Does Time have a Direction?

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Time is ordinarily perceived to move in one direction from the past, through the present, and into the future. Many opposing accounts of temporal direction have offered insight into the unresolved question, 'Does time have a direction?'. The purpose of this essay is to illustrate the notion of a temporal direction and how it might be understood. Moreover, the essay will contrast a potentially fruitful account for the direction of time and argue that the entropic reductionist does not persuasively support that time has a direction. Firstly, I will introduce the intuitive notion of temporal direction, further explicating the orientability of time and how it provides directed relations between events. I will also outline the relevance of a grounded asymmetry between past and future events. Secondly, I will focus on the reductionist approach, and show how a direction of time may be derived from the contents within time. I will then focus more deeply on entropic reductionism and explain how an asymmetry in the second law of thermodynamics and Albert's (2000) past hypothesis may ground the asymmetry of time. Lastly, I will explicate two responses to the entropic reductionist's account, which appeal to the fundamental insignificance of entropic macro-states and the insufficient explanation of the past hypothesis. I will contrast potential replies from Boltzmann (1964) and offer a response to the remaining limitations and adequacy of the reductionist views expressed by Albert (2000) and North (2011). I will conclude that entropic reductionism is not a persuasive account for an objective direction of time.

Notions of Temporal Direction

The perception of temporal direction prompts an inquiry into whether the direction of time is objective. The past seems immutable, and the future appears like a set of unknown possibilities. By observing that others may share this experience, it might be taken for granted that a temporal direction extends beyond subjective intuition (Earman, 1974). For the purpose of this essay, it will be helpful to consider the question, "Does time have an objective direction?". Some have been affirmative and tried to objectively ground temporal direction (North, 2011; Maudlin, 2008; Horwich, 1987; Reichenbach, 1956). Others have denied a "strong" sense of temporal directionality and only advocated a subjective notion of time (Price, 2011; Boltzmann, 1964). Although, these various accounts may provide insight into the essay question, the given context of this writing justifies the particular focus that will be taken. Accordingly, requirements for a *strong* objective account of temporal direction will be outlined before a focused investigation on a popular entropic reductionist approach.

Orientation, Directed Relations, and Asymmetry

Investigation into an objective basis for temporal direction has entailed the identification and grounding of an asymmetry between the past and future (Boltzmann, 1964; North, 2011; Maudlin, 2008; Price, 2011). For an account of temporal direction, irrespective of the observer, there must be something which grounds the *orientation* of time. The account requires a distinction between directions, and moreover, a ground to derive which of these directions is the actual one (Price, 2011). Notably, a temporal direction implies directed relations between events. These relations indicate which of two non-simultaneous events is *earlier* and which is *later* (Maudlin, 2008). To identify directed relations between events, each event must be assigned an orientation, such as 'positive' or 'negative' (Price, 2011). For a strong account of time, there must be a *ground* for the distinction between the assigned orientations. This ground may be provided by an *asymmetry* between past and future.

Objective Grounds for the Direction of Time: Entropic Reductionism

Reductionism is a widely endorsed approach that can be used to argue for a strong account of temporal direction (Albert, 2000; Fernandes, 2022; Horwich, 1987; North, 2011; Smart, 1963). It asserts that the direction of time is grounded in the material contents of time. In other words, the asymmetry of time can be reduced to an asymmetry in the *objective content within time*. Some have tried to ground this asymmetry in the contents of memories (Smart, 1963) and the causal connections between events (Horwich, 1987). However, perhaps the most popular method has involved thermodynamics.

The second law of thermodynamics states that the total entropy of an isolated system either increases or remains constant in any spontaneous process (Nelson, 2022). Entropy may be considered a measure of disorderliness of the state of objects in a system. The distinction between a system in a low entropy (orderly) and high entropy (disorderly) state is exemplified in Figure 1. According to the second law, low entropy states are less common than high entropy states. This is because there are potentially more ways that a system can be "disorderly" than "orderly" (Albert, 2000). An isolated system will therefore approach a higher entropy macro-state due to the possible number of disorderly states being vastly more common.

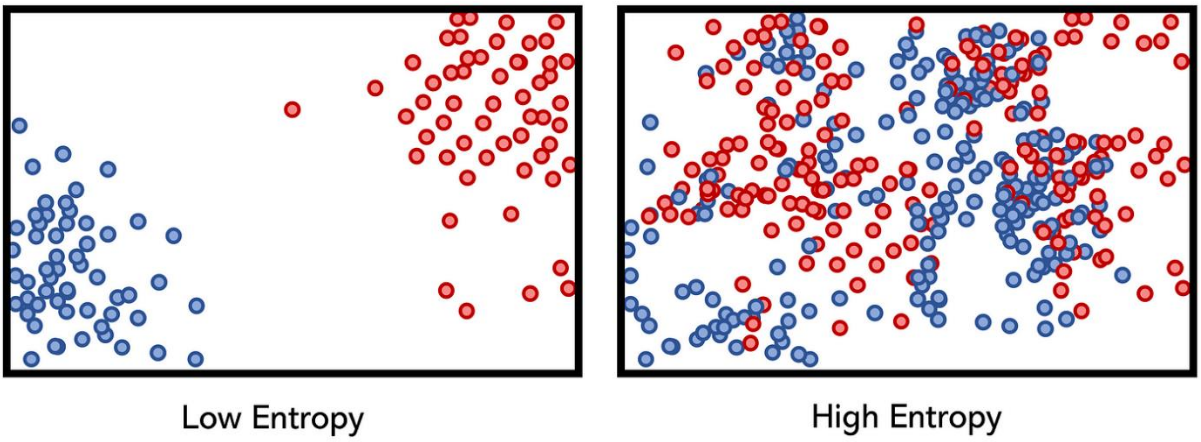

Figure 1. A representation of states within distinct isolated systems that are comparably orderly (low-entropy) and disorderly (high-entropy) (Ye, 2020).

If the universe is considered an isolated system, there is an asymmetry in its entropy. As the second law suggests, the global entropy within the universe should increase with time (Shenker & Hemmo, 2011). This is a consequence of the original state of physical matter within the universe. Namely, the *past hypothesis* is that the universe came from an event in which all matter was in an extremely low entropy state, presumably near the big bang (Albert, 2000). Out of the possible future states of such a system with low entropy, it is most likely that entropy increases, as there are significantly more potential disorderly states than orderly states. The past hypothesis is a statistical explanation for the asymmetrical measure of entropy in the universe.

The entropic reductionist approach attempts to ground the direction of time in the apparent *asymmetry* of the universe's entropy (Eddington, 1928). The direction of time is distinguished by the direction of global entropy increase. The past hypothesis proposes a boundary condition for temporal properties in the universe, and a conjecture for why entropy always increases in the direction of time (Albert, 2000). In this sense, any temporal movement follows the direction determined by a system's entropic increase. This account argues that there is an objective direction of time that is grounded in the universe's asymmetrical entropy gradient that is explained by the past hypothesis.

Responding to the Entropic Reductionist Approach

(1)

The entropic reductionist's ground for the direction of time wrongly conflates the correlation between the asymmetries of time and entropy. Arguably, the asymmetry of entropy is not fundamentally significant due to its macroscopic nature. It cannot provide a necessary ground within the contents of time. Expressly, the states of individual particles in a system are fundamental micro-states and the entropy of a system is a macro-state. This macro-state is calculated by condensing the *overall* micro-states into a useful quantity (Nelson, 2022). Entropy is a calculation which has no fundamental significance over all the micro-states in the system. Macro-states are not fundamental properties of nature. Objectively, the universe is only ever in *one* set of micro-states, as the total energy of an isolated system remains constant over time. The change in macro-states are based on the available/chosen information of those micro-states (Shenker & Hemmo, 2011). In this sense, entropy is a non-fundamental measure of the partial information one has of the system from a particular perspective. Therefore, the reductionist cannot ground temporal direction to an entropy gradient, as it is a subjective measure and *not* objective content within time. The reductionist provides a correlation between the asymmetries of time and entropy, but in doing so, conflates an objective notion of temporal direction with a non-fundamental macroscopic calculation in the universe's set of micro-states.

(2)

The initial low entropy condition of the universe requires further explanation. Price (2004) argues that reductionist accounts do not sufficiently justify why the past is synonymous with a system's decrease of entropy and vice versa. In response to a reductionist position, the boundary conditions may have conceivably been different (Earman, 1974). Expressly, the reductionist should offer a reason as to why the past universe was in such a highly improbable low entropy state. The hypothesis explains the globally increasing entropy gradient through statistical description but does not provide an explanation for why the hypothesis is true.

Boltzmann (1964, pp. 402-403) offers a causal conjecture in relation to (2), suggesting that the past hypothesis is due to a fluctuation within a larger system. He asserts that the improbable initial state of the universe may be a large fluctuation away from the entropic equilibrium in a vastly larger universe. In other words, the observable universe is a sub-system that was subject to a fluctuation of low entropy, which Boltzmann (1964) terms a *'small-world'*. This sub-system makes up a small part of a larger universe that sits in a more probable higher entropy state. One may further invoke an anthropic principle to justify a position within this improbable sub-system. This principle would claim that the observation of the improbable sub-system may be justified by its possession of properties necessary for the existence of observers. However, an anthropic justification is arguably non-explanatory, as it offers a redundant observation rather than a causal explanation (Deltete, 1993). Although Boltzmann's (1964) response to the highlights from Price (2004) and Earman (1974) in (2) are intriguing, the conjecture lacks verifiability and may be considered speculation.

In response, entropic reductionist positions, such as Albert (2000) and North (2011), do not offer any adequate defence to (1). These approaches solely rely upon the evident correlation between the asymmetry of time and entropy. It is still an open question as to why entropy, as a macro-state with no fundamental significance, is connected to an objective direction of time. Arguably, entropy, being a non-fundamental measure of the available information of the universe's micro-states, is wrongly conflated to be objective content within time. Additionally, Boltzmann's (1964) speculative conjecture to (2) likely require further exploration; otherwise, a novel explanation or brute-fact approach (endorsed by Callender, 2004) for the past hypothesis is required. Overall, the inadequate responses to (1) and (2) are not sufficient for a persuasive reductionist account of objective temporal direction.

In conclusion, an objective account of temporal direction requires a grounded orientation to identify directed relations between events. Furthermore, the entropic reductionist encounters limitations in explaining why the objective direction of time should be connected to a non-fundamental macro-state such as entropy, and the explanation for the past hypothesis seemingly rests on a speculative conjecture. Therefore, entropic reductionism does not offer a persuasive answer to whether time has an objective direction.

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