A Description of Entropy as a Level-Bound Quantity

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Abstract
In this paper, entropy is portrayed as a property which is dependent on the levels of description (LODs) taken into account. LODs are abstractions in terms of which an observed system may be described. They highlight different qualitative or quantitative aspects of a system. For nested systems, the outcome of a measurement depends on the observer's position and extension, his internal differentiation and assignment conditions. The concept of interface complexity as a measure of entropy is introduced. Finally, a differentiation is suggested between $\Delta S_{(endo)}$, $\Delta S_{(pseudo\text{-}exo)}$ and $\Delta S_{(exo)}$, which correspond to the inside, pseudo-outside and outside perspectives, respectively.
Keywords: entropy, endo-observers, pseudo-exo-observers, exo-observers, interface complexity

1 Introduction

Entropy is a relative measure. We do not measure an absolute value but only differences in entropy, either in the form of a decrease or an increase. The outcome of such measurements depends on the observer's internal differentiation, his position and extension and the interfacial cut between the observer and the rest of the world.

As we cannot look at our universe from the outside, i.e. from an exo-perspective, we have to describe it from within, i.e. from the endo-perspective [1]. Only a super-observer would be able to monitor the entire universe from an exo-perspective. This super-observer would be located outside the system he observes, on an inviolate level in Hofstadter's sense, i.e. on a LOD which cannot be manipulated from embedded LODs [2]. In fact, individuals on the embedded LODs would not even suspect the existence of the super-observer's LOD, unless they were faced with a strange loop or a tangled hierarchy.

An observer can only differentiate between an open or a closed system if the borderline between the embedding and embedded system has been made out and crossed. Only from the perspective of the embedding system may we draw conclusions about boundary conditions. For most observers, however, this is not a real option, as they are embedded in a subsystem. Unless they have managed to widen their perspective by looking at the system they are located in from the outside, all they can talk about is interface reality, i.e. the way phenomena present themselves on their world-observer interface.

A temporal limit must be taken into account when we talk about observation. As mortal observers who wish to describe the universe we are embedded in, all we can actually observe is a glimpse, an almost negligible fraction of the timespan of the universe. Therefore, we have to talk about freeze-frame observations, which in general do not allow us to make assumptions about temporally embedding systems if we do not have access to them. The only way out would consist of an observer extension, i.e. in an observer's engulfing of embedding systems and integrating these into his measuring chain. This re-arrangement of the interfacial cut is the only way we may take account of embedding systems. It is not possible to do so from an inside perspective, as the borderline to the next-embedding systems has to be crossed in order to define the embedded system as either an open or a closed one.

An anlaogy can be drawn between an observer who interprets a multi-layered signal as a one-dimensional one and thus falls for an auditory illusion and certain observer types who measure entropy from an endo-perspective. Both would be at the mercy of a level-hopping dynamics. Another possible observer type who is subjected to level-hopping would be a super-observer who does not display the internal differentiation necessary to lock into the nested LODs of the system observed. This is the classical outside perspective. It disregards possible one-to-one mappings between observers whose internal differentiation links with the LODs of the embedding environment. This renders it impossible for an outside observer, who is not embedded in the system he wishes to describe, to link LODs between subsystems and himself, let alone to register consonance between these relations. There is only one observer type who may overcome these difficulties and not fall for an illusion: an observer who is embedded in the system he wishes to observe and who is aware of the structure of his fractal temporal interface. He is in a position to grow into an extended observer by assigning his immediate and not-so-immediate surroundings to his side of the interfacial cut. In contrast to this priviledged observer type, the notion of an pseudo-exo-observer is introduced, who is under the impression that he does not fall for an illusion. This pseudo-exo-observer exemplifies many a scientist's endeavour to describe the system he is embedded in from an outside perspective without realizing that he is committing a logical fallacy based on over-contextualization.

2 Embedded and Embedding Subsystems

There is a persisting conviction that entropy in the universe increases – a notion I believe is not tenable for two reasons: First, nobody knows the extensions of our universe, whether it is finite and what it actually consists of. Therefore, I think it is rather brave to claim that, in total, entropy increases, if this total refers to the entire universe. Second, an observer monitoring this universe or parts of it, must obviously be located somewhere, i.e. within a subsystem. Within this subsystem, this observer can carry out a measurement only within a very limited timespan. These facts are usually disregarded.

Let me illustrate this by means of a thought experiment: Imagine a universe which consists entirely of of ice cubes and hot water bottles, nested inside each other. Now imagine a number of observers, each situated in an ice cube or a hot water bottle. Observers located in an ice cube will register a increase in entropy, whereas observers located in a hot water bottle would register an decrease in entropy. This is so because for the observer located in the ice cube, the embedding and embedded hot water bottles will make the sandwiched ice cube melt and thereby increase the entropy of the subsystem. Analogously, for an observer in a hot water bottle, entropy would decrease, as the embedding and embedded ice cubes would cool down the water [3].

It is important to keep in mind that when these observers take their measurements, they do this within a very limited period of time. Against the background of the time scale of an evolving universe, these measurements may be regarded as freeze-frames. Therefore, the argument that, *in total*, entropy will eventually increase or decrease (depending on whether the outermost embedding system is an ice cube or a hot water bottle) is futile, as all these embedded observers may register is a change in entropy within a very limited temporal interval. It is a snapshot of the evolving universe which is taken by these observers, not a measurement comprising aeons of interactions. These snapshots taken by the individual observers are the result of their *endo-perspectives*.

These endo-perspectives are perspectives from within – the views of observers who are embedded in the system they wish to observe. These observers have no access to other observers located in the embedding or embedded subsystems. If they cannot look at their own subsystem from the perspective of the next system embedding their own, they are not in a position to make any statements about the boundary conditions affecting their own subsystem. A level-crossing would enable them to do so. Only an immortal super-observer located outside the system he wishes to observe could span the time the universe exists and take account of all nested subsystems from an *exo-perspective* – an outside perspective.

For the individual mortal observers (*mortal* refers to the fact that they have only a very limited timespan within which they may carry out measurements) who are located in the various subsystems, this all-encompassing perspective is out of reach. In fact, they would not even suspect that there is a wider perspective which embraces several or all subsystems, as they can neither cross the borderline into the embedding system nor make contact with observers located in an embedding or an embedded subsystem. In fact, they would not even have a clue about the existence of these nested and nesting reference frames.

Only a super-observer located outside the sytem he wishes to observe is not subjected to this limiting observer-time frame: his object of study is the universe as a whole.

The ignorance of individual endo-observers resulting from a limited interval of observation and the inability of the super-observer to take the perspective from within embedding and embedded subsystems define their respective observer frames.

3 Assignment Conditions

As an observer who is located in a subset of the hot-water-ice-cube-universe is already embedded in what he is observing, he cannot monitor the universe from the outside, from the exo-perspective. His endo-perspective is best analyzed by following a phenomenological approach which deals with the observer-world interface. The interface reality generated by this observer-world interface is the object of this paper.

The term interface reality also goes back to Otto Rössler's endophysical description of the world [4]. Rössler also suggested that, when we describe an observer-world interaction, we have to take account of the assignment conditions, which state what part of a system belongs to the observer and what part belongs to the world. He had microscopic assignment conditions in mind when he developed the idea. Here, however, I shall refer to the *macroscopic* manifestations of assignment conditions.

The interfacial cut may be set between the observer's brain and a measuring chain or directly between the observer and the outside world. The observer could also be a smart detector with anticipatory faculties, i.e. a detector which can modify the structure of its interface along the way.

4 The Observer's Nested Interface

I believe a temporal observer-world interface, the Now, is fractal, that it has a nested structure generated by the observer and the world around him. Why is that? Allow me to take you on a short excursion into phenomenology: The nested structure of the observer's Now, his only access to the world, was first described by the German philosopher Edmund Husserl [5].

Husserl pointed out that when we listen to a tune, we hear a succession of musical notes. But we don't perceive simply a succession of unrelated notes - we hear a tune. We are able to do this because we internally connect the note we have just heard with the present one and the tone we anticipate to follow it. But we don't connect them in an arbitrary way: we remember a tone (*retension*) and anticipate the next tone (*protension*) within the consciousness of the present, the Now. As we do this over and over, we create a nested temporal pattern within the observer's Now.

Without memory of the preceding note and no anticipation of the next one, we would only perceive a succession of isolated, unrelated notes. But as we are able to perceive a tune and not just a succession of isolated notes, we must assume the observer's Now to provide for *both* succession and simultaneity. Succession and simultaneity within the Now generate a nested, fractal structure. Again, it is this extended structure of the Now we have to assume to explain our ability to perceive a tune or any other time series as a meaningful entity.

5 Fractal Time

In my Theory of Fractal Time, I have taken account of the observer's extended Now, which is shaped by nested retentions and protensions, by differentiating between Δt_{length}, Δt_{depth}, and $\Delta t_{density}$ [6]. Δt_{length}, the length of time, is the number of incompatible temporal extensions in a time series. It measures the succession of events on one LOD. Δt_{depth}, the depth of time, is the number of compatible temporal extensions in a time series. It measures simultaneity and provides the framework time which allows us to structure events in Δt_{length}. It is important to realize that there is no Δt_{length} without Δt_{depth}

- there is no succession without simultaneity. $\Delta t_{density}$, the fractal dimension of time, is the temporal density of a time series.

Newtonian time metrics may be defined as a special case of fractal time. It is the set of successive intervals measured in units of Δt_{length}, on nesting level ∞, i.e. $\Delta t_{depth} = \infty$.

An example for such a fractal time series is given by the frequency ratios of musical notes which are played simultaneously. The simplest frequency ratio between two musical notes is 2:1, which defines the interval between them as an octave. An oboe A, for example, has a frequency of 440 Hz. Therefore, the next higher A played on this musical instrument would have a frequency of 880 Hz, and so on:

> "The idea of consonance is ultimately grounded in the notion of commensurability, an essential in Greek mathematics. We recognise consonance when we perceive a certain number of vibrations of one frequency exactly matching a certain number of another frequency." [7]

The consonance created by such overlapping frequencies which are easily translatable into each other by their frequencies generates Δt_{length} and Δt_{depth}.

6 A Different Set of LOD-Dependency for Dissipative Systems

This differentiation into LODs is not limited to linear systems, which allow a precise simultaneous arrangement into embedded subsystems, as in the musical example above. Also systems lacking specific borderlines which define the individual nested subsystems may be related to an observer in terms of mutual LODs.

Deterministic chaos describes non-linear systems which display sensitive dependence on initial conditions (SDIC). Ilya Prigogine used the SDIC property of chaotic systems to explain irreversibilty as the result of an infinite entropy barrier [8]. No matter how far one zooms into a phase space which describes the dynamics of an underlying system, one always encounters trajectories leading to differing developments of the system. Therefore, the problem cannot be resolved by a better resolution – coarse graining effects are irrelevant for such systems. Yet, there is a useful method to define subsystems for such dissipative systems. The subsystems may be linked to the observer's internal differentiation, as not only the outside chaotic systems to be monitored display SDIC. The observer's internal dynamics also shows various levels of chaotic behaviour [9]. Both the observer's internal dynamics and that of the system observed therefore create their own individual entropy barriers as a result of their SDIC.

As zooming from one LOD to the next does not change the situation for systems which are governed by deterministic chaos, the only promising way to relate LODs is *between* systems, i.e. relating the observer and the system to be observed in terms of their internal differentiation (LODs). Below (8. Interface Complexity), I shall try to relate such deep nestings on the inside with those on the outside.

7 Physical Theories Reflect the Temporal Limitations of Observer Types' Referential Frames

The observer's Now is a limitation encountered by anyone who wishes to develop a theory about the universe. This limitation also reflects the way our physical theories are constructed. This was shown by Pöppel [10] and others. Therefore, when talking about observer types and referential frames, we have to keep in mind that we are discussing anthropocentric notions. Let me differentiate between two observer types who generate very different referential frames: non-fractal and fractal observers.

A non-fractal observer, who can perceive only isolated notes in a tune or isolated events in a time series, would not be able to observe either successive or simultaneous events. Succession, simultaneity and memory formation would be unknown to him, as he would not be able to generate a Temporal Fractal Perspective through continuous nesting. He would live in an eternal succession of unconnected Nows, in which no learning or reflection could take place [11].

A non-fractal observer frame lacks a differentiation into levels of description: all incoming stimuli may be measured, but not put into a translatable relation. This is so, because at least one framework time is required to provide a background against which successive impacts from the outside world may be related in the first place. Non-fractal observer frames may therefore be defined as being limited to $\Delta t_{depth} = 1$ (as a result, Δt_{length} cannot be defined, as no internal relations between the individual registered events can be established).

A fractal observer, on the other hand, is able to observe events on a number of LODs. He has an interface differentiated in both dimensions, Δt_{length} and Δt_{depth}. He can perceive both succession and simultaneity. This allows him to generate a Temporal Fractal Perspective, observing simultaneity and succession of events directly, in real time. Again, a non-fractal observer has a less differentiated interface: without Δt_{depth}, he can perceive neither simultaneity nor succession (as there is no Δt_{length} without Δt_{depth}).

Therefore, a fractal observer frame space may be defined as having two temporal dimensions at its disposal, which may be measured in Δt_{length} and Δt_{depth}, respectively. In order to differentiate further between observer types and their reference frames, I would like to introduce the notion of *interface complexity*.

8 Interface complexity

Interface complexity (IC) may be measured in the number of simultaneous *un-plaiting performances* carried out by the observer. To explain the notion of un-plaiting, I shall start with an example from the field of auditory illusions. I shall then draw an analogy to entropy.

$$IC = \frac{LODs_{(observer)}}{LODs_{(world)}}$$

Complete congruence would result in IC = 1.

8.1 Example 1: The Shepard Scale

"A *Shepard tone* is a sound consisting of a superposition of tones separated by octaves. When played with the base pitch of the tone moving upward or downward, it is referred to as the *Shepard scale*. This creates the auditory illusion of a tone that continually ascends or descends in pitch. (...) This can be constructed by creating a series of overlapping ascending or descending scales (...) Overlapping notes played at the same time should be exactly an octave apart, and each scale should fade in and fade out, so that it is hard to hear the beginning or end of any given scale." [12]

The discrete Shepard scale displays a self-similarity in its signal, which prompts an auditory illusion because the listener focuses only on pitch relations and thereby tries to extract a one-dimensional signal from a multi-layered one. If 8 scales are played simultaneously and the observer registers a rise in pitch as a result of arranging ascending tones on one LOD,

$$IC = \frac{LODs_{(observer)} = 1}{LODs_{(world)} = 8}, \quad IC = 1/8$$

In the Shepard scale example, the listener tries to extract a one-dimensional signal from a multi-layered one. But if the signal is multi-layered to start with, a multi-layered interface would simplify the signal for the listener. By differentiating the layers through a multi-layered interface, i.e. by un-plaiting it, the listener does not perceive an auditory illusion - he hears parallel distinguishable tone sequences or may switch his attention between LODs. This way, the observer has created a choice regarding his perception and cognition.

Interface complexity is measured in Δt_{depth} matchings, i.e. the number of one-to-one mappings of LODs belonging to the manifestations of the observer's assignment conditions and those belonging to the world. Maximum interface complexity (IC=1) is defined by complete congruence between the LODs belonging to the manifestations of the observer's assignment conditions and those belonging to the world.

A non-fractal observer cannot un-plait the stimulus, as he cannot process stimuli simultaneously on more than one LOD – he cannot generate Δt_{depth}. A fractal observer can generate a higher degree of Δt_{depth}, he can carry out numerous simultaneous un-plaiting performances, i.e. un-plait a complex structure into a more simple one. In order to be able to do this, however, he needs to learn how to differentiate between the individual layers of the multi-layered signal and adjust his internal differentiation accordingly.

To a fractal embedded observer, the world appears more simple than to a non-fractal observer, as he can make more sense out of it or knock more sense into it and can navigate through the world more easily. As a rule of thumb, all individuals who are able to communicate are fractal observers and all reference frames which are mutually translatable into each other display a fractal interface.

8.2 Example 2: Entropy

For nested systems, entropy is a multi-layered measure of complexity. What is normally measured, entropy in Δt_{length}, is only a one-dimensional abstraction of the entire system. If, however, the observer tried to extract a one-dimensional signal from a multi-layered one, he would jump from one LOD to the next in Δt_{depth} and thus experience the entropy-analogue to an auditory illusion.

Let me draw the analogy to auditory illusions step by step. Neither entropy nor the musical scales described above describe absolute values but focus on the relative differences in entropy or the relative intervals, respectively. The ever-increasing entropy and the ever-ascending tones are both the result of focussing on a one-dimensional signal/measurement rather than registering the overlapping, nested systems individually and simultaneously. For changes in entropy, the level-hopping results from an abstraction which manifests itself on the interface of a fractal observer who has not learned to consciously differentiate LODs. He does not register the individual subsystems as separated entities but selects subsets sandwiched by systems with increasing entropy only. This is the result of his intentionalism which is based on his knowledge about the second law of thermodynamics. Although the observer is aware of the fact that some subsystems, such as a refrigerator, may decrease entropy, he automatically contextualizes this subsystem by embedding it into the next level of description: the fridge and the power plant, which generates the electricity to run the fridge. At this point, he is likely to set an artificial cut and define these subsets collectively in the first step in his entropy balance as the system which consists of both subsystems, namely the fridge and the power plant, which together cause an increase in entropy. The observer's expectation or anticipation is fulfilled as a result of his selective abstraction. Just as the listener focusses only on pitch relations following an ascending scale, the observer measuring entropy expects the next-embedding subsystem to rectify the 'fridge anomaly' and therefore registers only steps of entropy production. This is the result of the observer's desire to contextualize, i.e. to look at subsystems which are not isolated (which exchange matter and energy with their embedded and embedding systems) only in context with their sandwiching neighbours. If, however, as I pointed out earlier, we can agree that, as mortal, embedded observers, all we can observe and measure are freeze-frames within this nested universe, these sandwiched subsystems may pragmatically be treated as isolated systems. We may disregard the individual boundary conditions, as the resulting effects are negligible for very short time intervals. If the nested system observed consists, for example, of 5 subsystems (2 of decreasing entropy and 3 of increasing entropy, nested inside each other so that layers of increasing and decreasing ΔS alternate), with entropy increasing in the innermost and outermost subsets, then

$$IC = \frac{LODs_{(observer)} = 2}{LODs_{(world)} = 5} \quad IC = 2/5$$

This observer does not arrive at IC = 5/5, as all he selects as valid outcomes of his measurement are the two nested subsystems which are sandwiched by those systems for which ΔS increases. Both the illusion of an ever-ascending tone and the impression that entropy increases appear on our observer-world interfaces as the result of a filtering effect. This filtering effect is caused by the structure of our interfaces. Fractal observers may be trained to re-interpret multi-layered signals as simultaneous individual scores or as subsystems with increasing and decreasing entropy. If an endo-observer has learned to differentiate between simultaneous subsystems, he generates a fractal temporal interface by means of which he can make out a beginning and an end within the nested subsystems and is able to treat them as isolated, independent systems measured as freeze-frames with a minimal timespan.

An observer who has not learned to differentiate LODs, i.e. identify his subsets, experiences an entropy analogue to an auditory illusion. He interprets the multi-layered processes as one event and remains at the mercy of a level-hopping-induced illusion: the illusion that continued contextualization leads to a 'true' measurement. This may subject him to the illusion that he is able to describe a nested system from the outside, i.e. from the point of view of a super-observer located outside the system he wishes to observe, turning him into a *pseudo-exo-observer*). This, however, is not possible. Consequently, we have to set artificial limits to our contextualization and admit that our embedding game is necessarily determined by our observer position and perspective. Boundary conditions may only be taken into account if one has already crossed the respective boundary and, having taken a step back, may then look at the embedded system, from outside that system. It is not possible to talk about boundary conditions from within. Hofstadter described this attempt as a stange loop or tangled hierarchy:

> "Something *in* the system jumps out and acts *on* the system as if it were *outside* the system." [2]

A pseudo-exo-observer, i.e. an embedded observer with a fractal temporal interface who has not learned to treat embedded subsystems as independent systems, would suffer from the need to over-contextualize. This is not a healthy approach, as the result of over-contextualization is an idealized construct which cannot be matched by an observation which is limited to a freeze-frame (which, alas, is all we can hope for as mortal, embedded observers). The exo-perspective of the super-observer and the *pseudo-exo perspective* of the over-contextualizing endo-observer are idealized perspectives which cannot be established.

The good news is that there is room for improvement in the shape of an *extended observer*. An endo-observer whose internal differentiation resembles that of the hot-water-ice-cube-universe would match internal and external LODs. If the interface complexity measured showed complete congruence, the observer would not register any increase or decrease in entropy. This may happen in the case of an extreme observer extension – a notion I shall introduce below.

9 Observer Frame Extensions

For an embedded observer, entropy either increases or decreases. This change in entropy is measured without knowledge of the boundary conditions, as the embedding system is not accessible. (The boundary conditions may only be defined if both the embedded and the embedding systems are describable, i.e. accessible).

It is, however, possible to conceive of an extended observer who, as a result of an insight, an intelligent guess, a theory he has developed, or an actual extension of his measuring chain and interfacial cut in spacetime, endeavours to take account of different endo-observer perspectives as well as of a possible exo-observer's perspective. If this gifted observer's internal structure matched that of the ice-cube-and-hot-water-bottle-universe, each subset of the observer would be in a one-to-one mapping with each subset of the hot-water-bottle-ice-cube-universe. In this case, this observer would not register any change in entropy (if he takes account of all embedding and embedded subsystems): His reference frame would display the same structure as the entire subset of the universe he encompasses. Therefore, his internal differentiation, his high degree of internal complexity, would condense the degree of the complexity (here: ΔS) of the outside world on his observer-world interface to next to nothing.

To introduce the concept of an observer extension, consider how men see and feel their cars as a physical extension of their own bodies. (Women don't do this). Things which extend an observer or a detector range from glasses, hearing aids, guns, dogs, cyberspace goggles, gravitational lenses, etc. to complex selection effects such as social and linguistic conventions.

An extended observer has transformed his immediate temporal embedding environment into part of the measuring chain and, in the wake of it, assigned the previously embedding environment to the observer side of the interfacial cut. This measuring chain may be extended arbitrarily with the effect of the interfacial cut being shifted outwards, thus increasing the physical and temporal extension of the observer.

Temporal embedding for a brain would consist of nested memory and anticipation (retension and protension) within the observer's Now, thus extending the observer's Now through repeated nesting.

A shifting of the interface by means of observer extension would result in differing measuring results for observers of unequal extensions: An increase in observer extension changes the endo-perspective, which takes account of interface reality only. As a result, a subset of the universe which was not part of the observer has been assimilated by him and will change the structure of his interface. At the same time, an increase in observer extension decreases the number of embedding systems which are accessible from the exo-perspective.

Observer frames may thus be defined by the structure of their temporal interfaces. The main distinction is to be drawn between exo-observers, pseudo-exo-observers and endo-observers. Endo-perspectives form the more convincing observer frames, as they do not commit the logical fallacy pointed out by Hofstadter (which pesudo-exo-observers are subjected to). And endo-observer who is aware of the structure which forms his temporal fractal interface would measure complete congruence for the above example with 5 nested subsystems:

$$IC = \frac{LODs_{(observer)} = 5}{LODs_{(world)} = 5} \quad IC = 1$$

A pseudo-exo-observer would also measure complete congruence. This, however, would be the result of the logical fallacy he commits by pretending he can jump out of the system he is located in and act upon or observe this system as if he were outside it. An endo-observer without over-contextualization habits measures $\Delta S_{(endo)}$ which corresponds to IC= 1/5 in the above example. An pseudo-exo-observer measures $\Delta S_{(exo)}$, which takes account of embedding systems, be they accessible or not (for an exo-observer, they are accessible; for a pseudo-exo-observer, they are not). The pseudo-exo-observer would measure complete congruence (IC = 1), albeit an illusory one.

For an exo-observer, IC is not defined, as we cannot specify the number of LODs at his disposal. In fact, we cannot make any assumptions about this observer's internal differentiation. For this type of exo-observer, $\Delta S_{(exo)}$ increases, as he sees the universe from the outside and therefore treats it as an isolated system.

An endo-observer who is in a position to consciously relate his internal LODs to multi-layered signals which penetrate his interface from the outside world may grow into an extended observer (as described in 9. Observer Frame Extensions). By re-setting the interfacial cut everytime he assigns parts of the outside world to his side of the interface, he may, at least theoretically, grow as large as the entire universe and thus encompass the very system he wished to observe. This is, of course, an extreme example and the self-referential entanglement resulting from an observer who encompasses the entire universe lead would lead to an infinite regress of self-observation.

It follows that entropy is a measure of complexity which depends on the number of LODs in existence on the observer's interface, his internal differentiation, position and extension,
and the assignment conditions, which determine the structure of the observer's temporal fractal interface.

A fractal observer or detector which represents an observer frame with a fractal temporal interface is an example of strong anticipation [13], as the interfacial structure contains a model of both the observer and the outside world. This manifests itself in the ability of such systems to avoid the blind level-hopping which an observer who is not aware of the structure of his fractal temporal interface is subjected to. An embedded fractal observer who is aware of the structure of his interface may interpret multi-layered events, which as impacts from the outside world shape his interface, as a multi-layered structure. For human observers, this matching ability is very likely the result of a selection effect [14].

To summarize, we may conceive of four observer types who measure entropy (in the form of interface complexity) in very different ways:

Table 1: Observer Types

observer types	**un-plaiting performances measured in IC**	**increase or decrease in ΔS**	**accountability**	**logical coherence**
The endo-observer who is not aware of the structure which forms his fractal temporal interface	IC = 1/5	$\Delta S_{(endo)}$ increases	falls for a temporal illusion	logially coherent
The endo-observer who is aware of the structure which forms his fractal temporal interface (and who may turn into an extended observer)	IC = 1	$\Delta S_{(endo)}$ neither increases nor decreases	does not fall for a temporal illusion	logially coherent
The extended observer aware of the structure which forms his fractal temporal interface and able to reset the interfacial cut	IC = 1	$\Delta S_{(endo)}$ neither increases nor decreases	does not fall for a temporal illusion	logially coherent
The exo-observer (an idealization)	IC = not defined	for an exo-observer, $\Delta S_{(exo)}$ probably increases, as he sees the universe as an isolated system	falls for a temporal illusion	logially coherent
The (over-contextualizing) pseudo-exo-observer	IC = 1	is under the impression that $\Delta S_{(pseudo\text{-}exo)}$ neither increases nor decreases	is under the impression that he does not fall for a temporal illusion	commits a logical fallacy

11 Conclusion

So, is there an overall increase in entropy in the universe? My answer to this question is: *not necessarily*. Entropy may increase or decrease, depending on the number of LODs taken into account, the observer's position and extension, the limited timespan available for observation and measurements, as well as the position of the interfacial cut.

A distinction between endo-, pseudo-exo and exo-observers needs to be drawn. Only an embedded fractal endo-observer who can consciously relate to the outside world on various nested LODs simultaneously and is able to treat them pragmatically as isolated systems (for very short timespans, i.e. freeze-frames) is in a position to escape a temporal illusion. This is also true if this fractal endo-observer grows into an extended observer. Endo-observers who are not aware of the structure which forms their temporal fractal interface are doomed to engage in a level-hopping exercise. Pseudo-exo-observers are under the impression that they do not fall for a temporal illusion. This, however, is a logical fallacy, as they pretend they may jump out of the system they are embedded in and observe this system as if they were outside it (and may thus define the boundary conditions for the system they are embedded in). An exo-observer does de facto not exist. It is a mere idealization and therefore subject to speculation regarding this observer's internal differentiation and perspective.

To conclude, a differentiation between observer frames is necessary when we talk about the interpretation of multi-layered signals or changes which take place within nested systems, as the measurements of endo-observers differ from those taken by exo-observers or pseudo-exo-observers.

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