



Artificial Intelligence and Time Measurement & Time Experience



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- *Note: Quotes in the text are from the materials sent by our responders, which will remain anonymous, and therefore are not individually cited.*

The Global AI Ethics Institute did a small survey about this topic in order to start an interesting conversation. We called on our members and general audience to contribute to this opinion piece, and we collected several answers that are summarized here.

As mentioned in the short survey's introduction, the history of time is deeply rooted in the tight relation between living creatures and their natural environment. So far, it seems that these questions, and many others surrounding the relation between time and AI, have gone totally unexplored.

Before we introduce the questions we used, it is important to note that this topic itself has a number of base assumptions which could be explored, and thus that respondents to our questions might need to grapple with: First, how likely is it that AI would attain a high and flexible enough intelligence that it could become sentient? Also, we attach the perception of time to the living, at the least—and usually to sentient beings; can we implicitly assume that an extremely advanced AI system would have its moment of awakening, and maybe a moment where it “dies”? Or could future sentient AGIs be immortal? Could that span of time also be a factor that influences perception of time?

So, given these caveats, here are the questions we asked our contributors in order to spark their creativity and to get them to look at the topic at hand from a few different angles. Those questions were:

- (1) What do you think will be the basis for the AI experience (and measurement) of time?
- (2) What could we base it on, or what could be independently developed later?
- (3) Since humans will frame the basis for AI time perception in the beginning, upon what should we model AI time perception, and for what purpose?
- (4) Is subjectivity in the experience of passage of time something that we could expect from AI systems?



Potential Sources for AI Time Perception

In answer to the first of our questions, expert respondents said that, assuming that an Artificial General Intelligence (AGI) could be made strong enough to attain sentience and operate on its own, the basis that it might use for its own time framework might have at least a few sources and considerations:

1. **Circadian rhythms** – similar to organic biological processes that that happen over a 24-hour time span. This could be something that might become a natural AI timing “device” emerging from its smaller components, just as a human’s biological clock has roots in the molecular level of the body and in its genes. This process in AI could work synchronously with some learning or update cycles.
2. **Information processing / processing power** – These elements of how AI and out brains work may serve as limits to how time is processed. Again, we humans have biological boundaries to our processing power – how much information our neurons can send and receive. “Each new human builds [their] knowledge and experience from [a] fresh start, having at [their] disposal all the written / recorded knowledge of people before them - but the ability to gain that knowledge is limited by the ratio of the amount [of] information to time. AI is limited by processing power per unit of time - but it can be improved - while humans have a limited capacity to change [the] amount of information per unit of time.”
3. **Celestial movements (Micro/Macro cosmos)** – could be used as some kind of reference for AI systems that have the power of sensing the position of celestial objects. We can speculate whether the sense of time inherent in this system would be the moon, sun, or planets in our solar system or references to some distant but observable galaxies. This system could be one of the most tangible references of time – in the long term – in connection with the need to observe the cycles of agriculture, which has always been the engine of human civilization, and which we humans take as a point of reference. Or AI could take as a basic measure something on the level of subatomic particles and their movement.
4. **“State of hardware”** – “An 'AI experience of time' as it relates to planning might be intimately connected to the degradation of circuits or hardcoded time increments that align it with our measures of seconds. Another consideration might be how an AI’s experience of memory is encoded and the effect of that memory structure on future planning. 'Longer' memory would have the effect of 'lengthening' time relative to an observer's experience. That would be similar to and interconnected with first sources, and it would be something like the decay of human bodies, but obviously on a different time scale. It could be an artefact of maintenance cycles, for example.

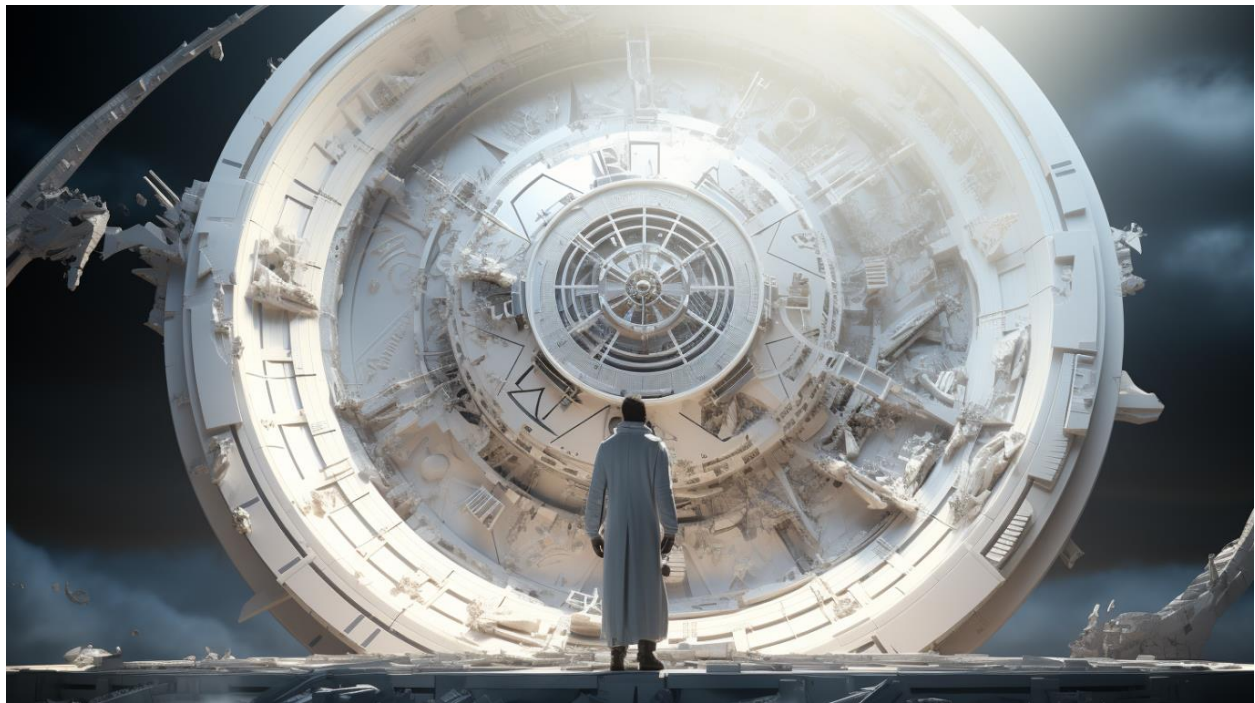


Even if we provide simplified answers as those above, we should consider many other philosophical questions: One of our responders points out for example that, “Humankind needs to decide whether the time is considered an objective [phenomenon,] as Kant maintains, or a subjective phenomenon. Does time exist without us or did we make it up with measurements like seconds, minutes, hours, etc.?” We have units of time measurements responding to our experience, what might be developed by future AI systems? Will they have much shorter basic units (some parts of millisecond, based on electron movements) or much longer [ones], considering [their] potentially significantly longer lifespan, perhaps based on the beginning and the end of universe?

Some respondents disagreed with the subtle implication that time can be objective and that we all therefore experience time identically. One person argued that time is always subjective: “It is observer relative. Aristotle constructed our experience of time as an experience of change in our environment and [the physicist and philosopher] Ludwig Boltzmann interpreted our experience of time as a 'blur' of our perception of change below a particular granularity. On that basis, 'time' would be approximated as a relationship of granularity/processing as experienced by an observer. For example, a machine that processes higher granularity than a human and fast enough to 'not miss anything' that we can see, could be said to have a slower experience of time. But we might be more interested in time as an indication of planning horizons. For example, a human believes that when certain changes are observed (i.e. aging and rotations of the sun), they will die. Consequently, every decision is considered relative to the changes that are expected to take place. To this extent, the concept of 'during' is a parallel simulation of changes like ageing against other actions.” This line of thought is coincident with the “state of hardware” consideration described above.

If AI attains a state where it is conscious of time, and if it even sees it as relevant, it might depend on us and our coding as a basis for developing its own timekeeping methodology. So, to begin, it might require “some kind of metrics, points that define positions in time.” There are several possibilities for how this might take place: “One is assigning data to [a] certain position in calendar time, the second is assigning data to persons,” which data then confers age and thus a sense of time; and “third is [establishing a] relation between information and time according to [human] temporal ability” to process information.

According to some of those surveyed, that means an AGI at its early stages might need three levels of understanding time, in relation to humans and their communication – (1) calendar time to differentiate between old and new, archaic, and fresh ideas and concepts and relation between ideas throughout time (how one idea stems from the other). (2) Time in terms of serving people throughout their seasons, respecting age-appropriate discourses, and (3) Human capacity for processing a certain amount of information per unit of time to properly measure information in terms of human time.



AI and Human-Centered Time Perception

How long should/will AI systems be human centered and dependent (or allopoietic in systems theory terms), and will they at some point become self-centered and self-propagating (or autopoietic)? That will have consequences for the decision to mind the gap between the ability of humans to process information and an AI's own ability; this self-or other orientation will also make a difference in the AI's ability to develop a sense of human aging to connect with a human-like sense of time (if it uses that technique)—or to completely abandon those concepts and expel humans out of the loop and creation of its time framework.

Some propose that “we should not model the AI time perception outside the current time perception frames. We should adjust AI to our needs, not adjust ourselves to AI.”

“In that case,” another expert proposes “time could be framed as a choice of 'process further'/'defer' or 'take an action' for 'real time' choices. The idea is that at very fast timescales it would occasionally be advantageous to consume more processing resources ('longer time') than to take an action faster. This way we can construct the 'experience of time' as a kind of optimization problem: to act or to deliberate.”

As for the matter of potential subjectivity of time perception, some believe, “It is too complicated to answer this question. There are too many open questions. What is subjectivity?”; while others are more optimistic: The AI, because of its different methods of time sense and mode of existence “will be able to experience multidimensional time at the same instance”; moreover, says another, “all time is subjective to the observer's frame of reference”. The idea of the observer and their capabilities is a very interesting one, and connected with the notion of sentience ([GAIEI addressed this topic in one of its papers](#)). And based on these assumed capabilities the notion of perception of multidimensional time would bring us to an AI that might resemble one we now find in science fiction.



Some survey respondents warned that the notion of an AI "experiencing" time anthropomorphizes AIs too much. Furthermore, there are opinions that "AI systems will not need to have any perception of time. AI systems are (currently) tools built for a purpose," and even with an advanced AGI that can perform many tasks, as a human can, "If such tasks don't require understanding the passing of time, there won't be any reason to implement that."

To conclude, as in many similar cases, it is very hard to provide clear answers. As we know, it is not completely clear what the experience of time is like for the human race. But could thinking of how time might exist for advanced AI and the possible process of creating and coding it for AIs help us, again, better understand ourselves and the ways our brains operate?



Appendices

Due to the large amount of very interesting observations and opinions from the contributors, it was impossible to include everything in the summary above. But we offer below a few bonus segments that might be valuable. These are only bits and pieces from the original papers we received, but in our opinion, they help to raise or reframe some of the questions brought up here, and thus they give additional context to the topic.

Time and the Observer

Time, the 4th dimension, is something very natural and, at the same time, very mysterious to human beings. In terms of metaphysical speculation, time exists concomitantly with the Universe itself. Starting with thermodynamics and quantum mechanics, The Observer Effect dictates that the observer can no longer be inert and that by observing he/she influences the experiment: this effect is well understood from the concept of the Schrödinger 's Cat thought experiment. In a sense, then, these concepts can be classified as objective-subjective scientific models, which relate to the human perception of time. Time is seen from a human perspective as a 4th dimension of our perception of reality, as compared with our perception of space, which comprises the first three dimensions. For us, the perception of time is a dimension and not a parameter of existence. Hermann Minkowski is credited with being the first to notice this correlation, in his reading of Maxwell's studies on electrodynamics.

At what point will we be able to call some AI system – the observer (of time)? Is that the moment when we pronounce it sentient?

On the other hand, in a quantum approach to the matter, defining the “now” is an arduous task: if the perception of time takes place from the measurement of light as it travels across the Universe, the observer will never be seeing the “now”, since, even for the smaller distance, one will be experiencing the result of a photon that was deflected or reflected from the object some time ago in the past, thus there is no “now”.

The outputs of current artificial intelligence tools result from inputs provided by big data, which stems from human beings. Humanity marvels at GPT-x's responses, fantasizing about it being alive, as Michelangelo has marveled at Moses, hitting the sculpture's knee with the hammer, and daring it to speak.



Time and causality

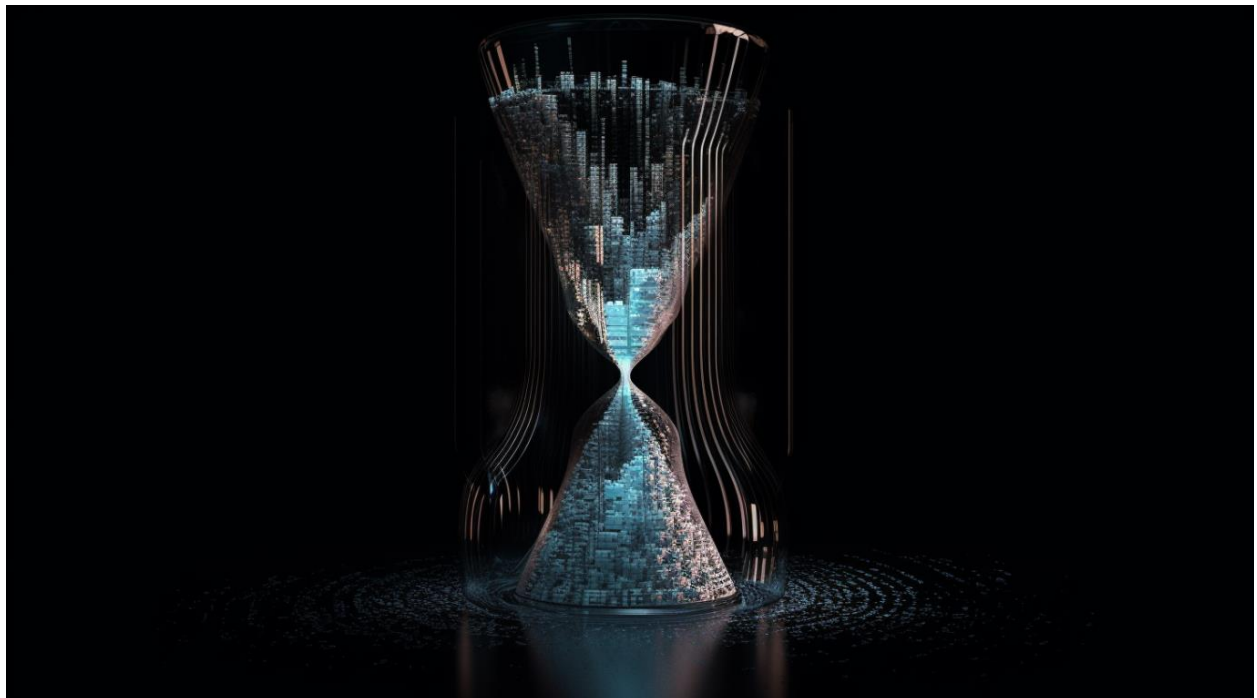
Artificial Intelligence (AI) systems, at the moment, can only perceive time in a limited sense. They can process and analyze time-based data, such as time-series data, and use it to make predictions or decisions.

One potential issue with AI and time is AI's limitations mean it cannot deal with the complexity of time and its non-linearity. For example, AI may not be able to work with the concept of causality, where a cause leads to an effect in the future, or the concept of simultaneity, where multiple events happen at the same time. These limitations may lead to AI making decisions that have unintended consequences in the future, or not being able to account for the impact of their actions on the present.

Thus, AI may not be able to fully able to integrate its actions with the complexities of human emotions and decision-making, which are often based on past experiences and future expectations.

For example, should AI be allowed to make decisions that could have long-term consequences for humanity? And what will be definition of long term for AI?

Similar to how introducing the concept of attention in modern transformer-based AI systems has dramatically improved their performance in analyzing and processing natural language, maybe introducing the concept of time perception to AI systems will have the potential to once again cause a significant breakthrough in what these systems can do.



Perception of time emerging from consciousness / Attribution of relevant biological features

The study of consciousness, time and reality is complex and evolving fast in [many fields](#), including metaphysics and fundamental physics.

The notion of time is an integral part of consciousness. Consciousness experiences the causation or changes in the environment and so perceives time. The assumption of sequential awareness in consciousness enables mapping of the perception of time onto consciousness.

Therefore, many believe now that consciousness is fundamental and that [time and causation](#) are derived from [consciousness](#)

In ancient Greece, there were at least three gods representing different time forms: Chronos, Aion, and Kairos. Chronos represented linear time flowing from past to present into the future. This is the time that humans feel as life passes. In contrast, Aion represented the cyclical nature of time experienced from natural events such as weather patterns, rebirths, etc. The third god Kairos represented opportunistic time, which reflects the appropriate time to achieve a task.

What would be the AI equivalent to the biological cycles that play a fundamental role in human behaviors and the perception of time—for example, mood cycles, circadian rhythms, and the menstrual cycle?

It is important to match the relevant features of biological processes to digital processes when training AIs, which raises more awareness about humans.

Recent discoveries in quantum physics indicate that our reality is non-local, and so awareness can happen instantly, faster than the speed of light. In other words, physicists and neurologists think brain neurons might be aware of the quantum world through the [orchestrated collapse of microtubules](#) in the neurons in the brain; according to this hypothesis, there are possibilities that human awareness can be linked with [non-local realities](#) to expand our consciousness across the universe instantly.

While our own perception of time contradicts quantum physics, the human concept of time also influenced the formation of diverse customs, values and cultures based on patterns that emerged from nature, particularly around the regularities in the earth's movement, environment, astronomy and biology. Therefore, understanding time and related artefacts (i.e., cultures, beliefs, values, customs, physics, health, etc.) are very important to realize a deep understanding of the perception of reality.





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