives both the huge time dilation and the object's squeezing, the human mind that dilates the subjective time perceives the object's squeezing (Fingelkurts and Fingelkurts, 2014). We suggest that, by the standpoint of special relativity, what happens at light speed in an inertial physical frame equals what happens when mental time is dilated. We hypothesize a relationship between the case of mental massive time dilation and the case of inertial observers at rest and objects moving close to the light speed (**Figure 1B**). If our suggestion is true, during visual imagery the human mind recalls objects with distorted physical features.

Summarizing, we claim that during visual imagery an individual experiences an object as contracted, due to the dilation of mental time attainable by his mind. In the next chapter, we will provide a proof-of-concept approach that guarantees empirically testable previsions concerning visual imagery and its relationships with Einstein's special relativity.

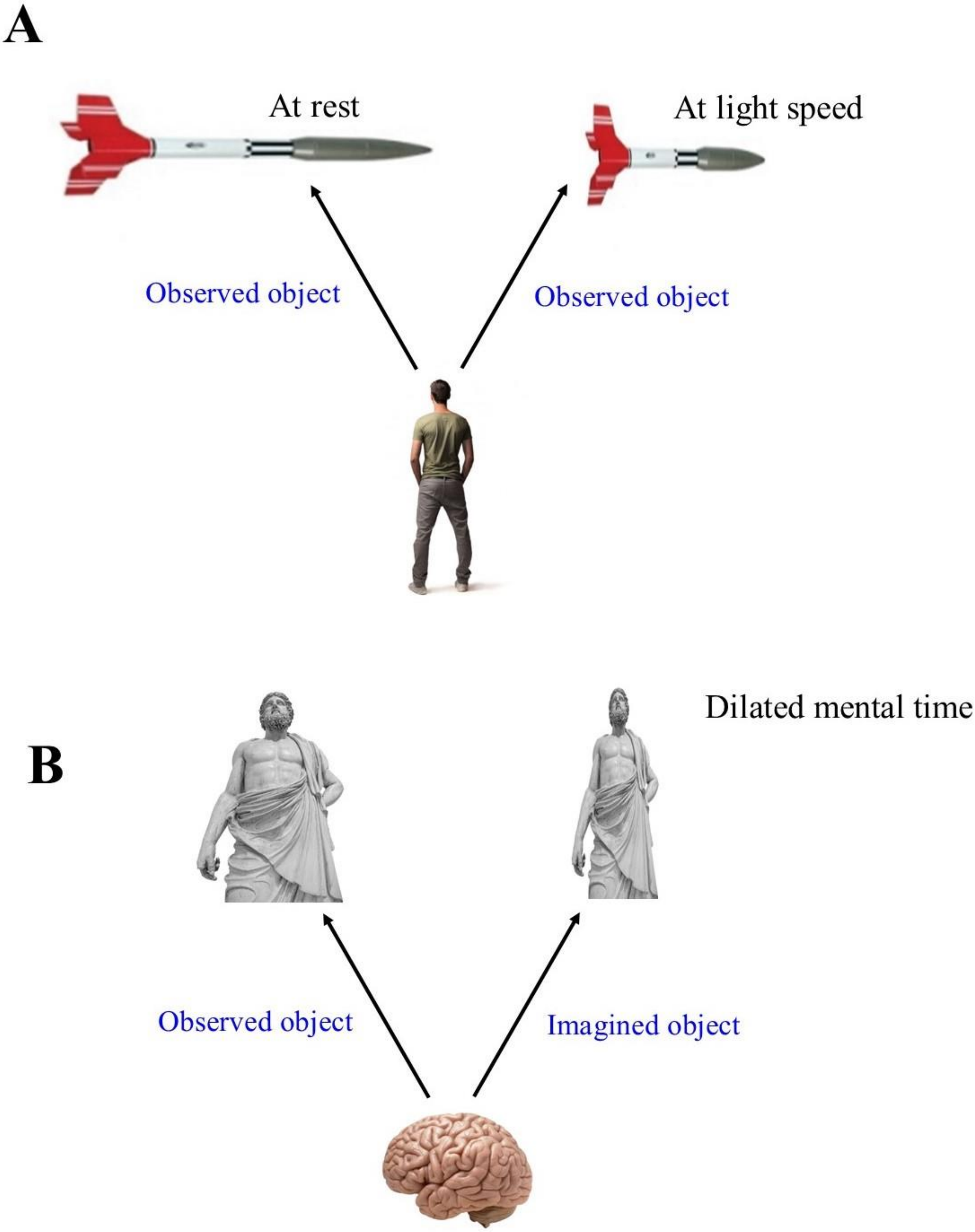

Figure 1A. An observer perceives a rocket as more or less contracted, depending on the rocket's speed relative to the observer. **Figure 1B**. During visual imagery, the brain experiences an object as more contracted compared with the real one. Therefore, the experience of an imagined object during dilated mental time matches the physical perception of an object traveling at light speed.

RESULTS

We provide a possible experimental setting to assess both dilated mental time and experience of imagined objects. Take a cube at rest, 1-meter sided, where L_0 stands for 1 meter. The cube is experienced by an observer through direct observation for one second, where t_0 stands for one second of direct observation of the cube at rest. Once the object is removed from sight, the subject under experiment is asked to mentally recall the object for a few seconds, say three seconds. In these three seconds, it can be stated that mental time is subjectively dilated. After three seconds, the hypothetical object deformation experienced by the subject during visual imagery can be calculated through the Einstein equation for time dilation:

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

During the perception related with visual stimulus, the cube's speed is zero and the time detected by the subject is t_0, i.e., one second, and the cube length is L_0, i.e., one meter. The next step is to examine what happens to the cube length when the subject imagines the same cube for three seconds. Starting from the above-mentioned relationship:

$$\frac{\Delta t}{\Delta t0} = \frac{L0}{L} ,$$

We achieve the following results:

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

Where x stands for the unknown value of the length L of the imagined cube experienced by the subject for three seconds. Solving by x, the required length tuns out to be 0.3333. Summarizing, when the cube is imagined for three seconds, it is experienced as a parallelepiped displaying the measures 1 x 1 x 0.333 meters.

Our theory predicts that the imagined object becomes progressively squeezed when the brain slows its mental time. When an individual imagines a one-meter-sided cube, as seconds go by, he would experience a progressive decrease in the length of one of the sides. Therefore, our hypothesis suggests that the human mind imagines objects and landscapes that are distorted.

CONCLUSIONS

We highlighted a relationship between the framework of special relativity and the mental experience of an object occurring in the absence of the corresponding external visual stimulus. Einstein's special relativity is framed on invariant quantities such as the light speed and on non-invariant quantities that may vary according to the subjective standpoint of the observer. While physicists focus their quantitative analysis on the "hard" data resulting from the invariant frame, it turns out that it could be the opposite for mental functions. Our theory depicts the brain as a device able to measure the non-invariant quantities of a relativistic-like inertial frame, providing a feasible explanation for the astonishing variability in mental activity experienced by different subjects.

In this paper we focused on the specific mental activity of visual imagery, suggesting that an individual might detect a subjective deformation in one of the sides of the object he is imagining. Our hypothesis might explain why the imagined objects seem to fade away with the passage of seconds. We predict that the longer an individual thinks about an object, the more the object is experienced as squeezed, until it disappears from the consciousness. It might be argued that the alleged mental phenomenon of object contraction is not noticed by the observer. One explanation could be that people are used not to pay attention to this deformation. Non-commitment is a pervasive component of mental imagery. Most people report non-commitment, rather than uncertainty or forgetfulness, to basic properties of specified mental scenes, including features that would be readily apparent in real images (Bigelow et al., 2022). In touch with Chang et al. (1996) who described the theoretical case of an observer rushing at light speed into a town street, evidence is provided supporting our hypothesis that mental shape distortion occurs during mental imagery. Published work evaluating distance estimates in cognitive maps point towards the possibility that our assumption could be true. Research showed a systematic shape distortion of map features. Costa and Bonetti (2018) assessed geometrical distortions in large-scale cognitive geographical maps used by the human mind to represent space, asking to participants to mentally recall and estimate the distance among European capitals. In touch with our previsions, participants estimated the polygonal shape connecting the European capitals as contracted in length along the axis x, compared with the real metric map. Further, oblique geographical units in cognitive maps tend to be rotated towards the orthogonal axes, so that alignment leads to misattribution of correct latitude and longitude. Also, it has been suggested that information judged from cognitive maps (Thorndyke 1981) can contain internally inconsistent spatial properties, with three derived angles forming a triad exceeding 180° (Moar and Bower, 1983). Moreover, the landmark effect suggests a general tendency to provide shorted estimates when traveling to a geographical landmark (Higgins and Wang, 2010). In touch with our hypothesis, Howard (2018) reported behavioral evidence that various types of memory may rely on a compressed representation of time and distance. Further, it has been demonstrated that both space and time are grossly distorted during saccades and that the two distortions are strongly linked (Binda et al., 2009). Our hypothesis seems to hold true also for cues different from the visual ones. It has been demonstrated that the brain rotates representations to auditory neural responses into orthogonal memory representations (Libby and Buschman, 2021). Still, the recalled vanishing location of a moving target has been found to be displaced downward in the direction of gravity, a phenomenon possibly driven by vestibular information (De Sá Teixeira et al., 2017).

The experimental methodologies to test the validity of our hypothesis are already available. The neural events associated with visual imagery can be empirically assessed through neuroimaging (Winlove et al. 2018). The neural correlates of imagination, illusions and hallucinations in which a perceptual experience occurs in the absence of a physical stimulus have been widely investigated (Rees and Frith, 2017; Fulford et al., 2018). To evaluate our hypothesis, the mental experience of visual imagery could be studied through neuroimaging in the special cases in which the mental time is peculiarly dilated. Certain psychoactive agents such as opioids can lead to the subjective experience a prolonged duration of thoughts (Tozzi, 2019), quantifiable through decreased synchronization among neuronal assemblies (Fingelkurts et al., 2006). We predict that mental imagery might depict an object which is more deformed under opioids administration than in the ordinary state characterized by standard duration of thoughts. Another experimental model to manipulate the subjective experience of time is the hypnotic state, where time is frequently experienced as slowed (Fingelkurts et al., 2007). Again, one would predict that the shapes of mental objects should be contracted during hypnotic states, compared with the ordinary wakefulness state. The last, but not the least, another feasible experimental model might involve sleep dreams, where the subjectively perceived time is frequently distorted (Fazekas and Nemeth, 2018).
The quantifiable features of objects during mental imagery are not invariant, stationary and fixed, rather they depend on the time length experienced by the observer. In our framework, Einstein's relativistic equation applies to the experience of time, and not to the (experience of) appraisal. The deformation of a mental object during mental imagery occurs regardless of the subjects' experience of time passing. Using the term "observer-dependent" when alluding to "point of view-dependent" could be misleading. In this paper, we refer to the well-established "point of view dependence", which is an objective property of an interaction (Tozzi and Peters, 2019). Recent suggestions based on the principle that there is a speed limit for action potentials flowing along myelinated axons point towards time and space in the brain as tightly mingled, unified in a nervous "spacetime" (Sapp 1993; Baer 2010; Ghaderi 2015; Le Bihan D 2019). Conscious entities experience their own perceptive space, perhaps with the kind of distortions predicted by Einstein.

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The Author warrants that the article is original, does not infringe on any copyright or other proprietary right of any third part, is not under consideration by another journal, and has not been previously published.

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