frontiers | Research Topics

Physical time within human time

Edited by
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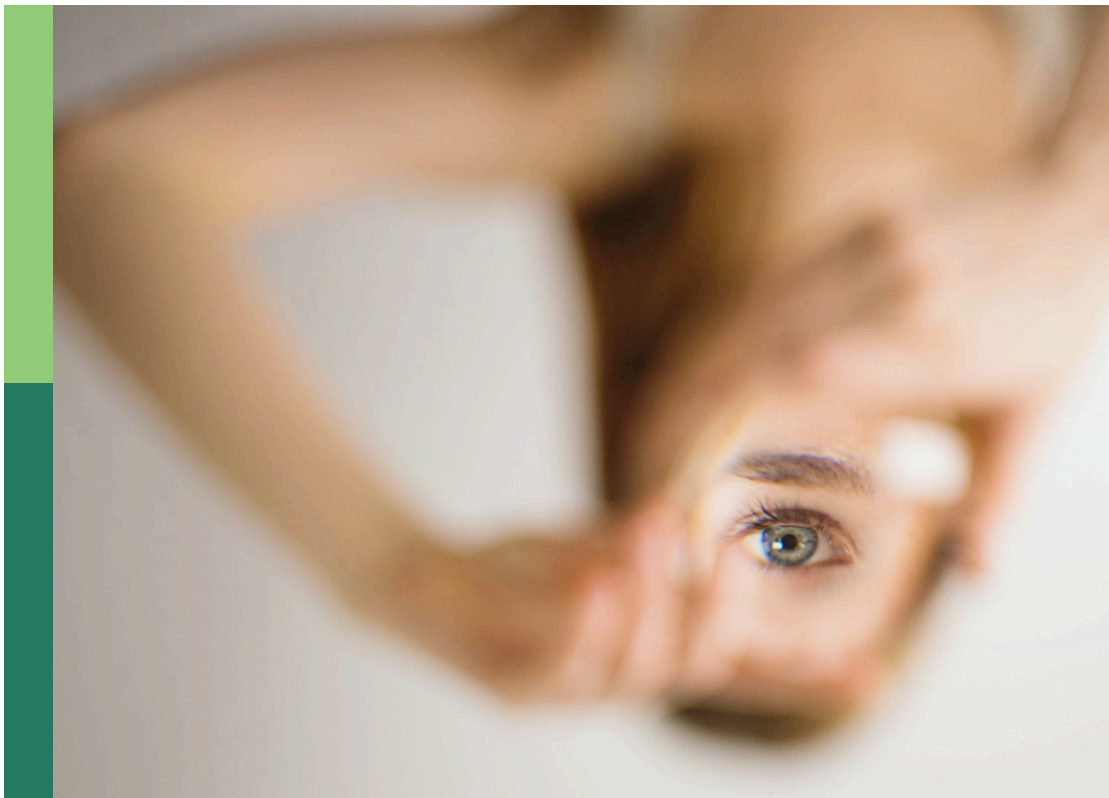
Published in
Frontiers in Psychology



ISSN 1664-8714
ISBN 978-2-8325-3887-6
DOI 10.3389/978-2-8325-3887-6

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Physical time within human time

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Citation

Giersch, A., De Assis, L. P. G., eds. (2023). *Physical time within human time*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-3887-6

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frontiers | Frontiers in Psychology

TYPE Editorial
PUBLISHED 24 October 2023
DOI 10.3389/fpsyg.2023.1293198

OPEN ACCESS

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RECEIVED 12 September 2023
ACCEPTED 06 October 2023
PUBLISHED 24 October 2023

CITATION
Giersch A and De Assis LPG (2023) Editorial: Physical time within human time.
Front. Psychol. 14:1293198.
doi: 10.3389/fpsyg.2023.1293198

Editorial: Physical time within human time

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KEYWORDS

psychological time, physical time, present time, block universe, time flow, quantum physics

Editorial on the Research Topic
Physical time within human time

Diving in the Research Topic "*Physical time within human time*" means giving up our intuitions about what time is. The notion of a singular, continuous flow of time has come under scrutiny in both physics and neuroscience, creating a challenge in reconciling perspectives across these research domains. Physics debates the very existence of time itself, questioning the presence of a past, present, and future in contrast to an eternal block universe.

Indeed, some physicists argue that the block universe model, which implies a timeless cosmos, can still explain the perception of the passage of time. They argue that the physicist's task is to describe how the universe appears from the point of view of individual observers. On the other hand, others argue that the passage of time is physical and that the future does not exist ontologically. They believe that the task of physics is to explain not just how time seems to pass, but why. There are also physicists who propose alternative models of time, such as the idea that gravity, not thermodynamics, points the arrow of time, or that time is a fundamental feature of the cosmos that emerges naturally from the structure of space time. But amid this variety of views with different models of time in physics, we see that there is an interest among physicists to understand why the models they build conflict with the human perception of time.

Neuroscience, including psychology, offers a distinct perspective on the concept of time, contrasting with the view in physics. Unlike physics, neuroscience explores the experience and perception of time. Neuroscientists recognize that our understanding of time is intertwined with cognitive processes and individual perspectives. They study how people perceive, process, and remember time, and the temporal dynamics of brain activity, cognition and behavior. By focusing on the psychological and neurobiological dimensions, neuroscientists reveal the complexities of human temporal experiences, which can vary across individuals, contexts, and cultures. Those questions open the door to a multitude of theoretical possibilities, that entail, or not, a reconciliation of the physical and psychological views of time.

We believe it's essential to consider a wide range of perspectives to understand the potential consequences of the new concepts of timing and to test these ideas. This Research Topic precisely offers that. The two papers by Buonomano and Rovelli (2022), as well as the modified IGUS model by Gruber et al. (2022), illustrate the issues we are facing, and the commentaries underline the difficulties encountered when trying to reconcile the physical and the neuroscientific view of time. Moreover, they reflect the diversity of the views and

problems elicited by the proposed solutions. Considering that various authors have explored related questions with diverse approaches and thematic focuses, we have structured this editorial into distinct topics.

What is veridical and what is illusory? Our subjective experience is reflecting something veridical?

Many commentaries emphasize the difficulty to distinguish between what is veridical and illusory. However, whereas some authors emphasize the importance of taking physics into consideration, others emphasize the importance of our subjective experience to define time ontology. Dorato remarks that it can be difficult to distinguish between what would be attributed to physics vs. psychology: what is "information" in physics, and how should we qualify the "illusory" output of a robot? He adds that time travel is not accounted for by e.g. IGUS, but also acknowledges that naive physics may not be the best choice to access time ontology.

Turning our focus to the subjective experience, the following contributors delve even deeper into this aspect.

Arstila acknowledges the merits of the proposed models but still asks whether it is really the case that any temporal component has two aspects, veridical and illusory, as proposed in the dualistic model of Gruber et al. (2022). Like several authors he questions whether the snapshot theory should be seen as veridical and the specious present as an illusion.

Dainton expresses dissatisfaction with labeling the snapshot theory as veridical, emphasizing the challenge in defining the present moment (3 seconds or less). He reminds us that any theory should account for our phenomenological experience of continuity and sense of present.

Wittmann also counters the claim made by Gruber et al. (2022) that the present moment and dynamic change are illusory. Wittmann asserts the reality of the present moment and argues that our perception of time reflects the temporal structure of the world. The article delves into the neurological and philosophical implications of time perception, emphasizing the importance of perceiving the dynamic passage of events for proper functioning. Wittmann explores the concept of phenomenal consciousness as a distinct experience within the continuous flow of time. Overall, the article challenges the idea that the present moment is an illusion and highlights its significance in our perception and experience.

Elliott investigates the concept of time from philosophical and scientific perspectives, tracing its historical origins and metaphysical implications according to Aristotle's interpretation. He argues that although experienced time is real, its dimensionless nature prevents its operational use in physics. He further insist that time processing in the brain does not necessarily lead to a conscious experience. Elliott suggests a broader understanding of temporal experience, acknowledging the challenge the distinction between physical and psychological time poses to reductionist science.

Miller and Wang question the subjective experience itself. They dive deeply in the topic of presentness by rejecting the idea that our experience of flow is one of a changing present. They similarly question the concept of self persistence, and this leads them to doubt that the experience of flow is an illusion.

Shifting our perspective away from exploring subjective time as we experience it, certain authors raise thought-provoking suggestion whether we should question those experiences.

What is veridical and what is illusory: should physics lead us to change the way we understand time?

Prosser delves into the intricate connection between time, experience, and neuroscience, cautioning against adopting a neuroscientific perspective that contradicts established principles in physics. He emphasizes the need for caution when drawing conclusions about the nature of time solely from subjective experience.

Glicksohn not only questions the fact that the passage of time is illusory, but also the linearity of the passage of time. After discussing how the passage of time can be explored, he suggests we should question the discontinuity and not only the continuity of time. As a matter of fact, since the time problem comes from an apparent contradiction between a frozen time in physics and the passage of time in psychology, an alternative is of course to question those statements.

Farr argues that the main problem lies between the time of experience and commonsense time, rather than between physics and the time of experience. He prompts us to reconsider whether quantum physics describes a static world and challenges the notion of our experience of time as one of flow.

Silberstein presents his argument that time is a relational property of beings with bodies, rather than a property projected by the brain. He supports a Jamesian form of neutral monism, which posits that the mental and the physical are neutral and not separate entities. According to this perspective, physics is rooted in and influenced by subjective experience. Silberstein also criticizes the primary/secondary distinction, asserting that the world cannot be neatly divided into categories such as physical/mental or subject/object. Additionally, he challenges the notion of consciousness as qualia, suggesting that intrinsic physical properties should be replaced by qualitative aspects such as qualia or subjectivity.

If defining timing is already difficult, the two papers by Buonomano and Rovelli (2022) and Gruber et al. (2022) also address the question of the link that can be made between the concepts of time in physics and psychology. Some contributors explore how this question can be investigated.

What is veridical and what is illusory: how should we use VR? Motion and change, and psychophysics as a link between psychology and physics?

Latham and Holcombe question how we can explore the experience of time in psychology. More specifically they question the way (Gruber et al., 2022) test the possibility for participants

to experience a past event as being a re-experienced present. They further stress the possibility that those participants have a vivid experience while knowing they are re-experiencing a past event. They propose some additional and interesting means to test this idea, using affordances.

Huggett, Deng, and Balcells all take the example of motion and change, and like the majority of authors, question what is illusory and what is veridical.

Balcells suggests that some changes can be described by physics and may indeed be veridical, while Deng suggests that "becoming" might be the illusory part of veridical change. Huggett proposes that motion and the sense of flow are not illusions but rather misinterpretations of perceptual information, which challenges the proposed models.

Grondin brings to our attention the objective of psychophysics, which is to define the relationship between the outer world and our perception of this world. He underlines temporal laws as old as the Weber fraction do not hold beyond some durations, as if reflecting a disruption of the flow of time: our perception of the world is constrained by the way the brain works, and our senses serve as evidence for the world's existence.

Embarking on the journey of reconciling perspectives on time in physics and psychology, the following authors explore the theoretical questions that arise from this endeavor.

Reconciling the manifest image of time with its scientific image?

Several authors discuss to which extent physical laws can be reconciled, or embedded in the psychological experience.

Balashov questions whether it is possible to "reconcile the manifest image of time" with its scientific image. He reminds us of the stage theory, in which objects are themselves states and are thus temporary. This leads however to a special role for the present, which may or may not be inconsistent with a physical view. The sense of present time plays an important role in many comments.

In his article, Dieks suggests that the core elements of human time can be found at a fundamental physical level. He proposes that quantum mechanics may provide a physical counterpart to the subjective nature of human time. He argues that temporal relations similar to those governing our experiential time might exist in fundamental physical systems, establishing a connection between quantum mechanics and human time.

Romero explores the distinction between physical time and psychological (perceptual) time, highlighting that they arise from the same underlying physical laws. Rather than being a passive response to sensory input, the experience of time is actively generated by the brain's predictive processes and the body's sensorimotor activities. Differences in how we perceive time are relative and reflect variations in the distribution of properties within the four-dimensional spacetime framework. To test the notion of a time constructed by the brain, the author proposes manipulating the information presented to the brain through an information gathering and utilizing system (IGUS).

Paganini examines the nature of time by exploring the theoretical proposals of Buonomano and Rovelli (2022) and Gruber et al. (2022). Rather than directly comparing their cosmological theories, Paganini focuses on the philosophical challenges presented by each notion of illusion. Gruber et al. argue for the illusory nature of our temporal experience due to the Block Universe concept, while Buonomano and Rovelli (2022) propose that our perception of time may hold validity in relation to local reality. Paganini refrains from taking a position on the accuracy or validity of these notions, but encouraging critical engagement and contributing to the discourse on the nature of time.

In conclusion, the diverse contributions presented in this Research Topic of Theoretical and Philosophical Psychology journal have shed light on the complex nature of time and our perception of it. The authors have explored the boundaries between what is veridical and illusory, delving into the domains of physics, psychology, neuroscience, and philosophy. While there is ongoing debate regarding the nature of the present moment, the experience of flow, and the relationship between subjective and objective time, these discussions have enriched our understanding and prompted critical engagement with the concept of time. It is clear that a comprehensive exploration of the concept of time requires interdisciplinary collaboration, bridging the realms of philosophy and science. By continuing to investigate and challenge existing theories, we can hope to deepen our comprehension of time and its profound implications for our perception and experience.

Author contributions

AG: Writing—original draft, Writing—review and editing. LD: Writing—review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE Opinion
PUBLISHED 10 October 2022
DOI 10.3389/fpsyg.2022.1031564

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 30 August 2022
ACCEPTED 23 September 2022
PUBLISHED 10 October 2022

CITATION
Glicksohn J (2022) From illusion to reality and back in time perception. *Front. Psychol.* 13:1031564. doi: 10.3389/fpsyg.2022.1031564

From illusion to reality and back in time perception

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KEYWORDS

time perception, Gestalt psychology, flow of time, illusion, time estimation

Assuming that time perception is, indeed, a form of *perception* (Glicksohn, 2001)—an area acknowledged as such, now and again, in textbooks on perception (Murch, 1973; Chap. 7; Coren et al., 2004; Chap. 11)—one can address what Gruber et al. (2022) refer to as the "two times problem", as a problem for perception, and not one whose resolution must necessarily span between psychology and physics. Indeed, in agreement with Smythies (2003, p. 53), who suggests that "if one wants to account for our psychological impression that there is a 'now' in time and moreover that time in some way flows, we must look elsewhere than contemporary physics, whether Newtonian or Relativity, to find it", it would be instructive to return to the Gestalt psychologist Kurt Koffka, who posed the classic question for theorists of perception, namely "why do things look as they do?" (Koffka, 1935; p. 76). In the present context, this can be rephrased as "why do we perceive time the way we do?" While Gruber et al. (2022) draw a distinction between "the veridical and illusory nature of time", for the Gestalt psychologists, as Epstein and Hatfield (1994, p. 166) stress, "phenomenal experience is real … it is not illusory or suspect in any way." Hence, even if the *flow* of time is considered to be illusory (Gruber et al., 2015), while time *estimation* might well be "real" (Gruber et al., 2020), both need to be addressed by psychology.

In a recent paper (Glicksohn and Ben-Soussan, under review)[1], it has been suggested that "While a minority of researchers … accepted that subjective time could be neither veridical nor linear… the majority embraced … [the] view that subjective time could be both veridical and linear." Either way, for Gruber et al. (2022) this would imply that subjective time (or, *apparent duration*, *psychological time*, or *estimated time*; Glicksohn, 2001; Buhusi and Meck, 2009) would be "real" (veridical, or not), to be contrasted with the flow of time (or, *temporal flow*, *passage of time judgment*, or *perceived speed of time*; Larson and von Eye, 2006; Wearden, 2015; Droit-Volet, 2018; Thönes et al., 2018; Vogel et al., 2020; Martinelli and Droit-Volet, 2022), which is "illusory". And yet illusions (flow of time?), as Zavagno et al. (2015) have argued, "can be effective tools in studying the brain in reference to perception and also to cognition in a much broader sense." Hence, even if the flow of time is an illusory construct, it might still be either correlated with subjective time (Eisler and Eisler, 2009) or dissociated from this (Wittmann et al., 2015; Droit-Volet and Wearden, 2016; Hancock et al., 2019). Of particular significance is the fact that the flow of time can be indicative of a state of flow (Larson and von Eye, 2006; Hancock et al., 2019; Kent et al., 2022) or a state of absorption (Woodrow, 1951; Glicksohn and Lipperman-Kreda, 2007; Glicksohn and Berkovich-Ohana, 2012; Mohr, 2018) in an ongoing activity.

1 Glicksohn, J., and Ben-Soussan, T. D. (under review). Discontinuity in time perception, or inadequacy of psychophysical fit?

Maybe, however, the flow of time is not an illusory construct. Koffka would probably disagree with Gibson's (1979) answer to his question, "that things look as they do because the information in proximal stimulation is what it is" (Epstein, 1994; p. 176).In turn, Gibson (1975) himself would probably argue against the very notion of time *perception*, and that time itself "is 'real' and can be directly perceived" (Larson and von Eye, 2006, p. 114). Nevertheless, it is still the case that the optic flow (Rogers, 2021) with which Gibson was primarily concerned might well be a ready source for the flow of time. Consider the case when your plane is descending toward the airport, and from the vantage of your window the optic flow is in continual flux. If the velocity were constant, your perceptual experience would be very different from the usual case wherein the plane is decelerating. One would not be surprised if the corresponding flow of time was also altered. In a recent study, a group of researchers looked at the flow of time on exposure to a starfield environment, and reported that "Passage of time experience was increased for faster stars and more dense starfields, but was not as much affected by the actual duration of the interval or the task difficulty. This shows that the salience of moment-to moment differences between individual frames is more directly associated with the experience of passage of time than is the actual duration of the interval" (Jording et al., 2022; p. 12). This comes in support of the suggestion made here that changes in optic flow might very well affect the flow of time. If that were the case, would both be considered to be illusory?

A reviewer of this commentary has questioned whether the issue of temporal *continuity* is ever *directly addressed* in passage of time judgments. Gruber et al. (2022) refer to the question asked of observers of "how fast time went"—namely, whether time was felt to pass quickly or slowly. As the reviewer astutely notes, that type of judgment can be affected by such a factor as boredom. Hence, the less or more bored one feels will affect the subsequent change in passage of time judgment, irrespective of the impact of the change in optic flow (as suggested here). My suggestion would be, therefore, to employ a question referring to the present, ongoing, subjective experience of the flow of time. For example, in a study employing virtual reality (Glicksohn and Avnon, 1997–1998), the experimenter lightly tapped the shoulder of the participant during the session, signaling the request for an introspective report. In a similar manner, one could send a text message to the participant asking for a current rating of the subjective experience of the flow of time. While this is certainly feasible, one should also consider the fact that in doing so, one is actually momentarily disrupting the ongoing experience of that participant. Sometimes, this can be fatal for the subjective experience under investigation. Nonetheless, in order to make a stronger argument regarding the suggestion made here relating change in optic flow with change in reported passage of time, this would be a necessary requirement for a future study in this domain.

A second way in which the flow of time might be affected can be derived from the multiplicative model for apparent duration (Glicksohn, 2001). According to this model, time production is a multiplicative function of two components: The size of the subjective time unit (which varies with context), and the number of these subjective time units. Kent et al. (2019) have recently applied this model in their discussion of time dilation, especially that related to depression. They suggest that "the mode of prospective time judgment in production tasks changes as intervals increase from around 1 s of the experienced moment into the 30 s range of mental presence" (p. 80). Specifically, "if it is assumed that the size of Glicksohn's (2001) time units can vary within the same interval, then units at the end of the interval will be *relatively* small compared to intervals at the beginning of the interval" (p. 78). This would suggest that "time accelerates as intervals increase, an effect which in itself may not be unique to depression. It may be a general feature of time perception that is simply more pronounced for depressed individuals" (p. 78). Hence, a reported change in flow of time might well be related to a discontinuity in time-production data [Glicksohn et al., 2017; Glicksohn and Ben-Soussan, under review (see text footnote 1)]. Indeed, as Martinelli and Droit-Volet (2022, p. 528) have recently suggested, the passage of time judgment curve "might not be as linear as observed" in their study, given extreme conditions. Perhaps, as Gruber et al. (2022, p. 1) argue, "the veridical system is a reflection of accepted spacetime cosmologies and through natural selection begets the illusory system for functional purposes". What this means for the "two times problem" discussed by Gruber et al. (2022) is that one needs to consider not only the question of temporal continuity, which they believe to be an illusory experience, but also that of temporal *discontinuity*. It is not, however, clear to me whether such temporal discontinuity would also be considered to be an illusory experience.

Perhaps, as Conway et al. (2016) suggest, "humans should have a psychological mechanism for slowing time down as motion speeds up"—what they refer to as a "spacetime processor". Who knows? Gruber et al. (2022) have certainly given us plenty of food for thought.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 14 October 2022
DOI 10.3389/fpsyg.2022.1025476

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 22 August 2022
ACCEPTED 20 September 2022
PUBLISHED 14 October 2022

CITATION
Miller K and Wang D (2022) Commentary: Physical time within human time.
Front. Psychol. 13:1025476.
doi: 10.3389/fpsyg.2022.1025476

Commentary: Physical time within human time

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KEYWORDS

flow, persistence, endurance, time, temporal experience

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). Physical time within human time. *Front. Psychol.* 13, 718505. doi: 10.3389/fpsyg.2022.718505

A reconciliation

Gruber et al. (2022) and Buonomano and Rovelli (2022) aim to render consistent the picture of time delivered to us by physics, with the way time seems to us in experience. Their general approach is similar; they take the picture of our world given to us in physics, a picture on which there is no global "moving" present and hence no robust temporal flow, and attempt to explain why things nevertheless seem to us as they do, given that our world is that way. In this, they follow in the footsteps of Hartle (2005), Callender (2017), and Ismael (2017), who argue that any information gathering system (an IGUS) will, in learning to navigate our world, represent the distinctions between past, present, and future, and represent their own changing trajectory through spacetime. While we are generally very sympathetic to this approach, there are several places where we disagree.

What to reconcile?

While Gruber et al. and Buonomano and Rovelli each take themselves to be attempting to bridge the gap between two ways of thinking about our world, the gap in question is a little different. Gruber et al. take themselves to be attempting to bridge the gap between the manifest image—the image of time had by each of us in ordinary experience—and the scientific image—the image presented to us in our best science. Buonomano and Rovelli's target is a little different. They take themselves to be attempting to bridge the gap between the way neuroscientists suppose things to be, in theorizing about our how we come to represent and experience the world, or perhaps even *the way neuroscientists* suppose that things *seem to us, in ordinary experience*, and how the image of the world presented to us in the scientific image. The former is straightforwardly a claim about the manifest image. The latter is a claim about what the scientific image (neuroscience) tells us about the manifest image. In what follows we will talk directly about these claims about the manifest image.

Both Gruber et al. and Buonomano and Rovelli hold that it is part of the manifest image that time passes: that it seems to us as there is a present moment, and that which moment that is, changes. Gruber et al. express this as the claim that it seems to us as though there is a *unique*, changing present. In addition, Buonomano and Rovelli hold that it is part of the manifest image (according to neuroscience) that presentism is true: that is, that only present things exist (past and future ones do not) though *which* things are present, changes. It's worth distinguishing two different claims that might be at issue here. The first is a claim about the way the world is presented to us in experience; the way it *experientially seems* to us. The second is a claim about how we take the world to be, pretheoretically; what we tend to *believe* about the world. We think that one aspect of their target—the presentist component—is a mistake.

Presentism

Ultimately, as we read them, Buonomano and Rovelli argue that the manifest image *as it really is*, rather than as neuroscientists suppose it to be, is consistent with the scientific image. We agree. Consider first the idea that we tend to believe that presentism is true. In fact, empirical evidence regarding people's beliefs suggests that *most* people believe that past, or past and future, objects exist (Latham et al., 2019, 2020). Most people do not have a manifest image of our world as being a presentist world. We also think that Buonomano and Rovelli are right to argue that there is little reason to think that the best description of our experiences is that it seems to us as though *only* the present exists. The fact that we are usually perceptually aware of what seems to us to be a single moment, the present, and that what we are aware of, changes, does not show that it seems to us as though there *only exist* present things, any more than the fact that typically each of us is only perceptually aware of what is spatially local to us, suggests that our experiences are such that it seems as though only things that are "around here" exist. So while neuroscientists might tend to model our experiences in terms of a single, changing, present, there is nothing in our experiences themselves that suggests that we experience the world as one in which presentism is true.

An illusion of flow

Buonomano and Rovelli hold that our experiences are *veridical* experiences of a *local changing indexical present*. According to the block universe model we are located at multiple locations in spacetime. At different locations we have different experiences. Further, because of entropy increasing away from the low entropy big bang, there are records (such as memories) of earlier events but not later ones, so at different locations our experiences represent that at earlier locations *we had* different experiences. We represent that our experiences change. Buonomano and Rovelli conceive of this as having a veridical experience of a local changing present. In this, they agree with Ismael (2012, 2017) and Sattig (2019a,b), who hold that representing these experiences as changing constitutes our having a veridical experience of time flowing. More generally, many block theorists hold that we have veridical experiences of *anemic flow:* the kind of flow that is present in block worlds and is consistent with physics (Dainton, 2011; Deng, 2013, 2019; Hoerl, 2014; Baron and Miller, 2018; Miller, 2019; Miller et al., 2020; Leininger, 2021). These authors deny that we have experiences of *robust* flow: experiences as of there being a *unique present* that changes, and hence they deny that our experiences of flow are illusory.

By contrast, Gruber et al. argue that our cognitive systems generate an illusion as of there being a unique changing present, where this illusion is a "more satisfying experience of physical time, [that produces] better adaptive behavior." But we see little reason to suppose that the relevant experiences here are indeed illusory.

To be illusory, our experiences would need to represent that there is a *unique present* that changes. We see little reason to think they do. Consider the way we represent things *as present*. Perhaps we perceptually represent *indexical* presentness. If so, perceptual experience is tensed: it is part of the content of perception that we represent the event perceived *as occurring at the time of the perception* (Peacocke, 1999; Kriegel, 2009; Phillips, 2014). In experiencing what is indexically present as changing, however, our experiences are veridical: what is indexically present does change in a block world. Or perhaps we do not represent *presentness* at all. Hoerl (2018), holds that things presented to us in perceptual experience are not presented to us *as* present because our perceptual experience has no temporal viewpoint. Then we are not subject to any illusion. Since we see little reason to suppose that people represent that there is a *unique global* present that changes, we doubt that they are subject to an illusion of flow: instead, they have veridical experiences of anemic flow.

Persistence: Endurance and perdurance

A second aspect of Gruber et al.'s account that we doubt is their appeal to the role of persistence in explaining the illusion of flow. Gruber et al. hold that endurantism is incompatible with a block world, so objects perdure. But if objects perdure then they do not persist. Since we have experiences as of objects, particularly the self, persisting, then those experiences are illusory, and they contribute to the illusion of flow.

While some argue that endurantism is incompatible with eternalism (Merricks, 1994, 1999; Barker and Dowe, 2003, 2005; Effingham and Robson, 2007; Giberman, 2017; Baron and Miller, 2018) it is generally held that the two are compatible

(Haslanger, 1989; Sider, 2001; Miller, 2004; Brower, 2010; Eagle, 2010; Daniels, 2014; Wasserman, 2016). So we should not conclude that if our world is a block world, then objects must perdure. Moreover, even if objects do perdure, it does not follow that our experiences of persisting things are illusory. Gruber et al. write, "…perdurantism…suggests that object persistence is not veridical (Gruber et al., 2022, p. 5)." This implies that perduring objects do not persist. However, endurantism and perdurantism are accounts of persistence: they simply disagree about the *way* in which objects persist.

If we experience persisting objects as enduring, when in fact they perdure, then our experience would be illusory. Prosser (2007, 2012, 2016) takes this to be so, and he thinks we *mistake* these illusory experiences for experiences of flow. But recent empirical research by Baron et al. (2022) tends to undermine this. Baron et al. (a) found that most non-philosophers did not judge that objects endure rather than perdure, and (b) found no association between people judging that our world contains robust flow and judging that objects endure rather than perdure and (c) found that when presented with a description of an experience of time robustly flowing, people were no more inclined to judge that the world was one containing enduring rather than perduring objects.

Perhaps when Gruber et al. talk about *enduring* as opposed to *perduring* selves they really have in mind the view that there is an *unchanging core* persisting self rather than a *series of short-lived momentary selves* that have *no unchanging properties*. Then the suggestion that it is because we experience ourselves as having an *unchanging core,* that we are subject to an illusion of flow. We take it to be an open question both whether people do experience themselves as having an unchanging core, and whether, if they do, they would mistake this as an experience of flow (as per Prosser's suggestion) or that this would partially constitute them having an illusory experience as of flow (as we take it Gruber et al. are suggesting).

While the IGUS-driven approach has much to recommend, we are not convinced by the dualistic model on which the IGUS not only has veridical experiences of a block world, but also has adaptive illusory experiences as of time flowing. We see little reason to posit this second aspect to experience.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 15 March 2023
DOI 10.3389/fpsyg.2023.1134397

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 30 December 2022
ACCEPTED 27 February 2023
PUBLISHED 15 March 2023

CITATION
Deng N (2023) Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time". *Front. Psychol.* 14:1134397. doi: 10.3389/fpsyg.2023.1134397

Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time"

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KEYWORDS

physical time, human time, temporal passage, illusion, temporal experience, local presentism, IGUS

A Commentary on

Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). Physical time within human time. *Front. Psychol.* 13, 718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). Bridging the neuroscience and physics of time. *arXiv.* 11. doi: 10.48550/arXiv.2110.01976

Both Buonomano and Rovelli (2021) and Gruber et al. (2022) contain interesting interdisciplinary proposals for how to think about the relation between humans' experience of time and what time is like. This is a complex topic. Tackling it requires confronting difficult questions about (i) which features of experience and which features of time are difficult to fit together (if any), (ii) which discipline(s) should attempt the required explanation(s) (if any are required), and (iii) what these explanation(s) might look like. I'm very sympathetic to aspects of each proposal. In what follows, I offer some comments, starting with Buonomano and Rovelli (2021).

At the outset, Buonomano and Rovelli (hereafter B&R) distinguish three reasons why "the theoretical physicist is led to reject the idea that the commonsense view of time could remain valid outside a limited domain." The first concerns the time reversal invariance of elementary mechanical laws, the second relativity's conflict with the notion of a global present, and the third the absence of a time variable in the basic equations of many theories of quantum gravity. They set aside the third as it pertains to the evolving frontiers of physics and concentrate on the first two, which pertain to well-established theories.

This is helpful, and it contrasts somewhat with the opening paragraphs of Gruber et al. (2022). My own philosophical disciplinary training would encourage putting the point here as follows: asking whether there is real passage (flow, becoming, and dynamicity) is different from asking whether time is real or fundamental, i.e., the block universe denies passage but not the reality of time. As it happens, my views are sufficiently unorthodox to make

me hesitant about putting it this way (briefly: I wouldn't want to claim that the content of "passage is (not) real" is so discipline-transcendently clear that it is obvious from the outset how these two issues are to be neatly distinguished). But I do want to suggest that B&R's starting point is helpful and that it is not advisable, in one's exposition of "the two times problem" (Gruber et al., 2022), to equate claims about time not being fundamental or not existing with claims about there being no real passage. After all, B&R's first and second reasons relate more clearly to the latter, while the third relates more clearly to the former. And despite the elusiveness of big, unifying labels like "passage," it helps to acknowledge that we're more concerned with passage and putative experiences thereof than with corresponding issues about time's (non)fundamentality.

So, what is the question? B&R describe it as "whether neuroscientists and physicists are talking about the same topic when they talk about time," to which they answer "to some extent, "no," [b]ut this may not necessarily mean there is an inconsistency." At first sight, one might wonder about this juxtaposition of thoughts. Prima facie, if the two disciplines aren't talking about the same thing, that would seem to make it *less* likely that there is an inconsistency (compare: presumably psychotherapists and musicians are not referring to the same thing when they talk about the blues. Does that make it more or less likely that their claims about the blues might conflict?) Indeed, a reader new to the topic may wonder why it is necessary to "assign portions of sovereignty to the two fields," when neuroscience studies the brain and physics the world (even if the world includes brains). But there is a perfectly good reason B&R say what they say, and I know of no other way to express it than to speak of *views of time*. If the two disciplines aren't talking about the same thing, that may indicate that the mind's view (picture, intuition) of time differs from the view of time suggested by the relevant physics. Put another way, different topics in the two disciplines may (or may not) suggest that there is some *content* to the way the brain is representing time that says something is the case which actually isn't, according to physics.

Putting it this way clarifies where B&R agree and disagree. For content like global presentism, they agree that (a) physics denies it, and probably also that (b) we represent it, if only in "intuition" (more cognitive aspects of temporal experience, perhaps a pre-theoretical view) or at least unschooled intuition. For content like static eternalism, they agree that (a) physics doesn't affirm or deny it, and (b) we don't represent it. So far, so good. Some intuitions have been proven wrong, but perhaps no deep illusion yet (affecting all aspects of temporal experience).

Now, what about content like local presentism? (a) Does physics deny it, and (b) do we represent it? Buonomano for one seems to answer "yes" to (b) ("irrepressible feeling"). As for (a), he probably answers "no," but there is also textual evidence to the contrary. While he takes local presentism to be incompatible with the block universe, he doesn't think relativity implies the block universe; also, the local element is intended to sidestep conflicts with relativity. On the other hand, the interest in whether or not "closed timelike curves [. . .] are a theoretical possibility" indicates an anticipated conflict with relativity, and presumably that conflict would go *via* some implied claim about the local past and future being as real as the present, i.e., the block universe again.

The way to clarify this further is to ask what (one thinks) the content of local presentism *is*, and whether (one thinks) it has a well-defined content at all (and corresponding questions for the other views). Both authors make comments that suggest important background commitments here, and without making those fully explicit, (a) and (b) are hard to tackle. In other words, a large part of the disagreement is in fact housed in metaontology.

Gruber, Block, and Montemayor (hereafter GBM) describe both B&R as "wanting to reify human time" so as not to posit a pervasive illusion. I take this to be a reaction to a feature of B&R's stances in Buonomano and Rovelli (2021), and especially Rovelli's (2019), which consists in a certain predilection for a very thorough kind of reconciliation, namely one that takes place at a meta-level. This predilection leads one to favor approaches to time that (somehow) transcend the dichotomy between dynamic and non-dynamic views, by (somehow) locating passage/flow/dynamicity *within* the block universe (I'm extremely sympathetic to these kinds of ("Tenseless Passage (TP)") approaches[1]; I have also come to think TP still requires a philosophical foundation).

GBM's own approach shares some commonalities with B&R's, most notably in the claim that the block universe is "not 'frozen'," and relatedly, in the wish to build on the use to which authors like (Ismael, 2016) put Hartle's notion of an IGUS. However, GBM's overall approach, and their own use of the IGUS, is closer to that of Callender (2017), which (despite some of Callender's rhetoric) is more firmly rooted in the traditional distinction between dynamic and non-dynamic views of time. GBM see a clear explanatory gap between manifest and scientific time and are attempting to fill it.

For GBM, the key to reconciliation is to combine two principles, namely that (1) as an IGUS, the human "has an experience of past/present/future that is consistent with the physical laws" and that (2) "[t]he phenomenon of dynamism is an experimentally demonstrable illusory experience." The resulting dualistic theory holds that there is a system producing veridical temporal experiences of the flow of time, but that this system also "begets a corresponding illusory system," which is "the product of natural selection" and whose "sole purpose is to enhance the human experience of time."

To interpret this, the first thing to ask is how the term "the flow of time" is being used and hence what exactly is at issue (see also the above comments on the opening paragraphs). On p. 4, GBM list the three most commonly associated ideas as "a unique (moving) present," "dynamism of change/motion" and "directionality (temporality)." On p. 6, they mention "becoming" and say that while it should be recognized, it need not be "treated as a separate component of manifest time" because change has been dealt with in depth. One question I have here is what becoming involves that a moving present and dynamism don't, so that one can be set aside while the other two are accounted for. Another is whether the point about becoming is (a) that all we experience is

1 Examples of TP views include, but are probably not limited to (here listing only one work per author) Savitt (2002), Dieks (2006), Dorato (2006), Maudlin (2007), Harrington (2009), Deng (2013), Mozersky (2015), Oaklander (2015), Fazekas (2016), Ismael (2016), Arthur (2019), Rovelli (2019), Saudek (2020), Leininger (2021).

(dynamic) change, without becoming, or (b) that all there is to the notion of becoming is contained in the notion of change, in which case an experience of change *is* an experience of becoming.

These questions have a direct bearing on how to interpret the dualistic theory. If, for instance, "becoming" denotes something similar to "dynamism" and the "moving" part of the moving present, and if these notions contain more than just the notion of change, then one would expect the dualistic theory to posit rather than deny illusory experiences of becoming alongside veridical experiences of change.

GBM do not dwell long on the distinction between perceptual and cognitive aspects of temporal experience ("the need to make a distinction between the terms cognitive and perceptual is not critical as Mroczko-Wasowicz [...] questions the close relationship between the two"). Yet, manifest time is a multi-faceted phenomenon, and the stated aim is to account for "[a]ll major dualistic components of manifest time." If nothing else, the distinction matters insofar as some pre-theoretical intuitions can be altered by schooling, while some aspects of perception cannot.

On p. 3, GBM claim that they are using the term "illusion" only because it is less cumbersome than "perceptual add-on," citing phenomena in which the brain fills in missing information and guesses correctly. However, as they acknowledge, in those cases there is no mismatch between what is represented and what is the case, i.e., the perception is veridical. Yet, in GBM's exposition of the dualistic theory, the terms "illusory" and "veridical" both play a central role, and it would be puzzling if they there meant the same thing. Moreover, GBM's suggestion that when "only cognition is involved such as a myth or belief it can be referred to as a cognitive add-on" adds to the puzzle, because a myth does suggest a mismatch between representation and reality.

While the "perceptual add-on" terminology seems intended to soften some of the original implications of the term "illusion," this is probably not helpful to a defender of the dualistic theory. The idea has to be that the first principle posits some (perceptual and/or cognitive) veridical aspects of temporal experience, and that the second principle posits some (perceptual and/or cognitive) illusory aspects of temporal experience, where these come in pairs. The illusory component of each of these pairs involves perceptual experiences as of x and/or a belief that x is the case, where x does not exist and is not the case, according to physics.

As a final illustration, consider GBM's stance on persistence. Miller and Wang (2022) helpfully point out that the block universe may well be compatible with endurantism and that perdurantism is in any case also a view of persistence. They further conjecture that GBM's view may be that there is no (unchanging core) persisting self. This seems likely, and it too strongly suggests reliance on the usual meaning of "illusory," because the idea is likely to be that while we don't persist, we seem to and/or ordinarily think we do. Thinking of the sense of a persisting self as a mere "add-on" in the sense of a filling in of information that turns out to be a correct guess would not fit with insisting that there isn't one, in reality.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 04 May 2023
DOI 10.3389/fpsyg.2023.1096280

OPEN ACCESS

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RECEIVED 11 November 2022
ACCEPTED 03 April 2023
PUBLISHED 04 May 2023

CITATION
Silberstein M (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1096280. doi: 10.3389/fpsyg.2023.1096280

Commentary: Physical time within human time

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KEYWORDS

time, consciousness, relativity, cognitive neuroscience, IGUS

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Why do we experience Presence, Passage, and Direction when none of these things is given to us in fundamental physics, i.e., in relativity? As Callender (2017, p. 27) puts it, "Peering into physical time is illuminating, but no amount of focusing will bring manifest time into view. It's not there." While special relativity (SR) is said by some to yield a block universe, when we get to general relativity (GR) and many accounts of quantum gravity (QG), things become even worse due to these three phenomenological aspects of time being absent (Silberstein et al., 2018, chps. 3, 6, 7, 8; Huggett et al., 2013, p. 250). This is especially troubling for some as these three temporal features of conscious experience are the most essential and fundamental aspects of daily conscious life and the features of experience that foundational physics is most concerned about explaining (Smolin, 2019). As Callender (2017, p. 27) says, "physics is really the only science we have that explicitly takes *time itself* as one of its targets of study".

It is important to begin by distinguishing two types of questions. There are physical/metaphysical questions, and there are phenomenological or experiential questions.

Traditionally, starting with Husserl, in a neo-Kantian transcendental spirit, the discipline of phenomenology has sought to "bracket" questions of experience from metaphysical questions. There are those who believe, however, that the metaphysical and physical features of time explain the phenomenological ones.

According to Price (2011, p. 277), the physical/metaphysical questions are as follows:

1. Is the Present moment objectively distinguished such that it is a frame-or-perspective-independent fact about which events are present as opposed to past or future?
2. Does time have an objective Direction such that for all events (e.g., two non-simultaneous events) the answer to which one is the earlier and which one is later, is a frame-or-perspective-independent fact? That is, for all events is there an objective fact about which Direction is toward the past, such as allegedly the Big Bang, and which toward the future, such as allegedly the heat death of the universe?
3. Irrespective of conscious observers, their frame of reference, or perspectives in the universe, is it an objective fact that there is a Passage or flow of time as suggested, for example, by dynamical presentism (i.e., there is an objective present, and it objectively moves/passes from past to future)?

Assuming SR and GR are true and complete and that our best theory of QG turns out to lack these three features of time as well, then the answer to each of these questions is "no." This is because the relativity of simultaneity is said by many to strongly suggest "eternalism" or the "block universe": the equal reality of the past, present, and future. Eternalism follows from special relativity precisely because there will be relativistic reference frames whose observers disagree about the temporal ordering of (spacelike separated) events into past, present, and future. That is to say, there will be disagreements as to which events are simultaneous with which. There will be frames of reference (such as planets at great distances from Earth or a spaceship moving by Earth at a large fraction of the speed of light), whose observers will disagree about how to order events in the universe into NOW-slices.

To use a film analogy, in the actual world, not everyone is watching the same movie. To spell it out, this suggests a block universe because if there are events such as a particular supernova explosion that is experienced by two different observers, but they do not agree as to when that event happened, the event must just be "there" statically, timelessly, to be experientable from both these different spatiotemporal perspectives. In principle, this will hold true for all events in spacetime. It is only from the "ant's-eye" perspective if you will that dynamical presentism seems like the best bet. From the 4D "God's-eye" perspective, as Hermann Weyl puts it, "The objective world simply *is*; it does not *happen*." This is why the alien with the God's-eye perspective in Kurt Vonnegut's novel *Slaughterhouse Five* says the following: "I am a Tralfamadorian, seeing all time as you might see a stretch of the Rocky Mountains. All time is all time. It does not change. It does not lend itself to warnings or explanations. It simply is." For a straightforward and streamlined argument for eternalism based on special relativity and the relativity of simultaneity, plus a few innocuous assumptions about the meaning of the word "real" (see Silberstein et al., 2018, chp. 2).

The implication of all this is that relativity (physics) is in no position to help explain any phenomenological features of temporal experience by offering an objective Present, objective Passage, or objective Direction; that is, we now have a mystery as to why we do not all experience the universe as the Tralfamadorians do.

As we will see, some might invoke cognitive neuroscience to dispel the mystery. But before we get there, it is important to note that there are moves one can make regarding physics and metaphysics. First, note that eternalism simply asserts the equal reality of the past, present, and future. Using the resources of Minkowski spacetime (M4), one is still free to try and cook up accounts of the Present, Passage, or Direction, however non-objective they may be. But such an account must explain the experience of these three features of time without the resources of say dynamical presentism such as modeled by Newtonian mechanics.

Second, one is free to deny that relativity is true and complete and many do. Smolin (2013, 2021) famously wants to add something like Passage, Presence, and Direction into his fundamental theory of physics. Smolin thinks that change, potentia, and the openness of the future are built into fundamental physics. Some interpretations of quantum mechanics, such as Bohmian mechanics, suggest the need for the addition of a preferred frame to relativity. Finally, many metaphysicians of time would say that the physics of time underdetermines the metaphysical nature of time—maybe there is more to the world than physics or even cognitive neuroscience.

However, neither Buonomano nor Rovelli seems to deny realism about Minkowski spacetime (M4) and neither seeks to supplement it with a preferred frame, etc. Both seem to acknowledge that given M4 alone, there is no preferred universal or global present, but at best many local presents. Simply put, they agree there is no unique way to carve 4D spacetime into individual 3D distributions of coexisting objects and events in order to create the individual frames for an objective film shared by all; that is, both seem to acknowledge that according to the relativity of simultaneity and the light postulate, there will be inertial reference frames that disagree about the ordering of events into the past, present, and future. Neither Buonomano nor Rovelli seems to want to take either of these two ways out.

Rovelli (2018, p. 209–110) and Buonomano (herein) are both on record as rejecting presentism and eternalism, but it is not clear what their physical or metaphysical alternative is. What is clear is that both want to resist saying that "time is an illusion, the world is static, and there is no change." This is indeed a frequent claim made by eternalists and blockheads. For one attempt to reconcile eternalism and the phenomenology of time, see our book *Beyond the Dynamical Universe* (Silberstein et al., 2018).

If one does not take either of these two ways out, then it would seem an explanation of temporal experience must be grounded in cognitive neuroscience as Callender (2017) and Gruber et al. (2020, 2022) attempt to do. If one is committed to physicalism, ontological reductionism, mechanistic explanation, etc., there is no other option.

On the phenomenological side, what we want to explain is the experiential arrow of time which has the following features:

- Passage: the world is in constant flux such that the future becomes the present and the present becomes the past.
- Presence: the present moment is experienced as special or ontologically privileged.
- Direction: time appears to flow from a distinguishable past to a distinguishable future.

If one does not take one of the preceding two ways out, must the explanation for the phenomenology of time be exclusively the purview of psychology and cognitive neuroscience? The answer to this question depends on to what degree you think physics constrains or contradicts the phenomenology of temporal experience. In other words, how decoupled is the phenomenology of time perception from physics? While there may be no necessary contradiction between physics and cognitive neuroscience in this regard, as we have seen, it does seem that physics lacks objective Passage, Presence, and Direction, as none of these are present in relativity theory, our best theory of time. Are there nonetheless resources in relativity theory that can help explain temporal experience?

Callender (2017, p. 31), for example, takes the following view, "I think we can explain why manifest time arises for us in a world governed by our physical laws. But doing so, if I am right,

will require embedding a subject like us in a world like ours, and not simply finding some structures in physics that plays[sic] the 'manifest time' role". Callender (2017, p. 306) is clear that he thinks physics provides some necessary conditions for explaining temporal experience but is non-sufficient. One of Callender (2017, p. 263)'s criticisms of a Smolin-type approach is that no matter what one does to modify a physical theory to give it something like Passage, Presence, and Direction, one must show that those modifications are the explainer/the cause of temporal experience. Part of Callender's point is that it seems absurd to think that we have special unknown sensory apparatus for detecting the physical esoterica of Passage and Presence.

Rovelli and Buonomano, on the other hand, seem to want to find a way of explaining temporal experience without either modifying our physical theories to include Passage, Presence, and Direction or relying *completely* on cognitive neuroscience for the answer. Rovelli (herein) suggests that the second law of thermodynamics underwrites Passage and Direction, but many of us have argued that thermodynamics and the second law in fact presuppose Passage and Direction, that is, time (Silberstein et al., 2018, p. 367–368). Regarding physics, Buonomano consoles himself as follows: "there is no empirical evidence to support a critical tenet of the block universe: that the past and future, physically speaking, are as real as the present." This however is not a very powerful argument for ignoring relativity, because we have good theoretical and formal evidence in our physical models for many things we cannot now confirm empirically. As mentioned earlier, the well-confirmed relativity of simultaneity plus a few widely held assumptions indicate a block universe. Buonomano does not appear to reject realism about M4 or any of the other assumptions in question leading to a block universe.

Buonomano also suggests that the possibility of time travel would be a necessary and sufficient condition for eternalism. He also asserts that time travel is impossible (at least via closed-time-like curves which GR does allow in principle if not in practice). The problem here is that it is now widely accepted that presentism (the metaphysical view of time that only the present is real) is also consistent with the possibility of time travel (Effingham, 2020). In short, the possibility of time travel is a red herring when it comes to the presentism-vs.-eternalism debate. Of course, there is unlikely to be any crucial experiment that settles this debate.

My conclusion is that in this particular exchange, neither Rovelli nor Buonomano engages deeply with the best physical and metaphysical arguments for eternalism, but they may do so elsewhere. I also conclude that neither of them finds an alternative to modifying relativity, etc., or falling back on cognitive neuroscience. To see such an alternative, read our book.

Physics aside, both authors seem to agree that it is at least *partly* the job of cognitive neuroscience to explain the phenomenology of Passage, Presence, and Direction. Of course, they both acknowledge that changing certain physical facts, such as the metric signature of M4, would affect our temporal experience (Callender, 2017, p. 156).

Here is where GBM (herein) enters the story with the IGUS model that might do the trick of explaining the experiential arrow of time. The IGUS model is a computational, functionalist model that could be implemented by the brain to produce the experience of Passage, Presence, and Direction (Hartle, 2005). Whether or not there is any evidence that human brains do implement IGUS, I have no idea. I will assume the reader is familiar with the IGUS model and its many improvements as suggested by Callender (2017, p. 232–235, 247–261). Hartle says we should "build this robot," and he believes that if done thoroughly enough, "even this simple robot can be said to 'experience' the present, 'remember' the past, and also 'feel' a flow of time" (Callender, 2017, p. 233).

Are Hartle and Callender claiming that such a robot with the right sensory apparatus, hardware, and software would be having such conscious experiences? In other words, are they literally claiming that such a robot is the answer to the hard problem of consciousness and the explanatory gap? I honestly cannot tell, although Callender does forego addressing the "mind/body problem" (p. 29) and suggests elsewhere that IGUS is a "toy model", a proof of concept. If, however, they mean this literally, let me be the first to place a bet that such a robot would be experiencing nothing whatsoever. Build it and let us find out. Perhaps the more charitable interpretation is that once we figure out how brains or computational devices could be having any experiences at all, IGUS might explain why they are having these particular temporal experiences.

The claim here is that the explanation for the experience of Presence, Passage, and Direction (PPD) must lie with cognitive neuroscience, thus making PPD secondary properties, like color. There are several philosophers, physicists, and cognitive scientists who argue that the brain must somehow *generate* the experience of PPD. Here is an analogy. The brain is somehow like an old-school movie projector that takes a static series of still frames (the block universe) and creates the "illusion" of PPD. However, instead of a film projector, we have IGUS. But one needs only contemplate this idea for a second or two to see the problem. Barring radical emergence, if physics is "frozen" in the block universe, then so are brains. The brain (i.e., the static 4D worldline of a brain in spacetime) cannot be the analog of the film projector, because it states no more movement or flow than anything else in spacetime. The "activities" of the brain are just more events "frozen" in the still frames; therefore, the brain is not like the film projector that brings PPD to the game "from the outside". Falling back on the "dynamical activity" of the brain poses the question of how a brain in a block universe could *generate*, *produce*, or *cause* **any** conscious experience, especially those involving PPD.

IGUS might get a pass on the hard problem (though of course, temporal experience is just a central subset of that problem), but it still must explain *the contents* of phenomenal consciousness, for example, as it pertains to temporal experience. Here, the same issue looms again. A brain "running" the IGUS program in a world with no objective Passage, Presence, and Direction, in a world with nothing but Humean regularities relating to 4D snapshots, is just a succession, a continuum of snapshots with a certain causal or temporal ordering. Such brain states "implementing" IGUS are *merely correlated* with a conscious precept on each slice or slices of that brain's worldtube. Those brains cannot *produce* or *structure* phenomenal consciousness more or less actively than physics can in such a world. It is IGUS *conceived as a dynamical computational process* that is supposed to explain what the physics in such a world cannot, but it has no more resources to do this causally or dynamically than the physics itself.

Take again the analogy of a film reel and projector—a very simple IGUS. Buonomano expresses this view perfectly with his claim that "the brain is a time machine" that produces the subjective experience of Passage and Presence (Buonomano, 2017). It is the movement of the film strip through the projection that yields the temporal experience. But, in the block universe, what plays the role of the projector? From a "God's-eye" perspective, nothing is moving; there is nothing to play the role of the projector. Brain states are no better off in this regard than any other physical process. As Dainton (2001, p. 389) states, "it is a mistake to conclude…that a continuous stream of consciousness can be formed merely by placing momentary experiences with static contents side-by-side, as it were...there is all the difference in the world between watching a movie and looking at a collection of still images". In such a world, it is very hard to see how brains could be "time machines" or "producers" of conscious content in any sense.

My conclusion is that neither physics nor cognitive neuroscience has time for the other. To see another way to fix this problem of time, take the time to read our book. We argue that time is neither a projection of the brain, nor is it built into fundamental physics. Time is a relational property of embodied agents, not a secondary property projected by brains. Indeed, our claim is that the primary/secondary distinction is a bad one. At least for basic Passage, Presence, and Direction, we seek to erase the dualism between the mind's time and the world's time. Thus, we defend a Jamesian brand of neutral monism which holds that the mental and the physical are neutral and non-dual–there is just one thing. In this view, physics begins and ends with experience. "Physics" is best conceived as constraints on what embodied experiences are possible, for example, the light postulates and relativity principle of special relativity. Thus, the "ant's-eye" view with Passage, Presence, and Direction, is just as real and fundamental as the "God's-eye" perspective of eternalism.

From the perspective of neutral monism, the claim that the world is carved at the joints in terms of physical/mental, inner/outer, subject/object, etc., is not a datum, but rather an inductive projection. As James (1905a,b, p. 1208) puts it, "Subjectivity and objectivity are affairs not of what an experience is aboriginally made of, but of its classification". Allegedly "inner" experience is not inherently or essentially mental, and the so-called "external" world isn't inherently non-mental or physical. "Pure experience" (as James calls it), in itself, "is no more inner than outer.… It becomes inner by belonging to an inner, it becomes outer by belonging to an outer, world" (p. 217). As James scholars have often noted, his "views were not well received or accurately interpreted" in his own time (p. xi). Some have even portrayed James' view as a kind of eliminativism or behaviorism because he says things of this nature, "Consciousness, as it is ordinarily understood, does not exist" (p. 109). James isn't denying the existence of conscious experience as such, but only a particular conception of consciousness, namely he is rejecting the idea of consciousness as qualia (inner tropes of experience that could exist without a subject as something over and above subjectivity). People often fail to appreciate this point because they leave out the second half of the preceding quote, "any more than does matter" (p. 109). Taking the quote in full, we see that James is really rejecting the primary/secondary property distinction and the idea that matter is a substance with essentially, intrinsic physical properties. Unlike panpsychism, James is not replacing intrinsic physical properties with essentially qualitative ones such as qualia or subjectivity.

As Thompson (2015, p. 61) notes in what follows, the view James espouses under the name neutral monism or radical empiricism has much more ancient roots in Buddhism and perhaps Hinduism:

> Take a moment of visual awareness such as seeing the blue sky on a crisp fall day. The ego consciousness makes the visual awareness feel as if it's "my" awareness and makes the blue sky seem[sic] the[sic] separate and independent object of "my" awareness. In this way, the ego consciousness projects a subject–object structure onto awareness. According to the Yogacara philosophers, however, the blue sky is not a separate and independent object that is cognized by a separate and independent subject. Rather, there is one "impression" or "manifestation" that has two sides or aspects—the outer-seeming aspect of the blue sky and the inner-seeming aspect of the visual awareness. What the ego consciousness does is to reify these two interdependent aspects into a separate subject and a separate object, but this is a cognitive distortion that falsifies the authentic character of the impression or manifestation as a phenomenal event.

Per neutral monism, there is no PPD without a subject/object cut (subjectivity), which requires some sort of embodiment. As Taylor (1996, p. xii) put it, "James' metaphysics of pure experience is aimed directly at the dualisms of mind and body and knower and known (subject and object, thought and thing, representation and represented, and consciousness and content)". There is no subject without an object and vice versa. It is this cognitive "cut" that leads to the experience of an ontologically distinct agent in a world in space and time.

Callender (2017, p. 262) notes that the IGUS temporal structure is contingent, and we can imagine radically different temporal structures consistent with the laws of physics and M4. In very interesting work, Gruber et al. (2020; 2022, using virtual reality (VR), instantiates some of these alternatives. However, that one can induce such changes to temporal experience should surprise no one and certainly does not confirm the IGUS account per se, or the idea that PPD is a projection of the brain. The alternative temporal worlds are imposed by VR on subjects who are already experiencing PPD. Thus, such experiments do not resolve the concerns I raised about accounting for Passage, Presence, and Direction in a block universe with just IGUS. Through experimental and pharmacological means (such as visual or bodily illusions and psychedelics), one can induce radically different alternative experiences in people regarding all sorts of perceptions, etc., but it does not follow that every experience is merely a secondary property projected by the brain. All experience is contingent in the sense that it can be radically altered without altering the physics of time as such. This does not mean that say the metric in M4 is not partly responsible for our everyday experience of time.

I think these experiments make the point that the phenomenology of time is relational. From the perspective of

neutral monism, what such alternative VR worlds do is de facto "change the physics." For example, a VR world or full-blown simulation with closed-time-like curves is the equivalent of living in an "actual" world with closed-time-like curves. We could be living in a simulation now. Exactly what temporal experiences are possible or not given certain constraints is of course an open and interesting question.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Acknowledgments

I would like to thank Ronald Gruber for helpful comments.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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TYPE General Commentary
PUBLISHED 25 May 2023
DOI 10.3389/fpsyg.2023.1097454

OPEN ACCESS

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RECEIVED 13 November 2022
ACCEPTED 02 May 2023
PUBLISHED 25 May 2023

CITATION
Arstila V (2023) Disjoint components of manifest time: Commentary: Physical time within human time. *Front. Psychol.* 14:1097454. doi: 10.3389/fpsyg.2023.1097454

Disjoint components of manifest time: Commentary: Physical time within human time

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KEYWORDS

time, manifest time, time perception, temporal experience, time consciousness

A Commentary on
Physical time within human time

Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13. doi: 10.3389/fpsyg.2022.718505

Introduction

Our everyday life—encounters with "moderate-sized specimens of dry goods" (Austin, 1962, p. 8)—gives rise to manifest time, the total of temporal phenomena as they appear to us and are rationalized by us. It depicts time as flowing, the present moment as unique, and that world includes various dynamic events. Physics, and especially spacetime cosmologies, on the other hand, suggest that time is static, does not flow, and that the present moment is not unique. How to reconcile these two conceptions of time gives rise to the "two times problem".

One response is to maintain that there is no real problem because the two conceptions concern distinct domains. This response is echoed by Buonomano and Rovelli (2023). They argue that physical time and time in neurosciences emerge from different scientific domains, which concern different and quite clearly partitioned research lands. Another option, though still compatible with the first response, is to take (Smart, 1980, p. 10) challenge seriously and try to "give some sort of explanation of how (the illusion of the flow of time) arises."

Gruber et al. (2022) adopt the latter approach and ground their explanation on Hartle's Information Gathering and Utilization System (IGUS). An IGUS captures images of its surroundings and is "conscious" of only the last image. The previous images figure in conscious states as part of the schema of the environment in which the latest image is situated. These differences explain how notions of past, present, and future emerge from the way in which IGUS processes information. Nonetheless, this provides only a partial answer to Smart's challenge since it is not evident that it accounts for the dynamicity of the purported flow of time in manifest time, and it is silent about other phenomena related to manifest time.

The authors address this shortcoming by making two general claims. First, a human model IGUS is augmented with add-ons ("gadgets") that deal with the remaining phenomena. The proposal includes many gadgets, presumably one for each separate phenomenon. Second, they put forward the *dualistic model* of manifest time. The duality here refers to the claim that all components of manifest time have illusory and veridical aspects. For example, there are veridical experiences of (neural) temporal order and corresponding illusory experiences of causational temporal order. The former refers to the order in which experiences succeed each other, and the latter refers to illusions that our actions succeed our decisions (i.e., that we have free will and "are in charge"). It is worth noting that the expressions "veridical experience" and "illusory experience" are somewhat

misleading. On the one hand, the outputs of gadgets include both perceptual and cognitive components. Thus, "experiences" refer to phenomenal states but also what the authors call "cognitions", states such as duration judgments. On the other hand, veridical experiences concur with accepted physics; illusory experiences do not. According to Gruber et al.'s (2022) definition, thus, illusory experiences are not illusions merely because they provide false information but because they cannot provide the correct information in the first place. They cannot do so, for the false information they provide contradicts the laws of physics. This is an uncommon definition because, in usual illusions, we perceive things that we can also perceive correctly in other circumstances (e.g., colors, shapes, lengths of lines).

No internal clock nor specious present

The dualistic model is, in my view, empirically plausible but also more controversial, and needs more justification and conceptual clarification than may first appear. Consider being an official in a running competition. You start the clock at the beginning of the race and take each contestant's time. Based on the timing, you know how long each contestant ran (duration) and their placement (temporal order). There is also a sense in which one could say that time was passing, one tick at a time, during the race (flow of time). In this example, various temporal phenomena are somehow related to the operation of a single clock. The idea of humans exhibiting a similar internal clock mechanism has been popular in time perception literature (Hoagland, 1935; Treisman, 1963; Gibbon, 1977; Wearden, 1991).

An IGUS augmented with gadgets operates very differently from an internal clock that grounds all temporal experiences since there are several gadgets, each (possibly) separate from the other. Nevertheless, for a human model IGUS, this characteristic receives support from more recent empirical literature. Indeed, as already argued by Pöppel (1988), different aspects of subjective time are due to separate mechanisms. Moreover, nowadays the idea of an internal clock even as regards duration perception is contested, and there is increasing evidence that duration judgments and the passage of time judgments are dissociated (Wearden, 2015; Droit-Volet and Wearden, 2016; Jording et al., 2022). Finally, visual change and motion perception, for example, rest on distinct mechanisms (for discussion on this point, see Arstila, 2018). Overall, concurring with the proposal at hand and with Buonomano and Rovelli (2023) as well, we can say that there are good reasons to hold the disunity of subjective time (Lloyd and Arstila, 2014).

However, the augmented IGUS within the dualistic model of manifest time results in a controversial account of temporal experiences (e.g., change, motion, succession). By far the most popular way of explaining temporal experiences rests on the notion of the specious present. In these explanations, our experiences appear as having temporally extended and structured contents. We experience change, motion, and succession directly because those temporal features manifest in the contents of the specious present. For example, we experience succession because a specious present presents us with two sensory experiences (say, sounds) that have occurred at different times. Similar to the idea of an internal clock, temporal phenomenology is subordinate to the postulated specious present, a fundamental temporal structure of consciousness. If the specious present did not exist, we would not have temporal experiences (or so the claim goes).

Gruber et al.'s (2022) proposal challenges this received view in two ways. First, as mentioned above, an IGUS is "conscious" of only the last image it captures. Consequently, the contents of the conscious states of an IGUS do not exhibit any explicit apparent duration or temporal structure. Such a view of the temporal structure of an IGUS's conscious states is a version of snapshot models of time consciousness theories, not the vastly more popular specious present theories. More precisely, since the authors maintain that we experience the dynamicity of change and motion, their overall position comes close to the dynamic snapshot models (which they acknowledge to some extent). Roughly, these models hold that streams of consciousness consist of succeeding short-lived snapshots—like frames on a film—that appear to a subject as having no apparent duration or temporal structure and—unlike frames on a film—still include dynamic phenomenology related to change and motion, for instance (Le Poidevin, 2007; Arstila, 2016, 2018; Prosser, 2016).

Second, the received view maintains that temporal experiences depend on specious presents, a single temporal structure of conscious states (or process underlying such structure). Gruber et al. (2022) however, explain temporal experiences with gadgets, and as different temporal experiences result from mostly different gadgets, they also reject the claim that temporal experiences depend on any single mechanism or process. This position is even more unusual than the dynamic snapshot model, for only Arstila (2016, 2018) has explicitly argued for it; Le Poidevin (2007) and Prosser (2016) versions of the dynamic snapshot model still appeal to short-term memory (e.g., a common mechanism) in their explanation of some temporal experiences. Then again, if some temporal experiences are due to a common mechanism, then the proposal would be closer to that of Le Poidevin and Prosser than Arstila's.

Reservations about the dualistic model

As one might expect, I find Gruber et al.'s (2022) overall proposal creditable and more promising than its alternatives. That said, I have reservations about the details of their dualistic model of manifest time. Let me end by providing just two examples where I think further explication and justification would be valuable.

First, there are reasons to doubt the reality of all purported components of manifest time. For example, in their theory, a discrete snapshot (of perception) is a case of veridical experience and the specious present is an illusory experience. While contrasting these two positions is common, snapshots and specious presents are typically contrasted as the purported fundamental temporal structure of consciousness. They are not experiences per se but concern the temporal structure of experiential states. It does not help to regard them as cognitions either, for it is not obvious whether we need a gadget for every correct or incorrect belief. Given that an IGUS is conscious of one image (arguably, a snapshot) at a time, it already operates based on snapshot perception. Accordingly, the need for a separate gadget for snapshots (and subsequently for specious presents) is currently

unmotivated. Recent studies illustrate that one can raise the same point concerning the claim that we have illusory experiences of a unique moving present (e.g., Latham et al., 2019; Miller, 2019).

Second, one can doubt whether all components have veridical and illusory aspects. Consider, for instance, retrospective and prospective duration judgments, which are cases of veridical experiences for Gruber et al. (2022) and the corresponding illusory experiences of the speed of duration judgments. The first thing to note here is that, as mentioned above, there is evidence that duration judgments and the passage of time judgments need to be separated. Given that the two vary independently and rest on different mechanisms, what justifies pairing them in the way Gruber et al. (2022) do? But, if they are not veridical and illusory aspects of the same component, then the dualistic model of manifest time necessitates that they themselves must have veridical and/or illusory counterparts. Presumably, this requirement can be easily satisfied as to duration judgments: they could still amount to veridical experiences (cognitions) and their corresponding illusory counterpart would consist of experiences of duration. Not only are we said to experience durations (e.g., Dainton, 2000; Phillips, 2012), but the dynamicity of these experiences—there is a sense in which the tracked duration is felt as growing—suggest that they are illusory rather than veridical. In this proposal, we can understand why the two types of "experiences" are grouped together, as they are indeed closely related. Moreover, the illusory dynamicity of the experience of duration needs to be addressed in any case. The situation is different, however, with the speed of the passage of time, for both judgments and experiences of it are illusory—neither of them has a "basis in reality". Thus, to save the dualistic model of manifest time, the authors need to give an account of the corresponding veridical experience, or admit that not all components have veridical and illusory aspects.

To sum up, Gruber et al. (2022) present a version of a human model IGUS that is augmented with several gadgets along the lines of the dualistic model of manifest time. The proposal concurs with well-established positions in time perception research and findings related to neural mechanisms underlying change and motion perception. However, due to the dualistic model, their explanation is almost the opposite of the dominant time consciousness theories. Hence, the proposal will need more justification in addition to the current exposition, since the position is met with skepticism, as demonstrated by the criticism of the dynamic snapshot models. These objections can be lessened by abandoning the requirement that all components of manifest time have veridical and illusory aspects. While this would be a deviation from the dualistic model, it could also help them concerning the unclearness of their detailed theory of manifest time.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Funding

The research relates to the Mind and Matter profiling action awarded to the University of Helsinki by the Academy of Finland. VA's Temporality in Predictive Processing project receives separate funding from the Academy of Finland (Grant Number: 342166).

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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TYPE General Commentary
PUBLISHED 26 May 2023
DOI 10.3389/fpsyg.2023.1110386

OPEN ACCESS

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RECEIVED 28 November 2022
ACCEPTED 28 April 2023
PUBLISHED 26 May 2023

CITATION
Dorato M (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1110386. doi: 10.3389/fpsyg.2023.1110386

Commentary: Physical time within human time

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KEYWORDS

time reversal invariance, brain limitations, IGUS model, anticipation, temporal perspectives

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

I will start my comments to the two target papers [Gruber et al., 2022 (GBM) and Buonomano and Rovelli, 2022 (BR)] with two uncontroversial premises, stressed in particular by BR:

1. "The function of our brains is to *anticipate the future*" (Buonomano, 2017, 232).
2. We anticipate the future in the present by using *relevant inductive information* stored in our memory.

I take it that 1 and 2 are sufficient to conclude that:

C. Across time we experience three different temporal perspectives about the *same* physical events: *anticipation, perception, and memory*. Notice that these events need *not* be temporally close to our present experience: I can anticipate my giving a talk next month and then remember it for a long time.

If this argument is correct, a few crucial questions arise:

3.1. How can the *same* event be first anticipated in the non-immediate future, perceived, and then remembered in the past?

3.2. What is the ontological status of the anticipated events? Do they exist tenselessly in a block (a) *or* do they come into being when they occur (b)?

3.3. Is there a genuine difference between the alternatives (a) and (b)?

By referring to the two target papers, I will focus on the first two questions[1] by briefly sketching three possible avenues of research: *physical, ontological*, and *neurocognitive*.

One *physically* necessary condition for C is that events "keep on happening" one after the other along worldlines. IGUSs rely on this presupposition too: our brains register the objective temporal succession of physical events, where the objectivity is given by the invariance of proper time. GBM agree: "the experience of happening is part of our experience of the flow of time" (p. 6). In BR, Rovelli insists that spacetime is replete with processes and therefore is "dynamic".

1 The literature on 3 is immense. For a negative answer, see Dieks (2006).

The *ontological* way to "explain" or describe this succession of physical events is to postulate a "locally growing block (Ellis, 2014), where *local* is added to prevent objections raised by relativity"[2] . I claim that evidence for this model are ***facts*** that do not involve our momentary experience of time that IGUSs[3] are meant to simulate but my *knowing* that, as I write at T, each *passing* day I am 1 day "closer" to the moment of my death D. Relatively to T, every minute the number of heartbeats separating T from D for me decreases in average by sixty: time for me passes in average one heartbeat per second!

The problem with the locally growing block is, as GBM correctly note, that it seems to be unable to shed light on the two-times problem from an *empirical* viewpoint. Yet, it is difficult to account for the facts above just by postulating a tenseless, "static" relation between T and D. I grant that this explanation can be given and that physics, obviously, does not require a privileged now. However, despite the following spatial metaphors, the claim that, relative to T, the *temporal distance* between T and D decreases seems much more plausible: this fact calls for a locally growing block regarded as a *primitive, fundamental ontological asymmetry* or as a "irreducible intrinsic asymmetry in the temporal structure of the universe" (Maudlin, 2007, p. 109).

A first difficulty is that, contrary to C, IGUSs work only for events that are closer to our present experience by including our short-term *memory*: as such, they do not seem capable to simulate the essentially predictive capacity of our brain (see 1 above). If anything, IGUSs can only refer to *short-term* anticipations (Dorato and Wittmann, 2020). Neither can "premonitions about the future" (p. 3) solve this problem.

More in general, the IGUSs presented by GBM seem too simple to account for the complexity of our experience of time. Evidence for this claim is that whenever some discrepancies between the IGUSs and our experience arise, the former must be supplemented with *additional* "gadgets" (GBM, p. 3). On the one hand, the simulation must be faithful. On the other, IGUSs cannot be too complex since this would imply providing them with too many contraptions[4]. Faithfulness and simplicity pull in opposite directions. In addition, the mere *possibility* to fabricate various IGUSs by using VR headsets to show that our experience of flow might be illusory does not imply that our *actual experience* is not veridical. If "the experiential flow component of the FOT is attributed to the utilizing system of the robot and not to the time of physics" (p. 2), the illusions that it generates are themselves "real" even if subjective, because the robot itself is *physical*. Furthermore, a thorny conceptual difficulty is generated by the widespread use in physics of the vague *epistemic* term "information" (which enters the definition of IGUSs): given that the notion contains a *semantic* feature that seems irreducible, what is information in physical terms? "To be informed that…" has a propositional content (a "that clause") and propositions are *abstract*, non-physical entities.

GBM hold that FOT presupposes "dynamism of change/motion" (p. 4). The problem raised by this quotation depends on the meaning of 'dynamism and change'. Correctly denying any motion of the now does not rule out some minimal form of tenseless becoming: the caption of Figure 1 tells us that "the robot experiences a stack of cards labeled a, b, c, d, e, f, whose top member *changes from time to time*" (GBM, p. 2). However, this sequence can more plausibly be interpreted as a worldline-dependent *coming into being* of events at instants of proper time, as suggested by the above argument concerning the decreasing distance between T and D. The anticipation of an event in the distant future and its later experience in the present presupposes some stronger kind of dynamism consisting in the addition of previously *non-existing* events in an *unrestricted sense of existence*[5] that cannot be explained away by the momentary experience of flow allegedly allowed by the IGUSs.

Within neurophysiology, if 1 above presupposes a capacity for *mental time travel* (a projection in different moments of time) it also requires an *enduring* self. Mental time travel has been the subject of intense experimental study (Suddendorf et al., 2009). For instance, the use of spatial metaphors in our talking about time may depend on the fact that "Time Travel and Mental Space Navigation could be consistently explained by similar cognitive mapping principles, namely: egocentric mapping and coordinate system conversion" (Gauthier and van Wassenhove, 2016, p. 66). Egocentric mappings are representations of time (and space) from our temporal perspective (like the "here" in a map). Coordinate transformations are self-projections maintaining "egocentricity of the map when adopting a viewpoint differing from the 'here and now"' (Gauthier and van Wassenhove, 2016). It seems to follow that the possibility of keeping the egocentric character of the map entails an enduring self.

It has also been stressed that within a *subjective*, *agential* perspective, the self must be regarded as an *enduring entity* (Paul, 2017)[6]. The *agential* viewpoint implied in our temporal projections is directly called into play by 1: the capacity to predict a future event has been selected by evolution and serves the subject's need to *act* in view of an anticipated event.

I agree with BR that time is a multilayered concept. The list from i) to ix) (p. 5) is an inventory of key temporal notions apportioned between physical and neuropsychological time: in this respect, I argued that the main bridge between them is an *ontology of events* (Dorato, 2015). Since this plurality of senses holds even among the various branches of physics (Rovelli, 2004, p. 58–62), progress in the two times problem depends on disentangling the various elements in the list.

First, a radical pluralism about time and a "dappled view of science" in general (Duprè J., 1993; Cartwright, 1999) would dissolve our problem: within this framework we shouldn't even try to *reduce* or *unify* notions of time belonging to very different "levels of reality". If physical time and experiential time have a limited, domain-relative range of validity, they cannot conflict. However, the two-times problem ought to be regarded as an attempt to bridge an *explanatory* gap and I take it that BR implicitly assumes that explanation need *not entail* reduction.

2 How local is "local" depends on the phenomena we want to describe.

3 Information Gathering and Utilizing Systems (Hartle, 2005).

4 Gruber (2008) is aware of this problem.

5 See Mozersky (2011) for a clarification of this notion of existence.

6 For Paul (2017, p. 262), however, the enduring and the perduring view of the self are compatible.

Second, reliance on the oft-invoked but unclear notion "*open future*" requires attention. BR identify "open" with "indeterministic": "Neuroscience builds on the existence of macroscopic traces and on the openness of macroscopic future produced by the thermodynamic arrow of time. The second, in particular, underpins the possibility of our experience of being 'free to choose', since different macroscopic futures are compatible with the same macroscopic past, choice depends on what happens in the organism" (BR). Also for compatibilists choice "depends on the organism." The existence of different possible futures all compatible with the same past requires *indeterminism* but the thermodynamical arrow of time depends on the initial state of the system. The fact that statistical mechanics is both *deterministic* and *time-symmetric* implies that the indeterminism in question is epistemic like the probabilities involved in the theory. In addition, the incompatibility between freedom and determinism is very controversial[7].

Also the expression "four-dimensional block" must be handled with care. Analytical philosophers usually argue that the block, regarded as the sum total of events and changes in four dimensions, is static, since changes and events happen *in* the block. Rovelli correctly reminds us that general relativity implies a different account of the "block" because its main novelty is that *spacetime itself* (i.e., the block) *is dynamical:* "The 4-dimensional universe is not an entity, it is a process.… a complex network of changes, not a static 4-dimensional block". I am sure that Rovelli agrees that in some sense the (observable) universe *is an entity* and that, unlike any other process, it does not occur *in* time, but has time as one of its dimensions.

Finally, Buonomano stresses the fact that the function of our brain, shaped by evolution (see 1 above) creates unavoidable limitations to the task of interpreting those physical theories referring to layers of reality that are very remote from our experience. He claims correctly that physics does not *force* us to adopt any particular temporal ontology and that, possibly as a consequence of the fact that our brain mainly relies on visualization, we cannot picture quantum jumps caused by photons hitting electrons in the nucleus. Yet, these limitations do not imply that realism about the ontological claims of physical theories is unjustified. The undeniable cognitive "inadequacies" of our brain are not a safe guide to ontology: both the discovery of inertia and of the relativity of simultaneity clearly show that the naïve physics implanted in our brain by evolution can be conquered.

7 Thanks to Carlo Rovelli for comments on this passage. See https://arxiv.org/abs/2007.05300.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Funding

This work was supported by the Italian Ministry of Education, University and Research through the PRIN 2017 program the Manifest Image and the Scientific Image prot. 2017ZNWW7F_004.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 02 June 2023
DOI 10.3389/fpsyg.2023.1101261

OPEN ACCESS

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RECEIVED 17 November 2022
ACCEPTED 28 April 2023
PUBLISHED 02 June 2023

CITATION
Elliott MA (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1101261. doi: 10.3389/fpsyg.2023.1101261

Commentary: Physical time within human time

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KEYWORDS

flow (dynamic), IGUS model, Aristotle, relativity, reference systems - methods, psychological time

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

The ideas of dimensional time, i.e., time as experienced flow, and of a zero to n-dimensional space–time are by no means new. Both ideas first appear in proto-European thought in the fragmented writings of Heraclitus in or around the fifth century BCE. The proximity of these ideas to concurrent Jewish ideas of time (related ultimately, according to some, to Mosaic teachings) suggests that the Greek and subsequently influential Latin ideas of time (particularly those expressed in Marcus Aurelias' *Meditations*) emerged from the prehistoric Egyptian mystery tradition. Ancient Egypt is known to have initiated several presocratic Greek philosophers before their return to the Hellenic world (Waterfield, 2000).

In the ancient concept of time, "experienced time" was held to exist as a past, present, and future within which changes or movements occur and time is experienced as a non-stationary present moment. This idea of time concerns the physical or, to us, the "knowable" world. In addition to the knowable, there was an infinite space–time with no beginning or end, of which only a fraction becomes experientially manifested as experienced time. Hinging upon the interpretation of Aristotle who argued in *Metaphysica* that an infinite future time could only exist in principle and, therefore, not substantially (Smith and Ross, 1908), infinite space–time was preserved in Western thought as the literal metaphysics, which was expressed in Plato's *Timaeus*. However, while expressible, we cannot, nevertheless, "know" or be able to measure this all-encompassing instance of time. Infinite time is consequently dimensionless but superordinate to time as flow, which relates more directly to the experience of the physical world and is inherently psychological. In addition, in early Jewish and the Neoplatonic and Gnostic schools of thought, although infinite time is unknowable to us, it might be "knowable" in different ways by sentient entities outside of our existential frame of reference (ultimately by God). Although not directly relevant to the topic as presented here, the importance of this idea lies in the acknowledgment that there is something other than the anthropocentric, existential "I" that has "knowledge" of time.

Our present discussion of psychological time occurs in the common scientific framework defined by physics. The entry of time into the calculus of physics could only occur post-enlightenment. Nevertheless, the idea of science is ancient and the groundwork for the entry of time into physics was laid originally by Aristotle. In *Physica*, Aristotle explicitly identified the idea of time with movement, and in turn with the flow of event structure. Important for the present discussion is the influential interpretation of this provided by Thomas Aquinas. St. Thomas clearly interpreted the Aristotelian idea of time flow as existing *only* in the experience of the soul (Hardie and Gaye, 1930; Snyder, 2000. Also note that Neoplatonist,

Plotinus in Enneads stated explicitly some 1,400 years earlier that "There is for this universe no other place than the soul or mind" and "We should not accept time outside the soul or mind", see Schopenhauer, 2000). Thus, by the late middle Ages, the eternal quality of time, while still present in cosmological theory, had become secondary to an understanding of physical time in terms of the anthropocentric and mental experience of time flow. Given his role in reconciling Christian dogma with Aristotelian logic, the influence of St. Thomas cannot be underestimated, and by virtue of his interpretation, the case is re-presented to consider time as primarily a psychological phenomenon.

For the sake of brevity, I skip past several thinkers on time from the middle Ages to the present day. In the broader context, there are thinkers on persistence through time and it is not possible to deal exhaustively with this topic in this contribution. The reader is referred to Haslanger (2003) for a review. In addition, and more specifically, there are a set of ideas considered relevant (i.e., Locke, Newton, Leibnitz, Kant, reviewed by Benjamin, 1966). These tend to concur with the idea preserved by St. Thomas that time is experienced as flow and flow concerns the mental experience of movement or change. Unfortunately, this provides us with the problem of treating time as the subject of scientific inquiry.

The problem is 2-fold: first modern theoretical physics defines experienced time as illusory because it is essentially dimensionless. This is because 4-dimensional space–time specifies that all events possess the same ontological status and are inseparable in the past, present, or future (see Poincaré, 1900; Einstein, 1905). In addition, this effective absence of dimensionality for experienced time is physical and not metaphysical. Consequently, experienced time cannot be an operational variable in the calculus of physics, and it can have no basis for consideration outside of physics either. Nevertheless, we still experience time as a non-stationary "moment now" bridging the future with the past. The problem for physics is partly retrieved by assuming that observations across a very small spatial scale will provide a measure of the experience of time flow as we know it. This is a reasonable compromise accepted by almost everyone. However, it is a compromise and the problem remains that the assumption of infinite space–time remains the province of theoretical physics, which, paradoxically, seems to prohibit an overarching and strictly scientific definition of experienced time.

Second, the problem refers to Feynman's complaint that analysis of experienced time depends on "murky notions of mentalism" (Gleick, 2011, on Feynman, 1963). Experienced time generally entails that time is experienced in the mind, and murky mentalism is another way of saying that mind–matter dualism is inadequate for scientific purposes. If we assume this to be a problem, it is (a) not resolved by empirical observation, because the observer's report of their experience is based on the mental experience and so is non-defeasible; (b) additionally, it is not resolved by correlational methods such as brain imaging, for which, brain data require a variable with *a priori* validity to correlate with; and (c) while models such as the information gathering and utilizing system (IGUS) model (Gruber et al., 2022) rely on empirical and defeasible behavioral or event data, they still rely on the reported experience of event structure to make sense in terms of experienced time flow.

However, a great deal of psychological science relies on murky mentalism, so much so that major psychological theories such as Gestalt theory premise on the validity of the phenomenal. It could be argued that the inherently non-physical defines a major remit of psychological science, which by Aristotle's definition can still be referred to as science. In the present context, approximately 2,500 years of thought on the phenomenology of time broadly concur with the idea that experienced time, including the non-stationary "now", is valid, existent, and not illusory. This tends to suggest that the most sensible solution to the problem of the scientific definition of time is to declare the criteria set by physics to be an overreach and not appropriate for the task of explaining the experience of time.

However, this theory does not help since it does not bridge the mind–matter division. Thus, here is an alternative proposition, similar in formal structure to the IGUS model: This proposition refers to the idea that time might be experienced, and indeed the way time is processed can be measured in entities other than the existential "I". Rather than appealing to God, I set my sights rather humbly on Elliott (2014), who showed that during the implicit coding of a repeating temporal sequence, a sequence presented so rapidly that its event structure was experienced but non-reportable, and not only was the timing of the sequence faithfully coded, but the coding mechanisms advanced in time their response to events in the sequence relative to those events. In this instance and without explicit report, or conscious experience of event structure, cognitive systems advanced their response in such a manner that event-related cognition occurred slightly ahead in time of the event to which it responded. It cannot be claimed that the observer has conscious access, that they can report anything as experienced by the "I", or that their first-person experience of derivative events occurs in future time. However, this evidence nevertheless shows that experience *in the receiver* can operate in future time, and to make this claim, one must adopt the position that in order to do so, it is the system as an "entity" that experiences events in future time, and consequently, event structure is separated into past, present, and future [For a related discussion based on the role of neural oscillation in perception, the reader referred to communication through coherence (CTC) theory by Fries, 2015].

Conclusion

In conclusion, science need not throw out the baby with the proverbial bathwater. Instead, the variables used to define temporal experience need to be examined carefully and broadened appropriately and not put into a conceptual frame of reference to which they do not fit. Of course, this is a problem for the strictest definition of science, but not necessarily for psychology. Psychological science might accept that it occupies a position that is a challenge to this strictly reductionist scientific agenda, and it might be content to define its own validity regardless. In this enterprise, there has been consistent

support on what defines the experienced time for a very long time.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 05 June 2023
DOI 10.3389/fpsyg.2023.1094736

OPEN ACCESS

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RECEIVED 10 November 2022
ACCEPTED 03 May 2023
PUBLISHED 05 June 2023

CITATION
Paganini E (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1094736. doi: 10.3389/fpsyg.2023.1094736

Commentary: Physical time within human time

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KEYWORDS

time experience, illusion, hallucination, block-universe, local past/present/future

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13, 718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). *arXiv.* doi: 10.48550/arXiv.2110.01976

1. Introduction

The aim of this contribution is to compare the interesting and challenging theoretical proposals of Gruber et al. (2022) on the one side, and of Buonomano and Rovelli (2021) on the other. A problem they both address is whether our experience of time (characterized by the recognition of the flow of time and the impermanence of the present) is a veridical or illusory representation of the physical reality of the Universe. My claim is that the two theoretic proposals are adopting different notions of illusions and that a better understanding of each of the two notions would be useful to further develop the proposals.

The theoretical positions proposed in the two essays are divergent: Gruber et al. (2022) claim that physical theories stipulate a universe without past, present and future (i.e., a Block Universe), and that our temporal experience (which instead discriminates between past, present and future) is illusory; Buonomano and Rovelli (2021) argue for a more complex and multilayered view of time: on the one side they acknowledge that past, present and future do not feature fundamental physics, not being "universal," but they are open to their being "locally" instantiated and our perception not necessarily being illusory about local reality. I am not going to compare the reasons in support of the two cosmological theories; I am adopting a philosophical perspective instead, my aim is to discuss the two philosophical notions of illusion that underlie the two different theoretical approaches, with a view to showing that each notion of illusion proposes interesting and pressing challenges to the respective theoretical proposal.

2. Illusion as cognitive or perceptual add-on

Our commonsense notion of illusion is connected to cases in which our perceptions are deceived by certain aspects of reality. For instance, when viewing a *tromp l'oeil*, we perceive a three-dimensional reality, even though the image is actually two-dimensional, or, in the case of the Müller-Lyer illusion, we see lines of different lengths, while we are

confronted with lines of the same length. In such cases, features of what is perceived (as the perspective in the *tromp l'oeil* or the bracketing lines in the Müller-Lyer illusion) cause our perception to be deluded. It is important to realize that this is not the notion of illusion Gruber et al. (2022) have in mind: they claim that "the term illusion refers to a perception which has no basis in reality" and they refer to illusion as a "perceptual or cognitive add-on" (Gruber et al., 2022, p. 3). If I understand them correctly, the idea is that the mind adds to what is perceived, allowing for the experience of the flow of time, which does not have any support in external reality. The experience of time—as presented by Gruber et al. (2022)—seems more like a hallucination or a mental projection (produced by certain characteristics of the subject independently of the surrounding reality) than an illusion.

This approach is in line with recent B-theorist philosophers' attacks on the A-theorist philosophers' claim that our perception of time reflects or is determined by an objective temporal flux. B-theorists argue that our experience of time is unreliable: for example, it is contended that perception mistakes fast discontinuous change for continuous change (Paul, 2010); moreover, it is claimed that temporal experience cannot represent an objective flow of time considered as a condition of any perception (Prosser, 2013); and, it is maintained that the feeling of the passage of time "is not a worldly representational feature of our experience" (Torrengo, 2017, p. 185). To these observations, Gruber et al. (2022) add that the IGUS experiment shows that "the actual "moving present" is a dynamistic illusory experience that is more related if not identical to the experience of "moving" which is itself illusory (Gruber et al., 2022, p. 4).

When confronted with all these arguments in support of our unreliable perceptions, the first question which arises is: is there any role for hallucinatory time experience in a Block universe? Is our hallucinatory experience useless? Why do we have these deceptive experiences? Gruber et al. (2022) writes that the illusory system allows humans to be "more functional" and to develop "adaptive behavior" (Gruber et al., 2022, p. 1 and 11). This is an interesting observation which differentiates Gruber et al.'s proposal from others in the literature. In my opinion, this interesting claim requires some explanation. First, it is not clear what the words "functional" and "adaptive" mean in a Block universe. In a changing perspective, a system is *functional* when it reacts adequately to certain stimuli and the reaction happens in a changing time; but what is a functional system in a Block universe? i.e., what is a Block-functional system? Moreover, in a changing perspective, species *adapt* to a certain environment when they develop features allowing for survival, where the notions of "developing features" and "survival" are interpreted in a changing time; but what is adaptation in a Block universe? i.e., what is Block-adaptation? Once these notions are explained, it would be useful to clarify why the illusory experiences—and not the veridical ones—allow humans to be Block-functional and Block-adaptive.

3. Illusion as misperception

If it is admitted—as Buonomano and Rovelli (2021) interestingly suggest—that past, present and future are "locally"—but not "universally"—instantiated, it is worth considering whether our temporal experience simply represents the local reality as it is. Buonomano and Rovelli's proposal does not require that the temporal experience be simply representational. They maintain that certain objective characteristics of the universe (as entropy gradients, traces of the past and the macroscopic under-determinacy of the future) "underlie the brain's ability to produce a subjectively vivid and richly structured "flow of time" (Buonomano and Rovelli, 2021). The idea is therefore that there are intrinsic "local" characteristics of the universe which are somehow interrelated to subjective experiences.

The proposal is reminiscent of Locke's secondary qualities (Locke, 1690). Locke distinguishes between primary and secondary qualities: primary qualities are properties of the external reality represented as they are in themselves, secondary qualities are properties of the external reality which have the "power to produce various sensations in us" (Locke, 1690, II, viii, 10). Locke's distinction is not between an external and an internal standpoint on the self[1], it is instead between two different ways in which objective mind-independent properties may affect humans' sense organs. Locke's idea is that secondary properties are not represented as they are, they interact with our perceptual organs to produce certain subjective experiences in us. The paradigms of secondary qualities presented by Locke are color, smell, taste, and sound. For example, the physical properties which produce the experience of taste in us do not have these experienced qualities in themselves, the experience of taste is the way we apprehend physical properties. Under this interpretation, the ability to experience taste, even if not simply representational, allows us to keep track of certain characteristics of the external world (i.e., the experience of taste allows us to keep track of certain physical characteristics of food).

Along Locke's ideas, I interpret Buonomano and Rovelli's original proposal of the subjective experience of the passage of time allowing us to keep track of certain external characteristics of the "local" reality, without necessarily representing them as they are. As Buonomano and Rovelli acknowledge, their hypothesis gives rise to many questions for investigation by physics and neuroscience; and—I add—also philosophy is useful in this respect. In my opinion, it is within this approach that A-theorist philosophers may defend their tenet against the B-theorist who considers the experience of the passage of time as an illusion or a hallucination, allowing instead our experience of the flow of time to be, even though not simply representational, able to monitor properties independent of the subjects themselves.

To further develop the research, I believe it useful to individuate the phenomenal characteristics which interact with the objective local flow of time, thus making it possible to further analyze any case of misperception. Considering again the case of taste, we may misperceive the taste of a particular ingredient when it is covered by the taste of another (therefore our perception of the covered ingredient may be illusory because of external factors), but it may also happen that the subject is unable to perceive an objective taste because of illness (in such a case an internal factor may create

1 A distinction which may be found in Fechner (1851), II, 362 translated in (Heidelberger, 2004, p. 77–78) between an internal perspective on the self ["a standpoint of inner self-phenomena"] and an external perspective on it ["an external standpoint"].

a hallucination or mental projection). In the case of time, once the physical data of the objectively local temporal passage and the phenomenal corresponding experience have been individuated, it will be possible to establish the causes of misperception in factors either external or internal to the subject. Far from constituting a reason for being skeptical about the passage of time, temporal experiences may keep track of external phenomena and, when they do not, they constitute experimental data for distinguishing between cases in which the illusion depends on external factors from cases in which it depends on internal factors.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Funding

I am grateful to the donor who invited me to contribute to the discussion on Physical Time within Human Time. This research was funded by the Department of Philosophy "Piero Martinetti" of the University of Milan under the Project "Departments of Excellence 2023–2027" awarded by the Ministry of University and Research (MUR).

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Gruber, R. P., Block, R. A., and Montemayor, C. (2022). Physical time within human time. *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 07 June 2023
DOI 10.3389/fpsyg.2023.1092351

OPEN ACCESS

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RECEIVED 07 November 2022
ACCEPTED 28 April 2023
PUBLISHED 07 June 2023

CITATION
Romero GE (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1092351. doi: 10.3389/fpsyg.2023.1092351

Commentary: Physical time within human time

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KEYWORDS

time, temporal experience, present, spacetime, IGUS, change, temporal order

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Time has always been a source of perplexity and fascination for human beings. Presocratic philosophers initiated the first discussions on the reality of time and its relation to change. Heraclitus presumed that change was a basic and irreducible ingredient of nature. According to him, the world would be a manifold of substances in permanent change. Parmenides, on the contrary, famously denied change. He argued, in what was possibly the first deductive argument in the history of ontology, that change is impossible because it demands that what is not, should somehow be. He relentlessly concluded that our image of a dynamic universe is a pure illusion: reality is fixed, coming to be and perishing are excluded from the cosmos, and whatever exists must be permanent (see Graham, 2006 for a fascinating account of Parmenides's challenge).

The discussion between Heraclitus and Parmenides permeates the entire history of Western thought and has ended up reaching our days in the form of a tension between two evidently irreconcilable conceptions of time: the flowing time and spacetime. The idea that time somehow flows is closely related to the idea that there is a specific instant called "the present" that, through change, is sequentially actualized: old instants no longer exist, so there is no past but just our memory of what once was. Future instants do not exist yet. Only the "now" is real and is permanently changing. Such a view is usually called "presentism."

The opposite view of presentism is "eternalism," also called the "block universe view." Present, past, and future moments (and hence events) exist. They form a four-dimensional "block" of spacetime. Events are ordered by relations of earlier than, later than, or simultaneous with, one another. These relations among events are unchanging. They cannot change because time *already is* one of the dimensions of the "block," and change is a variation with respect to time. It is not correct, however, to infer that this view represents a "static reality." Worldlines in spacetime describe physical processes, i.e., a series of changes in material things. A change can be defined by an ordered pair of physical states, each at a different time. A physical state is just a collection of the properties of a system at a given time. Therefore, it is said that something changes if, between two different moments t_1 and t_2, any of its properties do not remain identical. Thus, the "block universe" is full of change because the things that make it up are in different states at different times. Of course, what does not change, and cannot change, is the "block universe" itself. How could it change if time is one of its dimensions? To change, the universe would have to be a five-dimensional entity, and two of those dimensions would have to be timelike. Therefore, it might be possible to state that a

four-dimensional portion of the block changes with respect to the fifth dimension. Then, the five-dimensional "block" would be fixed, unless there is a sixth time dimension, and so on. However, the world does not seem to be like that: it is four-dimensional, with three spatial and one temporal dimension, and that is it. The change is already within spacetime. That is why general relativity, our best theory of spacetime, is a dynamic theory: It describes how entities in three dimensions can change with respect to a fourth.

Dean Buonomano has recently pointed out in a discussion with Carlo Rovelli that:

> "(…) unlike the empirically confirmed predictions of relativity (e.g., clocks slow down at high gravitational potentials), it is important to stress that there is no empirical evidence for the block universe. Indeed, it is far from clear that there are any testable predictions that could prove or disprove the existence of the block universe (other than the emergence of a confirmed time traveler)." (Buonomano and Rovelli, 2021).

I believe that this statement is disputable.[1] The "block" of the block universe has a geometric structure that is determined through Einstein field equations. According to these equations, any perturbation in the matter will result in a perturbation of spacetime; therefore, there will be an energy flux in the form of gravitational waves across the spacetime manifold. Such a flux can exist through empty spacetime only if its dimensionality is at least 4 (Romero, 2017). This means that, if presentism is correct and the world is essentially three-dimensional, phenomena such as gravity waves should not occur (Romero, 2018). However, the experiment indicates the opposite: gravity perturbations travel from distant sources to the Earth where experiments such as LIGO can detect them. We conclude that the world is four-dimensional and, consequently, past, present, and future exist. There is no need to resort to time travel, although the existence of time travelers is not forbidden by general relativity (as correctly noticed by Rovelli in the same article).

Even if presentism is inconsistent with general relativity, our brain undoubtedly experiences a sense of "newness." What is the origin of this sense? Earlier, I suggested,

> "I maintain that 'nowness' and 'hereness' emerge from the existence of perceiving self-conscious beings in a certain environment. What these beings perceive is not time, but changes in things (…). Similarly, they do not perceive space but spatial relations among things. In particular, we do not perceive the passage of time. We perceive how our brain changes. I claim that there is no present *per se*, in the same way that there is no smell, no pain, no joy, no beauty, no noise, and no secondary qualities at all without sentient beings. What we call 'the present' is not in the world. It emerges from our interaction with the world." (Romero, 2015).

Perhaps this can be expressed more simply by saying that what we call consciousness arises from groups of successive brain events arranged in some specific configurations in spacetime. Those events are changes and processes, that is, chains of pairs of states that associate properties of one part of the brain with properties of other regions, either in the same brain or in the local environment, at slightly different times. Since these properties are not the same across the time dimension, the illusion of a "time flow" arises. However, time does not flow in any meaningful, non-metaphorical sense. It is just one dimension along which spatial properties vary. The "flow" of time is just a brain construct, an illusion, albeit a very stubborn one because it is rooted in what defines our very identity. The variation, I insist, is only a relative difference in the distribution of properties along the manifold that represents the four-dimensional spacetime.

In their recent article "*Physical time within human time*," Gruber et al. (2022) reported on a new experimental setting aimed at verifying the hypothesis that the passage of time is a construction of the brain. The basic idea is that the experience of the flow of time is not a representation by a passive recipient of sensory stimulation but is generated by predictive processes of the brain and proactive sensorimotor activity of the whole body. Gruber et al.'s approach consists of enhancing and constructing an "information gathering and utilizing system" (IGUS) capable of manipulating the experience of the past, present, and future. This would allow us to put the hypothesis of a brain-constructed experiential time to the test.

The idea of IGUS was introduced by Hartle (2005) and discussed by Romero (2015) and Huggett (2018) from a philosophical and physical point of view. The practical construction of IGUS presented by Gruber and Smith (2019) opens the door to new laboratory experiments that might allow a thorough investigation of the biological basis of perceptual time.

To succeed in the manipulation of time perception, a specific IGUS should control the information on the environment provided to the processing system (the human brain). This is achieved with the immersion of the subject in a virtual reality fed with a system of cameras whose output is controlled and allows the researcher to switch between present, past, or future moments. The resulting "present" experienced is not unique and hence not a property of spacetime but rather of the specific IGUS. This is a very important result obtained by Gruber et al.: the two diverging ideas of time, the physical, objective time and the human, subjective one, are the result of the same and unique set of physical laws. The neuroscience and physics of time seem to accord through mechanisms that can be objectively tested.

Further experiments should evaluate the efficacy of different IGUS configurations to implement tasks related to the survival skills of the individual. Complexity and a variety of new tests can be obtained by introducing various gadgets. The comparison of the results of such research might lend support to the hypothesis advanced by Hartle (2005) that the IGUS of the human brain is that which is best suited for survival in its environment. The picture emerging from these investigations, to date, seems to tell us that:

> "(…) the present does not flow or move. Only material individuals (and their brains, if they have one) can change and move. Becoming is not a property of physical events but

1 I consider the classical general theory of relativity as the correct theory to model reality (and hence of time), at least at the scales relevant to the issues discussed in this commentary. My views on the ontology of the world and the reasons on which I base my support for a systemic form of a plural materialism of spacetime and quantum fields can be found in the study by Romero (2018) and especially in Romero (2022).

> of the consciousness of the events. We call 'becoming' to the series of states of consciousness associated with a certain string of physical changes. Events do not become. Events just *are*." (Romero, 2015).

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Funding

This study was supported by Grant No. PIP 0554 (CONICET), the Spanish Ministerio de Ciencia e Innovación (MICINN) under Grant No. PID2019–105510GB-C31, and through the Center of Excellence Maria de Maeztu award to the ICCUB (CEX2019-000918-M).

Acknowledgments

GR thanks Ron Gruber for the material on his work and discussions.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 08 June 2023
DOI 10.3389/fpsyg.2023.1130228

OPEN ACCESS

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RECEIVED 23 December 2022
ACCEPTED 28 April 2023
PUBLISHED 08 June 2023

CITATION
Farr M (2023) The Three-Times Problem: Commentary on Physical Time within Human Time. *Front. Psychol.* 14:1130228. doi: 10.3389/fpsyg.2023.1130228

The Three-Times Problem: Commentary on Physical Time within Human Time

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KEYWORDS

time, passage of time, illusionism, philosophy of time, physical time

A Commentary on
Physical time within human time

by Gruber RP, Block RA, Montemayor C. *Front. Psychol.* (2022). 13:718505. doi: 10.3389/fpsyg.2022.718505

1. Introduction

Much of our temporal experience is misleading. No doubt this is true in various ways; after all, scientific progress over the centuries has involved giving up ideas that seemed well-motivated by experience. But in the case of time, it has been common to make a very specific set of claims. The "passage" or "flow" of time, and the "presentness" of experience, are often held to be, in some sense, left out of the picture of time described by modern physics. Because of this, passage and presentness have been widely deemed illusory aspects of experience.

In the two feature articles for this volume, Buonomano and Rovelli (2021) and Gruber et al. (2022) focus on what the former call the "two-times problem," in short, the apparent lack of fit between time as described by physical science and our own temporal experience, where "experience" involves things like memory, anticipation, and perception of change and motion. In this short note I'll make the case that the two-times problem is less serious than it is often made out to be in the specific case of features like "passage" and "presentness" that are central to the "A-theory" of time — the theory that holds time to be composed of dynamic regions of "past," "present," and "future," and for time to genuinely flow or pass.

My contention is 3-fold: (1) the two-times problem is better understood as a three-times problem: rather than a conflict between "physical" and "manifest" time, what we have in the case of time is differences between the time of physics, the time of experience, and the "folk" concept of time. (2) Understanding the problem in this way helps deflate certain problems about the relationship of these three pictures; the time of experience and the time of physics are less obviously in a problematic conflict than often supposed; and the folk concept of time is what brings in problematic features of time hard to fit with either the time of physics of experience. (3) Understanding the time of experience as independent from the folk concept of time better fits the actual aims of the cognitive neuroscience with respect to the various features of our perception and representation of time.

2. The three-times problem

Gruber et al. (2022) use the term "two times problem" to refer to the often-discussed conflict between "physical" and "manifest" time [see also Callender (2017), who introduces

and discusses this distinction at length, based on Sellars (1962) famous distinction between the manifest image and scientific image and Eddington's (1928) two-tables problem], wherein physical time lacks certain features central to manifest time, such as passage and presentness.

On the issue of passage, Gruber et al. (2022) note that "the exact mechanism behind this dynamic experience is debatable," pointing to the diversity of ways of even describing the phenomenon in question, most generally referred to as the "whoosh" of experience, before offering a tentative account in terms of the function of IGUSes [information gathering and utilizing systems, as set out by Hartle (2005) and developed by Callender (2017) and Ismael (2015, 2017)]. Buonomano and Rovelli (2021) see this as a crucial disconnect between physics and neuroscience, suggesting that consilience can be found in explaining the "whoosh" as due to the time asymmetry of thermodynamics. The underlying thought in both cases is that passage/flow is a feature of our temporal experience, but not a feature of the mind-independent world described by physics.

Though there have been various attempts to explain an illusory experience of flow or passage—call this "illusionism"—[notable recent attempts being Paul (2010) and Prosser (2012)], an alternative position has received growing attention. Various authors (e.g., Deng, 2013, 2019; Hoerl, 2014; Farr, 2020; Miller et al., 2020) have motivated the alternative view that the passage of time is not even an illusion, since there is no obvious way in which the flow or passage of time is a feature of our perceptual experience, veridically or illusionary. Instead, Miller et al. (2020) suggest that we can instead think of passage as a kind of "conceptual error" that gives us the false belief that something like flow or passage is a feature of our temporal phenomenology, with Farr (2023) arguing that such concepts are even non-cognitive in nature, that though we describe time in metaphorical terms as flowing like a river, these are not even truth-apt beliefs about our temporal experience. As such, the role of our use of concepts when talking about temporal experience is itself quite distinct from our experience of time itself, and as such it is worth using a 3-fold account of time:

- **Folk Time.** The "folk theory" of time is the way in which we ordinarily describe and conceptualize time.
- **Experienced Time.** The "experience of time" is the multitude of ways in which we perceive various apparently temporal features of the world, such as motion and change.
- **Physical Time.** The "time of physics" is the set of ways in which time is referred to in contemporary physical theory, such as in relativity theory and quantum mechanics.

There is certainly disagreement about what is the "folk theory" of time and good evidence for thinking there's no universally shared folk theory (see Norton, 2021 for a recent overview). However, it is often taken for granted that folk time involves certain features that a central to the "A-theory" of time, such as the primacy of the present moment, the passage of events from future to present and past, and the "flowy," "dynamic" quality of time. In distinguishing experienced time from folk time, my idea is that we should be careful to distinguish which aspects of ordinary descriptions of time that form the folk theory are themselves aspects of our experience of time, and which are simply due either to false beliefs about our experience of time, or about what time must really be like, or instead some kind of metaphorical mode of describing time.

3. The relationship between times, and the aims of cognitive science

In the case of the passage or flow of time, where could a problematic conflict be found between the pictures of time? First we can ask whether physical time really hold time to be "static" in a way that contrasts with temporal experience. It is certainly common to understand relativity theory as portraying time as some kind of static block, mirroring the style of spacetime diagrams used to represent relativistic spacetime. But this is too quick. Many have suggested that relativity theory is perfectly capable of describing the kind of dynamism required to fit with manifest time. And, looking at it from a different perspective, there is a logical problem in holding the traditional four-dimensional block-universe conception of spacetime to be static in a way that contrasts with dynamism, as touched on by Buonomano and Rovelli (2021). They note (following Price, 1996, p. 13) that something ought only be considered as static if unchanging relative to some further variable. A chair is static if it stays still relative to the room surrounding it while the clock on the wall ticks clockwise. But in what sense is a four-dimensional block universe "static," unless there is an extra, secondary time dimension relative to which it is unchanging? Indeed, the standard response by those that reject the A-theory is that a passageless block universe can (and does) perfectly well give rise to the kinds of temporal experience that we have. In this sense, it is not well-established that physical time excludes the kind of flow or passage common to folk time.

Secondly, we can ask in what ways experienced time involves a notion of flow or passage that could be in conflict with physical time. There are ways in which the brain processes features of the world that are clearly temporal, such as tracking an individual object through a series of changes. And there are ways things appear to us as they change and move that we often refer to as experience of or awareness of time's "flow" or "passage." And there are the variety of ways in which we invoke the concept of time when recalling one's own memories or projecting forwards to a future event that we are anticipating. Certainly this range of experience gives rise to the idea of time as somehow flowing, and the present being special. It is at this point that many have looked to cognitive science to address deep metaphysical questions about time, such as whether it really passes, or really appears to pass (see Baron et al., 2015 for an overview). However, it is precisely here that I've argued (Farr, 2020) that we risk conflating empirical issues about time perception with a priori issues about the concept of time itself, ultimately conflating metaphysics with cognitive science and misrepresenting the actual aims and subject matter of cognitive science.

Several features of the A-theory, such as passage the privileged present moment, that are out-of-line with the scientific picture of time have widely been thought to stand in need of explanation by the cognitive sciences. However, just because we can describe time in such a way, it does not follow that we experience it as such, and it certainly does not follow that cognitive science is required to explain how illusions of the flow or passage *of time* (as opposed to ordinary moving/changing objects) come about. To

focus on our main example of passage, illusionists have searched for various ways in which our brain might falsely represent time as flowing or passing, such as Paul's (2010) suggestion that the "feeling" of passage is a kind of "filling in" effect due to smoothing over temporal snapshots of our local environment, analogous to Wertheimer's famous phi phenomenon, and the suggestion of Gruber et al. (2022) that the sense of flow is due to a representation of "the dynamism of a few temporal experiences from the illusory system, e.g., motion (dynamic movement), dynamic change, and the "feeling of succession" ("pure succession") of temporality" (p. 9). However, it is important here to note that the sense of "flow" one has from seeing a moving object is at best an analogy for the "flow" of time itself hypothesized by the A-theory, and many have argued that the analogy breaks down in key ways (see Deng, 2013, 2019; Hoerl, 2014; Farr, 2020), motivating the view that such aspects of our cognitive representation of motion and change do not equate to a representation of time as flowing.

Through framing the discrepancies between physical time and folk time as a problem of temporal experience, the metaphysics of time and the experience of time become conflated, together with an implicit pressure on cognitive science to address questions such as "why does time seem to pass." The trouble is that where there is important work on temporal experience that is relevant, such as change and motion perception, the work itself can be misinterpreted. In the case of motion perception, there are interesting studies on the "flow-like" quality of motion, such as in the famous studies of "motion-blindness" (aka akinetopsia; see Zihl et al., 1983; Zeki, 1991), where subjects lack an ability to sense motion despite seeing objects in sequentially different positions. In such cases there is a reported loss of flow-like elements of motion perception, with Zihl et al. (1983, p. 315) noting the patient's view of a stream of pouring coffee appearing "to be frozen, like a glacier." It is tempting here to draw the analogy with the idea of time itself appearing as "frozen" as opposed to flowing. However, there are again key differences to keep in mind: coffee can appear frozen through appearing not to continuously change or move over time; but it does not follow that time itself could in any sense appear not to similarly change or move through time.

4. In sum

There are many fascinating aspects of our experience of time and our ordinary beliefs and ways of describing time that are incongruous with the properties of time implied by physical theory, as expounded upon by the two feature articles. In this note I've suggested: (1) it is far less clear that the physical and experienced time are in a problematic conflict over any specific property of time; and we must exercise caution when (2) ascribing to "experienced time" certain features central to folk concepts of time that are not clearly aspects of experience, and (3) looking to cognitive science to weigh in on a priori metaphysical issues about the properties of time.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 14 June 2023
DOI 10.3389/fpsyg.2023.1087695

OPEN ACCESS

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RECEIVED 02 November 2022
ACCEPTED 11 May 2023
PUBLISHED 14 June 2023

CITATION
Huggett N (2023) Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time". *Front. Psychol.* 14:1087695. doi: 10.3389/fpsyg.2023.1087695

Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time"

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KEYWORDS

time perception, illusion, motion perception, philosophy, flow of time

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13, 718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). *arXiv.* doi: 10.48550/arXiv.2110.01976

1. Introduction

Consider Zeno's of Elea's paradox of the arrow, propounded in the fifth century BCE: when does the arrow move between points p and q, given (a) that instants of time are indivisible? Not *during* any instant, since then it would be divisible into an earlier part (when the arrow is at p) and a later part (when it is at q). If not during, then it could only be *between* instants; but given (b) that time is completely composed of instants, between them is no time at all. In other words, the arrow is stationary, moving at *no* time, contrary to experience!

A delightful argument, which cuts to the heart of the question of what a mathematical function is, something that was not fully understood until the nineteenth century development of analysis (Huggett, 2019). That conception, of course, is that functions—say, the position of the arrow—are *not* objects that "flow" or "move" with their arguments in some primitive, intuitive, and even experiential (but ultimately unexplicated) sense, as Zeno seems to assume (to demonstrate their non-existence). Instead, they are simply a pairing of each argument-value to a unique function-value, and concepts such as motion, flow, or continuity are then *defined* within this picture, using the limit concept of Bolzano, Cauchy, and Weierstrass (cf Courant et al., 1996, §V.3). For motion, we then have the "at–at" theory—the motion of the arrow entirely consists of its being *at* a place *at* each time,—while all that remains of flow is the differentiability of the series of places with respect to the series of times.

I start with this familiar example to illustrate the problems which the two manifestos, Buonomano and Rovelli (2021) (henceforth B&R) and Gruber et al. (2022) (GBM) seek to address. That is, there is a gap—or better, gaps, since the articles correctly emphasize time's multifacetedness—between the "everyday" conception of time, and the scientific (specifically physics') conception, and between the philosophical elaborations of those concepts. Similar

to GBM, let us refer to the former concept in Willfrid Sellar's terms as "manifest."[1] As the articles note, recognition of such gaps is as old as philosophy, and indeed one could read Zeno in this way: "manifestly the arrow moves, but by the lights of the contemporary physics of time circa 450BCE—including assumptions (a) and (b), and a view of functions as flowing—it cannot." As we just saw, Zeno's argument was undermined by (ironically!) changes in the scientific conception of time and change, specifically the development of analysis. However, that very development opens a new gap: some supposed experiential idea of temporal "flow" in motion on one side, which is rejected for the at-at picture of time and change on the other.

This idea of flow is arguably unexplicated beyond metaphor by its proponents, and I have no precisification to offer; except in the sense that I will argue that what people call "flow" is in fact something quite different. Under the circumstances, I hope that the vagueness in the term will be excused [NB: my target is motion as flow, which I will generally refer to as temporal flow, even though that arguably has other facets (Callender, 2017, chapter 11)].

Both B&R and GBM argue for a two-pronged attack on the general problem of the physical-manifest gap: on the physical side (including the physiological aspect of neuroscience), explain the physical environment and mechanisms underwriting temporal experience; on the psychological side, classify and explain the veridical and non-veridical experiences that result. As the references to the articles illustrate, many philosophers of physics, including myself, have taken this approach and I am very congenial to these arguments (and welcome increased interaction with psychologists). The alternatives seem to be either to abandon the idea of the unity of science, or radically rethink physics; neither option seems palatable (I argue against the latter in Huggett (2014), which also discusses the following example).

My aim here, then, is to pursue such an approach to "flow," but thereby offer an important friendly clarification of that approach. In particular, "illusion" is defined and used too loosely, obscuring some distinctions that are important for the explanation of temporal experience: "illusion refers to a perception that has no basis in reality" (GBM, p. 3).[2] Trivially, all perceptions have some "basis" in reality since they are caused by something real, so GBM has something more restrictive in mind: that there is some special relation *X* in which veridical perceptions stand with respect to the world; for instance, that they properly *represent* their objects, while illusions do not. Now, the question of perceptual content is an entire sub-field of philosophy, which I cannot settle here. However, my argument is largely independent of any specific account: all that matters is that some relation between percept and world ("basis in reality") holds for veridical perceptions, and fails to hold for illusions. Let us call that relation "representation," but without overburdening it with philosophical baggage.

Then my clarification will be that there can be veridical perceptions, properly representing physical time, which nonetheless lead to a manifest conception of time at odds with the scientific conception. For GBM, it seems that only an illusion could lead to an erroneous conception of time, whereas I will claim that it is also possible to be *mistaken* about what it is that a veridical perception represents. For instance, in the waterfall illusion, one has a percept of motion, where there is none. But imagine that on seeing a stranger in the street, I mistake them for a friend. But did I suffer an illusion, and perceive someone who was not there? Perhaps instead the perception properly represents the stranger, but I am mistaken about who it represents. In the following, I propose an analogous analysis of the supposed perception of flow.

2. "Illusions" are not what they seem

Consider the well-established motion detection mechanism, a Reichardt detector, thought to be implemented in the visual cortex (Mikami et al., 1986).[3] Crudely, a pair of spatially separated high-contrast edge detectors in the retina (or perhaps lateral geniculate nucleus) are connected, as it were, to a logical AND gate, with a time delay in one input: if a light patch moves across the retina, the first one then the other detector will fire, and if the first signal is delayed for exactly the time it takes the patch to move between the detectors, then the AND gate will fire. Thus, the whole mechanism is a simple detector for edges moving across the retina, and so for the motion of physical bodies; likely one among a variety of motion detectors, for which it will serve as a representative in what follows.

The phenomenon of apparent motion indicates that the outputs of motion detectors enter consciousness, though how is not settled. When they do, the resulting percept amounts to (invisible) mental vector arrows attached to objects in the visual field, indicating their speed and direction of motion; and the perception is veridical to the extent that it properly represents the motion, so to the extent that bodies move as perceived.

Consider the phenomenology of this percept, to see that it is the source of the manifest conception of temporal/motion flow. Motion illusions, including the waterfall and apparent motion can make us quite strongly aware of the percept, but its absence can also be striking. Stroboscopic light below 50 Hz can make moving objects appear to jump from place to place: just what is missing is, I claim, that percept which the folk refers to as "flow." It is not hard to see how such lighting can thwart motion detection: for instance, a moving object illuminated when it triggers one of the edge detectors in a Reichert detector, may be in darkness when it would otherwise trigger the other, so that motion is not detected—thus, the corresponding motion percept is absent.

1 In the philosophical literature, it is sometimes also called the "folk" concept: e.g., Latham et al. (2020). This work empirically investigates the question of what gaps between manifest and scientific images of time truly exist. This is important work: too often gaps are posited without careful scientific investigation of what the folk really think. What, for instance, is the folk understanding of temporal "flow," blithely assumed here, and in the articles? There is more to learn.

2 GBM acknowledges stretching the concept but, as I will explain, in a different direction from me. The use of, and complaints about, this terminology in the philosophy of time are of course not new: for recent examples see Paul (2010) and Callender (2017, §11.4.1), respectively. For an entry into the large literature in the philosophy of perception concerning the nature of illusion, see e.g., Egan (2014).

3 An overview of these matters can be found in Mather (2016, Chapter 12).

Analogously, but far more dramatically, Zihl et al. (1983) famously reports a study of a patient with damage to the visual cortex, specifically around the MT region known to be associated with motion detection. Remarkably the only significant impairment that they suffered was to motion perception but despite the fact that they perceived objects at sequential locations, they (i) reported lacking a motion percept, and (ii) were unable to perform tasks requiring information about motion: "She had difficulty . . . pouring tea or coffee into a cup because [i] the fluid appeared to be frozen, like a glacier. In addition, [ii] she could not stop pouring at the right time since she was unable to perceive[4] the movement in the cup . . . when the fluid rose" (p. 315). The patient reported people and vehicles "suddenly" being "here or there," without having "seen them moving." Plausibly, these experiences arose from the integration of static and motion aspects of experience: current motion perception produces expectations of future spatial arrangements of objects, which were continually thwarted by moving objects. Whether objects stroboscopically jumped across her visual field, or moved continuously but to the "wrong" places (supposing such a distinction can be drawn) is unclear from the published reports. Regardless, the reasonable interpretation is that because the patient was lacking normal motion detectors, they were also lacking a characteristic motion percept.

These two pathological cases highlight—by their absence—a component of ordinary experience about which people are often confused. Specifically, motion perception is not merely a matter of experiencing an object in sequential locations, but also an awareness of instantaneous velocity, the "mental vectors" attached to bodies in the visual field. No doubt the reader has also noticed the connection to Zeno's arrow: the gap between the conception of motion in a flowing time and the at-at account of motion parallels the gap between the experiences of a moving body with and without functioning motion detection. Indeed, I submit that *the manifest image of (the motive aspect of) temporal flow ultimately refers to the very percept missing in these two cases* (and not to the visual experience of sequential location that remains): exactly what the folk would say about them is that they involve no experience of motion as flow.

But the neuroscience described indicates that in non-pathological cases this percept represents the at-at motion of bodies; mechanisms like the Reichardt detector work reliably on the basis of physical objects (and hence, the light they reflect) being at sequential locations at sequential times. No kind of "flow" is implicated at all in their proper operation. Moreover, the information that they provide for action is also of the at-at kind: at what place will an object be at a later time? In that case, the corresponding experience represents the at-at motion of the object, and *if one thinks that it is an experience of temporal/motion flow, one is simply mistaken about what it represents*.

However, it cannot quite be right to say that motion percepts are mistaken for flow percepts, since that suggests that there is such thing as a "flow percept." Given the dubious coherence and arguable non-existence of "flow," what could a percept of it possibly be? (and if it is nothing, then certainly flow is not an *illusion*, in the sense of having a flow percept without flow in reality). Thus, we should more carefully say that people are mistaken about *the physical correlate of the motion percept*, and the resulting confusion leads to vacuous talk of "flow."

3. Discussion

How then, do these considerations bear on GBM? In their scheme, it seems that the unphysical flow of time must be understood as arising from a "gadget" producing an illusory perception. We have indeed identified a gadget responsible for the concept of time flowing, namely Reichardt detectors and the like. But calling flow illusory erases an important distinction between what is going on here and in other cases: the motion detected and perceived is absolutely real (in the at-at sense), one simply misinterprets it. Nor can this error be understood as a "cognitive add-on" to perception (p3) since it does not modify perception, but misconstrues it.

I then have two programmatic concerns about the veridical/illusion dichotomy in GBM. First, if one had in mind that the supposed perception of flow had to be an illusion, then the desired explanation seems to be unavailable since the motion perceived is real, not illusory. Second, if "illusion" is ambiguous, then so is the dualistic hypothesis; how exactly are we to say whether a component of perception is veridical or illusory? On which side do motion detection and its misinterpretation fall?

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Acknowledgments

Many thanks to Maria Balcells, David Hilbert, and Kai Huggett. The work was carried out with the support of a Benjamin Meaker Distinguished Visiting Professorship, at the University of Bristol.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

4 My footnote: the inability to *perceive* motion does not seem critical; all that matters to explain the failure is the unavailability of the information, whether conscious or not.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 15 June 2023
DOI 10.3389/fpsyg.2023.1096592

OPEN ACCESS

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RECEIVED 12 November 2022
ACCEPTED 17 May 2023
PUBLISHED 15 June 2023

CITATION
Prosser S (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1096592. doi: 10.3389/fpsyg.2023.1096592

Commentary: Physical time within human time

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KEYWORDS

time, temporal experience, flow, passage, endurance, perception

A Commentary on

Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2021). Front. Psychol. 13:718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). arXiv. 11. doi: 10.48550/arXiv.2110.01976

Introduction

It is exciting to see a growing interest in and new ideas concerning temporal experience from multiple disciplines. Some brief critical observations about each of the two target papers are presented in an attempt to further clarify the phenomenon behind one specific thread by Gruber et al.

Comments on Buonomano and Rovelli

It seems odd to propose that neuroscience itself takes a view on the nature of time, let alone a view that is at odds with physics. Many sciences, especially those concerned with biological phenomena, can proceed as though classical physics were true, as though there were a single global present, and so on, for the reasons that Buonomano and Rovelli present, namely that, within their domain of inquiry, these classical claims hold approximately but to a high degree of accuracy. Even physicists sometimes proceed in this way, for example, when dealing with macroscopic phenomena or some of the practicalities of setting up experiments. It is another thing to suggest that any science other than physics is thereby in a position to take a view on the objective nature of time. Evidently, the only sense in which an opposing view of time essentially figures in neuroscience relates to the fact that neuroscience is in the business of explaining experience (among other things), and our experiences tend to suggest a world in which there is an objective present, time passes, and so on. However, great care is needed when inferring anything about the nature of time from the subjective character of experience. For experience could only inform us about the nature of time if there were a plausible mechanism that would make the characters of our experiences sensitive to the kinds of objective temporal facts in question. Yet, if no physical apparatus can detect the supposed passage of time, the global present, and so on, it follows that the brain, as a physical system, cannot do so either (see Prosser, 2016 for an extended discussion of this issue).

Comments on Gruber, Block, and Montemayor

Gruber et al. covered a wide range of related topics very quickly, sometimes at the expense of clarity. It was hard to determine how to understand the "dualistic" proposed model. The talk of "two times" appears unnecessarily confusing, as it ultimately amounts to the familiar distinction between appearance and reality applied to time. Physics tells us certain things about time. Our experience of time suggests to us that time has a different nature than that suggested by physics. Physics is presumably right; therefore, either our experience involves some kind of illusion or there is something about our experience of time such that, even though the experience itself is veridical, it invites false beliefs about the nature of time. This is not happily described in terms of two different kinds of time, one inside the brain and one everywhere else. If someone's visual experience of a banana made it appear straight when it was curved, we should not say that there were two bananas, a curved one in the outside world and a straight one in the brain. There is no banana in the brain, not even a "mental" one; there are just numerous firing neurons and other physical processes that collectively constitute the experience of the banana and make it seem, to the subject whose brain it is, that the banana is straight.

Hartle's notion of an IGUS is doubtlessly useful in thinking about temporal experiences. It follows the principle that, if you want to know how something works, think about how to build one. One starts with a simple model and then gradually modifies it to bring it closer to the real thing. The metaphor of adding "gadgets" is not always helpful, however, since it suggests that the modifications in question involve simply adding further systems without fundamentally changing the underlying system. This is not automatically correct. In some cases, the gadget might alter the functioning of the underlying system. Moreover, in the case at hand, it sometimes appears that Gruber et al. interpreted the addition of gadgets as the basic IGUS having veridical experiences with a certain character and gadgets as adding a further, illusory character to the experience while leaving the underlying experience unchanged.

In some cases, it was not clear what was supposed to be illusory. Consider, for example, the discussion of experiencing motion and change. Gruber et al. seemed to follow Koch's (2004, p. 274) description of motion being "painted" onto an otherwise changeless "snapshot" (see Prosser, 2016, p. 125–127 for a discussion of what is wrong with this). In the case of phi or beta motion, where the stimulus consists of blinking static images, the experienced motion is illusory. However, in ordinary motion perception, where the stimulus is moving, no case was made by Gruber et al. for saying that anything is illusory. An object appears to be moving, and it is indeed moving in the straightforward sense of occupying different positions at different times.

A similar issue arises in the discussion of William James's observation that a succession of experiences is not sufficient for an experience of succession. The experience of succession is not usually construed as an illusory add-on to the succession of experiences. We typically experience succession veridically, insofar as "succession" consists of different things happening at different times. Both the "dynamic snapshot theory" (defended by Arstila, 2016, 2018; Prosser, 2016) and the views that it opposes are intended as theories of the generally veridical experience of motion and other changes and do not suggest that the contents of these experiences are in any way in conflict with the account of time given by physics (Prosser, 2012 suggests that there is an illusory "endurance" element in motion experience, but this is a separate claim and is not an essential commitment of the standard theories of change perception). Gruber et al. may have assumed that there is no motion or change in the "block" universe of modern physics and that experiences of motion or other change must therefore be illusory. However, the block theory does not rule out changes that consist of one state of affairs at one time and a different state of affairs at another time. Further research is needed to show that the experiences mentioned above concern anything beyond what has been described thus far.

The role of endurance

Gruber et al. mentioned the philosophical notion of "endurance" and cited studies by some philosophers who proposed that the mind represents the experiencing subject, or other things, as enduring and that this has an important role to play in the illusory element of temporal experience. A brief suggestion will be presented here concerning the relevance of this to the illusory sense of "moving" through time and the extent to which this is compatible with the dualistic account.

An increasing number of philosophers (including those cited by Gruber et al., along with Prosser, 2012, 2016) have reasoned as follows. If we consider ourselves to persist by perduring, that is, by having different temporal parts at different times, this does not seem to allow for the notion of moving through time. Each temporal part remains at its temporal location and nothing changes. Then, perhaps, instead, our minds represent ourselves and perhaps other things, as enduring, such that the very same entity (and not merely parts of it) is located at one time and then another. This representation may be illusory, but it helps explain a sense of motion through time (this "sense" may or may not be strictly phenomenological. For example, it might arise from one's current sense of being at a certain location in time while remembering being at an earlier time). In terms of the dualistic model of Gruber et al., however, while the representation of oneself as enduring may be illusory, it is not clear what would count as the underlying veridical representation.

Let us consider this more carefully. Nothing can literally move through time. Moving through space means being in different places at different times. Thus, moving through time should mean being at different times at different times, but taken literally, this means nothing.

Moreover, the notion of being at one position in time and then another indicates that we must understand endurance in terms of being entirely located in one position in time (this is not the only way in which philosophers have construed 'endurance,' but it seems essential here). However, an object that is located entirely at one position in the time series exists only momentarily; it does not exist at any other time. Such an object does not move through time. If presentism were true, and the world were unextended in time,

then there would be a sense in which all objects would exist only at one time. Nevertheless, it is not clear why representing the world as though presentism were true should create a sense of moving through time since there would be no extended region of reality through which to move. Instead, there should be a constant change in properties. Therefore, on its own, the subjective endurance claim faces problems.

Consider, however, the possibility that even though there is only one real-time dimension, our minds have two separate ways of representing it. Let us call these $time_1$ and $time_2$. Then, it could at least appear to make sense, from the subject's point of view, to say that an object was first at one location in $time_1$ and then at another location in $time_1$, where "then" implies "at a later location in $time_2$." Thus, an important question for empirical study is whether the brain has two separate ways to represent time (see Hoerl and McCormack, 2019, for one possibility, though it does not seem a perfect fit).

Where would this leave the notion of endurance? A perduring object moves through space by having different temporal parts in different spatial locations but is entirely located in one spatial location at any given time. Given the model above, it might appear that an object could seem to move through $time_1$ by seeming to have different $temporal_2$ parts at different $times_1$. However, this would still involve representing the object as located entirely at one position in $time_1$ at any given moment in $time_2$. If objects objectively perdure, what would be represented at each time would be a temporal part. However, either way, an object (or person) would be represented as though it existed entirely at one time, and hence endured, relative to $time_1$.

At first glance, the distinction between $time_1$ and $time_2$ might appear to support the dualistic model. This would presumably depend on whether one represented time series could be construed as a veridical representation belonging to the simple IGUS, with the other added as an illusory "gadget." However, it does not seem clear why the representations of $time_1$ and $time_2$ would stand in quite this relation.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 13 July 2023
DOI 10.3389/fpsyg.2023.1096890

OPEN ACCESS

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RECEIVED 12 November 2022
ACCEPTED 03 July 2023
PUBLISHED 13 July 2023

CITATION
Dieks D (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1096890. doi: 10.3389/fpsyg.2023.1096890

Commentary: Physical time within human time

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KEYWORDS

physical time, human time, perspectivalism, information, quantum mechanics

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2021). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). *arXiv*. [preprint]. doi: 10.48550/arXiv.2110.01976

1. Introducton: physical vs. human time

Buonomano and Rovelli (2021) and Gruber et al. (2022) emphasize that time as it figures in physics is different from time as we experience it. Physics provides us with an analysis of temporal features of the world that are independent of whether or not there are observers, whereas experiential time is private and subjective. Moreover, experiential time possesses properties that seem completely absent from physical time. For example, our temporal experience is dynamic, characterized by a privileged instant on the time axis, the Now, that continuously shifts from Past to Future. Physics does not recognize such a privileged moment, and motion of time itself (as opposed to ordinary motion, i.e. change of spatial position as a function of time) seems even impossible to define from a physical point of view.

Buonomano and Rovelli (2021) and Gruber et al. (2022) argue that these differences are not in conflict with the universality claim of physics: physical time may without contradictions be assumed to govern us and other organisms no less than elementary particles, planets and stars. However, the way we (and other organisms) experience time is not only determined by the nature of physical time, but also by how we process it and how we represent it to ourselves. The nature of human time consequently at least partially depends on the organization of our sensory system and brain.

To understand phenomenological time we therefore have to invoke neuroscience and psychology. We must consider how organisms process information coming in from events in the external world and how organisms internally represent that information. For this purpose Hartle (2005) first introduced a simple model of an "Information Gathering and Utilizing System" (IGUS). Hartle's IGUS contains a number of registers, one for novel information and some for storing data about the past. In the IGUS the contents of these registers are constantly updated and compared—see, e.g., Callender (2017, chapter 11). Gruber et al. (2022) present an overview of the architecture of more sophisticated IGUSs, with details about how they could explain features of human time, in particular our experience that time *flows*.

2. The Now and perspectives

A key factor in the explanation of our time experience is that our Now is not point-like but has a finite duration (the "specious present"). This implies that information from different temporal stages of an observed process can be part of the same experienced moment, which makes it possible to be "instantaneously" aware of change. This is relevant for the explanation of our awareness of time flow: the presence of differences between successive stages of a process during one specious moment may be responsible for a "state of tension" associated with a subjective feeling of flow.

Another point to be explained is our intuition that our Now is spatially extended, so that it makes sense to speak about the global state of the world around us *now*, at any given moment. Perhaps surprisingly, modern physics denies the objectivity of such a global now and the global simultaneity on which it relies. Nevertheless, physics is capable of explaining our intuition: Things around us typically change little during the time needed by light signals coming from them to reach us and this creates the impression of instantaneous contact even with objects at a distance. However, in reality physical information transfer takes time, so that we actually are in contact with the past. That our experiential global Now in reality corresponds to a physical time window during which we receive information from the past is not difficult to understand and accept, however, and it is not impossible for us to adapt our intuitions accordingly. This is a step that brings experiential time and physical time closer together.

Another essential feature of experiential time, however one less frequently discussed, is that it is *perspectival*: all our temporal judgements are made from our personal vantagepoint. This "subjective" aspect of experience, the fact that it always presupposes a "point of view," is shared by all experiential qualia. This unavoidable perspective-dependence has frequently been used to argue that there exists an unsurmountable barrier between human experience and the objective, perspective-less facts of physics, with the consequence that experiential facts cannot be reduced to physical facts (see Nagel, 1974 for a famous argument along these lines). The validity of the argument is not uncontroversial, but in any case it is interesting to note that during the last decades the notion of judgements and descriptions that are inseparable from a vantagepoint has been gaining prominence even within fundamental physics. Partly, this is because it has become more popular, especially in quantum mechanics, to interpret theories as practical tools, used by agents, rather than as objective descriptions of nature. If a view of this kind is accepted, human perspectives automatically become important. But this is not the only way perspectives have entered physics: it has been proposed that perspectives are even essential in more traditional views, according to which physical theories are not merely tools but provide objective descriptions of the world, quite independently of the presence of observers or human agents.

3. Perspectives in physics

The view that physical theories are merely instruments is exemplified by QBism, a recent interpretation of quantum mechanics. According to QBism it is not the aim of quantum mechanics (or even of physics in general) to provide a true representation of the external world. Rather, the states that are assigned to physical systems, the mechanisms that are judged to apply, and the predictions that are made are all taken to represent beliefs of agents using the theory. Accordingly, all quantum descriptions and predictions become relative to human users. That human time becomes primary is one of the consequences.

A core motivation for this "subjectivist" position is the wish to create room for the possibility that different agents adopt completely different beliefs about situations in the physical world. A divergence of subjective points of view is of course nothing unusual. But in quantum mechanics there are reasons to think that there are perspectival differences that should be recognized even if one does not subscribe to QBism and its subjectivity. This motivation for perspectivalism is illustrated by situations of the "Wigner's Friend" type.

In Wigner's Friend scenarios an experimenter in a hermetically sealed laboratory (the "Friend") successfully performs a measurement and finds one definite result. However, an external observer ("Wigner"), who cannot receive information from within the laboratory, is licensed by quantum mechanics to describe the lab and its contents with a "superposition" state, in which all possible internal measurement results are represented and in which his friend's actual result is not privileged. This superposition of all possibilities is different from what common sense would lead us to expect, namely a state of ignorance about the actual internal outcome. The quantum superposition corresponds to a situation in which there *is* no definite outcome inside. The outside observer can verify, experimentally, that his external view involving a superposition is correct; but this view does not dovetail with the internal description, which can also be verified by experiments, but this time *within* the sealed laboratory. Cases like this suggest a perspectivalism in which different agents arrive at descriptions that do not fit together but are equally valid from their own points of view.

Despite this formulation in terms of observers who perform experiments, the perspectivalism under discussion is meant to have an objective meaning. One may replace Wigner and his friend by inanimate measuring devices, or information processing systems in the sense of IGUSs. One may even go further, and think of elementary physical systems that do not possess the internal IGUS information processing capabilities. This leads to the idea that physical properties quite generally are perspectival, in the sense of being defined only as relative to other physical systems.

This proposal goes back at least to Everett's "relative state interpretation" of quantum mechanics and was later developed by others (Everett, 1957; Rovelli, 1996; Laudisa and Rovelli, 2013; Dieks, 2022). Accordingly, properties of physical systems have the logical status of relations rather than of monadic properties. It is not only that the *values* of physical quantities may vary depending on the reference system from which they are judged—that would be unremarkable, familiar as it is from classical physics and daily life. In quantum mechanics a much stronger perspectivalism manifests itself, according to which it may be perspective-dependent *which* quantities possess definite values at all. Thus, in the Wigner's Friend situation the quantity internally measured has a definite value, after

the measurement, for the friend but not for Wigner who is outside the lab.

4. Discussion

The relevance of all this for the comparison of physical and human time is that most ingredients of human time may already be present on the most fundamental physical level. For the IGUS-Now and its dynamism it was crucial that the connections to the outside world did not remain constant over specious presents. Something very much like this occurs quite generally in the physical world, regardless of whether the systems involved are complicated enough to mimic the functioning of IGUSs, with their registers. Physical information transfer requires interactions and transformations, in a process that takes a certain time—it is not possible to have an impact on a physical system in a literally size-less point-event. Processes of change require a "physical specious present" of finite extent.

As we have indicated, quantum mechanics gives us reasons to think that the information received by a physical system has a relational character: it is specific to the system's perspective, and in this sense not shareable. It is seductive to see here at least an analogy to the private character of human qualia, and in particular to the subjective experience of time flow.

The differences between human time and physical time may therefore be even smaller than argued by Gruber, Block and Montemayor, Bonomano and Rovelli, and others. It is true, evidently, that elementary particles do not have an internal representation of time flow as humans have. For that, a more complicated architecture like that of the IGUSs with their registers seems necessary. But temporal relations with the same structure as those determining experiential time seem to be present even on the level of fundamental physical systems.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Acknowledgments

I thank Ronald Gruber for his invitation to participate in this Reseach Topic.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Psychology

TYPE Opinion
PUBLISHED 26 July 2023
DOI 10.3389/fpsyg.2022.1082844

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 28 October 2022
ACCEPTED 30 December 2022
PUBLISHED 26 July 2023

CITATION
Latham AJ and Holcombe A (2023) What do VR experiments teach us about time?
Front. Psychol. 13:1082844.
doi: 10.3389/fpsyg.2022.1082844

What do VR experiments teach us about time?

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KEYWORDS

virtual reality, temporal experience, IGUS, temporal passage, time

Gruber and Smith (2019) have conducted some interesting virtual reality (VR) experiments, but we think that these experiments fail to illuminate why people think that the present is special. Their experiments attempted to test a suggestion by Hartle (2005) that with VR one might construct scenarios in which people experience the *same present twice*. If that's possible, then it could give us a reason to think that when we experience the present as being special, that's not because it's *objectively* so. Instead, our experience of the present being special is a feature of having a psychology like ours. While we are sympathetic to the thought that there is no objective present, we do not think that these experiments give us a reason to think this. That said, VR experiments, such as Gruber and Smith's, hold much promise for being able to illuminate various aspects of our temporal psychology.

According to Hartle's (2005) IGUS model (which is meant to resemble entities like us) sensory information is routed to two kinds of processes: conscious processes *C*, which cause behavior, and unconscious processes, *U*, which construct a schematic representation of the environment. Hartle proposed that we experience the present as being special because of the sensory information at each time entering into *C*. For Gruber et al. (2020), the succession of sensory information entering into *C* underpins our experience of time passing. Our experience of time passing is *illusory* because it fails to be veridical with how things are physically in the world (according to leading theories in physics, there is no change in physical time. See Buonomano and Rovelli, forthcoming for an accessible discussion). We have a genuine experience of time passing but time itself does not physically pass.

Alternatively, it could be that we do not experience time passing at all, rather people who claim to have an experience of time passing have false beliefs about their experience (Miller et al., 2020). We don't think that the illusion vs. false-belief debate is critical here; on either account, it would be interesting if people's claims about their experiences change while participating in Gruber and Smith's (2019) VR experiments.

Based on his IGUS model, Hartle (2005) suggested that if people are induced to sensorily process information concurrently from both the present sensory feed and a feed from the recent past, then their experience of the present would change. More specifically, Gruber et al. thought that in this scenario, people might experience the *same present twice*. With sensory information from the past routed back into *C*, the thought is that we might be able to experience that information as being the present again. In their experiments (Gruber and Smith, 2019), participants wore VR goggles and shifted their gaze around a scene of someone arranging three rows of dominoes. Participants were encouraged to press a button and were informed that pressing it would change what they were seeing from the present feed to a past feed. When we say *present feed*, we just mean that they receive sensory information *via* the VR system regarding how things are currently around them, whereas *past feed* means that they receive delayed sensory information *via* the VR system. For example, the participant can switch from watching the present feed of the experimenter laying out a third row of dominoes to the past feed and see the second row of dominoes being laid out again.

After the virtual reality session, participants were asked two probe questions. The first was: "seeing the second row of dominoes again was just as real as the first time."

The second probe was: "during the VR replay of the second row of dominoes it seemed like I was 'there.'" All participants (though how many participants were tested was not reported by Gruber et al.; we implore all future researchers to report the details of their testing protocols, participants, and results) responded affirmatively to both probe questions and Gruber et al. took this to mean that participants experienced the past snapshot as being present again. That is, Gruber et al. think that participants experienced both sensory feeds, the present feed and the past feed, as having equal status as being the present. If that's right, it gives us a reason to think that our experience of the present being special is *not* because of anything objective about time. After all, if participants' experience of the present being special was tracking an objective feature of time, then people should only experience at most one of these sensory feeds as being the present.

However, there is an alternative and more straightforward explanation of participant's responses to these probe questions. Participants in this experiment chose which feed is fed into *C*, and recognize the past feed shows events that they have already experienced before. We think that they conceptualize the past feed as a recording (which it in fact is), so what they experience as the present is them viewing a recording. This is a bit like when a person recalls a past event—rather than thinking that they are experiencing the past event as being present again, what they experience as the present is the recalling of a memory of a past event. We think the participants' responses to the probe questions are consistent with this explanation.

Participants agreed with the statement that events in the past feed appeared as real as the first time, and that it felt like they were there. This is meant to be evidence that people don't just experience events as being present when they are viewed in the present feed but also when they are viewed in the past feed. But when participants responded that things in the past feed seemed just as real as when they were in the present feed, this doesn't require that they experienced the event of seeing the second row of dominoes as being present twice. We can imagine someone who recalls a vivid memory of an event responding that the event in their mind seems just as real as when it occurred. All this tells us is that the VR environment is rich and immersive, not that people are experiencing events in the present and past feed as having equal status as an objective present.

Gruber et al. say that they didn't ask people if they felt they were "in the past" because no participant has ever been in the past; but this seems to be what we want to know! Knowing whether participants experience the same event as being the present twice requires knowing whether participants experience past events being present again. Of course, we are sympathetic to the thought that probing this directly would be problematic. Participant responses will no doubt be influenced by their knowledge that things are not that way, making people reluctant to report that they seem that way too.

An additional problem is raised by some of our own work on judgments about time—people have difficulty grasping different models of time and their implications. Sometimes over half a sample has to be dropped due to comprehension failures (e.g., Everett et al., forthcoming). As a general principle, caution is warranted when interpreting participant reports.

Perhaps future studies could coach people. Once it is explained that we can have genuine experiences of things being a certain way that are not veridical with how things are (such as experiencing a past event again as present), then affirmative responses might be more interpretable. The unsolicited responses by participants reported by Gruber and Smith (2019) suggest this could be a fruitful endeavor, but at present they too might be explained away due to comprehension failures. Take, for example, the moving-spotlight model of time (e.g., Cameron, 2015). According to this model, while past, present, and future times all exist, one time is "illuminated" as the objective present and which time is illuminated changes. To genuinely experience a time as being the present twice would require that a time be illuminated as the objective present twice. But likely no one thinks anything like this is occurring in these experiments (even if it's consistent with what participants report). The only reason that participants recognize they are experiencing something like the same event twice is because when they experience the event the first time, it was incorporated into their schematic representation of how things are/were! But, this also means that these reports are consistent with A-theoretic models of time, according to which there is an objective present.

To bring out this line of thought further consider a different set of critical probe questions. We wonder what people believe their action affordances are while viewing the present feed and past feed. Imagine that you are in the VR experiment and while in the present feed you watch the experimenter as they lay out a third row of dominoes. Now imagine switching to the past feed, does it seem open to you that you can stop the experimenter laying out the third row of dominoes? The motivating thought here is that if people are experiencing the past feed as the present, then affordances for action that were apparent when the event was in the present feed should be similarly apparent again (although this depends somewhat on what one thinks counts as experiencing as the present). But as we have already noted, that seems unlikely. When you experience the experimenter laying out the third row of dominoes in the present feed, you update your schematic representation of the world such that there is now a third row of dominoes. Switching to the past feed does not undo this.

This thought is entirely consistent with Hartle's IGUS model. Our experience of the present is not just a function of the current sensory information being taken from the world but also our schematic representation of the world constructed from past sensory information. When the past feed is being fed into *C* it has already been incorporated into the schematic representation of the world. Thus, our present experience (or at least how it seems to us), while being similar to when the event was experienced for the first time, is nevertheless quite different from it. The consequences of the event in memory are already part of your schematic representation of the world and so the affordances that were present when the event was first experienced are also not the same. For example, if the experimenter knocks over the third row of dominoes in the present feed and then I switch to the past feed, I don't then think that I have an affordance to knock over the dominoes. My schematic representation of the world already represents things such that the affordance to knock over the dominoes is not available.

In summary, we suspect that when participants switch to the past feed, they experience it as the recording that it is, rather than as an objective present. We do not think that VR experiments are well placed to answer questions about

the nature of time itself (see also Buonomano and Rovelli, forthcoming). However, we do think that they provide a powerful means of probing our temporal psychology. Immersive VR experiments could be used to adjudicate between different accounts of the mechanisms and processes responsible for our temporal beliefs and experiences, including what could cause people to make erroneous statements about their own temporal phenomenology.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 31 July 2023
DOI 10.3389/fpsyg.2023.1095221

OPEN ACCESS

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RECEIVED 10 November 2022
ACCEPTED 26 May 2023
PUBLISHED 31 July 2023

CITATION
Wittmann M (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1095221. doi: 10.3389/fpsyg.2023.1095221

Commentary: Physical time within human time

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KEYWORDS

time perception, passage of time, present moment, neurological, philosophical

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). Front. Psychol. 13:718505. doi: 10.3389/fpsyg.2022.718505

Phenomenal consciousness can be viewed as an island of presence (what is happening right now) in the continuous flow of events over time (Metzinger, 2004). This phenomenal characterization encompasses two complementary elements, namely the experience of presence and the sense of dynamic flow. In their dualistic notion of manifest time, Gruber et al. (2022) questioned the verity of these two experiences and concluded that they are illusory, i.e., there is no unique (moving) present, and the dynamic flow of time is rather the existence of a series of discrete snapshots instead of the smooth motions we perceive.

In this study, I will briefly discuss two issues brought up by the authors regarding (1) the illusory nature of the present moment and (2) the illusory nature of the flow. I maintain that we must talk about the veracity of a unique present moment as well as the biological functionality regarding the perception of the dynamic passage of events. Phillips (2014) argued that the temporal structure of experience mirrors the temporal structure of the world. Events in the world unfold in time, and experience mirrors this temporal passage within an extended subjective present (Dorato and Wittmann, 2020).

The concept of the illusory nature of the present moment

The authors present Hartle's information gathering and utilization system (IGUS) and provide empirical evidence for the theory that an IGUS robot could experience different present times if a split visual screen conveyed both a present event and simultaneously a recent past event. This system would enable the robot to experience the same present twice, which would defy the notion of a unique present. The authors discuss subjects' reports when wearing virtual reality (VR) headsets projecting split screens. Participants in their study claimed to experience a previously presented event (the same event presented twice) "just as real as the first time," and they felt like they were experiencing "being there," allegedly an experience of presence.

I want to make a distinction between the subject and the object of perception. The perceived object was first projected to split screen 1 and then to split screen 2 (two events in sequential order). The viewer first perceived object-event x on split screen 1 (as present) and

then on split screen 2 (again as present). The object appeared twice on the two screens, but sequentially, within a unique (moving) present. Object-event x appeared to occur in a unique present in both split screens, a unique present at t_1 and a unique present at t_2; only the event as object changed its temporal–spatial position, as at t_2 the subject was aware (knew from short-term memory) that the object in split screen 2 had just been shown in split screen 1 at t_1. The viewer experienced the same event twice sequentially but in a unique subjective single (sliding) present. When subjects were allowed to switch back and forth between "past" and "present" screens by pressing a button, they perceived the event as subjectively present in the past screen and, when changing to the present screen, also perceived it as in the subjective present, the moving (sliding) present[1]. Importantly, with this notion of the present moment, I do not imply an "objective present moment" as theorized in physics. I am referring to the subjective sense of the present moment, the experience of nowness.

The concept of the illusory nature of time passage

The authors distinguish between an "illusory change" and a "non-illusory" (completed) change. The first experience relates to events actually happening (dynamic change); the second relates to not having seen the change actually happen. The latter experience was only deduced after a completed change had occurred. While the first experience relates to our everyday, apparent experience, such as a car driving past quickly or a ball being thrown, the second experience is mainly derived from experimental results. Systematic manipulation of dynamically changing or moving stimuli interspersed by different durations of blank inter-stimulus intervals creates subjects' impressions ranging from experiencing dynamic changes (shorter blanks) to not seeing changes actually happening (longer blanks). The former experience represents illusory change; the latter is termed "real" change without the dynamic happening in between. According to the physical notion of a "frozen" block universe or the B-series philosophical model, only the perception of completed change in the order of events is considered real. Perceived dynamic change is merely a perceptual addition, subjectively "painted on" the frames of underlying slow, discrete processing mechanisms underlying the real change in events.

What I contradict is the authors' concept that the apparent dynamic motion of change simply augments experience and has no functional use, that these additions "do not necessarily provide significant information for the observer other than to indicate [. . .] that there are multiple events of unspecified type in between two temporally adjacent stimuli" (Gruber et al., 2022; p. 6). The question is whether an experience governed by neural processes should have some important biological and psychological function. Why has the perception of apparent happening (as dynamically experienced) developed when "real change" is functionally sufficient? The authors claim that certain patients with brain damage have problems perceiving apparent motion but are otherwise not functionally impaired and still receive all essential information.

Individual neurological cases exist in which perceived movement breaks down and patients are functionally affected. One patient with posterior brain damage after an ischemic cerebral infarct was unable to detect continuous visual movement and change (Zihl et al., 1983). Gruber et al. (2022) maintained that the patient had probably lost her ability to perceive apparent motion but still perceived real motion. For example, she had problems properly pouring coffee into a cup because she could not perceive the steady rise of liquid in the cup. She could consequently not find the right moment to stop pouring the coffee. She also reported problems crossing a street with ongoing traffic: "When I'm looking at the car first, it seems far away. But then, when I want to cross the road, suddenly the car is very near" (Zihl et al., 1983; p. 315). This description approximates the notion of real time described by Gruber et al. because it seems as if the patient perceived a series of stills at disparate time points without anything happening in between, thus lacking the impression of a smooth flow of events. This patient reported a severe functional impairment. Such extreme cases are rare. A variety of subjective time distortions has been collected in patients with brain damage of different etiologies which confirm that disruptions in the perception of time passage can create massive functional problems (Blom et al., 2021). The perception of the dynamic happening of events seems to be a prerequisite for proper functioning.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

1 A remark on these theoretical deliberations: virtual reality (VR) is a powerful tool to test and alter experience. Anyone who comments theoretically on the article by Gruber et al. (2022) ideally should have had the experience with the VR headset.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 03 August 2023
DOI 10.3389/fpsyg.2023.1085761

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 31 October 2022
ACCEPTED 27 February 2023
PUBLISHED 03 August 2023

CITATION
Dainton B (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1085761. doi: 10.3389/fpsyg.2023.1085761

Commentary: Physical time within human time

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KEYWORDS

time-consciousness, specious present, externalism, presentism, snapshot, stream of consciousness

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Time and illusion

For Callender the two times problem is more serious than the problem posed by Eddington's two tables. The two tables do appear very different: the solid colored object that we can see and doesn't seem to be mostly empty space. However, in this case we have the beginnings of a plausible story about how the manifest table emerges from its basic ingredients, but we don't have this in the case of time. Our everyday experience suggests that the present is special and very different from the past and future. If we take physics as our guide none of the ingredients of manifest time are to be found in real time: "our best science of time suggests that manifest time is more or less rubbish" (Callender, 2017, p. 2).

Callender finds the size of the gap between manifest time and physics-based time disturbing, and sets himself the goal of establishing that it's at least *intelligible* that manifest time could emerge if the physics-inspired model of time is correct. His project is one of de-mystification. In their "Physical Time Within Human Time" Gruber, Block, and Montemayor (GBM) find a lot to like in Callender's project, but adopt a somewhat different goal (see Gruber et al., 2022). Their dualistic approach seeks to isolate those aspects of experience which correspond to real features of reality and those illusory aspects which don't. By showing that some aspects of manifest time are *not* illusory they hope to console.

About one thing GBM are under no illusions: the complexity and difficulty of their project. Some of these difficulties derive from ongoing disagreements about the nature of temporal experience, but others derive from physics, where there the nature of time continues to be hotly debated. In a recent paper (Gruber et al., 2020) the same authors heroically considered a total of 10 different spacetime cosmologies, many of them providing very different conceptions of time. Unfortunately Callender's "best science of time" is still a long way from having a settled story on what time really is.

The project of Buonomano and Rovelli in "Bridging the Neuroscience and Physics of Time" is different again (Buonomano and Rovelli, 2021). They suggest that a necessary first step is to acknowledge that temporality is multifaceted and has a number of different aspects. After outlining some of the more important they propose a division of labor, with some problems going to physics for solutions and the remainder to neuroscience. Physics has the job of discovering "the general temporal structure of the world" along with additional

temporal features that become relevant at biological scales. Neuroscience has the task of explaining all the other features, such as the apparent difference between past and future, the (seemingly) special role of the present, memory and why time seems to flow.

Which science?

Buonomano and Rovelli agree on a good deal but they also disagree on one big issue: the nature of time, with Rovelli leaning strongly to the eternalist view that past, present, and future are all equally real, and Buonomano finding local presentism more plausible—on this view reality is confined to the here and now, and the past and future don't exist. Since I see the appeal of each of these positions I see nothing to criticize here. However, presentism and eternalism are surely contrasting positions on the *general temporal structure of the world*. Given this, I wondered whether they fully share the view that discovering the temporal structure of reality is solely the task of physics. The appeal of presentism is rooted in those features of our everyday experience which can make it seem *just obvious* that we live out our lives in a brief window of presence that is a steadily advancing, and that present things are real in a way that other things are not. Presentists are (typically) prepared to give primacy to features of the manifest world—even if this means rejecting what physics has to say. I suspect Buonomano is similarly motivated.

Buonomano has further reasons for finding eternalism problematic. These reasons are in fact scientific, but the relevant sciences are evolutionary biology and neuroscience. From an evolutionary perspective it would be odd if our feeling that time is dynamic lacks any survival value. But this would be the case if the eternalists are right and our experience of flow is illusory. Buonomano also suggests that much of the appeal of eternalism derives from peculiarities of the human brain that science has revealed. Like Bergson before him, Buonomano holds that our innate preference for spatial modes of thinking may well be misleading us about the nature of reality. More specifically, this spatializing tendency makes the four-dimensional conception of time more appealing that it would otherwise be.[1]

The Buonomano-Rovelli exchange serves as a useful reminder that while physics has an important role to play, when it comes to understanding time physics is not the only science that matters.

Streams and structures

These debates aren't confined to the sciences: philosophers have also long been engaged in debates concerning the nature of time and temporal experience. For better or worse, they are as far from reaching agreement on these topics as the physicists. Much of my own work in this area has been focused on temporal experience and the structure of our streams of consciousness. GBM make some claims about these topics which struck me as questionable.

Our sense that time is something that flows has several components, but a centrally important one is the experiential (or specious) present, that brief experienced interval during which we directly apprehend change and persistence. It's here that consciousness is at its most vividly dynamic. On the view I find most plausible the experiential present is a single experience whose successive parts are experientially unified, and which extends through ordinary physical time in much the way it seems to. How much time? It's not easy to be precise, but not much: a single second, probably less. Smolin and Varde concur: "The moments of awareness seem to define a thick present. There is also a duration of each experienced moment in time of about 0.5 of a second" (Smolin and Verde, 2021, §5).

Drawing on Pöppel's work GBM suggest that the duration of the experienced present is significantly longer than this: 3 s or so. If we take the experienced present to be a single unified episode of experience this strikes me as implausible. The main reason for this is simple: my own direct experiences of change simply don't seem to last anything like that long. If I clap my hands three times, at roughly one clap per second, by the time I hear the third clap I am no longer experiencing the first.[2]

There is a further important element of our ordinary temporal experience: *continuity*. If I listen to a succession of brief notes each note has its own short duration and each note is experienced as giving way to the next. In the case of the sequence (C-D-E), I hear (C-followed-by-D) and (D-followed-by-E). Here too there is a simple and plausible way of making sense of this: successive experiential presents *partially overlap*. Accordingly, in our current example we have two experiential presents (C-D) and (D-E), where the D-note in the first is numerically identical with the D-note in the second. This form of continuity is not confined to the auditory sphere, it is—I argue—found throughout our streams of consciousness. I have defended this "extensional" view of temporal experience on a number of occasions—see Dainton (2000, 2008, 2016, 2017), and in differing guises it has found favor with others, see Hoerl (2009), Rashbrook (2013), Phillips (2014), Piper (2019), and Dorato and Wittmann (2020).

Snapshots or streams?

In their closing section on possible tests for their model GBM venture that "the dualistic view predicts an existence of a discrete (snapshot) perception in the absence of the specious present." Defenders of the snapshot (or cinematic) view hold that our streams of consciousness consist of successions of momentary experiential phases that possess static motion-free contents, and that are also entirely distinct from one another. They deny that we directly experience change, and hence deny that specious or experiential presents—at least in the extensional guise of just outlined. I think GBM should pause and reconsider before embracing this view.

While it has some defenders, in the recent philosophical debates the snapshot theory is also widely seen as problematic. This is

1 This topic is explored in more detail in Buanomano (2017, chapter 10).

2 There's evidence of a different sort: in a recent comprehensive survey of relevant empirical work (White, 2017) finds little evidence to support the three seconds proposal, stating in his conclusion: "There is no three-second subjective present or experienced moment. There is, instead, an envelope of integration in which there are multiple qualitatively different representations of what is going on, each occupying different and variable time scales of integration…".

largely because (a) since our consciousness seems continuous and we do seem to experience change it is phenomenologically suspect, and (b) doubts about the empirical evidence cited in its favor. In this connection GBM mention the wagon-wheel illusion; but—as they acknowledge—there are competing interpretations which point in a different direction. They also point to Arstila's (2018) defense of a dynamic snapshot model. Arstila has suggested that snapshot theorists can appeal to the waterfall illusion order to explain how durationless experiences can seem dynamic without really being so. However, this move has itself come under sustained critical fire recently: Shardlow (2019) and McKenna (2020) find it flawed on several grounds.

If the snapshot view is problematic it is regrettable that something like it has been widely assumed in much scientific work on consciousness.[3] Northoff and Lamme (2020) review eight of the main neuroscientific theories of consciousness: global neuronal workspace theory (GNWT), predictive coding theory (PCT), embodied theory (EB), temporospatial theory of consciousness (TTC), integrated information theory (IIT), recurrent processing theory (RPT), synchrony theory (ST), and higher-order thought theory (HOT). Drawing on this Kent and Wittmann (2021) argue that nearly all of these theories have thus far assumed that our temporal experience is confined to isolated brief 100–300 ms phases duration. As a result these theories have all confined themselves (in effect) to experienced momentary *simultaneity*, they have nothing to say about experienced *succession*, and so all are fatally flawed. In a similar vein Singhal et al. (2022) criticize IIT for failing to recognize that unity of consciousness extends through time and they recommend an addition to IITs existing axioms: "experience always occurs to us as a temporal whole, i.e., experience always has an extension, is continuous and has an inherent direction that is asymmetric" (Singhal et al., 2022, p. 14). I couldn't have put it better myself—though we should also remember that we need an account of how these individual experiential presents combine to form streams of consciousness.

A final quick thought. On one issue Buonomano and Rovelli are in full agreement with one another: if a time traveler from the future were to arrive we could be certain that the eternalist conception of time is correct. You can't arrive from a location that doesn't exist, and presentists hold that the past and future don't exist. For better or worse, as things currently stand time travelers are confined to the realm of fiction. But there might be empirical evidence of a different sort that's relevant to the debate between presentists and eternalists.

Just as it is likely that there will always be some people who give primacy to their everyday experience of temporality when deciding on the view of time that is most plausible, there are also people who adopt the same policy when it comes to the nature of perception. Since the days of Galileo the scientifically respectable view has been that when you look at a red apple sitting on the table in front of you the resulting perceptual experience is some kind of brain-generated inner mental representation, and the redness resides not on the apple's surface but in your consciousness. But it certainly doesn't seem that way: it seems (very much) as though I am directly aware of *the apple itself*. For proponents of the "direct (or naive) realist" account of perception Galileo was wrong, and seeing works in the way it seems: colors really are outside in the world, rather than in our heads. Among contemporary philosophers of perception direct realism is certainly not the dominant view—see Crane and French (2021) for an overview—but it still has its defenders.

One objection to direct realism runs along these lines. We only see distant objects when light emitted by them reaches our eyes. In the case of distant stars or galaxies, the relevant light may have been traveling thousands or millions of years. Isn't it absurd to think we could be directly aware of an event in the distant past or an object which no longer exists? Direct realists do not take this to be an insuperable problem. As A. J. Ayer noted, this objection presupposes that we can only see what is present, but perhaps this assumption is wrong: "Why should it not be admitted that our eyes can range into the past, if all that is meant by this is that the time at which we see things may be later than the time when they are in the states in which we see them? And having admitted this, then should we also not admit that it is possible to see things which no longer exist?" (Ayer, 1982, p. 94–95). For a more recent defense of this position with regard to the perception of the past see Manzotti (2017 chapter 7, 2019).

If the direct realists are right and we are directly aware of past events then it can scarcely be denied that these past events are real. If the past is real then presentism is false. Moreover, presentism has been falsified by ordinary perceptual experience rather than the arrival of a time traveler. Of course, you may not find the direct realist view of perception an appealing one. But it's still of some interest to find out that two important ingredients of the manifest world—presentism and direct realism—are not compatible with one another.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

3 Widely but not universally—see Northoff (2016) and Piper (2019) for neuroscientific approaches that reject the snapshot view and focus on temporally extended neural processes that are compatible with extensionalism.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 14 August 2023
DOI 10.3389/fpsyg.2023.1084495

OPEN ACCESS

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RECEIVED 30 October 2022
ACCEPTED 10 March 2023
PUBLISHED 14 August 2023

CITATION
Balashov Y (2023) Commentary: Physical time within human time. *Front. Psychol.* 14:1084495. doi: 10.3389/fpsyg.2023.1084495

Commentary: Physical time within human time

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KEYWORDS

present, temporal experience, persistence, endurance, perdurance, exdurance, stage theory, fission

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Introduction

Gruber et al. (2022) and Buonomano and Rovelli (2023) contribute complementary perspectives to the flourishing debate about the experience of time, currently conducted at the interface of physics, philosophy, psychology, neuroscience, decision theory, linguistics, and other areas. The goal was to connect three vertices of a challenging triangle: the manifest image of time as reflected in common experience, the neuroscientific image of time, and the physical concept of time, which was initially hostile to both. Reconciliation is sorely needed but difficult to achieve.

Part of the problem lies in the substantive disagreement about what temporal experience involves in the first place (Skow, 2015; Prosser, 2016; Callender, 2017; Phillips, 2017; Sullivan, 2018; Sattig, 2019; Miller and Wang, 2022). At some approximation, which appears to be adopted by Gruber et al. and Buonomano and Rovelli, there are three core aspects to our manifest image of time: (i) the notion of a unique objective present (the "time of our lives"), (ii) the perception of time flow, and (iii) an asymmetry between the past and future directions of time: We think of the past as fixed and of the future as open, and we have memories of the former but not of the latter. All of that is difficult to square with the physics of time, which, in Callender's words, "suggests that manifest time is more or less rubbish" (Callender, 2017, p. 2). Quite apart from that, the notions of "experiencing the present" and "time flow" have proven to be singularly elusive and resistant to precise definition, which, of course, makes the problem philosophically interesting.

In the following section, I have attempted to focus on a particular aspect of the experience of the present which, in my view, has received insufficient attention.

Time and persistence

Gruber et al. (2022) and Buonomano and Rovelli (2023) (and many other participants in the debate) share the view known as the "Block Universe," according to which different times and their contents are similar to different places and their contents—all equally real; indeed, one way to think of times is to identify them with special regions of spacetime (e.g., achronal Cauchy surfaces), but many of those who subscribe to this view tend to believe that objects

persist over time by *enduring*—by being "wholly present" (or "multilocated")—at many instantaneous spacetime regions. Denying this latter claim does not amount to denying *persistence* altogether [here, I disagree with Gruber et al. (2022) and side with Miller and Wang (2022)]. It does add more to the analogy between time and space: Objects may persist through time much like rivers persist through space, by having distinct parts at different times. This mode of persistence, known as perdurance, is favored by some philosophers (e.g., Lewis, 1986; Heller, 1990) and, according to recent empirical research (Baron et al., 2022), may not be so foreign to common sense as previously believed. But there is a third view of persistence, known as stage theory, on which, rather than having distinct temporal parts or stages at different times, ordinary objects are stages (Hawley, 2001; Sider, 2001). They can still be said to persist by *exduring*—by having temporal *counterparts* at other times—by analogy with modal counterparts inhabiting disconnected regions of the Lewisian "pluriverse" (Lewis, 1986). This official statement of stage theory is also Block Universe-friendly but may be much less intuitive. The best arguments in its favor involve rather abstract philosophical conundrums of material coincidence and vagueness (Sider, 2001), but I contend that it can also be supported by reflection on a central feature of our temporal experience (Hoy, 1978; Torre, 2010; Parsons, 2015; Skow, 2015; Balashov, 2017), especially when this is followed by a leap of imagination inspired by influential thought experiments (Parfit, 1971, 1984, 2008).

Time and fission

In his groundbreaking work, Parfit (1971, 1984, 2008) invites the readers to join him in exploring the moral and metaphysical implications of a *fission* scenario in which a person, Ed, is physically and/or psychologically continuous with two future persons, Ted and Fred. Assuming the process goes smoothly (imagine Ed performing a mental operation of adding 47 and 38 just before the fission, and Ted and Fred both saying "85" immediately thereafter), we can suppose Ted to be happy and Fred to be sad (any pair of incompatible mental states will do). Suppose further that Ted says he is happy, and Fred says that he is sad. Each of them is unaware of what the other is feeling and saying. Putting ourselves in Ed's shoes, can we say that he *will be* happy or sad? More fundamentally, can we say of Ed that he is identical (across time) with Ted, Fred, or both? We can assume that Ed's relations to Ted and to Fred have "all the matters" for survival (i.e., physical and/or psychological continuity) and are, in that respect, on a par. This suggests that if Ed is identical with Ted, he is also identical with Fred, but one entity cannot be identical with two. The only alternative is to say that Ed is identical with neither of them. Much of Parfit's work can be read as denying a substantive difference between these two alternatives. If Ed's relation to both future persons has everything that matters, it is as good as it can get and may be sufficient for survival.

While Parfit's focus was on the philosophical implications of fission, he was aware that his scenario involves not only the *personal* and *spatial* dimensions of "self-location" (Ed may be wondering *who he is* after fission, Ted or Fred; relatedly, he may be wondering *where he is*) but also a temporal dimension (Ed may be wondering *when it is*). This becomes clear from Parfit's extended discussion of our attitudes toward future persons—ourselves as well as our relatives and friends, with no clear boundaries between them. This leads Parfit to the metaphysics of the self "scattered" or "fragmented" across all three dimensions: spatial, personal, and temporal, which, in turn, may have a distant similarity with Gruber et al.'s notion of the "impermanent" or "ephemeral" self (Gruber et al., 2022, p. 4f). I submit that it also offers a useful perspective on the stage theory of persistence: Just as Ed may be "split" between Ted and Fred (and their two spatial locations), he may be "split" among multiple temporal locations hosting his numerically distinct stages.

Time and self

Suppose Ed is sad on Friday and happy on Saturday and put yourself in his shoes. Next, situate this scenario in a Block Universe with *endurance*. This, I think, raises the problem of explaining Ed's *present experiences* and his beliefs about them: He is sad (let us assume) and believes it is Friday. The bottom arrow in Figure 1A represents his perspective on the Block Universe, tainted with sadness, but there are many other perspectives, including the happy one (the top arrow in Figure 1A, modeled after Figure 2 in Balashov, 2017), and nothing in the Block Universe favors one of them over another. What then explains Ed's belief that he is viewing the Block Universe exclusively from the Friday perspective filled with sadness, *rather than* exclusively from the Saturday perspective filled with happiness and joy? If Ed *endures*—if he is wholly present on Friday as well as Saturday—then nothing in the Block Universe allows his different temporal experiences to be "compartmentalized" the way they seem to be. To adapt Callender's (2017) term (he will disapprove this usage of it), the "ontic voltage" of the present experiences is too high for anyone to *endure*.

Suppose, in contrast, that Ed *exdures*—that, instead of the selfsame enduring Ed, there are multiple stages of him, each representing his perspective on the single Block Universe (Figure 1B, modeled after Figure 3 in Balashov, 2017). His Friday stage is sad and finds itself exclusively on Friday, thus giving Ed an illusory belief in the exclusive presence on Friday and his exclusive sadness, but the same can be said of his Saturday stage and the corresponding illusory belief that goes along with it. Importantly, in having the Friday belief and the corresponding experiences, Ed is *not aware* of having the Saturday belief and its attendant experiences. This is parallel to Parfit's reasoning about fission and its consequences. If the self is "scattered" across times in the same way it is scattered across places and persons, then the problem of the present experiences and the problem of the "split self" are resolved in the same way. As already noted, Parfit's work outlines the general shape of such a unified explanation; but it could, and should, be made more explicit.

This opening move is open to many objections, including the tendency to dismiss it as based on an obvious confusion between the tensed and tenseless uses of "view" and "feel," insufficient attention to the indexical nature of the phenomena described in this scenario, and more. I believe these objections can be addressed by further developing the scenario (Balashov, 2017). The problem of explaining the nature of the present

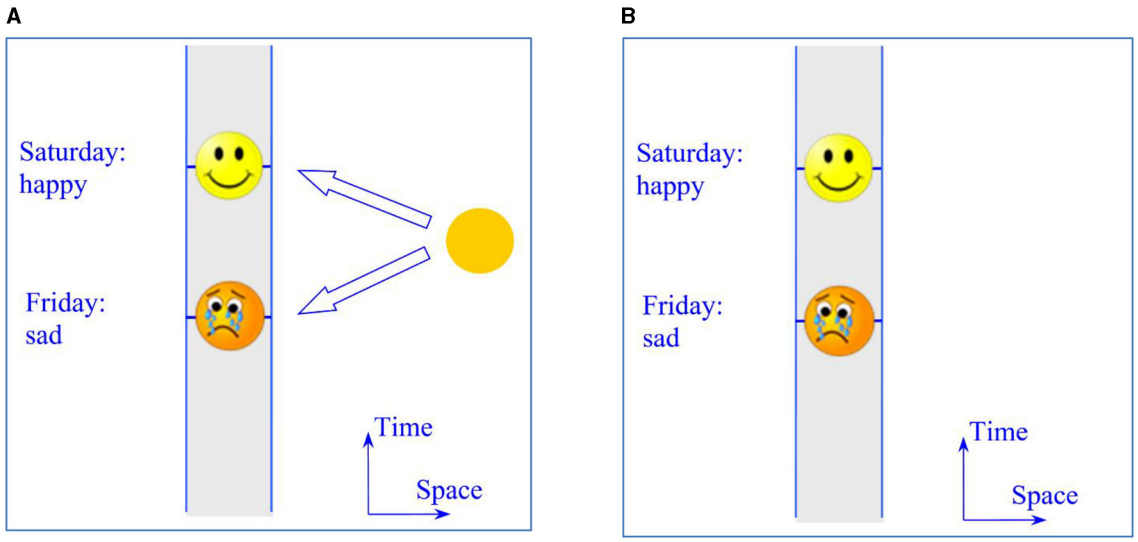

FIGURE 1
Ed's feelings in the Block Universe **(A)** with endurance and **(B)** with exdurance. The shaded regions represent Ed's path in spacetime.

experiences arises quite early in the process of reconciling the manifest image of time with its scientific image, and it appears to be relatively independent of the issues of time flow and time direction. It may be related to what Buonomano and Rovelli call "the special role of the present" and Gruber et al. discuss under the heading of "no unique present." In any case, the problem keeps coming back in various guises (Hoy, 1978; Parsons, 2015; Skow, 2015), which, I think, calls for more attention to it.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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frontiers | Frontiers in Psychology

TYPE General Commentary
PUBLISHED 23 August 2023
DOI 10.3389/fpsyg.2023.1123326

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Theoretical and Philosophical Psychology, a section of the journal Frontiers in Psychology

RECEIVED 13 December 2022
ACCEPTED 27 February 2023
PUBLISHED 23 August 2023

CITATION
Balcells M (2023) Commentary: Extracting robust passage from dynamic change. *Front. Psychol.* 14:1123326. doi: 10.3389/fpsyg.2023.1123326

Commentary: Extracting robust passage from dynamic change

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KEYWORDS

passage, special theory of relativity, illusory, persistence, motion, time

A Commentary on

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2021). arXiv. [preprint]. doi: 10.48550/arXiv.2110.01976

Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2021). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

The passage of time is known by us all too well. We praise it for healing past wounds, lament it for stealing away the warm spring of youth, and curse it for ushering us into the cold dusk of old age. Temporal passage is part of the fabric of our total temporal experience, which we may refer to as manifest time. However, the image of time utilized in science, in particular physics, seems much starker than the image given to us in experience. If we imagine spacetime in physics as being represented by a four-dimensional block containing all events—past, present, and future—then it is hard to see how such a model could adequately capture the passage or flow of time.

The project of reconciling the tension between these two images requires a multifaceted approach, one that attends not only to the nature of time, but to the nature of ourselves *in* time. Thus, there has been increasing dialogue on the matter between those working in philosophy of time, philosophy of mind, physics, psychology, neuroscience, linguistics, and cognitive science. Gruber et al.'s "*Physical time within human time*" (GBM) and Buonomano and Rovelli's "Bridging the neuroscience and physics of time" (BR) both provide insightful analyses from various disciplines that engage in the project of reconciling the two images (Buonomano and Rovelli, 2021; Gruber et al., 2021). The former does so by utilizing the IGUS[1] (information gathering and utilizing system) model of the human in time and outfitting it with dualistic components: one that perceives veridically and one that perceives illusorily. The latter does so by examining time as understood by physicists and neuroscientists and proposing a multi-layered understanding of time with the various and seemingly contradictory characteristics manifesting at different levels. Both projects attempt to resolve the tension, in part, by cordoning off those features of manifest time that are either absent from or incompatible with the image of time found in physics. Crucial to the project

1 This model of the human was first introduced by Hartle (2005) and later expanded upon by Ismael (2015, 2017) and Callender (2017).

of bridging the gap between scientific and manifest time is clarifying what exactly is described by the scientific image and what exactly the content of our perceptions is.

Below, I consider how a certain problematic conception of temporal passage, robust passage, often gets injected into our thinking about another less problematic aspect of the manifest image, namely dynamic change. I argue that while robust passage is indeed inconsistent with the scientific image of time, our experience of dynamic change is not. However, they appear in tension with one another because we tend to strip the scientific view of its dynamism and infuse our experiences of dynamic change with beliefs about robust passage.

Robust passage is typically unpacked as something like a unique, moving present that passes over events, bringing them into existence and extinguishing them into the past.[2] This is the typical target for those who deny the existence of temporal passage on scientific grounds. Einstein's Special Theory undermines the notion of absolute, frame-independent simultaneity and insofar as all events contained in the present occur at the same time, the existence of a unique present is likewise undermined (Putnam, 1967). Without an objectively special present, there is no sense in which the four-dimensional image of time in physics can house robust temporal passage. In fact, the scientific image of time not only lacks robust passage, but is hostile to it. Thus, any experience of robust passage would be illusory.[3]

GBM present a model of an IGUS containing dualistic systems; one veridical and one illusory. They identify three aspects of the manifest image to be incorporated into their model: "(1) a unique (moving) present, (2) dynamism of change/motion, and (3) directionality (temporality)" (GBM, p. 4). The first aspect seems, on the face of it, to be an expression of robust passage and, in fact, GBM point out that an experience of a moving present would be an illusion because of its absence from the scientific image (p. 4). However, GBM further claim that "[t]he actual 'moving present' is a dynamic illusory experience that is more related if not identical to the experience of "moving"—in other words "motion" (GBM, 4), effectively taking robust passage to be logically equivalent to dynamic motion. In doing so, they preemptively accept that an experience of dynamic change is necessarily illusory as expressed in one of the two principles for their dualistic approach: "[t]he phenomena of dynamism is an experimentally demonstrable illusory experience" (GBM, p. 3).

But, as pointed out by BR, the removal of robust passage from one's model of time does not leave it devoid of change and dynamism. Time itself need not change in order for the four-dimensional image of spacetime to properly represent dynamically changing objects. Time is not an object like bodies, or rivers. Time is the *arena* in which these things move, pass, and flow. To think that time's lack of movement thereby renders the four-dimensional spacetime static is "to imagine an additional external time variable" (BR, p. 4) against which we could judge the static or dynamic character of time. The scientific image of time need only utilize the at-at theory of motion (a term first coined by Russell based on Weirstrauss's development of Analysis in the 19th c.) which defines the motion of an object simply as being "*at* the appropriate point *at* the appropriate time" (Salmon, 1980, p. 137). However, if "[p]hysics is not the description of static entities [but] the description of processes" (BR, p. 4) and physics can adequately describe both static and dynamic processes, then what is the "experimentally demonstrable illusory experience" of dynamism to which GBM refer?

GBM claim that veridical experiences "are congruent with the views of modern spacetime cosmology" (GBM, p. 11) and it would follow that illusory experiences are incongruent with the scientific image or have "no basis in reality" (GBM p. 3). GBM, then, identify veridical and illusory experiences of change as follows: "completed change represents the 'change' in physics. A dynamic change simply augments that experience" (GBM, p. 6). Their distinction seems to be bound up with the phenomenon of apparent motion and its relation to the experience of real motion. A similar position is discussed by Paul (2010), who argues that because the experience of dynamic motion can be induced even when one is presented only with static images (e.g., the phi-phenomenon) the real motion that we experience in the presence of a continuously moving object is likewise illusory. According to this view, in both cases a kind of dynamism or animation is "painted on" the discrete states.

However, it is important to clarify what the discrete states are in these cases. Mather (2006) explains that the neural substrate for motion processing begins with photoreceptors which are spread across the retina and capable of detecting a change in illumination, for instance, when an object moves across the visual field and obscures or exposes background light, or when an illuminated dot appears and disappears. Paired together, these photoreceptors send discrete signals to a third comparator neuron. If received in the relevant way, the comparator neuron will output a signal that motion has occurred. While this form of motion processing deals with discrete bits of information about change in illumination, *what* that information is about is a change in the world, i.e., a dynamic process. GBM take the position that because the path from the world to the experience requires the brain to fill in some information, it is illusory: "[o]n the one hand "filling in" is illusory, on the other hand the brain guesses correctly" (GBM, p. 3).

However, it is not clear why, even in the case of the brain guessing correctly, we ought to consider the experience illusory. Deeming something to be illusory (or incongruent) only makes sense against an appropriate backdrop of veridicality (or congruence). In the case of apparent motion, it makes sense to say that there is incongruence between the world and the experience because the input involves distinct entities that are spatiotemporally discontinuous and yet we experience a single, continuously moving object. But making the further claim that our experience of dynamic, real motion is incongruent (even if not inconsistent) with the world requires one to treat the world as being composed of discrete, instantaneous events and further, that the collection of those events does not constitute a dynamic process. But if something being dynamic merely means that it changes over

2 This way of framing robust passage is often attributed to Broad (1923), in particular in his description of passage as representable as a policeman's spotlight passing over houses (read: events).

3 Some argue that even if there were robust passage in the world, it would not be the kind of thing that could be experienced directly because it is not the kind of thing that is causally efficacious. Thus, it would not cause in us a percept of passage (Price, 2011; Prosser, 2013).

time, then this can be described by physics. If it means something more, then it seems that robust passage is being snuck in. Hoerl refers to this position as *error theory*, which requires that "to get the phenomenology of perceptual experiences of movement and change right, we have to introduce the idea that such temporal experiences (at least sometimes) involve the seeming presentation of passage as … a mind-independent change all things in time are subjected to, which consists in their passing from the future, through the present, and into the past" (Hoerl, 2014, p. 2; see also Baron and Miller, 2015). What we have is a mistaken belief that the experience of dynamic change is an experience bound up with robust passage (a belief that stems, in part, from thinking that the way time passes must be akin to how objects change). Therefore, GBM's distinction between illusory and veridical perceptions of change places the mistake at the wrong level of cognition.

On a final note, GBM also consider the experience of dynamic change to be a "double illusion" because it falsely represents the flow of time *and* falsely represents an object as enduring *through* the change (see also Ismael, 2011; Prosser, 2018). They claim that "[p]hysical continuity is not in the cosmological scheme. Instead, what is expected by them is that events…be discrete" (GBM, p. 7). This assumes that all experiences of persistence (or physical continuity) are experiences of endurance, a view that requires the self-same individual to be present at each moment. However, endurance is only one of many philosophical views of persistence (Kurtz, 2006). The views of perdurantism and exdurantism, as well as some other forms of four-dimensionalism, are all perfectly consistent with the scientific image of time and do not require a more robust connection between temporal parts than spatiotemporal continuity which is, at least at some level, described by physics. Further, our experience of an object moving involves the utilization of an object file, "a midlevel visual representation that 'sticks' to a moving object over time on the basis of spatiotemporal properties and stores (and updates) information about that object's properties" (Noles et al., 2005, p. 325). It is not obvious that the object files represent endurance (a metaphysical view) rather than mere persistence. The more stripped-down version of persistence seems to be assumed even by GBM when they consider the experience of completed change veridical. After all, I experience the hour hand of the clock in a different position now than it was earlier because I represent *the same hour hand* at both times.

If the scientific image includes descriptions of dynamically changing objects, then we ought not think that our experiences of dynamically changing objects are incongruent with the world. Indeed, we may come to have the mistaken belief that those experiences are more robust than they are, but this is a cognitive mistake, not a perceptual one. Further, this mistaken belief taints the way we view the scientific image and causes us to treat it as more impoverished than it truly is. Thus, we should be mindful of what the scientific image expresses. And while there are certainly aspects of the manifest image of time that are in tension with the scientific image, we should treat our experience of dynamic change to be a case where we get things right.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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TYPE General Commentary
PUBLISHED 28 September 2023
DOI 10.3389/fpsyg.2023.1063327

OPEN ACCESS

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RECEIVED 06 October 2022
ACCEPTED 08 September 2023
PUBLISHED 28 September 2023

CITATION
Grondin S (2023) Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time".
Front. Psychol. 14:1063327.
doi: 10.3389/fpsyg.2023.1063327

Commentary: "Physical time within human time" and "Bridging the neuroscience and physics of time"

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KEYWORDS

time perception, psychophysics, psychological time, human times, Weber's law

A Commentary on
Physical time within human time

by Gruber, R. P., Block, R. A., and Montemayor, C. (2022). *Front. Psychol.* 13:718505. doi: 10.3389/fpsyg.2022.718505

Bridging the neuroscience and physics of time

by Buonomano, D., and Rovelli, C. (2022). Available online at: https://arxiv.org/pdf/2110.01976.pdf

Gruber et al. (2022) propose an interesting way of addressing the difficult, but fundamental problem of the nature of time. This problem is a long lasting one for physicists, mathematicians and psychologists or neuroscientists (see for example Buccheri et al., 2003; Buonomano and Rovelli, 2022). Gruber and collaborators propose an adaptation of the Information Gathering and Utilizing System (IGUS), acknowledging that both illusory and veridical times exist and guide behavior. This commentary will focus more on the part of the article of Gruber and collaborators devoted to the findings/concepts extracted from the literature in experimental psychology, which is more closely linked to the *global* (or even *local*) *presentism* position than to the *static eternalism* position that Buonomano and Rovelli describe.

1. About perception and psychophysics in general

A first impression that comes during the reading of the article of Gruber et al. is that fundamentally, what could be presented as opposing times, one inside and one outside the cranium, extends beyond the question of human time. Ultimately, a fundamental question that we have to face could be posited as follows: is there anything like a physical reality, and if there is, is it possible to capture it? Posited another way, and assuming there is such an objective world outside of us, one can ask to what extent we are prisoners of our sensory organs, limited in our representations of outer world and, consequently, in our representation of what time is or could be.

It is for capturing the links between material world and mental world that *psychophysics* was founded (Fechner, 1860). This field of research has provided methods to quantify the links between the physical world and the sensation we derive from it and which guides our representation of it. Fechner was interested in the relation between sensations and stimulus intensities (outer psychophysics) and the relation between sensations and brain

activity (inner psychophysics).[1] Outer psychophysics provides information mainly about the minimal energy needed to detect a stimulus, about the capability to discriminate stimuli, and about scaling, i.e., the assessment of the psychological value of stimuli as a function of their magnitude. The empirical work in psychophysics led to laws about the relationship between psychological (subjective/mental) world and physical (objective/material) world.

The question now is: can we use psychophysical information (methods and laws), developed to quantify and understand sensations, for addressing the problem of human time? Answering this question requires first to acknowledge some difficulties. Within such a perspective, what is the status of time? Should time be treated like a dimension or like a sense? If it's treated as a dimension, what is it the dimension of? Is it "the" fourth dimension (the block universe), or simply one dimension among several others? If time is treated like a sense, maybe psychophysics could help (Eisler, 1976; Glicksohn and Hadad, 2012; Kornbrot et al., 2013). However, for studying time in the light of psychophysics, we have first to acknowledge that, strictly speaking, although we can define time intervals with sensory signals, there is no "time stimuli" *per se*. As well, there is no "time receptors," like we have, for instance, the retina or the cochlea for studying properties belonging to vision and audition, respectively. Along the same line, there is apparently no such a thing like a "time cortex," a part of the brain dedicated to the processing of temporal information as is the case with the visual or auditory cortex for processing visual or auditory information, respectively. The brain, as a whole, can be seen as an inherently temporal organ (Buonomano and Rovelli, 2022), but when time comes to find a temporal resolution, there is a need for a contribution from several cortical and subcortical structures (Grondin, 2010).

As is the case for the perception of sensory stimuli, time perception will sometimes result from a contribution of top-down processes (a taking-into-account process, to use Helmholtz terminology), and the specific parameters (organization in time) of sensory stimuli marking time intervals will sometimes lead to illusions, i.e., an impression that something is there (occurred at a given moment, in the case of time; see for example ten Hoopen et al., 2008; for the description of the time-*shrinking illusion*) when it is not. Illusions are indeed neither a mirage, nor a hallucination; it simply shows the normal functioning of the brain.

2. About the continuity of psychological time

In their article, Gruber and collaborators take the direction of the flow of psychological time and review different notions and findings related to persistence, change/motion, temporal order, and specious present. The general question addressed is whether the flow of psychological time is punctuated by any interruption or discontinuity (see Chapter 3 in Grondin, 2020). From the very start, adaptation requires distinguishing successiveness from simultaneity; hearing, for example, is a clear case illustrating the need to efficiently integrate and segregate elements of information occurring in the flow of time (Bregman, 1989).

Gruber et al. brought to our attention numerous relevant examples to illustrate that there is a gap between physical reality and conscious perception. There are indeed several types of "temporal displacements" (Vicario, 2003, 2005). One fascinating example is that of the *flash-lag effect*. This phenomenon could be demonstrated when a flashing object and a moving target should be aligned. The flashed object will be perceived to lag behind the position of moving target (Hubbard, 2014). Note that this flash-lag effect could be viewed as a special case of another phenomenon called *representational momentum*. This phenomenon refers to the displacement of a moving target further along its anticipated path of motion (Hubbard, 2005). This phenomenon could be viewed as a mechanism compensating for delays in awareness due to neural processing latencies.[2]

Gruber et al. make some room to the notion of specious present in the "two time" debate. The idea here is to acknowledge that there must be some continuity within a given time window to assure that there is some unity in the flow of information reaching the brain. There is some ambiguity though about the duration of this window, with values reported in the article being 0.5, or 3 s, or even 7 s. One way of addressing this issue is proposed below, based on a classical psychophysical law.

According to Weber's law, the minimum difference between two stimuli (the discrimination threshold) needed to discriminate them depends on the magnitude of the stimuli. More specifically, this difference increases proportionally with the magnitude. In other words, the threshold to magnitude ratio should be constant (the Weber fraction is constant). For the study of human time, one can look at this Weber fraction as a function of physical time (or, to be more careful given the uncertainty about what physical time is, as a function of chronometric time). It turns out that there are instances where the fraction is not constant; in other words, Weber's law doesn't hold (Grondin, 2001). An increase of the Weber fraction for low magnitudes of chronometric time could by easily accounted for mathematically with a generalized version of Weber's law. However, the fact that this fraction increases when intervals to be discriminated are longer than circa 1.2 s (Grondin, 2012), or around 1.5 s, according to Gibbon et al. (1997), is more difficult to explain. Even counting at a 1.6 s pace, in comparison with a 0.8 s pace, will lead to much more variability (Grondin et al., 2015). This disruption in the capability to process a temporal extent could be interpreted as a limitation in the flow of psychological time; it could be viewed as a tool to quantify the "specious present" Gruber et al. referred to, and may also reflect a fundamental temporal limitation of short-term memory. And by the way, it turns out that humans have a way to go round this limitation by segmenting a time span into smaller chunks by using, for example, an explicit counting strategy (Grondin et al., 1999).

1 For additional information about fundamental questions in psychophysics and about the future of psychophysics, please see Hubbard (2020, 2021).

2 See Grondin and Hubbard (2024) for a review of different types of brief gaps in awareness of the external environment, and of potential disadvantages of awareness in some perceptual and cognitive processes.

3. Concluding remarks

What is human time? Just unifying psychological times is a challenge. There is no human time, but human times: temporal orientation, temporal perspective, temporal order of past events, distance of events in the past, speed of the passage of time, flow of speech or music, tenses in language, to name a few. Buonomano and Rovelli proposed their own taxonomy of time features, acknowledging the need to present time as a multilayered concept. Even within a simple experimental psychology perspective, where we want to keep explanations simple, the questions of the continuity of time and of the sources of time-adapted behavior are blurred by a multiplicity of findings.

Is there a physical/material world outside of us? There could be something, and there could be nothing. Both avenues are unbearable. Consciousness is a cruel coquetry of human existence, but also its most fascinating charm. Time is arguably at the heart of consciousness, considering the need that the brain constantly rearranges the timing of events, as Gruber, Block and Montemayor noted in their target article. Addressing the problem posed by the idea/notion of time and exploring the content of human time, as Gruber, Block and Montemayor have done, and trying to build bridges between physics and neuroscience, as Buonomano and Rovelli propose, is probably a good way to take significant steps toward an understanding of this elusive phenomenon that is that of consciousness.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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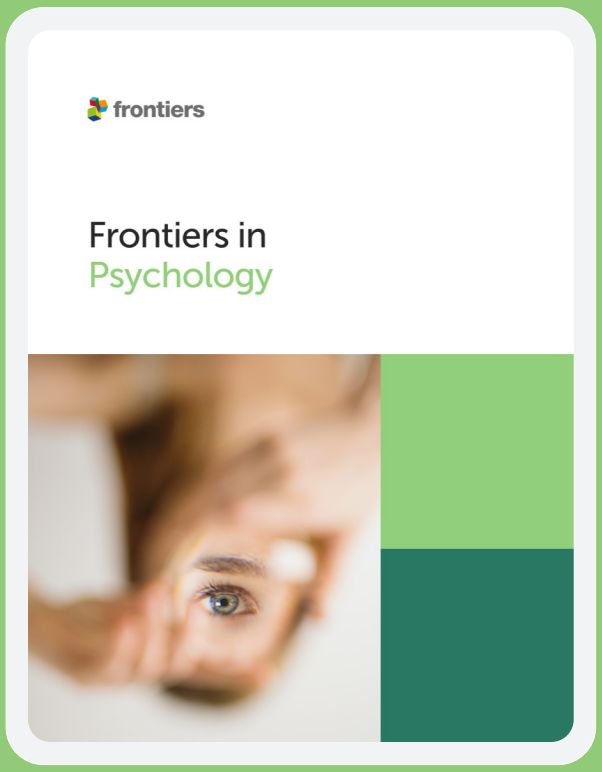

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