

THIS ESSAY ACCOMPANIES THE TAPE *RAVE SYNTHESIS APPROXIMATIONS OF GYÖRGY LIGETI'S CONTINUUM*, WRITTEN AND RECORDED BY STEPHEN SHARP AND ROC JIMÉNEZ DE CISNEROS FOR *SOUND PROOF 4*, LONDON, 2011.

CONTINUUM, EXPANDED*

1. INTEGRATION, A FRAMEWORK

Long before the relativistic revolution of the twentieth century introduced the modern notion of *spacetime*, the Incas understood time and space as a unified concept they called *pacha*. This dimensional integration – a belief that is still held by many Andean indigenous populations today – is but one of the many historical precedents of modern spacetime¹.

At the turn of the twentieth century, the German mathematician Hermann Minkowski put forward a radical new idea, a four-dimensional fabric made up of our three familiar dimensions of space and a fourth dimension: time. “Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality” (Minkowski 1952). This manifold did not negate the existence of either space or time – it simply negated the fact that they were independent from each other. Roughly a decade earlier, Henri Bergson had rather poetically expressed it by stating that “time, conceived under the form of an unbounded and homogeneous medium, is nothing but the ghost of space haunting the reflective consciousness” (Bergson 1889).

Breaking away from the Galilean and Newtonian principles that had ruled Western physics since the end of the Renaissance era, Minkowski presented a bold new mathematical picture of physical reality that could accommodate and merge a number of cutting edge theories on light, mechanics, matter, and energy. This new spacetime meant abandoning the absoluteness of Newton’s substantivalism and adopting a view in which both time and space were dependent on the observer. Building on previous and parallel work by Henri Poincaré, Hendrik Lorentz, James Clerk Maxwell and others, Minkowski contributed a great deal to the foundation of Albert Einstein’s special theory of relativity, which made extensive use of spacetime as its conceptual framework.

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¹ The notion of spacetime existed before Minkowski’s manifold (Jean le Rond d’Alembert, Joseph Lagrange, James C. Maxwell and Arthur Schopenhauer, for example), but I am concentrating on Minkowski’s view because this essay is somehow tied to relativity.

In its acceptance of spacetime, post-1905 physics invites us to treat space and time on equal footing, but in a sort of counter-intuitive twist, it also implies incompatibilities in the properties of time and space. We know from experience that we can move in all directions of space, but not in time – you may choose to walk towards the north, but you cannot move towards the past. Other differences are less obvious. In the Big Bang model, for example, the Big Bang singularity is a point in the *timeline* of the universe (some 13.7 billion years ago), but it is *not* a point in space, since all space was concentrated, yet to expand, at the moment of the singularity. Despite the conceptual integration of spacetime, direction in time and in space does not work the same way.

Space is isotropic; there is no *true* up or down, because such notions depend on where and how you are situated. The cosmological principle states that every direction of space is as *good* as any other: that is, spatial orientation and spatial direction are relative. However, the direction of time, frequently depicted as the metaphorical “arrow of time”, turns out to be much more rigid. Measurements of time are certainly relative, but the imaginary arrow always moves from past to future, never the other way around. At least in our region of the universe, the arrow always points in the same direction.² Unlike the case of space, this directionality is not relative: time is anisotropic, not symmetrical.

The nature of time has been extensively debated for centuries by scientists and philosophers alike, but it remains a particularly annoying puzzle: something that we cannot easily pinpoint, and yet constantly experience and quantify. The very notions of history, heritage and memory, all of which are firmly ingrained in the transmission of human culture, are also inextricably linked to time. But as soon as we start asking ourselves about the nature of this mysterious flow, we find that it is hard to define as an abstract entity separate from our day-to-day experience of the world. Furthermore, if we refrain from using abstractions borrowed from modern science, such as thermodynamic entropy, or the aforementioned arrow of time, things get even harder as we realise that we actually tend to refer to time in terms of space. Just like the ancient Incas, something in our intuitive grasp of reality makes our language correlate space and time.

Phrases and idioms such as the *passing* of time, the fact that time *flies*, the *flow* of time, and many more, suggest directionality and spatial

² Lawrence Schulman at Clarkson University is one of the major proponents of opposite-running time regions in the universe. Schulman's site (<http://people.clarkson.edu/~lschulma/>) contains many of his published papers and articles.

properties. We even speak of events taking *place* at some point in time. Past, present and future are often conceptualised in terms of spatial orientation too. All these orientational metaphors described by Herbert Clark (1973), are rooted in our physical and cultural experience, even if they are not universally interchangeable: most human cultures use spatial representations for time, but these can vary in their structural approaches.

George Lakoff and Mark Johnson (1980) point out that “though the polar oppositions up-down, in-out, etc., are physical in nature, the orientational metaphors based on them can vary from culture to culture. For example, in some cultures the future is in front of us, whereas in others it is in back.” Even in such cases, language seems to favour the unification of spatial and temporal dimensions. Jean Piaget’s conservation experiments in the 1950s suggested that children between the ages of two and five confuse the spatial and the temporal (Piaget 1954). That is, that the separation of the spatial and the temporal is, to a certain extent, learnt – it is cultural.

2. MAPPING EVENTS ALONG THE TEMPORAL AXIS

Studies have shown that established cultural characteristics such as the direction of writing in a language condition the structure of our temporal-spatial representations. Orly Fuhrman and Lera Boroditsky (2010) write:

Writing direction has [...] been shown to affect people’s patterns of perceptual exploration, drawings, aesthetic preferences, and mental images of scenes. For example, Maass and Russo (2003) asked Italian and Arabic speakers to draw action scenes described in sentences. Italian speakers drew the action as happening from left to right, putting the agent of the sentence to the left of the patient. However, Arabic speakers showed a reverse pattern and tended to draw the agent of the sentence to the right of the patient. Döbel, Diesendruck, and Bölte (2007) demonstrated that this pattern in behavior is closely related to reading and writing experience: German- and Hebrew-speaking preliterate kindergarteners did not show the spatial bias found in literate adults in both languages. Writing direction has also been found to affect numerical reasoning. Readers of languages like English and French that are written from left to right represent numbers spatially on a “mental number line” with numbers positioned from left to right in order of increasing magnitude, while readers of languages like Farsi or Arabic that are written right to left show the opposite pattern.

If written language conditions our ways of thinking about time and space, it should not come as a surprise that something similar happens in musical notation, where time is, at least in principle, essential. Traditional post-medieval Western musical notation has imposed a strong spatial bias in our understanding of music. Regardless of our ability to read musical scores, the left-to-right linear representation of continuous sound as a sequence of discrete events is a familiar construct in the Western world. This fairly rigid idea of time in music, commonly represented as a line, does not only underlie musical scores, but has also made its way into a number of digital audio and video production tools such as audio sequencers, digital audio workstations, and the like. Ned Markosian (2010) analyses the topological features of our somewhat biased linear representation of time:

It's natural to think that time can be represented by a line. But a line has a shape. What shape should we give to the line that represents time? [...] One natural way to answer our question is to say that time should be represented by a single, straight, non-branching, continuous line that extends without end in each of its two directions. This is the 'standard topology' for time. But for each of the features attributed to time in the standard topology, two interesting questions arise: (a) does time in fact have that feature? and (b) if time does have the feature in question, is this a necessary or a contingent fact about time? Consider the question of whether time should be represented by a line without a beginning. Aristotle has argued (roughly) that time cannot have a beginning on the grounds that in order for time to have a beginning, there must be a first moment of time, but that in order to count as a moment of time, that allegedly first moment would have to come between an earlier period of time and a later period of time, which is inconsistent with its being the first moment of time. [...]

It is also worth asking whether time must be represented by a single line. Perhaps we should take seriously the possibility of time's consisting of multiple time streams, each one of which is isolated from each other, so that every moment of time stands in temporal relations to other moments in its own time stream, but does not bear any temporal relations to any moment from another time stream. Likewise we can ask whether time could correspond to a branching line, or to a closed loop, or to a discontinuous line.

Markosian's mention of alternative topologies for temporal lines is of course not new either. Kurt Gödel famously put forward a view of the universe

in which time and change were nothing but illusions, a conception of reality that allowed for closed time-like curves and closed causal loops. In recent years, Kristian Vester, aka Goodiepal/Gæoudjiparl, has made a commitment to cast out the linear paradigm from his students' compositions.

Like Iannis Xenakis and others before him, Vester has expressed his preoccupation with the strong dependence on linear time representation in modern notation and computer music, and in his series of publications *Mort Aux Vaches Ekstra Ekstra*, he has advocated an approach that excludes time coordinates altogether. Vester's proposal includes a number of what he calls "musical objects" (often, vinyl records in odd and self-referential shapes) that the composer/student can arrange at will on a *time-less* score. In his method, Vester (2008)³ is basically trying to isolate time from space:

The simple rule is that all these *Mort Aux Vaches Ekstra* musical objects have to be seen as bricks or dots in your composition. [...] All you have to do is imagine that you are pulled in different directions by single dots, bricks, or events, which do not happen to exist in time, since they are objectified, made down to one single dot. They are infinitively non-existing, or only just existing, and therefore they pull. So each single dot is moving in one direction – essentially, its own direction – pulling as much as you, as a composer, allow it to pull.

[All objects] happen to pull with the exact same strength, and you are right there in the middle and have to notate what happens in that vacuum. You think: "well, I can just map out a sequence in which these events have to be played". But think again, because that won't work. You have two events, A and B. That equals a possible timeline, and you can obviously notate what is happening in that timeline. But what happens if I add two, three, four or seven objects pulling with the exact same power as A and B? This is not a question of moving from A to B, this is a question of notating something that pulls and at the same time exists in a vacuum, right there in the middle.

However, even though most of our surroundings are non-linear in nature, the departure from linearity and time-dependency in Gödel's cosmology

³ Goodiepal's vacuum force/pull idea is somewhat reminiscent of dark energy. Also known as vacuum energy, dark energy is a theoretical invisible form of energy that covers all of space, and exerts a gentle, subtle push that causes the constant expansion of the universe. Despite its mysterious nature, dark energy makes up over 70% of the matter/energy total of the universe. Both impressive and frustrating.

or Vester's deliberately obfuscated notation strategies does not seem to fit easily into everyday experience. So far, this has ensured the prevalence of the linear model over branching, closed, or discontinuous ones in all sorts of time-based data plotting, including music.

A score implies the mapping of events occurring on one or more spatially different regions onto a single temporal axis, and the (rather wild) assumption that it is in fact possible to reduce a piece of music to a finite number of parametrised values like pitch, tempo, and so forth. The graphical codification of the temporal that perpetuates Guido d'Arezzo's staff notation method is an attempt to reconstruct a continuous signal from a finite number of discrete data points.

3. DISCRETE VS. CONTINUOUS, TRANSYLVANIAN STYLE

Discussing the implications of infinite sets, John Barrow (2007) said that "most fundamental pictures of the physical world assume that the basic notions — fields, space, and time — are continuous entities rather than discrete bits. This issue of discreteness versus continuity is an ancient tension in natural philosophy that re-emerges in every era in new dress".

György Ligeti's 1968 *Continuum* was an elaborate take on the conflict between the discrete and the continuous, as well as a thought-provoking analysis of our subjective experience of time. Written for harpsichord (versions for barrel organ and player piano also exist), the piece challenges the performer's ability to play extremely fast sequences of notes on two keyboards, and the listener's perception of those notes, which no longer appear as individual sounds but as part of a sonic continuum. The silent gaps between notes are audible, but they become fuzzy, blurry, and almost disappear due to the high speed of the percussive grains and the noise of the strings being rapidly plucked by the plectrum.

Thus, Ligeti's perceptual study proves to be an *avant la lettre* demonstration of David Huron's principle of temporal continuity, according to which, "in order to evoke strong auditory streams, [one should] use continuous or recurring rather than brief or intermittent sound sources. Intermittent sounds should be separated by no more than roughly 800 milliseconds of silence in order to assure the perception of continuity" (Huron 2001).

Ligeti called his piece "a pattern-illusion piece à la Maurits Escher" (Ligeti in Chojnacka). The reference to Escher is more than appropriate here: it was the Dutch artist who proposed a new and radical take on the ancient technique of tessellation, which clearly resonates in the granular structure of *Continuum*. Escher, heavily influenced by mathematics and to-

pology, implemented concepts like the Möbius strip in a number of works in order to address an unfamiliar, often absurd take on change, flow and infinity. In Escher's prints, sequences of events such as the water running in the famous *Waterfall* (1961), defy the viewer's understanding of depth, perspective and everyday physics. Either time or space appear to go against common sense in these visual paradoxes.

Metamorphosis III, finished the same year as *Continuum*, is a large woodcut print in which Escher once again plays with illusion, symmetry and change along various grids and organic chequered patterns. As with the notes in *Continuum*, we cannot get much from isolating individual, discrete objects from the canvasses. The real purpose of the triangles, fishes, birds, horses, houses, and squares, is to bring about the emergence of a continuum that challenges our intuitive comprehension of spacetime and the way fundamental blocks compose larger entities.

In Ligeti's piece, the continuum illusion is a poetic one – we know there are gaps between the notes. But individual notes are too fast for the listener to examine on a one-by-one-basis, so even though the whole (the perceived continuum) is not actually real, it is easier to relate to than its fundamental blocks (this raises interesting parallels with the long history of argumentation in the philosophical literature on part-whole relations).⁴

As if peering through a microscope, *Continuum* reveals an invisible, imaginary lattice that dictates the strict order of all of its sound blocks. In describing the influence of sub-Saharan music in the illusory pattern deformations of *Désordre*, the first book of *Études pour piano* (1985), Ligeti (1990) says: "In Africa, cycles or periods of constantly equal length are supported by a regular beat (which is usually danced, not played). The individual beat can be divided into two, three, sometimes even four or five 'elementary units' or fast pulses. I employ neither the cyclic form nor the beats, but use rather the elementary pulse as an underlying gridwork."

Continuum can almost be understood as a musical analogy of the Nyquist-Shannon theorem, the basis for digital sampling of analogue signals, which states that a continuous analogue signal can be sampled and efficiently

⁴ Even though this has been one of my main interests for a while, I feel like elaborating on it here would be too much of a tangent from the current discussion. I recommend reading almost anything by Theodore Sider, Dean Zimmerman, or Peter van Inwagen. The literature is full of radically opposed positions, so checking out more than one author is a must! On a side note, Escher's *Metamorphosis III* is also related to mereology and parthood. Stephen and I recently completed a large EVOL work called *100 variations for solo hoover* that touches upon issues such as part/whole relationships, similarity, boundaries and so on (though, honestly, the point was simply to create a brutal, impossible to digest, piece of music).

reconstructed from a sequence of discrete samples if the sampling rate (per second) exceeds twice the highest frequency of the original signal. In *Continuum*, the discrete notes played at a fast rate (the *Nyquist frequency*, in this analogy) give rise to the illusion of continuous sound.

In fact, in its poetic quantisation of sound, *Continuum* draws attention to another pressing issue that arose in physics at the turn of the twentieth century, around the time that Minkowski introduced spacetime: how can a world that is grainy and quantised at a subatomic level appear continuous, smooth, and flowing in our macroscopic day to day existence? Is reality continuous or discrete? Does reality simply appear continuous to us as a by-product of our sensory system?

Aldous Huxley's concept of "mind at large", as described in his 1954 book *The Doors of Perception*, suggests that the brain's function is not to create, but to filter – to protect us from an overload of sensory inputs. Thus, the brain's job is to smooth reality, simplify experience and, ultimately, ensure the survival and reproduction of the species.⁵

For millennia, many of the psychotropic experiments advocated by Huxley in this and other books have been standard practice in religious and shamanistic cultures around the world. Descriptions of these experiences often include a completely different perception of reality, one in which time and space are drastically warped, even leading to the loss of the subject's sense of self. Amy Bauer (2004) compares *Continuum* to the "distorted" perception of time in schizophrenic seizures. At the very least, the time scale and note density of the composition seem to play with the aesthetic appeal of sensory overload.

Ligeti wrote *Continuum* three years after Tony Conrad made his film *The Flicker*. And despite the obvious differences between the two, both use a similar structural approach, based on pulse trains – sequences of alternating opposites. In Conrad's stroboscopic film, it is the black and white frames that alternate; in Ligeti's composition, it is the rapid fluctuation of notes and gaps.

Both pieces play with sensory manipulation and perceptual effects, and operate at a rate that is fast enough to induce illusory continuum to some degree, but also slow (or disconnected) enough so that persistence of

⁵ I had read about this notion in a number of essays about evolutionary theories, but I only recently heard about Huxley's idea in a panel at the Science Museum in Barcelona, where Carl Michael von Hauswolff made a point about "mind at large" while we were talking about human vs. animal time scales. Huxley's point may be merely a reformulation of previous ideas, but it is especially interesting in the context of psychedelic experiences.

vision, and its sonic equivalent in Ligeti's case, do not quite provide a clean, continuous stream.^{6 & 7} Along similar lines to the impression of seamless visual flow in recorded moving images (or grainier precedents such as zoetropes and flipbooks), a number of scholars in the field of neuroscience support a theory according to which consciousness emerges from the sum of many sensory data streams, each of which is no more than a collection of discrete inputs. In other words, that our perception of the world as a continuous flow is merely an illusion (O'Regan in Blackmore 2005). This view had been previously championed by twentieth century composers like Xenakis, who famously implemented grain-based techniques in his work. Xenakis (1991) said: "All sound is an integration of grains, of elementary sonic particles, of sonic quanta. All sound [...] is conceived as an assemblage of a large number of elementary grains adequately disposed in time".

4. DURATION, DILATION

In his analysis of the phenomenology of time, Edmund Husserl explained past, present, and future (the three divisions of our familiar representation of time) in terms of what he calls *retention* and *protention*. Retention allows us to experience (through memory) the past in the now, while protention provides us with expectations about the future. The experience of time always takes place in the present, the now, but through retention and protention, we are able to build a connected subjective experience of past, present and future – which we conceive as a continuum, a *potentially infinite* line. To put this in Minkowskian terms again, Russell Stannard (2008) says: "One of the disconcerting features about four-dimensional spacetime is that nothing changes. Changes occur in time. But spacetime is not in time;

⁶ In fact, stroboscopes are typically used to make moving objects appear to be stationary, or at least moving at a slower rate, just like the note sequences in *Continuum* induce a sort of perceived stasis. Increasingly faster strobes continue to be developed to obtain clearer pictures of increasingly small subatomic particles. One of the last big advances in the field (in 2001) was a strobe capable of emitting individual pulses of just 220 attoseconds, or 220 billionths of a billionth of a second.

⁷ Persistence of vision is still the accepted term for this phenomenon in the realm of cinema history and theory. In the early days of film innovation, it was scientifically determined that a frame rate of less than sixteen frames per second caused the mind to see flashing images. Audiences still interpret motion at rates as low as ten frames per second or slower (as in a flipbook), but the flicker caused by the shutter of a film projector is distracting below the sixteen-frame threshold (from Wikipedia).

time is in spacetime (as one of its axes). Events that we customarily think of as no longer existing because they lie in the past, do exist in spacetime. In the same way, future events which we normally think of as not yet existing, do exist in spacetime". In the formulation of his theory, Husserl was influenced by William James' pioneering work *Principles of Psychology*, which expanded the concept of the *specious present*, coined a few years earlier by E. Robert Kelly. James (1890) defined the specious present as "the short duration of which we are immediately and incessantly sensible".

This view of the present, no longer a *durationless* instant, but a short lapse, helped James and others explain, for instance, why we are able to see movement. After all, motion occurs over an interval, not a point-like instant. Thus, if the present were durationless, "we would not see pictures on the television screen or VDU of a computer, since these are built up from a moving electron beam. More generally, we would not see anything at all, since light itself is a motion" (Gombrich (1964) in Le Poidevin 2004).

The implications of the notions of duration and the present, which go back to St. Augustine's considerations on time written around the year 400, turn out to be crucial in the perception of music and musical time. Husserl often uses music (the notes we have just heard a few moments ago, the anticipation of melody progressions, musical surprise) as a metaphor for the experience of time. Reflecting on the perception of sound and duration, Bergson (op. cit.) reconstructs the hypothetical ringing of a bell, the sounds of which reach his ears one after the other, much like the sequences of fast cascading notes in *Continuum* reach the listener:

Either I retain each of these successive sensations in order to combine it with the others and form a group which reminds me of an air or rhythm which I know: in that case I do not count the sounds, I limit myself to gathering, so to speak, the qualitative impression produced by the whole series. Or else I intend explicitly to count them, and then I shall have to separate them, and this separation must take place within some homogeneous medium in which the sounds, stripped of their qualities, and in a manner emptied, leave traces of their presence which are absolutely alike.

The question now is, whether this medium is time or space. But a moment of time, we repeat, cannot persist in order to be added to others. If the sounds are separated, they must leave empty intervals between them. If we count them, the intervals must remain though the sounds disappear: how could these intervals remain, if they were pure duration and not space?

Bergson's account references the opposing ontologies of time known as "presentism" and "eternalism". In the former, only the present (the *now*) exists, while in the latter, also known as block universe, spacetime is conceived as a four-dimensional block. According to eternalism, there is no real change, time does not pass – all we can do is measure durations between events, much like we can measure distances between objects in space.

Casey O'Callaghan (2005) uses an enticing mental image to reflect on the perception of sound duration. He speaks of sound waves "as an event-like particular that unfolds at different places in the medium over time, domino-wise". The falling dominoes analogy suits *Continuum* well. As in a domino chain, or in Zeno's view of time as a sequence of many indivisible *nows*, the notes in *Continuum* fly by at great speed. Every pair of keystrokes produces a discrete sonic unit and their durations are uniform – though somewhat flexible, as we shall see.

Ligeti did not specify precise durations for these atoms. In *Continuum*, the only tempo indication is *prestissimo* (really fast) at the top of the score, and a footnote that adds: "the correct tempo has been reached when the piece lasts less than 4 minutes [...] there is neither beat nor metre in this piece" (Ligeti 1970)⁸. In an unpublished paper, Mark Fell (2011) states that "The primary function of the score is the symbolic representation of the temporality of sound: a conceptual apparatus for encoding and constructing time-based process. From this apparatus the performer is able to re-enact, re-actualise and re-temporalise the sonic form". Ligeti adopts an unorthodox approach to this re-temporalisation of the sonic form. Just as time is not absolute in special and general relativity, but rather depends on the observer's frame of reference, the duration of the work is also dilated, merely an approximation. That is, Ligeti's instructions rely on interpretation. Playing at rocketing speeds, Glenn Gould had already shown in his 1955 recording of Bach's *Goldberg Variations* that a subjective interpretation of the score was unavoidable. If a score fails to map and encode the totality of the work, then we must accept the relativisation of some parameters.

⁸ There are records of several ancient graphic notation techniques that also lacked directions for note durations or metre. Scores for the Yang chanting tradition in Tibetan music, for instance, are believed to date as far back as the sixth century and do not provide any tempo directions for duration nor rhythm. They do, however, contain "detailed instructions concerning in what spirit the music should be sung (e.g. flowing like a river, light like bird song)" (Schøyen Collection), much as the Italian tradition uses tempo markings like *piano*, *allegro*, *moderato*, and so on. Ligeti uses *prestissimo*, but it could have been a *piacere*, another classic Italian direction that leaves tempo up to the performer's own discretion (in this case, their discretion to complete the piece under four minutes).

Two years after Gould's rise to stardom, Fred Hoyle's science fiction novel *The Black Cloud* depicted an alien super-intelligence making contact with human scientists. After hearing a recording of a Beethoven sonata, the cloud replies: "Very interesting. Please repeat the first part at a speed increased by thirty per cent".

In a similar way, Ligeti's instructions do not directly concern note durations, but the duration of the overall piece. From Ligeti's directions, one could assume he is mocking the validity of standard terms such as *prestissimo*. The composer knows that no matter how fast the piece is played (on average, notes are around 70 milliseconds each), it will be at least more than three minutes. But within these limits, variation is assumed.⁹

Ligeti figured out that the barely playable sequences of *Continuum* (sixteen to eighteen notes a second) were – perhaps contrary to common sense – an effective way to simulate stillness: the composer manages to induce a sort of stasis sensation by using fast repeating patterns.

Psychophysical experiments have proved that "when many stimuli are shown in succession, a low-probability 'oddball' stimulus in the series tends to last subjectively longer than the high-probability stimuli, even when they are presented for the same objective duration. This is true in both vision and audition" (Eagleman et al. 2005). By calling attention to the listener's perception of time-based events, *Continuum* sheds light on the distinction between the human experience of time and time as a seemingly fundamental property of the universe (time as a component of spacetime) – that which Newton called absolute time.

Continuum is a perceptual exercise on the nature of change, and its structure constantly plays with attentional shifts: the listener is confronted with long streams of sound quanta that alternate between phases of steady, almost-linear stasis, and sudden variation. The overall melodic progression of *Continuum*, from the first sections where equilibrium appears solid

⁹ As I was finishing this text, in late September 2011, news broke of an experiment conducted between CERN and the Gran Sasso Laboratory in Italy, in which neutrinos were observed to travel faster than the speed of light. If confirmed, this result would force us to rethink everything since Einstein's groundbreaking theories, which were built upon the speed of light as a universal, unbreakable constant. This has sparked a lot of debate and it will have to be confirmed by further tests – there have been claims that the experiment could have been flawed, or somehow inaccurate, or that it is not neutrinos that were detected, but tachyons (a so far hypothetical particle which is indeed expected to travel faster than light, though I fail to see how that is of any consolation). But in the meantime, and from the comfort of my layman perspective, I rejoice as a bunch of subatomic particles seem to challenge the foundations of contemporary science and echo some of the thoughts developed in this essay about events unfolding at speeds greater than we might expect.

to later sections of pure melodic disequilibrium, echoes archetypical descriptions of chaotic systems and entropy.¹⁰

5. SIMULTANEITY

The awareness of subjective time is a key element in all of Ligeti's micro-polyphony: from the seemingly stationary sound masses of *Atmosphères*, to the rather theatrical *Poème Symphonique for 100 metronomes* that preceded his *pattern-meccanico* technique. But it is the methodological and conceptual implications of *Continuum* that suggest a deep insight into the phenomenology of time and concepts such as the relativity of simultaneity. After relativity, the concept of simultaneity lost its usual, intuitive meaning. But even if we take a Newtonian standpoint and ignore the fact that simultaneity is completely relative in Minkowskian spacetime, we face a problem of detail, fineness and scale, which Richard Dawkins (2005) calls *Middle World*:

Our brains have evolved to help us survive within the orders of magnitude of size and speed which our bodies operate at. [...] Middle World, the range of sizes and speeds which we have evolved to feel intuitively comfortable with, is a bit like the narrow range of the electromagnetic spectrum that we see as light of various colours. We are blind to all frequencies outside that unless we use instruments to help us. Middle World is the narrow range of reality which we judge to be normal as opposed to the queerness of the very small, the very large and the very fast.

Lisa Randall (2005) explains our constant process of information loss in terms of the concept of “effective theory”, which “only asks about things you could hope to measure or see. If something is beyond the resolution of the scales at which you are working, you don't need its detailed structure. [...] The paint on a wall, or a clothesline viewed from far away, are examples of things that

¹⁰ Around 2004-2005, when I was working on nonlinear algorithms and pseudorandom functions in EVOL, I became quite obsessed with the Logistic Growth Equation proposed by Pierre François Verhulst around 1840 and rediscovered by Robert May in the 1970s. May found that, given the appropriate parameters, this equation which had been conceived as a tool to calculate population growth, behaved in a totally chaotic fashion, returning values that oscillated between steady patterns and apparently random series. In Ligeti's score, the fast repeating two- and three-note patterns that evolve towards longer sequences (until they are long enough to appear random to human eyes) are not far from that behaviour.

seem to extend in fewer than three dimensions. We overlook the paint's depth and the clothesline's thickness".

Similarly, the time scale at which our senses operate does not allow us to measure with enough precision the timing of events we commonly refer to as simultaneous. They may appear to be so by our human-friendly metrics – minutes, seconds, maybe some fractions of a second – but if we could measure these in nanoseconds, picoseconds, atoseconds and so on, we would easily get a whole different picture of simultaneity. Hence, simultaneous events in musical performance are hardly ever simultaneous in a literal sense, but Ligeti's score set out to put that to the ultimate test, both for the audience and the performer, who has to carry out extremely fast sequences of hand movements on two different keyboards.

Huron (op. cit.) points out that "the concept of synchronization raises the question of what is meant by 'at the same time'? Under ideal conditions, it is possible for listeners to distinguish the order of two clicks separated by as little as 20 ms (Hirsh 1959). However, in more realistic listening conditions, onset differences can be substantially greater and yet retain the impression of a single onset." In the context of Minkowski spacetime, it is not even meaningful to ask whether two spacetime points are simultaneous.

In Einstein's Special Relativity, each observer has his or her own plane of simultaneity, each with a unique set of events according to the observer's very own *now*. The Andromeda Paradox derived from the Rietdijk–Putnam–Penrose argument is a famous thought experiment proposed by Roger Penrose to question the absoluteness of time, in which "two people pass each other on the street; and according to one of the two people, an Andromedan space fleet has already set off on its journey, while to the other, the decision as to whether or not the journey will actually take place has not yet been made. How can there still be some uncertainty as to the outcome of that decision? If to either person the decision has already been made, then surely there cannot be any uncertainty. The launching of the space fleet is an inevitability" (Penrose 1989).

A study conducted in 2000 proved, as Sean Carroll puts it, that we "live in the past". That is, that there is a constant lag, a short compensation time factor of roughly 80 milliseconds that our mind applies to all of its sensory input in order to compose the synced final picture: "Use one hand to touch your nose, and the other to touch one of your feet, at exactly the same time. You will experience them as simultaneous acts. But that's mysterious – clearly it takes more time for the signal to travel up your nerves from your feet to your brain than from your nose. The reconciliation is simple: our conscious experience takes time to assemble, and your brain waits for all the relevant input before it experiences the 'now'" (Carroll 2011).

6. LEGACY

Neither the liner notes nor the labels of Elisabeth Chojnacka's avant-garde harpsichord compendium *Clavecin 2.000* (on Philips' influential *Prospective 21e Siècle* series) mention the year of publication, but it is most likely to have been between 1968 and 1970. In any case, Chojnacka's album was not the first to feature *Continuum*. A bit earlier, Wergo had published the piece performed by Antoinette Vischer, the Swiss harpsichordist who commissioned the work and premiered it in Basel in 1968.

However, on Wergo's LP, Ligeti's work was the last track on side B. Chojnacka was the first to bring it to the forefront: *Clavecin 2.000* proudly opens with *Continuum*. The back cover of the album advises: "The listener is expected to play this recording at full volume and in total darkness". Chojnacka wants the listeners to submerge themselves in what Seth Horvitz (2009) refers to as "a 'stroboscopic' work for solo harpsichord, a work which feels at once like a physical object hurling through space, a machine about to explode, and an uncanny attempt to simulate granular synthesis with an antiquated instrument of the baroque era".

Ligeti was certainly not alone in his vindication of the clavichord: Mauricio Kagel, John Cage/Lejaren Hiller, Francis Poulenc, Elliott Carter and a host of avant-garde composers wrote pieces for harpsichord around the same period, with mixed results. About a decade earlier, in the mid 1950s, Ligeti had spent some time with Karlheinz Stockhausen and Gottfried Michael Koenig at the famous WDR electronic music studio in Cologne, where Ligeti had access to a number of pioneering tools and techniques that seemed to perfectly fit the scope of his interests in music.

However, he only wrote a few electronic works, and soon decided to distance himself from electronic technology and went back to composing for old, familiar instruments. It is simply impossible to ascertain how much of his post-Cologne pieces was a direct result of the time spent at the WDR. But the truth is that many of his instrumental and choral works after Cologne contain electronic-sounding textures (*Continuum* is no exception!) – which indeed seems to suggest that the composer decided to apply the teachings and influence of the WDR experience to more traditional tools, such as the harpsichord. Whether or not it was a sign of the times, Ligeti took an instrument from the late fourteenth century and embraced its history, its legacy and technical characteristics, without an apex of nostalgia. On the contrary: thanks to one of the most progressive composers of the time, *Continuum* managed to accommodate radical musical ideas and cutting edge scientific theory into this six-hundred-year legacy. A daring perspective for the twenty-first century.

APPENDIX: EXPAND THE BAGGAGE

Parts of this text originated during a four-way email conversation with Thom Blake, Theo Burt, and Peter Worth. The trigger for that conversation, which went on for several weeks, was a piece of code written in the SuperCollider language.¹¹ I had been using this block of code for over a year to manipulate musical patterns and decided to ask Thom, Theo and Pete about its conceptual implications – namely, its possible validity as a clumsy metaphor for the notions of time dilation and length contraction in special relativity. This led to a series of related considerations on “musical time”.

Several audio and video examples were exchanged during the conversation to illustrate some of the ideas, and Ligeti’s *Continuum* was of course one of them. At some point I decided to transcribe as best as I could (not very well) Ligeti’s score onto a SuperCollider patch, to test how my *time-bending* task would distort the continuum effect, to see how much you could mess with the tempo before the effect disappeared. This turned out to be boring, but I started making recordings of the piece using different synthesizers. To my surprise, once out of context, many sections sounded fairly similar to the patterns and melodies of old school hardcore tunes – “it’s a rave stab gold mine”, I wrote in one of my emails.

Some time later, during a trip to Stephen Sharp’s home in Alloa, Scotland, to eat really good curry and record some new EVOL tracks, we started using *Continuum* as a starting point for some recordings. Nothing much happened, but we had fun playing the piece through some classic stab synthesizers. Months later, Seth Horvitz was kind enough to send me a MIDI file of Ligeti’s piece. A few days later, Pete Worth managed to split the file in two: one for each hand/keyboard of the original piece. I sent the files to Stephen to try and record some approximations¹² of *Continuum* using iconic club culture sounds. We tried more or less conservative hoovers,¹³ detuned

¹¹ The code is a SuperCollider task that changes the value of the environment’s tempo in BPM to a random value every one second. But since the tempo changes every time the task runs, the duration of each iteration varies. For the software, this duration always remains one second, but it may in fact take longer or shorter than one second depending on the newly created tempo value: at 60 BPMs, we perceive one second as one second, but at 120 BPMs it becomes 0.5 seconds because tempo is twice as fast. At 240 it is 0.25, and so on.

¹² *Versions* would be too strong a word here.

¹³ For further information and experiments with hoovers see *Rave Slime* (12”, ALKU 103, 2010) and *Wormhole Shubz* (CD, Entr’acte E122, 2011). The latter includes a conversation with sound designer Eric Persing, accidental father of the Hoover sound.

supersaws, house-style pianos and the like. The tracks in the tape that accompanies this text are what came out of it. These should not be seen as finished tracks, but as rough studies. The speed of the note sequences makes the synthesizers behave in strange ways, and odd timing artefacts are easy to spot in a piece like this. In any case, the tracks are not presented here to prove how unforgiving Ligeti's score can be even for non-human performers.

I have a long-standing fascination with recontextualisation in electronic music. This includes a plethora of examples, from the Moog fever of the 1960s and 70s, when pretty much any remotely popular tune was synthesized, to the countless, massively slandered club anthems that abuse recognisable classical melodies, Christmas carols and whatever else they can get their hands on, as a pretext for arpeggio-loaded floor fillers.¹⁴

Reframing *Continuum* in the context of Rave Synthesis is not simply a nod to the original. I am very much interested in how certain sounds become standards, icons, and clichés, assimilated at different levels of pop culture. One of the most fascinating theories in recent cosmology is Max Tegmark's *Mathematical Universe Hypothesis*, which suggests a view of reality as a mathematical object, since all structures that exist mathematically also exist physically. Tegmark proposes a way to describe everything around us without making use of the "baggage" derived from human language and experience. As we have seen, our writing systems, our linguistic devices and our mind at large, are biased and loaded after all.

However, as mind-blowing as I find Tegmark's theory, I doubt it could be easily applied to art, where heritage, legacy and baggage are both unavoidable and exciting. Not only that, they are inconspicuous. At some point, we discover, much to our surprise, that certain sounds, certain mannerisms and practices, have quietly made their way into our collective unconscious. Standards seem to pop up overnight. And once they do, it's hard to get rid of their presence, their influence and their baggage. Processes of integration – artistic or otherwise – are fucking sneaky.

Roc Jiménez de Cisneros, Barcelona, 2011.

¹⁴ Fine examples of this tradition can be heard in practically any European country since the early nineties, but I must say Spain would probably rank in the top three if someone ever went to the trouble of keeping tabs.

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