Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 22 November 2019

THE PHYSICAL FEATURES OF VISUAL IMAGERY

Arturo Tozzi
Center for Nonlinear Science, Department of Physics, University of North Texas, Denton, Texas 76203, USA
1155 Union Circle, #311427
Denton, TX 76203-5017 USA
tozziarturo@libero.it
Arturo.Tozzi@unt.edu

ABSTRACT

Visual imagery, i.e., the mental experience of an object occurring in the absence of external visual stimulus, might encompass diverse content according to different observers. Further, subjectively experienced time is encoded in the later entorhinal cortex. Starting from these two observations, and considering Einstein's account of spacetime, we show how, in terms of special relativity, the content of visual imagery is not stationary and fixed, rather depends on the standpoint of the observer. We elucidate how the subjective definition of time (perceived by our mind as static) might give rise to modifications in the length of the imagined object which are experimentally assessable and quantifiable. In particular, based on recent neuroscientific literature, we show how changes in our mental time windows are able to squeeze the visual content of mental imagery.

KEYWORDS

Brain; nervous system; Einstein; relativity; spacetime; mind

INTRODUCTION

In our daily mental experience, the contents of our conscious states occur "now" and "here" (Droege, 2009; Fingelkurts and Fingelkurts, 2014). It has been recently shown 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 proposed that conscious awareness necessarily demands mental images 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 discuss the standpoint of the observer during visual imagery, i.e., a type of sensory imagination characterized by subjective experiences similar to perception, or at least by the mental representations that underlie such experiences, but occurring in the absence of the corresponding external stimulus (Winlove et al., 2018). It is still unclear whether the mental representations that mediate visual imagery are a) depictive, i.e., they arise from activity in a visual buffer with crucial spatial properties (Kosslyn, 2005), or b) propositional, i.e, they stand 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) performed a meta-analysis to identify activated regions across 40 neuroimaging studies, investigating the parcellation of 180 anatomical regions of the brain in 464 participants. They found that V1 was typically activated during visual imagery, even when participants have their eyes closed. This means that, during visual imagery, the visual areas of the brain are activated. consistent with influential depictive theories of visual imagery.
Once estabilished that during visual imagery we recall an image with visual features, here we ask: can we assess the content of a visual thought? how is our mental image of an object? Does it display (at least a few) physical features that can be quantified? Further: are we allowed to use Einstein's special relativity to assess visual imagery? How many quantifiable features does a previously observed object encompass, when it is recalled by our brain? Are the features of visual imagery invariant? Here we show how, by joining concepts from far-flung scientific disciplines, a novel and suitable framework can be drawn to quantitatively assess (at least some of) the physical features endowed in mental images during visual imagery.

© 2019 by the author(s). Distributed under a Creative Commons CC BY license.

EINSTEIN'S SPECIAL RELATIVITY COMES INTO PLAY

To try to answer to our questions, we need to project the mental activity of visual imagery into the field of the special relativity (Einstein, 1905). By the standpoint of an observer in uniform translatory motion, an object seems to modify when its 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. **T**he formula of time dilation at increasing speeds is provided by Einstein. Nevertheless, 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. 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 modifies, depending both on the standpoint of the observer and the speed of the observed object. 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 of the observed object.

The time interval between two events Δt and the length of a moving body L are correlated through the formula:

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

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

This means that, in a *gedankenexperiment*, a spherical object at rest seems more or less squeezed by the standpoint of two hypothetical observers, one at rest, and another traveling at the speed light. According to the different motion and speed of the observer, the spherical surface is more or less deformed. In special relativity, the Minkowski norm of 4-vectors makes sense, so that 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 these apparently non-invariant quantities display different quantifiable content. According to the different standpoints of different observers, the features of the object change at relativistic speeds, e.g., close to the speed of light. Therefore, when the observer moves inside an inertial system, the quantifiable features of the analyzed object he detects modify. Indeed, in an inertial system, the quantifiable content of the object must change when the speed of the observer varies, because also the surface of the object modifies. When an observer analyzes an object, he detects different features, according to his relative speed: the faster the observer, the more features he gains about the object at rest being analyzed.

The above-mentioned Einstein's framework turns out to be valid 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 to assess and quantify also mental operations such as visual imagery, which take place at very low non-relativistic speeds? Because brain operations cannot reach the light speed, the parameter speed must be kept invariant and fixed (Le Bihan, 2019). However, there is a parameter in Einstein equations that does modify during our mental activity: *time*. Indeed, our mind is able to subjectively dilate 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 during visual imagery, the observer recalls an object which physical features (in particular, the length on one of its dimensions) modify. In other words, due to the dilated time achievable by our conscious mind, an object is deformed during our visual imaginery.

ASSESSING VISUAL IMAGERY VIA MENTAL TIME

By using simple calculations, our theoretical approach allows us to formulate empirically testable previsions related to visual imagery. 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 an observer for one second, through direct observation. In this case, t_0 stands for 1 second. After the object has been removed from the visual sight of the subject, he persists in thinking to it for, e.g., 3 seconds. At the end of the three seconds, the length of the imagined cube could be calculated. In other words, we need to calculate the object's deformation that occurs in the mind of the subject, when his mental time is subjectively dilated. The calculation is the following. From the mental standpoint of the observer during visual imagery, time is t_0, while the cube length is L_0. Therefore, the Einstein equation for time dilation is:

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

Where t_0 stands for one second of direct observation of the cube at rest, therefore at 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 imagines the 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 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 visual imagery, the cube detected by the mind of the subject has the following side measures: 1 x 1 x 0.333.

When the brain slows its mental time, the mentally recalled object is squeezed . In sum, our theory predicts that, when a person thinks for three seconds to a one-meter-sided cube, he would mentally detect a progressive decrease of one of its sides, until the value of 0.3 meters. In touch with Chang et al. (1996) who described the theoretical case of an observer rushing at light speed into a town street, our testable hypothesis suggests that our mind subjectively imagines distorted objects and landscapes .

Recent findings provide strong clues confirming our hypothesis of mental shape distortion occurring during mental imagery and memory recall. Costa and Bonetti (2018) assessed geometrical distortions in those large-scale cognitive geographical maps that our mind uses to represent space. The Authors asked to the participants (unsupplied of maps) to mentally recall and estimate the distance among European capitals. The conclusion was that in cognitive maps oblique geographical units tend to be rotated towards the orthogonal axes, so that alignment leads to the misattribution of correct latitude and longitude (**Figure 1**). Overall, their data show remarkable effects of rotation, alignment, shape compactness, regression towards the mean in large-scale geographical cognitive maps.
Also, in touch with our framework, Howard (2018) reported behavioral evidence for a compressed representation of time in memory. 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.

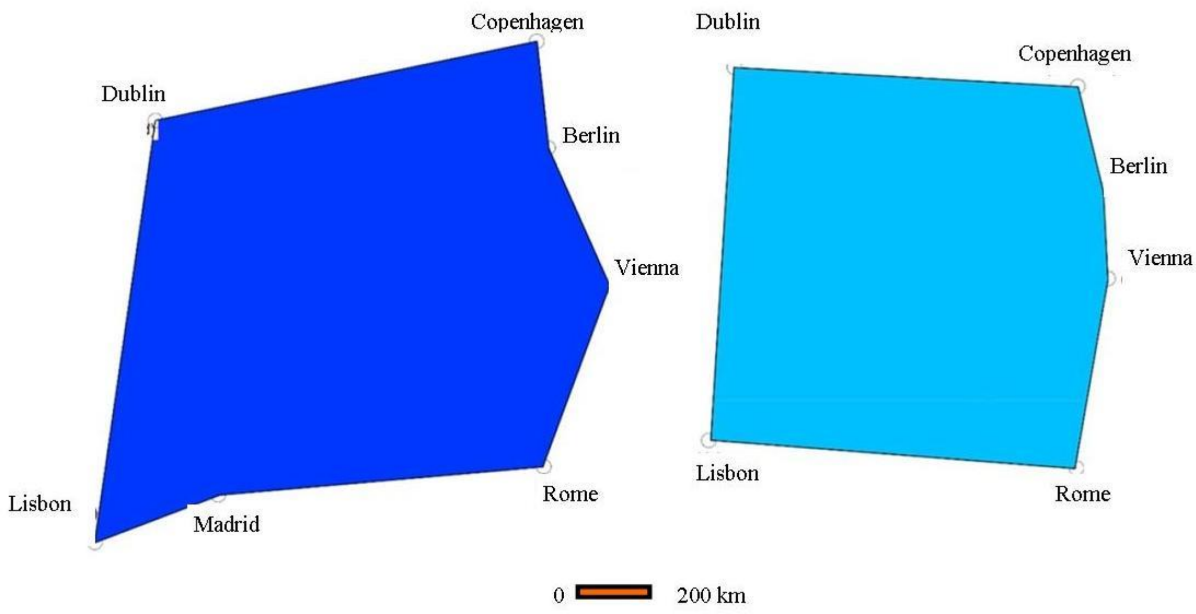

Figure 1. Polygonal area connecting European capitals in the metric map (left) and in the sketch map provided by distance estimation of the observers (right). Note that, in touch with our previsions, in cognitive maps the irregular polygonal shape that connects the capitals is transformed in a squeezed, polygonal shape mainly characterized by a decrease in length along the axis x. Modified from Costa and Bonetti (2018).

CONCLUSIONS

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 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. Our theory depicts the brain of the individual 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. In particular, in this paper we were interested in the specific mental ability of visual imagery, leaving apart other issues such as, e.g., brain processing of external image during a visual stimulus, the possible use of a "Kantian" predictive coding and backward propagation, the exixtence of topological invariants in perceived images, and so on.
Our claims suggest that an observer who thinks to an object in a dilated mental time will detect a subjective deformation in one of the sides of the object. 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 are used not to pay attention to such deformation (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 the objects in our thoughts seem to fade away with seconds passing.

Empirically, the neural events associated with visual imagery can be assessed using neuroimaging (Winlove et al. 2018). To make a few examples, Rees and Frith (2017) and Fulford et al. (2018) discussed studies exploring the neural correlates of imagination, illusions and hallucinations in which a perceptual experience occurs in the absence of a physical stimulus. Visual imagery can be studied in 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 (Tozzi, 2019). 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 mental imaginery depicts an object which is more deformed 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. 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, describable 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 shapes of mental objects should be more squeezed during a neutral hypnosis state, when compared with the ordinary wakefulness state characterized by thoughts of normal duration. Another feasible experimental model is sleep dreams (Fazekas P, Nemeth G. 2018). 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 though(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 this hypothesis (Fingelkurts and Fingelkurts, 2015). In this example, one would predict that mental objects should be more distorted in non-REM dreams, when compared with REM ones, or with wakefulness imagery.

The quantifiable features of objects during mental imagery are not invariant, static, stationary and fixed, rather depend on the experience of time of the observer. In literature a distinction can be drawn between experience of time and the (experience of) appraisal of time, and their relationship to the alleged neural “clock cycle”. In our framework, Einstein’s relativistic equation applies to the experience of time, and not of appraisal. Indeed, independent of our consciousness of time passing, the deformation of a mental object during mental imagery necessarily takes place. Using 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 (see, for example, Tozzi and Peters 2019), leaving apart features of the ensuing experience, which depend on the observer per se (e.g. from size constancy to expectations). By a philosophical/epistemological standpoint, leaving apart objective reality, a relative reality can be adopted in which conscious entities perceive their own perceptive space. In such space, their own observations of objects appear, and presumably appear with the kind of distortions Einstein predicted. Indeed, recent suggestions point towards time and space in the brain as tightly mingled, unified through a brain “spacetime” based on the principle that there is a speed limit for action potentials flowing along myelinated axons (Le Bihan D 2019; Ghaderi 2015). Recognizing that the constancy of the speed of light is a perceptive statement applicable to a self contained observer who is changing at his own constant rate is not main stream, but slowly emerging in physics as an acceptable possibility (Stapp 1993; Baer 2010, Walker 2000).

ACKNOWLEDGEMENTS

The Author would like to thank Andrew and Alexander Fingelkurts for commenting upon an earlier version of this manuscript.

COMPLIANCE WITH ETHICAL STANDARDS

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.

The Author does not have any known or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

This research does not contain any studies with human participants or animals performed by the Author.

The Author had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. The Author performed: study concept and design, acquisition of data, analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, statistical analysis, obtained funding, administrative, technical, and material support, study supervision.

REFERENCES

1) Baer W. 2010. Introduction to the Physics of Consciousness. Journal of Consciousness Studies, 17, No. 3–4, 2010, pp. 165–91.
2) Chang M-C., Lai F, Chen W-C. 1996. Image shading taking into account relativistic effects. ACM Transactions on Graphics (TOG), 15(4), 265-300.
3) Costa M, Bonetti L. 2018. Geometrical distortions in geographical cognitive maps. Journal of Environmental Psychology. Volume 55, February 2018, Pages 53-69
4) Droege P. 2009. Now or never: how consciousness represents time. Conscious. Cogn. 18, 78–90 10.1016/j.concog.2008.10.006
5) Einstein A. 1905. ZurElektrodynamikbewegterKörper. Annalen der Physik (Berlin) (in German), Hoboken, NJ (published 10 March 2006), 322 (10), pp. 891–921, Bibcode:1905AnP...322..891E
6) Fazekas P, Nemeth G. 2018. Dream experiences and the neural correlates of perceptual consciousness and cognitive access. Philos Trans R Soc Lond B Biol Sci. 2018 Sep 19;373(1755). pii: 20170356. doi: 10.1098/rstb.2017.0356.
7) Fingelkurts AA, Fingelkurts AA, Kivisaari R et al (2006) Increased local and decreased remote functional connectivity at EEG alpha and beta frequency bands in opioid dependent patients. Psychopharmacology 188(1):42–52.
8) Fingelkurts AA, Fingelkurts AA, Kallio S, Revonsuo A (2007) Cortex functional connectivity as a neurophysiological correlate of hypnosis: an EEG case study. Neuropsychologia 45:1452–1462.
9) Fingelkurts AA, Fingelkurts AA. Present moment, past, and future: mental kaleidoscope. Frontiers in Psychology. 2014;5:395. doi:10.3389/fpsyg.2014.00395.
10) Fingelkurts, A.A.; Fingelkurts, A.A. Operational architectonics methodology for EEG analysis: Theory and results. Neuromethods 2015, 91, 1–59.
11) Fulford J, Milton F, Salas D, Smith A, Simler A, et al. 2018. The neural correlates of visual imagery vividness - An fMRI study and literature review. Cortex. 2018 Aug;105:26-40. doi: 10.1016/j.cortex.2017.09.014.
12) Ghaderi AH. 2015. Brain Activity and Special Relativity: Estimation and a Novel Hypothesis to Explain Time Perception. Am J Psychol and Cognitive Sci, 1(2): 66-74. http://www.aiscience.org/journal/ajpcs .
13) Howard MW. 2018. Memory as Perception of the Past: Compressed Time in Mind and Brain. Trends Cogn Sci. 22(2):124-136. doi: 10.1016/j.tics.2017.11.004.
14) James W. 1890. The Principles of Psychology, Vol. 1. New York, NY: Dover; 10.1037/10538-000
15) Kosslyn S. 2005. Mental images and the brain. Cognitive Neuropsychology, 22 (3): 333-347, 10.1080/02643290442000130.
16) Le Bihan D. 2019. Is the brain relativistic? arXiv:1908.04290v1
17) Pöppel E. 1988. Mindworks: Time and Conscious Experience. Boston, MA: Harcourt Brace Jovanovich
18) Pylyshyn Z. 2003. Return of the mental image: Are there really pictures in the brain? Trends in Cognitive Sciences, 7 (3) (2003): 113-118, Doi: 10.1016/S1364-6613(03)00003-2
19) Rees G, Frith CD. 2017. Methodologies for Identifying the Neural Correlates of Consciousness. Book Editor(s): Schneider S, Velmans M. The Blackwell Companion to Consciousness, Second Edition, Chapter 42. https://doi.org/10.1002/9781119132363.ch42.
20) Revonsuo A. 2006. Inner Presence: Consciousness as a Biological Phenomenon. Cambridge: MIT Press
21) Stapp HP. 1993. Mind, Matter, and Quantum Mechanics. Springer-Verlag: Berlin.
22) Tozzi A. 2019. The multidimensional brain. Physics of Life Reviews. doi: https://doi.org/10.1016/j.plrev.2018.12.004.
23) Tozzi A, Peters JF. 2019. Entropy balance in the expanding universe: a novel perspective. Entropy, 21(4), 406. https://doi.org/10.3390/e21040406.
24) Tsao A, Sugar J, Lu L, Wang C, Knierim JJ, Moser M-B, Moser EI. 2018. Integrating time from experience in the lateral entorhinal cortex. Nature. https://doi.org/10.1038/s41586-018-0459-6.
25) Walker H. 2000. The physics of Consciousness. Perseus Publishing ISBN 0-73820436-6 .
26) Winlove CIP, Milton F, Ranson J, Fulford J, MacKisack M, Macpherson F, Zeman A. 2018. The neural correlates of visual imagery: A co-ordinate-based meta-analysis. Cortex. 2018 Aug;105:4-25. doi: 10.1016/j.cortex.2017.12.014. Epub 2018 Jan 2.