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Auditory perception and the subjective representation of time

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Abstract
The phenomenology of time perception is highly important for auditory perception and the assessment of the effects of sound. Pure psychic effects of sound need to refer to a definition of subjective exposure time and dose. Time variant sounds are sequentially perceived. However, the Gestalt that is configured during the process of perception includes uncertainties of the time axis, which can be highly individual and may show distinctly variable scaling.
Perceived time usually refers to aspects of space. It is thus represented as a concept of subjective space-time, which is essential for sound perception. How does this cognitive concept influence the formation of auditory Gestalt, the decoding of nonverbal information and the psychic strain caused by noise? How does the subjective representation of time actually correspond to the physical time?
In consciousness, transformations happen from temporal to spatial aspects of sound. The related processes are connected to conversions of coordinate systems and subjective scaling. Audible periodicities can cause a subjective standstill of time, a phenomenon for which the term *circulatio paradox* is proposed.
The formation of the subjective space-time is essential for numerous applications: interpretation of feedback-signals, perception of music, and detection of aspects of movement in sound and music. It is also of major importance for the assessment of emotional effects of auditory signals.

Keywords: hearing, psycho-acoustics, time perception, phenomenology, noise control.

1 Introduction

The subjective representation of time plays a major role for the assessment of the psychic effects of sounds and music. The conscious sensation of annoying noise over a longer period provokes a stronger negative impact than a casual perception that is interrupted by distracting activities. This is plausible with reference to the noise of a dentist's drill that is audible in the waiting room. Reading a journal can significantly reduce the annoyance and moderate unpleasant expectations.

Furthermore, the question remains as to what extent the expectation of dynamic changes affects the instantaneous perception of sound. As an example, this applies to the sudden occurrence of squealing tires, which with reference to perceptual experience implies apprehension of the subsequent bang of an accident. To what degree does the current and past perception of an auditory event determine the estimation of a change in the near future – and by this means, its present effect?

The field of subjective representations of time is an element of the discussion on perceptual quality, which has been introduced by the author in 2019 [1].

Due to the complexity of the topic, in this paper it is only possible to provide a first approach to the phenomenology of time perception as far as it may be relevant for hearing.

A special topic is the evidence of a subjective space-time as an essential phenomenon of auditory perception. The establishment of subjective space-time has extensive consequences for the interpretation of acoustic signals, such as functional feedback, musical processes and, especially, the detection of movement content of sound and music.

Two applications of sound assessment are of major interest:

1. The subjective *dose* as assessment value of the psychic effects of sound, such as annoyance, but also for the positive effects of sounds and music.
2. The estimation of the subjective response to *expected* sounds and the incidences presumably connected to them.

2 Objective time

The existence of an objective, continuously flowing time is usually presupposed by science as well as by the experience of daily life. This assumption of an infinite time axis allows for the imagination of a point in time and of a time span with appropriate scaling. The time scale of imagination may comprise either a few nanoseconds, some hours or numerous light-years. Even the space-time continuum, which quantitatively exceeds our living environment to an extreme extent, can be accessed via notional projection of different locations onto different sections of the time axis.

However, it can be questioned whether or not such a single time axis that covers all temporal phenomena exists in reality. Is the specificity of the existence of time similar to the evidence for the existence of objects that are characterized by physical and/or biological features? However, the question about the fundamental existence of time as a given fact is of secondary importance here. Changes and movement of objects undeniably exist. Moreover, it is observed that processes develop in a causal manner. For scientific description of processes, an auxiliary quantity is needed, such as the variable ‘t’. This variable gains quantitative content by means of the comparison with – obviously existent – periodic events, such as the standardized pulsing of clocks. This variable enables the description of all kinds of natural changes with appropriate accuracy, independently of the question regarding the objective existence of a continuous and all-embracing time.

3 Subjective time

The subjective perspective of time appears to be totally different to the assumed evidence of objective time. However, during daily life, we are used to align our perception of changes and duration of processes with the aforementioned periodic references, such as a clock. By such means, we tend to support the idea of an identic absolute time, which is valid for both physics and perception. In fact, physical assumptions are certainly not valid for the subjective world of individual consciousness.

The subjective flow of time as experienced during the “ordinary banality of being” (adopted from Heidegger’s term “durchschnittliche Alltäglichkeit des Daseins” [2, p. 43]) is an extremely variable phenomenon. It is thus difficult to grasp. Furthermore, it is clearly independent from what can logically be derived. If we imagine our perception of the present moment as a position on a virtual time axis, we stay in the present as an intersection between past and future. This perspective of such an *A type time series* will subsequently be explained in more detail.

If we stay in the present with our view on the flow of time, neither the past nor future exist logically. If we further sharpen our focus on the current moment, the interfaces to the past and to the future come infinitesimally close and factually eliminate the existence of the present. However, such a logical approach to the reality of the present does not lead to a result that is in accordance with our experience of daily life. We feel the existence of time. In consciousness, it is evident that the present is not reduced to a quasi-mathematical point on the time axis. In daily life, the reality of the present covers a larger area in our consciousness. As an example, Figure 1 shows a graphic of past, present and future depicted by a test person [3]. Imagination of the present does not only enfold in a split second, but rather in a larger time frame that depends on the topic considered: the next motoric activities, "this morning," "the weeks until holidays," "the history of the first quarter of the 21st century," and so on.

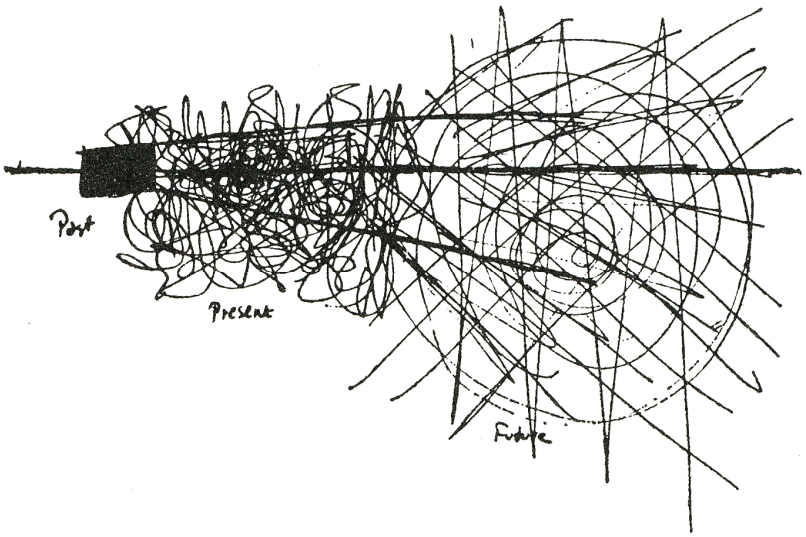


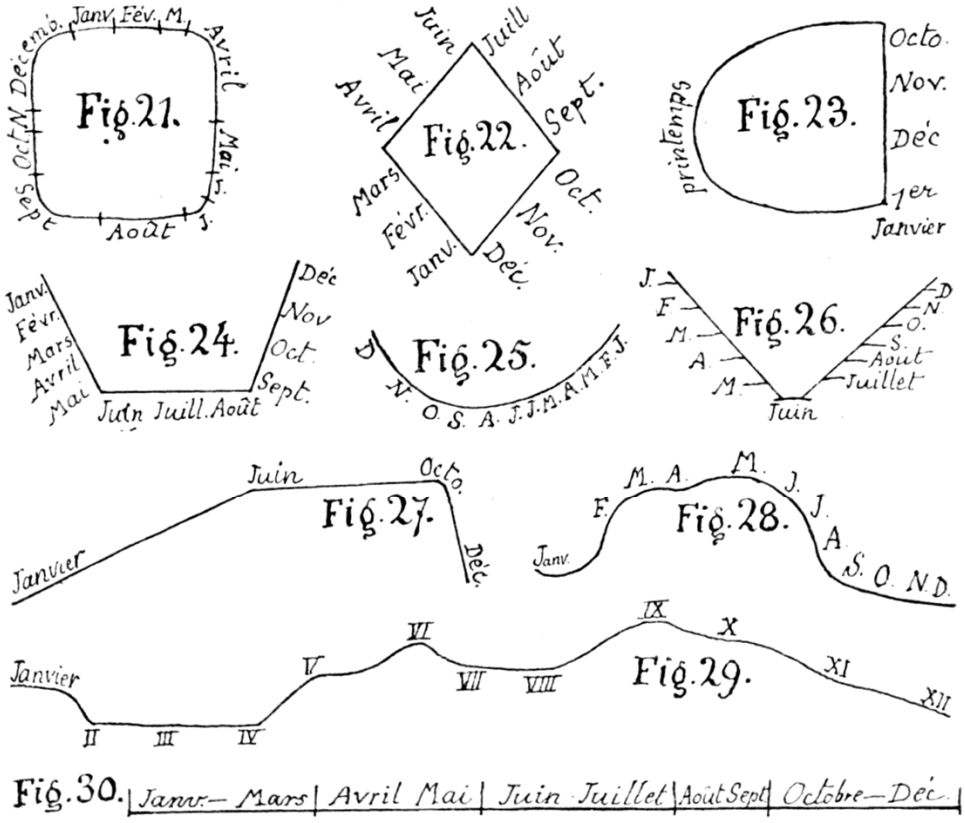
Figure 1 – Depiction of past, present and future by a test person, from left to right. The person comments: "The *past* is solid and complete, but still influences the present and the future. The *present* is complex and not only a result of the past and leading to future, thus overlapping both, but is an entity in itself (black dot). The *future* is least limited but influenced by both, past and present". [3, Fig. 22]

The subjective experience of changes is fundamentally different from what can be hypothesized regarding the "objective" world of physics. A human being preserves the feeling of personal identity and unity throughout their whole life. However, our perception of ourselves and of other individuals depends on processing, storage, and memory of numerous images. These images of one subject show a strong variability of appearance, especially in cases where our observations cover a large part of the person's lifespan. Nevertheless, these highly diverse images are usually assigned to this single person, who physically exists exactly once at every point in time. Interestingly, the unity of a person is not damaged in our consciousness, even if our impression is based on a very high number of very different pictures stored. Otherwise, the images would show confusing multiple existences of the given person in question.

At first, recognition is characterized by the reproduction of these manifold impressions. Subjective time provides a concept of collocation, which enables us to solve the paradox of the assignment of numerous memorized images to one identical person (or object). By means of the assumption of a continuously flowing time, dissimilarity of these images is plausible as a function of a scaling that clarifies change as a temporal process. This scaling features a distinct analogy to spatial coordinate axes. We can thus paraphrase time with attributes of spatial movement, such as the "course" or "length" of time.

Already during the 19th century, it was known that the sequence of the months of the year can be represented with a variety of forms in the conscious. Figure 2 demonstrates that a survey of adults and children revealed linear, curved or closed forms of subjective representations of a year [4].

During that time, such visual phenomena triggered by non-visual content were named *phostisms*. Today, we speak about *ideasthesia* if the representations are concept-driven in contrast to *synesthetic* representations caused by sensory stimulation [5].



Exemples de diagrammes annuels, type fermé, type ouvert et type illimité. — *Fig. 21.* F. 27 ans. (Ages de la vie.) — *Fig. 22.* F. 11 ans. (Photismes.) — *Fig. 23.* F. 19 ans. — *Fig. 24.* H. 46 ans. (Semaine et série numérique, obliques descendantes.) — *Fig. 25.* F. 19 ans. — *Fig. 26.* F. 35 ans. (Semaine verticale descendante, série numérique ascendante.) — *Fig. 27.* F. 30 ans. — *Fig. 28.* F. 23 ans. (Photismes.) — *Fig. 29.* H 22 ans. (Photismes.) — *Fig. 30.* H. 22 ans. Années à divisions scolaires. (Année abstraite circulaire.)

Figure 2 – Subjective representations of a year reported by various persons according to a survey by Theodor Flournoy, 1893 [4].

Evidently, a transformation happens in consciousness from perceived or imagined temporal processes to spatial models by means of variable coordinates. Such models can include different spatial concepts. They are strongly variable with respect to scaling. They can refer to microseconds or to light-years. Scaling is non-essentially equidistant.

Acousticians are used to reference thinking about physical processes to Cartesian coordinate systems. In common diagrams, time elapses from left to right. Intuitive plausibility of such time axis is supported by the direction of writing in the respective culture area. This convention possibly has an influence on the experience of time in daily life.

The following discussion thus uses the term *subjective space-time*. This term should not be misinterpreted as a reference to the relativity theory of physics.

4 Subjective space-time

The cognitive system models spatial representations of the subjective time with specific reference to the nature of the respective process, such as the falling of a water drop or the past schooldays. For this reason, in consciousness, numerous time series can exist in parallel. Simply spoken, they compile an available set of measures for subjective comparison with perceived processes. A crucial feature for differentiation is the subjective perspective of observation, which can either emanate from a point on a time axis or be uncoupled from it [see e.g., 6].

The first case is based on the *A series* of time (germ. "Modalzeit") that spans from the instantaneously experienced present to both past and future – Figure 3 top. It grounds on the subjective point of view, which distinguishes past, present and future with respect to the own position in the now. Beside the aforementioned hypothesis of the non-existence of time, this approach logically enables further theses which either accept only the past and present, or just the present, as given facts.

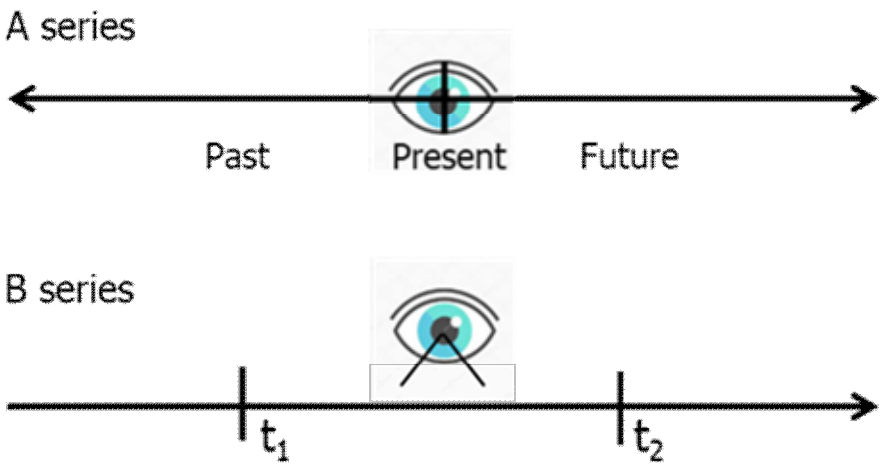


Figure 3 – A and B series as basic approaches on subjective time scales [7].

In contrast to the perspective of the *A series*, in the case of the *B series* (germ. "Lagezeit") the observer is quasi not located in time, but views the time axis from a timeless position outside – Figure 3 bottom. This makes hypotheses imaginable that accept the whole past, present and future as to be existent all the time.

Both the *A* and *B series* of time are imagined as spatial configurations. However, the transformation into space includes the experience of temporal movement, with time proceeding ("flying by") alongside a line.

Movement is an essential feature of time variable sounds and of music. The auditory attribute "movement" can be imagined as curve. Alexander Truslit developed a system for the visualization of musical movement by means of curved lines. He stated that three principle types of movement are most appropriate for a plausible interpretation of a composition: the closed, opened, and winding form. The musician must evaluate which combination of forms will work best during a performance. This is accomplished by means of the

movement of the hand and arm, like the gestures made by a conductor. Therefore, the diagrams of musical movement are characterized by curved and sometimes circular shapes. Figure 4 shows a diagram for the performance of a piano piece with reference to the appropriate musical movement [8]. Due to the fact that such curves include loops, they do not represent mathematical functions in Cartesian coordinates. Time proceeds alongside the curve. In contrast, the score is based on linear temporal progress from left to right.

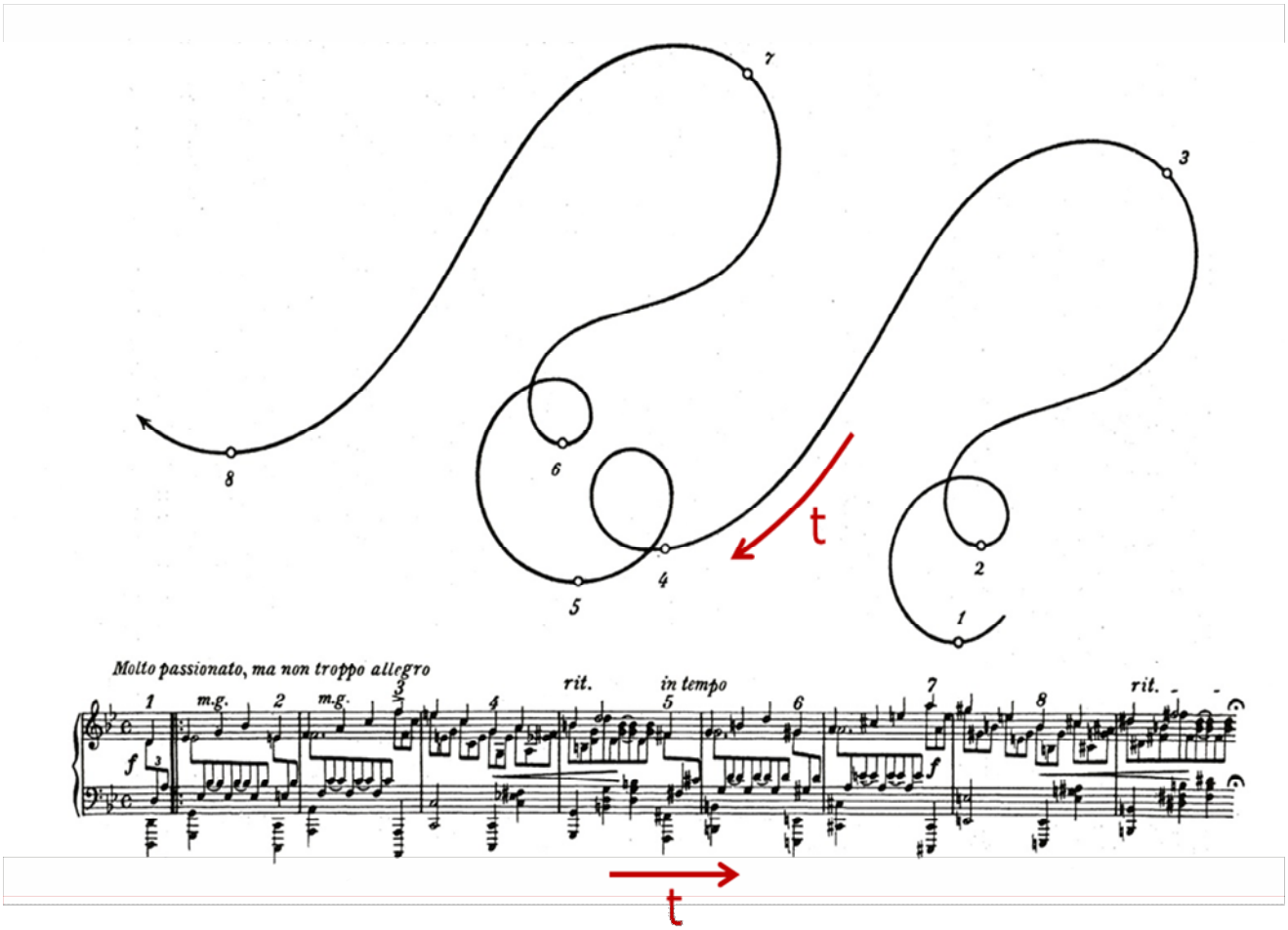


Figure 4 – Movement curve depicted by Alexander Truslit with “closed” and “winding” movements for the performance of the Rhapsody Op. 79 No. 2 by Johannes Brahms [8, p. 144].

The perspective on time according to *A series* does not simply refer to the coexistence of imaginations of the past, present and future. In contrast there is a complex interaction of representations of the three categories, as shown in Figure 5.

Edmund Husserl argued that instantaneous perception, the *impression* in his definition, essentially biases our imagination and interpretation of the past, the *retention*. In the other direction, past experiences define our conscious view of the present as well as our imagination of the future, the *protention* [9]. This corresponds to the discussion about Figure 1.

For an assessment of the subjective effect of sound and music, it is thus not sufficient to take the present state into account, i.e., the instantaneous stimulus, which has been in the focus of early psycho-acoustics.

Moreover, the past contributes via perceptual experience. As an example, this applies to the expectation of the progress of a sound in near future, such as the noise of an accident following the sound of squealing tires mentioned earlier on. It is beneficial to “hear it coming.”

The subjective space-time is of great importance because cognitive transformations of temporal aspects to spatial configurations occur. This includes coordinate systems and scaling of conceptual models. The type and extent of the scales that are assigned to an auditory event are essential features that need to be considered for the analysis of perception.

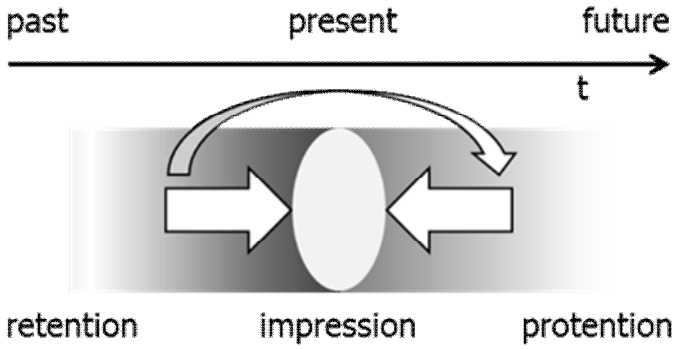


Figure 5 – Simplified scheme of “Modalzeit” (*A series*) in consciousness according to Husserl [9].

5 The circulatio-paradox

Cyclic processes, which are expressed by an audibly periodic sound are often less annoying than those with pure random behavior. The predictability of future sensations calms psychic tension and moderates emotion. Truls Wyller points out that the repetition of temporal sequences generally implies a specific way to master subjective time [10, p. 79]. Cyclic processes such as the partition of days, months, years, regular bank holidays, or religious celebrations dominate daily life. Figure 2 showed that such cycles are often represented as closed forms in consciousness.

Various musical forms have a potential to convey the impression of a circular movement. The *circulatio* is a basis for this effect. In its original meaning, it is a rhetoric figure that expresses a circular movement within a text. In music, it usually consists of eight notes [11, p. 114ff].

With a fast tempo, this circular movement is clearly perceived. In this case, the subjective time does not proceed alongside a linear axis, but periodically returns to its starting point. Musical movement thus “runs on the spot”, it “marks time”. In this case, the perception is paradoxical: in spatial imagination, an obviously dynamic and thus temporarily developing process is simultaneously assigned to a time-invariant location. Naturally, this is only valid if the periodicity is audible. With increasing velocity of temporal changes, the temporal aspect is finally lost. Then, the sound implies a pure spectral quality. As an example, the fluctuation of sound shifts to roughness. From a phenomenological point of view *time disappears*.

The sine-sweep with increasing mid frequency of Figure 6 induces the illusion of rotation. Although it can be described as a mathematical function within a Cartesian coordinate system, it is sensed as a circular movement. Furthermore, it is superimposed by a virtual upwards movement. For this reason, early film

sound design preferred using such sounds for rotating UFOs. Truslit depicted similar musical processes by means of winding movement curves, e.g., the waving of Isolde in “Tristan und Isolde” by Richard Wagner [8, plate 6].

6 Conclusions: relevance of time consciousness for auditory perception

Phenomenology collects essential approaches regarding the role of subjective time imagination for auditory perception. However, for the definition of a subjective noise dose, further analyses in combination with perceptual experiments are needed.

The given approaches clearly show that the effect of sound and music is not only caused by instantaneous stimulation, but also by cognitive representation of past impact, *retention*, and the resultant estimation of future progress, *protention*.

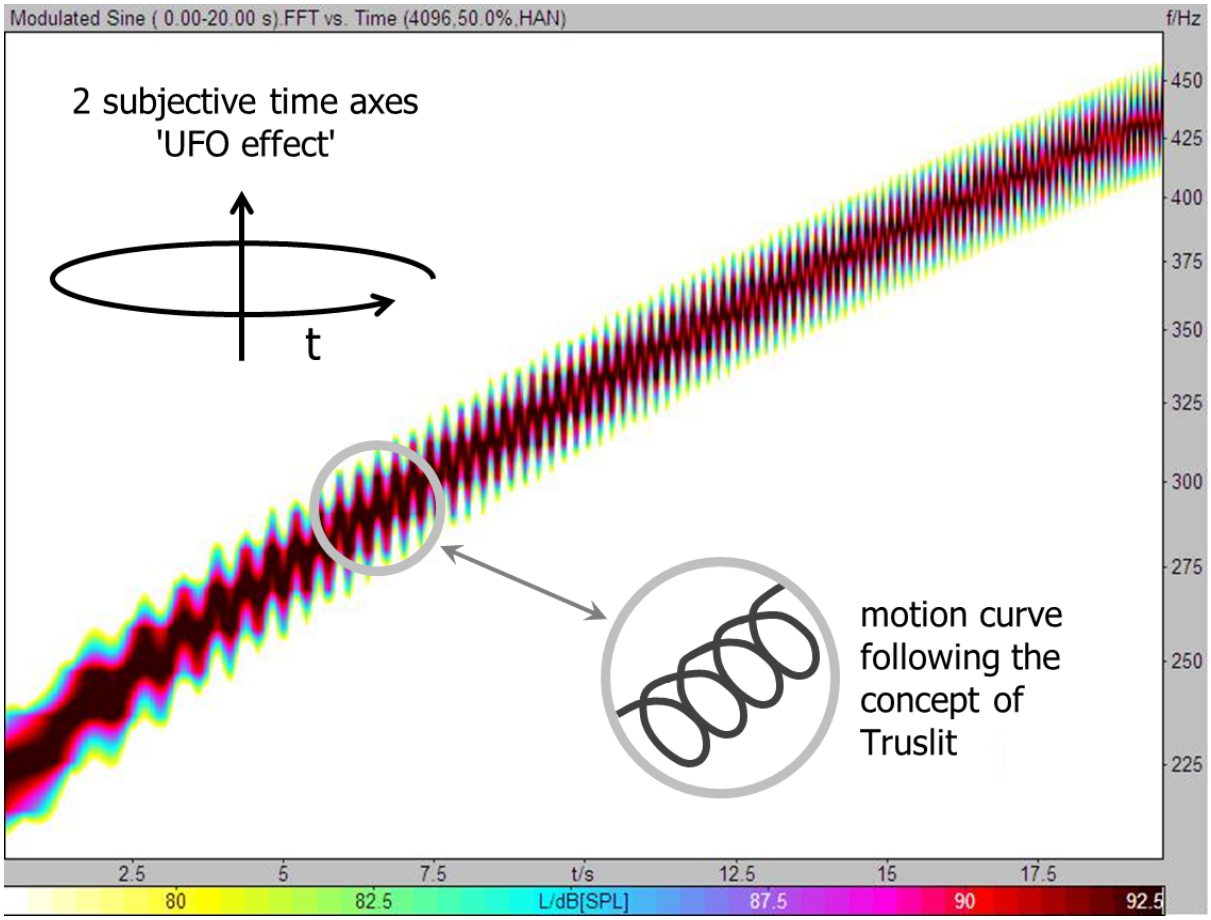


Figure 6 – A modulated sinusoidal sound with increasing mid frequency causes perception of rotation or of a spiral movement curve.

At any time, retention and protention determine the instantaneous effects, which include physiological reactions and emotions. For this reason, estimation methods that enable reliable results need to be developed. Possibilities to evaluate general predictions based on unavoidable individual preferences need to be proven.

The perception-driven spatial transformations of heard processes are essential for the subjective significance of sound. This is caused by pervasive cognitive time-space transformations. The representation of time interacts with imaginations of auditory movement. By this means, periodicities can calm – or completely eliminate – the movement aspects of sound. A precise understanding of subjective representations of time and movement is essential for the assessment of sound and music. The preferred ways of spatial transformation of time need to be evaluated by means of perception experiments. The results must be utilized for sound analysis and assessment.

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