RECURRING PHENOMENA, MOTION DYNAMICS AND PERCEPTION OF TIME

EXPLORING: MOTION DYNAMICS EMERGING FROM PARTIAL FEEDBACK LOOPS AND THE EFFECTS OF PERCEIVED MOTION ON THE SUBJECTIVE EXPERIENCE OF TIME.

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Master's Thesis

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The Hague, May 2021

Acknowledgements

I would like to thank Marion Traenkle, Raviv Ganchrow, Arthur Elsenaar and Robert Pravda for the support, inspiration and advice; Jaap Meijers and Lex van den Broek for sharing their expertise; Neofytos Sakellaridis Mangouras for fighting the text and Rolf Schmitt for the loving support and patience.

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ABSTRACT:

This thesis follows the effects of perceived movement and stimuli repetition on the subjective experience of time by reviewing relevant literature and conducting *micro*experiments.

The subject of human time perception is treated as a nonlinear phenomenon and examined through the analytic and comparative using dynamics of biological and electromechanical systems. The perception that interests this writing is both; short term duration judgements and the general perception of longer time-scales. This is explored by conducting simple motor-driven motion experiments with dc motors and various sensors that together exhibit partial feedback loops.

The conclusions offered thereby are paired with theories and models developed in the field of neuroscience, cognitive psychology, physics and the history of time. The goal is to broaden the understanding of the effects of the spatial kinetic installations built by the artist.

Through the research it was found that stimuli repetition and fragmentation is inherently part of the human internal time keeping mechanisms. Furthermore, the anticipation of- and the synchronisation between repetitions in motion is essential regarding duration judgements and the dynamics of systems inside and outside the body.

“Change” was identified as the bridging factor between the experience of time and the complex development of motion dynamics in partial feedback loops. Perceived motion and its velocity was found to be responsible for both: duration estimation and perceptual temporal distortion.

Further, the study has revealed that the subjective experience and the physical description of time are both human constructs and are, by default, illusions.

Finally a new hypothesis is introduced which asks wether the observation of complex nonlinear dynamics in small systems might be the only way to comprehend time as it is, “time” as a subjective phenomenon of the universe.

INTRODUCTION:

The presented artistic research investigates motion dynamics emerging from cyclical movement produced by electromechanical systems that exhibit partial feedback loops.

What this work aims toward is to investigate the effects of perceived motion and stimulus repetition on the subjective experience, or sense, of time. With this work, I will address both; short duration judgements as well as the perception of longer time-scales.
Within this research's context, the subject of human time perception is approached as a nonlinear phenomenon by analysing and comparing the behaviour and dynamics of different electromechanical and biological systems. The most crucial topics are recurring events (repetitive movement and feedback loops), motion dynamics and illusions linked to motion perception. I will discuss and compare the types and effects of such phenomena through the fields of neuroscience, cognitive psychology, physics, and history of time measurement.

For the practical application of this concept, I attempt to create a number of simple electromechanical systems (often referred to as motion models) that are fed by oscillating signals such as light or sound. These signals are picked up by various sensors and are transformed into cyclic motion patterns by dc motors. The motion models, in return, influence the incoming signal through various ways and thereby create a partial feedback loop.

The overall objective in doing so is to create multiple models that simulate the dynamics of time perception models and at the same time influence the subjective experience of duration in physical spaces in real time.

The following research is motivated by my artistic practice where I seek to create kinetic installations that exhibit repetitive movement processes. These processes undergo gradual or abrupt changes through the impact of the given conditions of the installation's physical environment. The aim is to challenge and reformulate the perception of the encountered stimuli of existing spatial contexts. Further, it is to explore if and what causes the experience of time to shift; slow down or speed up during the displayed motion events.

More generally speaking, through the conducted experiments in this thesis I wish to deepen my research on the perceptual effects and physical dynamics of the kinetic installations that I build to explore further research possibilities within my practice.

In the following chapters I will refer to the aspects concerning the human perception as the "receptor" research and to the physical part (the motion models, physics, and physiology of the brain) as the "stimulus" research. The "Receptor" is the human receiving information namely the "stimulus" .

This is an attempt at indicating the shift in perspectives between the sciences of perception and the sciences of physics.

First of all, I will elaborate on the different topics included in my research through three different anecdotes (0.Three stories).

The following three chapters embody three main questions that I isolated regarding my investigation on time perception in relation to the kinetic installations that I make:

1.Why time perception, repetition and feedback loops?
2.Why time perception and motion dynamics?
3.Why time perception and illusions?

These three questions will be discussed utilising different theories developed by the corresponding fields of sciences and by harnessing the empirical data retrieved from the presented motion experiments.
To conclude, I wish to make separate statements based on the findings of both research fields: the 'receptor''s and the 'stimulus''s. Finally, I bring the similarities of both in perspective to the aspects described through the following three anecdotes.

0.Three stories:

(1. short story - 2016)

I'm alone in a room.

The sun is shining through the window projecting large rectangles onto the floor and the chair that I am sitting on. It is a hot but cloudy day. It is windy and the clouds move rapidly in front of the sun creating a rhythmic pulse of heat on my skin.

It is quiet. But there is a noise, a distinctive beep or ticking sound that echoes consistently through the hallway outside the room. Probably it is a fire alarm signalling that its battery is low. As I sit there, I sharpen my attention and carefully listen to the returning beep. The perceived rhythm and I seemingly merge. I can feel a pulse on my eyelids. My ears pump in perfect synchronisation with the recurring beep.

Together, the sun, the room, the fire alarm, and I enter into a state of odd symbiosis; I imagine that we interact and create a continuously changing composition.

Time passes. The rectangles have moved all the way to the other side of the room.

I wonder what time it is. I can estimate more or less from the time I had lunch to the position of the sun in the room that it must be around 17:00. The clock reads 16:46. Not bad.


Figure 1 Screenshots of video installation /"On rhythm"-part 1 2016

I think to myself: I wish I could follow the displacement of the sun on the sky in real time. Somehow we, as humans, are lacking the ability to perceive the continuity of movement when it becomes too slow or too fast. We are bound to our senses which only allow the experience of a specific range of speeds in movements. We are living in our own "time", a time that is defined by the parameters of the senses. The senses define the pace and rhythm to which the events we perceive unravel in our minds.

The change between day and night, the transition between brightness and darkness, is just too slow for me to internalise and appropriate its rhythm in the same way as I did with the fire alarm's tick. I will never be able to feel the sun's returning cycle as a pulsing beat on my eyelids, I can only imagine. I wonder how time would feel if I could. I go home.

(2.short story-2018)

I am sitting on a bench outside.

Pigeons and seagulls had gathered to tackle a bag of bread that someone had thrown onto the street. After pecking at the last remains also the last bird had decided to leave the scene. The plastic bag just lays there, unattended, completely empty and folded open.

From now and then a gentle breeze hits the bag and fills it with air. Slightly to the side and then back to its initial spot, the bag moves back and forth as if it would swing to a beat. Inevitably the movie scene of 'american beauty' pops into my head where the main character shows the footage of a "dancing" plastic bag he had filmed.[1] Suddenly, the bag lifts up and starts to swirl as if it had read my mind.

[1] American beauty plastic bag scene: https://www.youtube.com/watch?v=gHxi-HSgNPc

“American beauty” - 1999seems to struggle, plastic bag scene

I have to think of continuity, the motion between all physical things and time as it passes while I sit here and watch this bag move. Meanwhile the plastic bag had managed to roll itself across the street to the pavement. Repeatedly it tries to crawl up the edge, to no avail. I’m surprised how emotionally invested I had become in the bag’s journey. I wonder if the bag’s shape and the fluidity of its movement had somehow triggered some sort of empathy in me by comparing it to a living organism. I had starred at the bag for quite some time now and hadn’t noticed the man walking up to the bag. Swiftly he pinches it with two fingers to then stuff it into his pocket. The journey is over. I go home.

(3.short story-2020)

I’m in my studio.

Lost in thought, I’m playing with the end of a string. My initial plan was to clean up my desk and finally untangle the growing knot of different ribbons and ropes in front of me, but instead I’m just sitting there winding on and off a piece of elastic thread around my finger.

As I get up to walk to the other end of the room I tie a loop into the piece in my hand. I’ve decided to hang it onto a hook that I had screwed to the wall some time ago.

As I walk back to my desk I attach the other end to the inside of a grooved wheel that I had picked up from the shelf on the way. Leaving behind a trail of curling string I return to my seat. Not thinking of much, I grab the drill and push the wheel onto the bit, it fits perfectly!

I play with the drill’s trigger. Pushing it softly then hard, I watch the wheel spin in circles. Accompanied by a rhythmic buzzing sound, it wobbles and then spins smoothly again. I begin to focus on the fuzzy end of the string that sticks out from the side of the wheel. Now, I’m barely pushing the trigger anymore, the buzzing sound is fluctuating, and the string’s end is moving repeatedly in slow circles.

In the meantime, the string had lifted off the ground to slowly form a straight line across the room.

I can feel the tension slowly building up. As I keep on observing the wheel I see, in the corner of my eye, the sting's other end increasingly stretching on the hook across the room.

I'm well aware that it won't withstand the pulling strength of the drill much longer. The sudden slap, however, felt unexpected as if I did not see it coming at all.

Bang!… Not the string had ripped but the hook together with the attached end had exited the wall to catapult itself across the room. I could feel it pass my face with a "woosh" to then hit the row of glass tubes aligned on the windowsill next to me. The glass shattered on the ground. One single harsh pulse enters my chest. That was close!

All of a sudden, I have to think about cinematographic techniques. How suspension builds up in a storyline and stretches the experience of time and then the sudden release, bang! We anticipate the release and yet we startle every time. I also have to think of Jan Erichsen, [2] a performance artist who makes simple setups wherein he creates automated procedures of physical tensions between materials that cause emotional tension in return with the audience. There is something very special about emotional tension and perception of time, I conclude.

"staring contest"Jan Erichsen, performance artist

I didn't actually see the hook fly across the room. Or did I? In any case, the sudden movement and the sound of the shattering glass felt disconnected from each another. Another thought that crosses my mind is the way the dissonance between sound and perceived movement might have a disorienting effect on the receptor (the one experiencing the event).The apparent connection between

2 Jan Erichsen makes setups that show different types of tension and release procedures. Some of them ending abruptly and others transition slowly into a different state,
Jan Hakon Erichsen, Staring Contest,
http://www.janhakon.com/

cause and effect seems essential when it comes to estimating time and spatial properties. This inconsistency may cause temporal and spatial illusion.

As I walked home, I thought about the rotating movement of the wheel. Somehow the circular movement has a strong immersive quality to it…Maybe that caused the misjudgement of the ensued event.

Through the three stories I want to show the following aspects:
The first aspect is the effect of stimulus repetition on our sensory experiences.
A repeated stimulus, such as a fire alarm's beep (story 1), can change the perception of other stimuli that are perceived at the same time. Recurring stimuli can have quite opposite effects. At times the repetition might annoy the perceiver or trigger nervousness and at other times it might serve as a tool to navigate through relaxation exercises, meditation, or even hypnosis. Furthermore, a recurring sound might fragment and shape the visual experience of another stimulus in the same room. A repetitive stimulus (light, sound or touch) might cause sensory cross-talk[3] which might result in optical or auditory illusion. Finally, the mental state, the personal sensitivity towards the specific stimulus and most importantly the level of attention by which it is addressed is essential when discussing the effects of stimulus repetition at all. I will elaborate on these aspects in chapter one and three.
Further, the stimulus's intensity, speed and physical context plays an important role and determines how the individual (receptor) includes its presence actively in their sensory experiences. Another example is the factor of speed in motion, as described in story one and is also relevant in story three. The speed of a motion is crucial for it to be recognised as repetitive or to be recognised as motion at all for that matter. I will address the physical properties of recurring phenomena in chapters one and two of this thesis.

Next, a commonly known drive is to imitate rhythms that are part of our sensory field.[4] Not only music but also more crude beats, for example the rhythm of a dripping faucet or a self cleaning coffee machine might invite us to tap or snip fingers in conjunction. This leads me to the aspect of sync: the tendency of the individual (receptor) to synchronise, internalise or appropriate recurring phenomena around them. This aspect also incorporates the ability to predict and plan ahead which adds the time perception aspect. One needs to be able to estimate the time that passes between beats to be able to imitate its rhythm. The drive to synchronise has not only been observed in intelligent species but this phenomenon extends from oscillators to plants, atoms, planets and so forth. I will discuss the effects of beat synchronisation on our perception of time in the second chapter.

[3] aka Synesthesia

[4] by sensory field I mean the spectrum of all perceivable matter around an individual (receptor)

Another aspect is the immersive quality of- and empathy for certain types of developing movements 5(story 2). We as humans tend to develop an emotional connection with moving objects that somehow remind us of- and thereby make us compare them to - other living organisms. But it goes further than the comparison between objects and living things. The perceived movements make us experience “struggle” or “pain” which is proof for empathy6. We live momentarily through a moving thing and experience their journey through our own body and mind. Why is this important to this research? I realised that these moments of empathy have a great emotional impact and therefore have a strong immersive quality. This led to the hypothesis that the deep mental involvement with the unfolding event (in shape of a motion dynamic) causes a type of distortion in time perception and duration judgement through a type of intense immersion. The aspect of emotion, attention and time perception becomes relevant in chapter three.

And thereby, finally, the aspect of perceptual illusions in time perception. As in story three, certain movement create visual and auditory illusions that mess with our spacial and temporal perceptions. Also the way a stimuli is presented within its spacial context has great influence to the way it is processed and estimated. I will discuss and elaborate the relation between time perception and illusions in chapter three.

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[5] aka motion dynamics

6 empathy is derived from the Ancient Greek ἐμπάθεια (empatheia, meaning "physical affection or passion”) , https://en.wikipedia.org/wiki/Empathy

1.Why time perception, repetitions and feedback loops?

Time seems to flow in a constant stream towards the unpredictable future, or at least this is how most people describe their experience of it. The decay of organisms, plants and our own bodies suggests that there is a linear progression of things supporting the idea of multiple causal events that lead to an end. Therefore, the thought of repetitions and feedback loops in the context of time perception might seem counterintuitive at first.

The idea of a unit that repeats itself in time again and again, inevitably brings along the idea of timelessness. Theoretically, in order to complete a phase, something that repeats itself returns to its initial location in time, which means that there is no real “progression” in relation to space.

However, repetitions, oscillations or feedback loops are important elements that define the way we conceptualise “time”. More importantly, they become indispensable when facing time measurement systems in both; biological and electromechanical systems. The renewal and periodical change between things is part of the core dynamics of the universe and thereby defines the way we, as receptors, comprehend time.

This dual idea of repetitions and time as a linear “flow” was the first milestone when facing the relation between motion dynamics and time perception.

To proceed, we must first have a look at the history of time measurement, its fragmentation, oscillations and perceived “flow”. Then we will move on to the different theories developed on time perception by addressing feedback loops and the perception of repetition. Further, I will introduce and define different repetitive motion categories in physics as a reference base to all following motion experiments (motion model presentations). Finally, I will present and discuss the outcome of the first two feedback loop experiments.

1.1 Time measurement , flow and fragmentation

The concept and measurement of time seems rather self-evident. An hour consists of sixty minutes, a day of 24 hours, and a year of 360 days. The duodecimal system is deeply integrated in our societies and shapes the way we perceive and organise our lives. But we rarely think about the fundamental nature of time as it just is and develops or expands continuously. What is time, if it even exists?

Time is “passing” without a break and we follow it with clocks and calendars. Yet we cannot study it with a microscope as a physical matter nor do we own a specific organ designed to measure time ‘accurately’. We, as receptors, are unable to describe objectively what exactly happens when it passes. The idea of time itself and what we make of it, stays highly subjective. How does the way we measure it influences the way we perceive time and estimate duration? More importantly, how is our perception of time linked to our perception of repetition and motion?

To be able to answer these questions we must first take a dip into the history of time measurement.

Prior to 1500 B.C in ancient Egypt the history of time measurement began with the invention of sundials. However, the time measured by the Egyptian was not the same as the time today's clocks measure. For the Egyptians, and indeed for a further three millennia, the basic unit of time was the period of daylight. The Egyptians divided the period from sunrise to sunset into twelve equal parts, which was the pre-runner for today's duodecimal system that is still in place. However, the Egyptian hour was not a constant length of time, as it is the case today. Rather, as one-twelfth of the daylight period, it varied with length of the day, and thereby also with the seasons. It also varied from place to place on the surface of the Earth. And of course, time as a measurable concept effectively ceased during the hours of darkness. This puts the hours of the night, into a timeless space until the sun rises again. We could argue that the way the Egyptians measured time probably comes much closer to the way we perceive time as humans internally. Our perception of time is strongly influenced by the external stimuli such as light and temperature and thereby we could assume that it varies and is, indeed, strongly influenced by the length of the day. This aspect will be revisited later in more depth.

The need for a way to measure time independently of the sun eventually gave rise to various time measurement devices, most notably sandglasses, water clocks, and candles. The first two of these utilised the flow of substances to measure time, the last one uses the steady fall in the height of the candle. All three provided a metaphor for time as something that flows linearly, and thus began to shape the way we think of time. The idea of time as a constant progressive stream or motion emerges.

It was not until the thirteenth century that the first mechanical timepieces "time machines" were introduced in Europe. The conception of time as something that flows accompanied the introduction of these first clocks: the idea of measuring time by splitting it into equal intervals and counting them in a circular and repetitive manner. By the division of time fragments the only part that stayed connected to the actual physical progression of things is the repetitive revolution of the earth, the movement of the Earth around its axis. The division of that period into 24 equal hours, the division of each hour into 60 minutes, and the further division of each minute into seconds are all conventions that we as receptors invented. The clock remains the master of this structure, the world-wide manager and organiser of seconds, hours, and days. We all live by the same system which speaks volumes about how we, humans, conceptualised "time" globally. Opposed to calendars, holidays, rituals etc , the clock is the one device that stays the same. We might live in different time zones but the rule, the equal repetitive intervals stay the same: we are all counting the same ticks and tocks of an oscillator. Furthermore, all clocks depend on the laws of physics, which provide potentially reliable (not entirely precise) timepieces in the form of oscillators. Oscillators, pendulums, and any other object that exhibits equal repetitions of the same unit can therefore be used as a time keeping device.

From the above we can therefore conclude, that the human concept of time is marked by the perception of motion. The act of actively following the development of a motion, such as the flow of a substance (watercock or sandglass) introduces the idea of movement as a time-'guide'. Any movement or displacement of physical objects indicates a type of "change" and therefore describes a development in the perceived event. This change we often associate with the passage of 'time'. This aspect of movement as an active time-guide of perceived events has been an important factor in my previous kinetic installations and becomes even more relevant during experiments in this thesis.

Further, the mathematical accumulation of intervals is an important aspect of the human concept of time. The oscillator as the mechanical centre piece for time measurement introduces the idea of repetitions as a way to fragment and tell time. Every rotation has to be identical in order to measure time spans 'accurately'.

However, up until today, "time" itself stays a subject that is difficult to grasp or quantify. Even more is our subjective experience of time. The estimated duration of a bus ride might vary largely to the time spend at lunch with some friends. How we memorise events, imagine the *future* and perceive time momentarily is flexible and constantly changing in speed and intensity. How do we measure time internally? Do we also count the intervals of an internal oscillator? We as humans are capable to estimate time to a certain degree but how does that really work?

1.2 Time perception models and the perception of repetitions

As stated before, the human experience of time is fluid and a rather fragile mechanism. Even though our neural time measuring tools aren't as precise as the ones of clocks we are able to estimate the unfolding of events and regulate chemical processes in our bodies in time intervals. We, as receptors, are constantly fed by sensory informations and stimuli which help us estimate the durations of events, generate coordinated motor responses and navigate us through our sleep-wake cycles. Our nervous system processes temporal information, over a wide range, from microseconds to circadian rhythms[7]. But is our internal time keeping mechanism comparable to a clock's oscillator? Is a metric fragmentation of identical repetitions in time part of our internal systems?

One of the most famous models explaining our timing abilities in the milliseconds to seconds range suggests, indeed a clock-alike system in our brain.[8] According to the analogical "internal clock model" (Treisman, 1963; Gibbon et al., 1984), this system consists of a pacemaker and an accumulator. It is said that at the beginning of the perceived stimulus, a switch controlled attention gate closes, and the pulses emitted by the pacemaker flow into the accumulator. Within this framework, the pulse count provides a linear metric of time, and temporal judgments rely on comparing the current pulse count to that of a reference time. The subjective duration thus depends on

7 Uma R. Karmarkar1 and Dean V. Buonomano, Timing in the Absence of Clocks: Encoding Time in Neural Network States, page 1, (2007)

8 Here I mainly addressing short-term duration judgment

the number of pulses accumulated. When more pulses are accumulated, time is judged to be longer. How many pulses are entering the accumulator dependents on attention levels, emotional state and context of the perceived stimulus. However, the physiological and anatomical support for the putative accumulator remains elusive and mounting evidence indicate that clock models are not entirely consistent with the experimental data. Nonetheless we can identify a clear link to the idea of time fragmentation and interval accumulation in early theories that are also found back in later models regarding time perception. It is interesting to note here that even in the attempt to tackle the timing mechanisms of the brain within scientific research fields there is a clear tendency to appropriate a linear metric system: an accumulation of pulses.

After the “internal clock model” a number of models for timing have been suggested. Models as the state-dependent networks (SDNs) introduced by Buonomano (1995and 2000) suggests that short-term timing happens on complex cortical levels of the brain through the interactivity of oscillating neurons. This model is one of the most reliable and recent models on time perception up until today. Though going further into details regarding the physical aspect of timing and time fragmentation in the brain is valuable it will sidetrack the work for now. But, by addressing the perception of repetitions in the visual or auditory field (in reference to story one and three in the introduction) I will further investigate the question: what effect has the experience of a repeated stimuli or simply; a recurring phenomenon on the way we perceive the duration of the event?

Research claims that prior experience with a specific stimulus strongly affects how it is processed, perceived, and acted upon. It is said that repeated stimuli seem to appear shorter than novel or rare ones.[9] The theory argues that the perception of a new stimulus demands more “memory space” in the sense that the encoding of the perceived stimulus is more complex. Through the process of encoding the perception of the event’s perceived duration increases. This link between the processing and identifying of a stimulus and the perception of stimulus duration has important implications for theories of timing, and for broader accounts of the organisation, purpose, and neural basis of perception. This theory goes hand in hand with the filled-time and change model that I will discuss in chapter two (Why time perception and motion dynamics?). To make an interim conclusion of what has been said so far: stimulus repetition is described as a time shortening factor in time perception and there is a general tendency for a metric linear order in timing models.

According to the cyclic motion models that I build this could mean that identical repetitions in movement could shorten the experience of time during observation. (elaborated during experiments). This introduced the important aspect of repeated intervals of movement in relation to short term duration judgement to my installation work. The anticipation of the following motion events play an important role regarding the immersive quality of the work and thereby with the level of attention it is addressed. This defines how actively the work affects guides the experience of the audience’s

9 William J Matthews and Ana I Gheorghiu Repetition, expectation, and the perception of time, (2016)

perception of duration. This introduces the question: how does the brain perceive the durations between events? The intervals in a sequence of sounds, such as rhythms we hear in music?

The study by researchers at Wellcome Trust Centre for Neuroimaging (2011, University College London (UCL) and Newcastle University) presented a theory that the brain uses distinct timing mechanisms to measure the duration between the intervals in a sequence of sounds.[10] Results suggest that distinct parts of the brain are involved in these timing mechanisms. An experiment was conducted, where sequences of clicking sounds were presented to eighteen volunteers in a magnetic resonance imaging (MRI) scanner. Participants were asked to judge if the duration of the last interval was shorter or longer than the second last. By varying the regularity of the preceding intervals (from very irregular to regular, containing an isochronous beat like the second hand of a clock), the researchers were able to show that the brain uses different mechanisms and areas for the timing of regular and irregular sequences of sounds respectively. The network found in the basal ganglia of the brain was activated specifically for the timing of regular sounds while for irregular sounds the cerebellar network was found to be more active. Both areas are linked to the motor areas of the brain (frontal cortex a.o.) responsible for planning and known to be involved in time perception. Griffiths (2011) explains that the cerebellar network measures the absolute duration of individual time intervals comparable to a stopwatch while the basal ganglia network is rather involved in measurement of time relative to a regular repetitions of beats. Repetitive stimuli and, more specifically, rhythm perception has a strong effect on the way we perceive time. In following, the imitation of rhythmic structures seems to be deeply rooted in our neural systems and is a known research topic within the field of pedagogy and research on Parkinson disease.

To conclude, the above research posits fragmentation, repetitions, rhythm perception and impact as big portions of time perception and the distortions found therein. Further, the motor areas of the brain (frontal cortex mostly) are responsible for the planning and predictions of events and are inevitably linked to the short-term duration judgement mechanism of our brains. The perception and anticipation of a repetition is crucial for us to navigate through the physical world and are therefore part of my research on repetitive motion stimuli. The rhythmic pulse felt on my eyelids in the first story in the introduction could be caused by a neural response to the anticipated stimuli that resulted in a physical sensation (eyelids). The above research is all linked to short-term duration judgements. But what about our day and night cycles of our bodies? How does our body know when it is time to sleep and when to be awake? How is this cycle constructed and is able to fragment time intervals to produce a continuous rhythm in time?

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[10] Wellcome Trust Centre for Neuroimaging, University College London (UCL) and Newcastle University, Rhythm and the perception of time, (2011)
https://www.ucl.ac.uk/news/2011/mar/rhythm-and-perception-time

In the following section, I will have a look at the circadian clock as a rhythm generating system disregarding its role in time perception and other cognitive processes. The circadian clock, in this case, merely represents a model for repetitive phenomena and system dynamics and thereby is addressed as a stimulus (definition found in introduction). For my research it is important to look at internal processes to analyse and apply elements in the mechanic systems I build. The aim is to gain further understanding on how internal time keeping systems are constructed to subsequently explore the potential physical dynamics of such systems through mechanic simulations (motion models).

1.3 Circadian Rhythms and Cell Oscillation Dynamics

One rhythm that most of us probably are not aware of completely is the circadian rhythm. We experience different levels of sleepiness and alertness throughout the day which helps us maintain a relatively stable sleep-wake phase every 24 hours. But what is it that causes these repeated changes in our body?

These 24-hour rhythms are driven by the **circadian clock** (latin: circa-(about)diem(a day)), and have been widely observed and studied in plants, animals, fungi, and cyanobacteria [11] .

The internally synchronised so called ‘master clock' is influenced by a host of external stimuli (light and temperature, humidity etc), and enables the organism or plant to anticipate daily environmental changes corresponding with the day–night cycle and adjust their biology and behaviour accordingly.[12]

In vertebrate animals, including humans, the cycles of this biochemical oscillator are controlled by a part of the brain called the Suprachiasmatic Nucleus (SCN). The SCN is a group of cells in the hypothalamus that respond to light and dark signals. From the optic nerve of the eye, light travels to the SCN, signing the internal clock that it is time to be awake. Besides other function, the SCN is responsible for the production and distribution of melatonin from the pineal gland into the blood stream, which is the number one hormone responsible for sleep-wake cycles in the body.

Here, it is important to note that the influence of light plays a major role in maintaining an equal interval oscillation in the circadian clock. Solar light acts, in this case, as a recurring signal input stimulating a synchronisation of cycles in the brain. The neural pulses of the SCN hereby synchronises to solar time. The synchronisation between recurring event has proven to be relevant in time measuring models, electronic devices and many more phenomena. Therefore I will use this aspect during my simple motion experiments.

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[11] Circadian rhythm, Wikipedia, https://en.wikipedia.org/wiki/Circadian_rhythm#History

[12] Logan Foley, Sleep/Wake Homeostasis and Sleep Drive, (2021) https://www.sleepfoundation.org/circadian-rhythm/sleep-drive-and-your-body-clock

Further, we could assume that the circadian clock is completely relying on external factors that determine every cycle period per period through rhythm synchronisation. However, it is known that cells are not simply switches governed by external stimuli instead they have their own internal rhythm, as Dean Buonomano explains in his book 'Your brain is a time machine'[13] .

Namely, he explains: when isolated and kept at a constant temperature in a stable biochemical milieu, many cells show a circadian rhythm of their own.[14] Their protein levels rise and fall in a 24 hour rhythm without any external stimuli signal input. This means that molecular circadian rhythms are generated by gene-regulatory feedback loops in which protein products regulate the transcription of their own genes. This happens either by themselves or in combination with other so-called clock proteins. This suggests the idea that plants and animals have their own personal clocks in the shape of oscillating cells maintained by the biochemical environment of their own systems.

It is important to point out that if we talk about the fact that a single cell oscillates, it doesn't mean that it physically vibrates like a quartz crystal or a swinging pendulum. Rather, the oscillations refer to the changing concentrations of proteins in a cell. Also, cells are not steady entities exhibiting a regular change of proteins in equal intervals, instead they drastically change their behaviour according to the surrounding circumstances. For instance, the cells found in the lining of the intestine changes rapidly the level of digestive enzymes during a meal.

Nonetheless, we can categorise an oscillating cell as a repetitive phenomena, something that shows a changing pattern over time through changes in protein levels. The intervals can vary a lot, however, periods can be identified through a repetition from the presence and the subsequent absence of substances.

Observation:

We can deduce three main aspects on the repetitive oscillatory behaviour of circadian clocks. First of all, the circadian clock is partially synchronised to external 'Zeitgeber'.

"Zeitgeber" (german: time indicators/givers) are rhythmically occurring natural phenomena which act as a cue in the regulation of the body's circadian rhythms. I define such as stimuli which specifically play a role in timing mechanisms such as light, temperature and movement. This means that there is a direct link between the behaviour found in the SCN and the information of the physical world (the

[13] Dean Buonomano, Your brain is a time machine , The Neuroscience and Physics of Time, Chapter 3, page 41

[14] Dean Buonomano, Your brain is a time machine , The Neuroscience and Physics of Time, Chapter 3, page 42

stimuli). Hereby, the 'Zeitgeber' functions as a periodic signal input for the SCN. This specific aspect I will apply to my electromechanical feedback loops.[15]

Secondly, we know now that molecular circadian rhythms are generated by gene-regulatory feedback loops in which protein products regulate the transcription of their own genes. This aspect is also crucial regarding the construction of the systems that I build(motion models).

In order to simulate the dynamics of internal timing mechanisms in kinetic systems I can deduce the following aspects: Feedback loops, stimuli; such as light and temperature, changing oscillations and self regulating feedback loops will be subject to further investigation.

In order to present the first two motion experiments on repetition and feedback loops I will first discuss and define the terms in question in the field of physics.

<u>Side note:</u> Possible synchronisation and nonlinear dynamics within the SCN will be discussed in chapter two: "Why time perception and dynamics?" in section "dynamics and emerging synchronisations" .

1.4 What are repetitions, recurring phenomena, oscillations, rhythms or feedback loops and what do they have to do with time?

We might all agree on the fact that these are events that are intrinsically repetitive in one way or another. The most commonly known example might be the repeated cycle of day and night. However, also more subtle occurrences, such as a dripping faucet, a flickering light or a clock's tick are all events that we might identify as 'repetitive'. Depending on the physical property of the event it either exhibits a pattern, reappears randomly or results in changing dynamics. These recurring events all rely on one common factor; time. At the same time, they are important indicators for time passage ("Zeitgeber") for the one perceiving them (receptor).

Linguistically speaking, what is the difference between recurring phenomena and reoccurring phenomena? In general, the first describes a repetition, something that happens repeatedly. The second, however, could stay random and isn't inevitably of repetitive nature. It is important to make this distinction in order to identify recurring phenomena as patterns in time opposed to reoccurring events which are potential single happenstances which are not necessarily bound to intervals. In this thesis we will mostly focus on recurring phenomena, time intervals which are bound to motion dynamics and not linear events.

[15] Reminder from the introduction: The overall objective in building the motion models is to simulate the dynamics of time perception models through motion dynamics and at the same time influence the subjective experience of duration in physical spaces in real time.

Furthermore, each repetition, periodic event or oscillation in time brings a type of change along. We could argue that each repetition contributes to an ongoing transition in space. The intervals of the repetition can either be 'identical' or vary over time but the conditions around or interactions with the environment always result in some type of change. The factor of change is an important part of this research because 'change' is the main ingredient for two things : motion dynamics and time perception (chapter two: Why time perception and motion dynamics?).

By addressing repetitions and time perception I will focus specifically on repetitive motion and the perception of motion as a stimulus. Motion, in the context of this thesis, describes mechanic motions (motions that are bound to a physical material) but I will also take a leap into the electromagnetic field of motions (such as brain waves) and cellular oscillations.

In this section of my thesis I will describe different types of periodic motions and dynamics in physics, the 'stimulus'. This represents the counter piece to the previous section on the receptor's internal repetitive and oscillatory mechanisms.

Talking physics, "motion" is the phenomenon in which an object changes its position over time.

Opposed to "linear motion", "periodic motion" carries out a repetitive movement. Further characteristics of periodic motions are the velocity of the moving object, the period and the amplitude.

Periodic motion is seen in various waveforms and types of motions for instance cyclic or oscillatory.

Examples of periodic motion is an oscillating pendulum, a bouncing ball, a vibrating tuning fork, the water's waves. These are all phenomena that exhibit a periodic pattern and are evidently coupled to the factor of time(t).

Each complete time interval of each repetition, or cycle, of the periodic motion is called "a period" 16, often expressed as the letter T. The frequency of a periodic phenomenon is defined as the number of cycles per unit time (ex: cycles/second).

Talking equations: the frequency is usually denoted by a latin letter f or by a Greek letter v (nu).17 The frequency is the quotient of the number of times "n" a periodic phenomenon happens over the time "t" in which it occurs:

$f = n / t$

In fact, most natural observed phenomena are periodic and repeat themselves at some point in time or behave in periodic motion. As mentioned before, these phenomena are bound to a temporal factor (t) described as a time interval or period that repeats itself in time. Periodic motion itself has been used in

[16] The Editors of Encyclopaedia Britannica, Periodic motion, https://www.britannica.com/science/periodic-motion

[17] lumen learning, Periodic Motion, https://courses.lumenlearning.com/boundless-physics/chapter/periodic-motion/

prior time keeping devices such as the pendulum clock and is therefore part of this research. Also in my previous kinetic installations I have utilised the element of repetitive motion or integrated the existing repetitive conditions of the space. This has been done to simulate the gradual transition of natural phenomena through cyclic and recurring events.

Further, **Oscillatory motion** is a repetitive motion that, in practice, eventually comes to rest due to damping or frictional forces 18. However, one can force their propagation by means of some external forces. A number of oscillatory motions together form waves like electromagnetic waves (e.g:Radio waves, microwaves, visible light, and X rays). Contrary to physical “motion” electromagnetic waves refer to the waves in the electromagnetic field; waves that vibrate between an electric field and a magnetic field. These motions are not consciously perceivable as periodic motion or as repetitive stimuli at all but might affect internal processes of the human body in a similar oscillation spectrum. We will discuss the aspect of brain oscillation entrainment through stimuli repetition later on (chapter three: Why time perception and illusions?).

Electromagnetic waves are not bound to a material medium in order to travel. For example sound waves are longitudinal and can be described as mechanical waves which require a medium like air or water in order to move. Electromagnetic waves, such as light, are transverse which means that this type of waves can travel in vacuum. Both, however, can be described as periodic and will serve as signal input for experimentation mentioned later on. Also stimuli like light are one of the main signal inputs for maintaining our inner clocks and are therefore a part of this research.

Feedback loops are one of the most essential parts of the research fields of both; the stimulus and receptor. Opposed to the idea of a linear causality where factor A simply leads to factor B and while B has no demonstrable effect on A, a feedback loop continuously is influenced by the outcome of B; A feeds into B, B feeds into A again. Fundamentally, the encountered loops can be categorised into two main groups: positive- and negative feedback loops. In short, a positive feedback loop is amplifying the total of the phenomenon’s effect and a negative feedback loop is creating an equilibrium between factor A and B over time. For example, a positive feedback loop in ecology is when the decay of plants is continuously increasing the growths of other plants which ultimately leads to a growing forest. A negative feedback, however, is defined by the coexistence of two species where specie A is the predator of specie B. By devouring specie B, naturally, specie A limits the exponential growth of species B. By doing so, at the same time species A limits the food source for its own specie and regulates the further growth of its own kind. As you might notice feedback loops are quite essential to all processes and are found in most phenomena. For my research, feedback loops are especially poignant since they represent a certain repetition in events which produce a change that is, to some extent, controlled by its own system. Additionally, as opposed to linear timing methods described

[18] Topr., Periodic and Oscillatory Motion, https://www.toppr.com/guides/physics/oscillations/periodic-and-oscillatory-motion/

earlier (mathematical description and timing models of the brain), the idea of feedback loops as a way to comprehend 'time' introduces a new conceptual perspective on time perception that I would like to further discuss through my work. Hereby I am mostly interested in partial feedback loops which are still strongly influenced by the surrounding factors as opposed to locked in phase synchronised feedback loops. However, both partially linked and locked in phase, positive and negative feedback loops are of importance during my experimentations. Both present effective ways to fragment stimuli within my kinetic installations. Further, feedback loops are a big part of the receptor's own biological system (as stated before) and more specifically of the principles of our time perception hub: the SCN.

Finally, **rhythm** describes a strong repeated pattern of movement, sound or visual. It is usually associated with the systematic arrangement of sounds in music compositions, principally according to duration and periodical stress. A rhythmic pattern by different intervals of time that fragment the "flow" of a stimulus. Even though we can describe rhythm as a repetition of elements in time it seems less important than previously, for instance in mathematical descriptions, that the intervals of the repetition stay the same.

In the context of this thesis, rhythm plays an important role since the perceived time between repeated elements seems most relevant to a rhythmic composition. At the same time, rhythm plays a major role in time perception in the motor-areas of the brain (chapter two: Why time perception and dynamics?). A composition, a music piece for instance, is relying on the temporal distances and speeds between each repetitive element. We can hereby conclude that a place where a number of periodic, recurring events happen at the same time, a rhythm might emerge that is shaped by the perceived time between different oscillations within. These structures can shape another recurring event in time or create a changing dynamic by influencing one another. Wether it is one or the other, mainly depends on the types of recurring events included in the composition. Hereby it is important to note that not every recurring phenomenon exhibits patterns of equal intervals. A personal note here is that during the motion model experiments I'll refer to the changing dynamics in motion as "rhythm" since rhythms is not bound to equal intervals.

To conclude, periodic or cyclic motion, feedback loops and rhythms are events that are repetitive and which become, depending on their speed and physical properties, experienceable as such by receptors. Why are these stimuli crucial regarding time perception?

First of all, repetitive phenomena usually contribute to some type of change. The experience of change is one of the main ingredients regarding the perception of time. Further these events are capable of influencing and fragmenting the receptor's sensory experience of the physical world. (story 1, Introduction). Additionally, physically speaking, equal repetition can serve as a time keeping tool by accumulating individual intervals. Further, the biological and neural systems of the receptor is regulated by oscillations and repetitions, thus repetitions are inherently part of time experience mechanisms. Furthermore, the repetition of things enables the receptor to compare units in time. The possibility of comparison is essential especially regarding gradual changes in the environment. By comparing factor A to B we can identify the changes in-between. Finally, the urge to synchronise to recurring beats and imitation of rhythm is another important aspect regarding time perception. Following a repetitive sound, movement or visual could result in a emotional or mental immersion with the stimuli.[19] This aspect I will further investigate in my work.

Finally, recurring phenomena play an important role in both; the physical time keeping (calculating time) and the distortion or formation of duration judgements (short term - timing).

1.5 Simple feedback loop experiments

Experiment 1

The first simple feedback loop experiment comprises: a 12 volt dc motor (500rpm), a solar panel and a plastic light filter sheet.

Basic setup:

The motor is attached upside down on a metal construction.

The filter sheet is attached to the axis. The solar panel is placed below the spinning sheet. The motor speed is regulated by the panel's input:

A lot of light =fast

Little light= slow

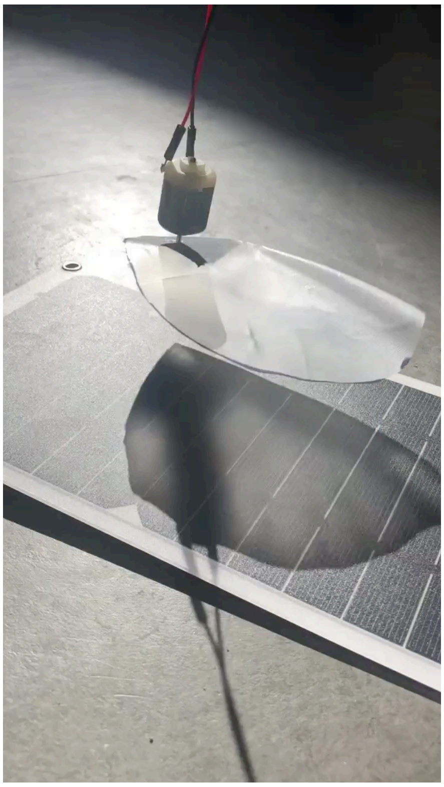
No light= no movement

The sensor's exposure to light is influenced by the spinning of the filter sheet creating a rhythmic movement between fast, slow and barely any movement.

If both factors, the exposure to light and position of the motor are stable the rhythm stays the same. It is a recurring event that is self regulating its own behaviour. However if the conditions change around the setup the movement and further development will, evidently, change as well.

1.Setup: I change the light sources with external light sources around the setup to see if the motor's movement create new motion patterns. The goal is to see if the motion dynamics that arise from the changing conditions are developing new pattern over time and thereby show more variation.

[19] As described in story three in the introduction: the repetitive rotary movement had a strong immersive quality.



Scan code to watch sketch:

<u>1.Outcome:</u>

The motion dynamics are reacting to the varying conditions but always fall back into a steady rotation after a certain amount of time. A rather obvious and foreseeable phenomenon when treating feedback loops is that there is a loop between input and output that stabilises after a certain time (negative feedback loop).

<u>2. Setup:</u> I change the fixation of the motor.

I attach the motor to elastic bands which allows vertical motions to a maximum degree of 65° in all directions.

2.<u>Outcome:</u> The developing motion dynamics have increased in exhibiting change. The combination of two varying factors broadens the variety in response and therefore also in motion dynamic. As before, however, the motor and the disc find an equilibrium.[20]

<u>Observations:</u>

The motion dynamics seem predictable.

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[20] **Equilibrium** describes the average condition of a system, as measured through one of its elements or attributes, over a specific period of time.

It is a recurring event that finds an equilibrium over time (negative feedback loop). It repeats itself and has an immersive quality to some degree but after some time it seems to become boring. Why is that?

The predictability of the movement on one hand contributes to the fact that as an observer you can estimate the development of the motion. The possibility to follow the cause and effect of the event describes a case of short term duration judgement. At the same time, however, this causes a disinterest in how the motion further develops. This means that the change and unpredictability in motion dynamics maintain the immersive quality of the motion event as an active ‘Zeitgeber’ or ‘time-guide’.

The immersive quality of the movement lies in the factor of change between repetitions. Even after manipulating the income source the response only varied slightly. The recurring stimulus itself, in this case, isn’t strong enough to cause a temporal distortion through motion empathy (e.g immersion into the motion event (elaborated in chapter two)).

Further, adding unstable factors to the setup extends the time until the motion find its equilibrium again. This feedback loop synchronises the input to the output, creating a stable rhythm in time.

<u>Future setup possibilities:</u>

Through multiple equal setups of solar panels and individual motors with filters I could analyses the interactivity between the setups. The desired effect would be that, much as in the SCN (section: Circadian rhythms and cell oscillations), the repetitive movements would influence the input of one another and create partially synchronised motion patterns. Further, the predictability would be challenged to a larger degree. The all so famous topic of complexity in systems would be interesting to discuss in the future.

<u>Experiment 2</u>

The second simple feedback loop experiment comprises a piezo, a 9volt motor, a plastic stick, a glass tube and an audio amplifier.

<u>1.Setup:</u>

The plastic stick is attached directly onto the motor’s axis. The stick together with the motor are hanging loosely in the large glass tube. The plastic stick is touching the piezo disc’s surface (contact microphone) which is positioned closely under the glass tube. The piezo is directly connected to the amplifier’s audio input. The amplifier’s output leads directly to the motors voltage input providing ac electricity. The feedback loop is created!

Observation:

(from the moment the amplifier is switched on)

The motor starts moving back and forth. The stick is hitting the surface of the piezo disc in an irregular oscillating pattern providing the motor with a signal in return. This continues for about 10 second then the motor stops moving.

Conclusion:

It seems as if this input/output setup of the experiment finds an equilibrium too rapidly. As soon as there is a break in signal input the motion is stopped since it doesn't receive new information about its own movement. I would need to add an unstable factor to extend the reaction time of the movement (creating a lasting motion dynamic) in order to maintain he feedback loop.

2.Setup:

I distance the glass tube from the piezo enabling the plastic stick to dangle more freely across the piezo. This setup provides a mechanic delay to the signal input since the oscillation of the stick across the piezo enables lasting changing information about the motion.

Observation:

(from the moment the amplifier is switched on)

The motor is in motion. The stick is jumping across the piezo. In signal breaks the plastic stick keeps on dangling for a short moment which provides the piezo with new information. The motion dynamic varies a lot.

After 20 seconds a rhythmic motion pattern appears. It varies between abrupt fast rotations to abrupt slow rotation phases.

Conclusion:

The periodic motion of the stick moving (dangling) across the piezo during no signal input phases creates a delay that helps the feedback loop to keep on feeding and being fed by information (piezo:input, motor:output). Thus an unstable factor or a type of lingering “consequence” factor is needed to keep the feedback loop working.

General Conclusion:

For further research a disequilibrium factor has to be integrated (as in Simple feedback loop experiment 1). A common platform between multiple setups of the same would support an interactivity between individual setups and would broaden signal input. More specifically, the motion of setup1 would influence the signal input (through the shared surface of the piezo) of setup 2 and 3.

The experience of the motion was interesting since it was difficult to follow at times. The complexity seemingly stretched the experience of time. I worked on the setup for longer then I anticipated in contrast to “Experiment 1”.

Important to note here: Opposed to the idea of reproducing equal repetitions in motion the aim in my research is to experiment with nonlinear motion that arise from partial feedback loops.

The experiments aren’t about measurement they are about behaviour. [21]

How does time behave ? More importantly, how does time behave in ourselves and how can such simulation help reshape the idea of time itself and structure the way we experience time momentarily. I will elaborate on motion dynamics and types of feedback loops in the following chapter. I will continue bridging theories of the receptor (perception) and on the stimulus (physical systems) to present and elaborate upon the effects of stimuli repetition and motion dynamics on time perception.

As mentioned in the first section of the chapter, one of the “Zeitgebers” (time indicators) that help us estimate duration is movement. The physical displacement of things around us, their change in position in space, introduces the idea of “speed” and thereby inevitably also the thought of some kind of “duration” wherein the motion event is unravelling. Further, It seems that the experience of motion has great impact on the ability to plan future motion acts ourselves and to estimate the behaviour of a motion. In the following chapter I will elaborate on the question: why time perception and motion dynamics?

2.Why time perception and motion dynamics?

The passing of time is closely connected to the concept of space. According to the general theory of relativity, space, or the universe, emerged in the Big Bang some 13.77 billion years ago.[22] Before that, all matter was packed into an extremely tiny dot. Simplified, that dot also contained the matter that later came to be the sun, the earth and the moon, and, ultimately, the reference to time passage and time measurement. One of the most peculiar qualities of human time measurement is the fact that it is initially measured by motion and it also becomes evident through motion. First, through the perceived movement of the sun, moon and stars and later through devices telling time.

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[21] The aspect of time behaviour instead of time measurement is important to keep in mind throughout the thesis.

[22] Matt Williams, What is the Big Bang Theory?, Universe Today, (2015)
https://phys.org/news/2015-12-big-theory.html

This observation describes my main focus and motivation behind my research: the effect of cyclic motion on time perception. Thereby, my hypothesis is that the receptor is by default strongly influenced by the experience of any recurring motion (stimulus) and especially cyclic motion regarding time perception. The perception of physical movements such as oscillations, rotary movement and repetitions in general are closely linked to our concept of time itself. The rotation of Earth, the perceived motion of the sun across the sky, the first time-measurement devices and different types of mechanic clocks today all have in common that they tell time through motion. By focusing on cyclic and repetitive motion the question arose: What are motion dynamics and dynamics in general? What kind of dynamics exist inside and outside the body (receptor and stimulus) and how do they influence our perception?

In this chapter I will first introduce the research field of dynamics (stimulus research) and emerging synchronisations of feedback loops. Hereby I will present two motion experiments. Further I will discuss theories and models developed concerning the effects of motion dynamics on time perception (receptor's research). Finally I will introduce the effects of empathy with movement and time perception.

2.1 Dynamics and emerging synchronisations

Motion dynamics become especially relevant when analysing and identifying movement patterns in the mechanic feedback loops that I build (motion models). As mentioned before, the goal is to break down motion dynamics emerging from cyclic movements linked to partial feedback loops and the phenomenon of emerging synchronisation between multiple setups. Thereby, I wish to reflect inner time keeping mechanisms through mechanic models in order to take a closer look at the subjective experience of time through the perceived movements (empirically). Therefore, it is important to analyse the dynamics found in systems described in physics and neurology.

In this section of the chapter, I will focus on the stimuli (physical output of the models) by introducing briefly the research field of dynamics and nonlinear dynamics in physics. I will take a closer look at the emerging synchronisation models and take a leap into the dynamics of the SCN (suprachiasmatic nucleus) tissue. Thereafter, I will present and discuss two versions of a motion dynamic experiment.

The study of dynamics is the study of bodies in motion. The aim of the research field is to describe motion and explain its causes. The fundamental concepts in dynamics are space (relative position or displacement), time, mass, and force. Further, the research includes velocity, acceleration, torque, moment, work, energy, power, impulse, and momentum. However, I will not elaborate on these aspects specifically. My focus lies on identifying motion dynamics emerging specifically from cyclic motion and feedback loops.

Nonlinear dynamics in mathematics and dynamic studies are for instance motions where the change of the output is not proportional to the change of the input. Nonlinear dynamics are of interest for most scientific research fields because, in nature, most systems are inherently nonlinear[23]. The exhibited changes in variables over time, may appear chaotic, unpredictable, or counterintuitive, contrasting with much simpler linear systems. The frustration with nonlinear dynamics is that there is no single equation that is applicable to all nonlinear phenomenon and therefore nonlinear systems are commonly approximated by linear equations (linearization). This works well up to some accuracy and some range for the input values, but some interesting phenomena such as solitons[24], chaos and singularities are hidden by linearisation. It follows that some aspects of the dynamic behaviour of a nonlinear system can appear to be counterintuitive and unpredictable. This is especially interesting when facing time perception theories. Predictability in events, planning and accuracy in motion is an important part in the way we estimate duration. The inaccuracy in such movement might have distorting consequences. We could argue that our timing mechanism and metric measurement of time is actually a linear process where fragments are accumulated, or future events are estimated. The unfolding of all events, however, is nonlinear and their perception and measurement becomes only partially predictable by receptors. For example, some aspects of the weather are seen to be chaotic, where simple changes in one part of the system produce complex effects throughout. This nonlinearity is one of the reasons why accurate long-term forecasts are impossible with current technology.

We could argue, however, that nonlinear phenomena (and dynamics) are all completely determined and predictable but we, as receptors, are incapable of grasping the total of the event with all its possible factors and deviations. This aspect is equally relevant thinking about time itself in contrast to how we perceive it momentarily. Carlo Rovelli's (The order of time, 2017) theory on time seems a good fit in this respect: "..our perception of time's flow depends entirely on our inability to see the world in all its detail". This means that we, as receptors, are unable to comprehend the unravelling of time before us and so are nonlinear dynamics. Through that inevitable perceptual ignorance, we can only create rules that are applicable for short moments or accept the illusion of time as an experience.This aspect is also relevant when discussing the motion models. I noticed that when observing motion dynamics of created installations that the more complex the event the harder it is 'followable' and the greater the dissonance. I will elaborate on the consequences of the inability to comprehend motion events in chapter three "Why time perception and illusions?".

Moving on, spontaneously emerging synchronisations is a much-researched phenomenon in which a population of coupled oscillators (usually of different frequencies) self-organises to operate in unison. The phenomenon is observed in physical and biological systems over a wide range of spatial and temporal scales. For example the metabolic synchrony in yeast cell suspensions, flashing fireflies,

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[23] Wikipedia (definition), Nonlinear system, https://en.wikipedia.org/wiki/Nonlinear_system

[24] Wikipedia (definition), Soliton, https://en.wikipedia.org/wiki/Soliton

Josephson junction arrays, laser arrays, and others. Besides the synchronous firings of cardiac cells that keep the heart beating, synchrony is desired in many man-made systems, e.g., in parallel computing, whereby computer processors must coordinate to finish a task on time, and in electrical power-grids, in which generators must run in synchrony to be locked to the grid frequency. Synchrony could also be hazardous, e.g., in neurones, leading to impaired brain function in Parkinson's disease and epilepsy. As previously mentioned, research argues that the cellular voltage exchanges of clock cells in the SCN (chapter one : Circadian rhythms and cell oscillations) might also find synchrony and thereby regulate the rhythms of our timing mechanism.[25]

Collective synchrony in oscillator networks, such as the brain, has attracted immensely the attention of physicists and applied mathematicians, and finds applications in many fields, from quantum electronics to electrochemistry, from bridge engineering to social science. But what exactly happens when order between oscillations appears spontaneously ?

Spontaneous Order implies that there is a chaotic, disorganised state at first. A self-organising system is a system that somehow, through its own dynamics, organises it's pulses, patterns or rhythms and creates a more organised/synchronised pattern in time. The term "spontaneous synchronisation" seems like a rather modern phrase but the first time it appears goes back about sixty years. It can be found in the final chapter of "Cybernetics"(1948) by the mathematician Norbert Wiener.

Wiener was the first to look at the question of collective synchronisations of systems in the natural world. He was the first one to introduce a theory on the observed phenomenon in 1958. He presented the Wiener's spectrum taken from his book "non-linear problems and random theories" published a few years before. He was interested in brain waves ranging in the alpha-band (10-12 Hz)[26]. These are the dominant oscillations, mainly when our brain is in a state of relaxation. Wiener noticed two depression curves on each side of the measured spike of the alpha oscillations and suggested the following.

First of all, he imagined that the brain contains all kinds of different oscillations ranging in different frequencies, which today is found to be true.

Secondly, he thought that there is some kind of gaussian distribution of natural frequencies and due to an interaction between those oscillations, the ones close enough to 10 Hz (the spike's rate) get pulled

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[25] I will elaborate on the dynamics of the SCN in the next section of this chapter later on.

[26] Alpha-band oscillations: it is suggested that alpha-band oscillations have two roles (inhibition and timing) that are closely linked to two fundamental functions of attention (suppression and selection), which enable controlled knowledge access and semantic orientation (the ability to be consciously oriented in time, space, and context).

in from the wings creating a spike and by depleting the surrounding area creating the depression curves on either side.

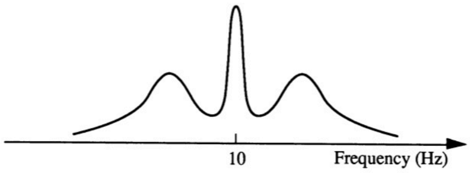

Fig.1. Wiener's schematic sketch of the spectrum of human alpha waves, redrawn from Wiener (1958, p.69).

Wiener predicted through the frequency pulling theory that through the number of similar oscillation rates a spike is shaped that dominates all the other oscillations. In the following years, several researchers have tried to uncover the suggested synchronisation phenomenon. Besides brainwaves many other synchronisation phenomena have been studied.

A specific example of unwanted emerging synchronisation in the field of motion dynamics that baffled many people was the wobbling motion of the Millennium Bridge some time ago in London. On the opening day in June 2000, 8000 people showed up to take a walk across the newly build bridge. After some time, the bridge started to wobble slowly in a periodic 1Hz motion from left to right, horizontally. Research explained later that through a critical number of people walking across the bridge one common periodic motion arose from the general motion behaviour of the walking pedestrians and was amplified by the pedestrian's attempts to keep their balance while walking. A similar phenomenon happens on a paddle boat. Once you lose your balance it is hard to find back the equilibrium in the boat. Since the countermovements in return amplify the disequilibrium and increase the rocking motion of a new periodic motion which develops every second phase of your own (Footstep 2Hz / Bridge 1Hz).

Of course, I cannot compare the bridge's motion phenomenon to oscillations in the brain but I can set up an argument that runs parallel with common rules found in the developed models.

After a row of different approaches and model proposals for the synchronisation phenomenon of brain oscillations, Kuramoto (1975) finally introduced the most famous model in the field, the Kuramoto model. The model introduces the factor of coupling strength between oscillations (factor K in equations). Kuramoto argues that individual oscillations only merge into synchronisation if their phase does not differ too much or the communication between them is strong enough. Thereby we can distinguish between not locked in phase, partially locked in phase and locked in phase synchronisations in natural phenomena.

I try to explain this in a more intuitive way. If we imagine running around a track in a circle with a friend and the friend is faster than you but both of you are trying to adjust the speed to one another, you will manage to synchronise your running pace at some point. However, if a runner is much taller than you with much longer legs it makes it impossible to adjust your running speed to their pace since the difference in physical properties is too big.

Kuramoto's statement is that the interactions (so the response to the signals between oscillations) depend sinusoidally on the phase difference between each pair of objects. If K (coupling strength, communication between runners) is high enough all oscillators are capable to synchronise only the ones that are completely out of the norm won't manage (the fast runner).

Coming back to Wiener's spectrum, Kuramoto explains that the main spikes measured in the alpha range spectrum are all the synchronised oscillations that managed to lock their phases. The bumps on the side (depression curves after Wiener) are the frequencies that are unable to synchronise because of the large phase difference to the ones locked in phase (spike). The oscillations that aren't part of the synchronised spike are influenced by the spike but are never part of it. To conclude, synchronisation between events only happens if:

1. communication between repetitions (oscillations, periodic motion e.t.c) is strong enough(coupling strength)
2. The repetitions do not differ too much in phase sizes.

Why is the phenomenon of emerging synchronisation inside and outside the human body relevant to the stimulus's research and to the composition of the motion models?

Firstly,The synchronisation of oscillations, recurring phenomena or periodic motion describes inherently a communication between and within systems. The interactivity and communication between elements could be described as motion dynamics[27]. Dynamics emerging between successive events are interdependent elements that partially react onto their surrounding conditions. This aspect becomes very relevant during experimentation.

Just as previously mentioned, most things can be categorised as repetitive and so does the far-reaching drive to synchronise. The synchronisation between recurring phenomena extends from plants to animals and atoms to planets[28]. It seems only legitimate to include the theories of such phenomena into the mechanic motion models. It is interesting that we strive to synchronicity and almost a type of

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[27] dynamic: a force that stimulates change or progress within a system or process

[28] Steven Strogatz, Sync: The Emerging Science of Spontaneous Order, 2004

harmony but at the same time feel more interested or attracted in/by the unpredictable: nonlinear motion dynamics.[29]

Secondly, the topic of communication between oscillations brings along the concept of feedback loops. A feedback loop is ultimately a loop of communication between elements that feed one another and thereby create changing dynamics.

In this perspective, creating a feedback loop system that is partially locked in phase (as described in de Kuramoto model) would mean that the emerging motion dynamic would be comprised of repetitive movements that exhibit variations and changes in dynamics. The unstable factors (chapter one: feedback loop experiment 1+2), changing conditions of the environment and the parts of the repetition that are incapable to merge into the main recurring motion will theoretically, produce change within the total of the movement event. I will elaborate on the element of change on time perception in the section : "2.4 The effect of motion on time perception" of this chapter.

Before conducting a simple motion dynamic experiment on synchronisations in motion I take a small leap back into the oscillations found in the SCN (chapter one, section:Circadian rhythms and cell oscillation dynamics). I will do so as in order to gain more information about the dynamics of biological systems responsible for time keeping mechanisms to apply aspects onto my own work. Furthermore, through the research on emerging synchronisation, the question arose: If brainwaves, heart cells and many more internal systems regulate and coordinate their pulses through synchronisations, is it possible that the SCN tissue functions the same way? Or at least similarly?

2.2 Dynamics of the SCN

Returning to the suprachiasmatic nucleus (SCN), the master circadian clock, a rhythm generating tissue of thousand of neurons, I want to take a closer look at the behaviour of the oscillatory signals that are sent out to the brain and to other organs of the body. When a nerve cell fires a signal it includes fluxing calcium ion concentrations inside and outside the cell which generate a charge difference that then sparks an electrical impulse. The charge difference can be measured in volts. I was wondering if the SCN cells would synchronise just as heart cells do to shape a network-wide synchronised 'beat'. This would mean that the SCN could work as a self-regulating clock of many synchronised oscillators.

A team of researchers at Hokkaido University and colleagues in Japan successfully measured voltage changes in SCN cells over several days. The team introduced a gene that encoded "voltage sensors" into cultured SCN slices from newborn mice. The sensors are formed by fusing a fluorescent protein

[29] as concluded in the previous two motion experiments.

with another protein that can sense voltage. The intensity of the sensor's fluorescence changes significantly with changes in voltage, which becomes visible by a special microscope. The results showed that voltage rhythms were synchronised across the entire SCN. "This was unexpected because previous research found neuron groups in various SCN regions express circadian rhythm genes differently," explains Ryosuke Enoki at Hokkaido University.[30] While measuring voltage changes, the researchers simultaneously measured calcium ion concentrations across the cell tissue and found the, similar to so-called "clock genes," were not synchronized across the entire SCN. This finding supports previous research that the cells oscillations differ from region to region. However, the researchers suggested in their published study (Proceedings of National Academy of Sciences), that the SCN could be maintaining a network-wide coherent rhythm through synchronised voltage changes despite asynchronous calcium rhythms.

To conclude, according to the presented studies there is a synchronised voltage rhythm between the SCN cells that exists alongside asynchronous calcium rhythms. This presents a phase difference between voltage rhythms and calcium ion oscillations.

But what does that mean? Coexisting rhythms in the SCN?

Following to this research immediately the question arose: Is it possible that we host nonlinear dynamics within the SCN through different frequency oscillations?

Indeed, in a recent article, a research group from the Institute for Theoretical Biology (Charité and Humboldt Universität zu Berlin) together with the Master Program Neuroscience and Cognition (Utrecht University, Utrecht, The Netherlands) present their research results on nonlinear phenomena through models of the circadian clock. This research has been done under the objective to contribute to the understanding of molecular mechanisms of circadian dysregulations such as insomnia, or other diversions of a regular 24-hour rhythm. It is important to remember, in this case, the fact that molecular circadian rhythms are generated by gene-regulatory feedback loops in which protein products regulate the transcription of their own genes (chapter one). The research group argues that changes in the degradation of clock genes and proteins greatly alter the dynamics of the system and can induce complex nonlinear events. These nonlinear events have been described at the organismic and tissue level, but whether they occur at the cellular level is still unknown. The results show that period-doubling[31] and chaos appear in different models of the mammalian circadian clock with interlocked feedback loops and in the absence of external forcing. I will not further investigate this matter but I

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[30] Ryosuke Enoki, Yoshiaki Oda, Michihiro Mieda, Daisuke Ono, Sato Honma, and Ken-ichi Honma, Synchronous circadian voltage rhythms with asynchronous calcium rhythms in the suprachiasmatic nucleus, PNAS, 2017
https://www.global.hokudai.ac.jp/blog/synchronized-voltage-rhythms-could-maintain-the-bodys-clock/

[31] In dynamical systems theory, a period-doubling bifurcation occurs when a slight change in a system's parameters causes a new periodic trajectory to emerge from an existing periodic trajectory—the new one having double the period of the original.

found it note worthy that the circadian clock exhibit nonlinear dynamics. Further, the idea of interlocked feedback loops, overlapping oscillation and the effect on the clock's dynamic inspired the setup of the mechanic feedback models. However, it is important to note that the comparison of physical and cellular dynamics is a dangerous ground since their "motion" is not comparable. Nevertheless I wish to integrate these aspect into the analysis of the mechanic feedback models (motion models).

<u>To surmise and proceed:</u>

The dynamics of our internal time keeping mechanisms could be explained as partial feedback loops. The neurones of the SCN are constantly fed by internal and external informations and react accordingly. Additionally, the rhythms influence one another in their oscillatory behaviour creating constantly chaining dynamics.

In the spirit of emerging synchronisations inside and outside the receptor's body I will present in the following experiments two mechanic motion models. The purpose of the following setup/models is to experiment with motion dynamics in the field of emerging synchronisations in multiple partially linked movement sources.

Further, it is important to note that the results, especially the ones on perception impact, are based on personal judgements and are not applicable for all setups or all receptors.

2.3 Simple motion dynamic experiment 1 and 2: (Spaghetti furniture)

The first motion dynamic experiment on emerging synchronisations comprises three dc motors, a rectangular board, a round board, thin ropes, weights, uncooked spaghettis, 9v batteries, two pulleys and elastic bands.

<u>1.Setup: *rectangular board (spaghetti swing)*</u>

The motors are attached by elastic bands stretched across three individual round holes cut in the rectangular board. The board itself is suspended by thin ropes. Carried by two pulleys, two weights (125 gr. each) are attached to each end of the two ropes. Each axis of the motor extended by round coupling pieces. On the outer line of each piece holds a single uncooked spaghetti. All three spaghettis are facing down and standing on a wooden floor. The whole construction thereby stands on the three spaghettis with a semi-stable counterweight of 250 grams (2 x 125).

Three batteries are powering the motors (approx. 500rpm).

Scan code to watch sketch:

First observation:

Every motor spins individually their spaghettis with the same speed and the same weight carried

on top. However, each spaghetti exhibits their own movement pattern. One is hopping irregularity from one side to the other. The second one is slightly bended and rotates in small circles around in a larger circle. The third one circulates on the spot to then jump to the side from time to time. The reason for the irregularity in patterns could be explained by the attachment manner and different angular positions of the motors.

Second observation:

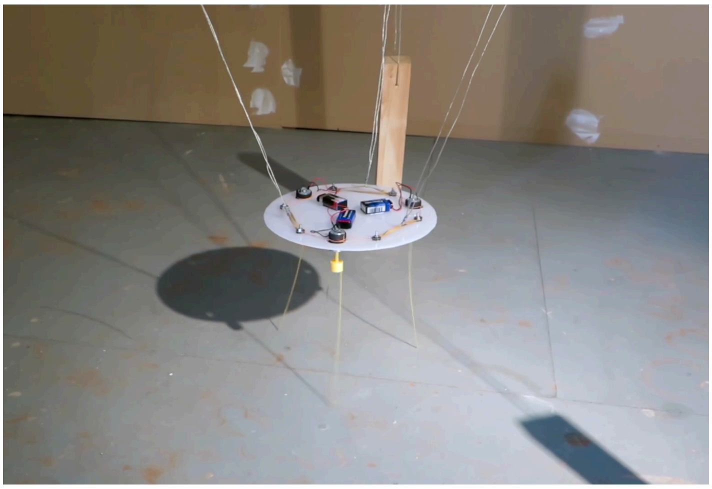
After some time, the rectangular board starts to move. First, to the front and back like a swing. and then slowly merging into a rotary movement. The individual spaghettis start to compensate and counteract the receiving movement from the others. Together they synchronise to shape a single rotary movement.

(Millennium bridge example)

Third observation:

Slowly, the oscillatory and rotary movement of the board become smaller than the individual movements become more random again.

Note: the experiment has been repeated five times. The variety in movements, what first seemed rather unpredictable, became predictable.



Scan code to watch sketch:

2. Setup: a round board (spaghetti stool)

The motors are fixated by elastic bands across three holes positioned in a triangle shape from one another. The circular board is suspended by three thin ropes. Three weights are holding the board in a horizontal position. Each axis, as in “1.Setup”, is extended by an uncooked spaghetti. The rest of the setup is identical.

Observation:

From the moment the motors start spinning (approx 500 rpm) the platform starts to move in seemingly unpredictable patterns.

After about 15 seconds the platform started to exhibit horizontal quarter rotary movements, back and forth.

After about 12 Seconds the platform stabilises. The motors have found an equilibrium.

Conclusion:

Through the three fixation points, the platform has less mobility in comparison to “1.Setup”. The motion patterns were much more limited and less change was perceivable. It became clear that synchronisation always happens and when it does, it usually is followed by a neutral state/equilibrium with little change. What I mean by that is that the main observed pattern with both setups (1+2) was:

First: seemingly random and uncontrolled motion patterns of the individual spaghetti.

Secondly: synchronisation, forming one main rotary or periodic motion.

Thirdly: finding an equilibrium with little variety.

General conclusion:

In these experiments, it became clear that the coupled movements of the motors were determined to find an equilibrium through balance. Because of gravitational forces and the suspension method, even through the integration of unstable factors an equilibrium is found.

We can hereby conclude that a negative feedback loop was taking place. The factors, the motors, were balancing each other out.

The repetitive changes in motion maintained the focus level on the motion event. Especially the second state: Synchronised motion (slower movement through unison) had an immersive and interesting effect. On one hand the predictable rotary motion of the synchronised motion had an almost hypnotising effect and the additional subtle changes kept me invested in the further development of the motion dynamics. The motion seemed “relatable” and thereby followable. It appeared as if I had empathy with the motion.

By timing the experiments I can conclude (on the level of longer time-scale perception research) that the swing experiment (“1.Setup”) felt much longer than the stool experiment (“2.Setup”). It appeared as if the change caused the event to appear longer (change model, Brown).

Comparing the results of the first feedback loop experiments to the ones of the simple motion dynamic experiments it becomes clear that when observing the chaotic movement of the stick on the piezo the interest is found in the future development of the motion event and therefore the attention level maintains steady throughout the motion event. The attention level when observing the synchronised rotary motion of the spinning spaghetti is not found in the further development of the movement but rather lies in the rhythm of the synchronisation. It had a meditative effect wherein I focused on the repetitiveness of the stimuli itself. In both cases they had a distorting effect on my perception of the motion event’s duration.

In the following section I will elaborate on the effect of motion in time perception. In this section I will focus on the receptor’s end (perception); on the effects of perceived motion. This is in reference to the second story of the introduction (rotating wheel on the drill).

2.4 The effect of motion on time perception

The role of stimulus events[32] in timing has been the focus of much theoretical work and experimentation (Block,1990,Poynter,1989). Numerous auditory, tactile and visual stimuli tasks have been used to analyse human timing abilities. In the past sixty years, several models have been

[32] A **stimulus event** is one stimulus and associated parameters that describe one particular presentation of that stimulus. Stimulus event parameters specify things about the stimulus presentation, such as when it occurs.

introduced supporting different theories about the effect of perceived motion, change and varying number of stimuli on the human experience of time and duration judgement.[33]

One of the early models, brought forward by Ornstein (1969), is the “storage-size model”. According to the theory, the perceived time is a function of the amount of “memory space” needed to encode and store the perceived event. This means that complex events i.e. events containing numerous new and unknown stimuli are usually experienced to be lengthier than the ones containing little new information (a.o repetitive events)[34]. This so called: “filled-duration illusion” was analysed through the storage-size model but yielded contradictory results. The status of this model remains controversial.

Nevertheless, in the coming experiments and theories, the factor of change within stimulus events stayed relevant. Among other theorists(Block 1982,1990, Fraisse, 1963, 1978; Gibson,1975) Poynter advanced specifically the importance of stimulus change in time perception: “Change is the psychological index for time passage”(1989).

By addressing “change” as one of the main “Zeitgeber”, it seems rather self-evident that the perception of motion plays a big role in time perception since “motion” literally means, the change in position of a body in space. Speed, space and time remain closely linked, not only regarding measurements and their physical behaviour, but also how they are perceived as stimuli and processed by receptors.

After the controversial status of the first model the focus clearly shifted. Opposed to the previous assumption that the number of stimuli perceived are lengthening the experience of time it is said that change is the main guide of time perception. The effects of change opposed to no change, and motion opposed to stationary stimuli, became the main focus of investigations.

The hypothesis brought forward, claims that moving stimuli must lengthen perceived time because of the change it exhibits in contrast to stationary stimuli which doesn’t show any change.

The first experiment, set up by Roelofs and Zeeman (1951), presented a series of **stationary** opposed to a series of **moving** stimulus displays of the same length (duration)[35]. The subjects had to estimate the duration (short-duration stimuli : 0.2-3.2 sec) of each display. The moving stimuli were presented at a speed rate of 7.5- 60 centimetres a second. The moving stimuli tended to be judged as lasting longer than stationary stimuli. Similar results were reported by Goldstone and Lhamon in 1974. In each of these studies, the moving displays were judged to be longer in duration than the stationary displays. So far, the hypothesis that change lengthens the perception of time stays intact.

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[33] experience of time: The overall experience of time passage of events. Duration judgement: specifically being able to judge the duration of an event proportionally to the way it is measured in the physical world.

[34] Scott W. Brown, Time, change, and motion: The effect of stimulus movement on temporal perception (page 105), Perception and Psychophysics, Spinger, (1995)
https://link.springer.com/article/10.3758/BF03211853

[35] The stimuli were light squares projected on a screen

The second issue involves the effect of stimulus **speed** on perceived time (the physical velocity of a body in space).

Several experiments that have been made indicated that faster moving stimuli lead to progressively longer temporal judgments (Fraisse, 1962, Leiser, Stern, & Meyer, 1991, Piaget, 1961/1969, Tayama and Aiba, 1982, Tayama 1987). These studies involve a variety of stimuli, durations, and speeds (up to 90 cm/sec). Other research suggests that the way the speed of a stimulus is perceived, is strongly influenced by the type of stimulus and the stimuli's physical context (the spacial factors surrounding the moving stimuli).

It is suggested that the experience of speed is partially moderated by various stimulus- and subject related characteristics (i.e. context related). Evidently numerous factors might vary between stimuli tasks which inevitably lead to difficulties in evaluating and comparing results effectively.

Even though the research by Roelofs and Zeeman (1951) contains numerous apparent interactions between stimulus speed, duration, distance traveled, and presentation order, the data analysis is rather sketchy and these effects stay difficult to evaluate.

The following research results on the effect of different motion speeds on time perception bring forth even more contradictions. Some studies found no effect of stimulus speed on time judgments (Bonnet, 1965, Experiment I; Bonnet, 1967, Bonnet, 1968, Fraisse, 1962). This failure to obtain the expected result has been attributed to one of two possibilities that the stimulus speeds were too fast (Fraisse, 1962), or that the durations were too short (Bonnet, 1965). Some studies even indicate that faster stimuli are associated with shorter temporal judgments (Bonnet, 1965, Brown, 1931; Matsuda, 1974,). Matsuda has referred to this result as the i' effect, which she defines as an opposite counterpart to the kappa effect [36].

The kappa effect, first described as the "S-effect" (Suto,1952) suggests that the distance between two stimuli which are displayed simultaneously is influencing the length of time perceived between them. This suggests a clear correlation between perception of time and space (meaning perceived distance). For instance there is a lengthening of the perceived time separating two sequential stimuli when the distance between them is lengthened. For example, if three light bulbs are flashed simultaneously (A,B and C) and B and C are further apart than A and B, the time between flashes is usually experienced to be longer between B and C. The perception of distance, becomes rather relevant addressing the kappa- and i' effect. Matsuda (1974) and Bonnet (1967) have speculated, however, that different temporal cues may exert different effects on time judgments. The suggestion is that if one relies on the distance an object moves, time judgments are lengthened; if one focuses

36 Goldreich (2007) refers to the kappa effect as "perceptual time dilation" in analogy with the physical time dilation of the theory of relativity., Time dilation, https://en.wikipedia.org/wiki/Time_dilation

instead on the speed at which an object moves, time judgments are shortened. Not only distance appears relevant but attention levels are addressed in Matsuda's theory. To briefly conclude, spacial focus (attention on distance) lengthens the temporal perception of the moving event and the focus on the moving body (perceived velocity) shortens the experience.

Again, this hypothesis is challenged by research results showing that both speed and distance can lengthen perceived time (Bonnet, 1968, Rachlin, 1966). Even though numerous experiments have been effectuated on the above named subjects the correlation between time perception and perceived movement in velocity (speed) and stimuli, remain inconclusive and slightly confusing.

Brown's reevaluation

Because of different experiment setup methods, researchers were unable to isolate reliable and clear results on the above-named subjects.

J.F. Brown reevaluates in the article "Time, change, and motion: The effect of stimulus movement on temporal perception" (University of Southern Maine, Portland, Maine) the findings on stimulus motion and perceived time. The primary goal of the experiments presented in the text is to determine whether there is a reliable lengthening effect through stimulus movement on temporal judgments. Another part reconsiders the hypothesis that increased speed in stimulus presentation amplifies the temporal lengthening effect. Brown presents five different experiments that analyse different motion stimuli paired with different timing tasks (short term duration judgement). The groups of participants are diverse in age and sex.

In Experiment 1, subjects reproduced the duration of displays consisting of stationary or moving (at 20 cm/sec) stimulus figures. In Experiment 2, subjects reproduced the durations of stimuli that were either stationary, moving slowly (at 10 cm/sec), or moving fast (at 30 cm/sec). In Experiment 3, subjects used the production method to generate specified durations for stationary, slow, and fast displays. In Experiments 4 and 5, subjects reproduced the duration of stimuli that moved at speeds ranging from 0 to 45 cm/sec.

A consistent finding was that moving stimuli were judged to last for a longer duration than stationary stimuli. In this case the results replicate the findings of the earlier reports (Goldstone & Lhamon, 1974; Lhamon & Goldstone, 1975; Roelofs & Zeeman, 1951; Tayama & Aiba, 1982). This temporal lengthening effect is in line with a basic assumption shared by many theorists namely, that the perception of time is ultimately the perception of stimulus changes.

Secondly, the question if there is a link between the perceived velocity in motion and perception of time stays the problem child during experimentation. However, bear with me, Brown is able to isolate outcomes across the experiments that lead to a conclusion. Stimulus speed was varied in four experiments, three of which showed the predicted effect of faster speeds associated with longer time judgments. This outcome aligns with some previous findings and directly contradicts the i'effect, where a negative relation between speed and perceived time was reported (Matsuda, 1974). However, the results also indicate that the influence of speed may be moderated by stimulus duration. In the longer experiments ranging between 15 and 18 seconds the role of speed has less influence on the timing of the stimulus displays. The effect also aligns with Poynter's (1989) notion that different cues, strategies, and timing mechanisms vary in importance across different contexts. It is important to highlight the notion of the context of perceived movement. The experience of space (distance) and time (duration) stay interconnected.

The main conclusion Brown draws here is that subjective experience of velocity (phenomenal velocity, perceived speed), can be put into a parallel equation to the physical equation of speed (speed= distance/time (s=d/t)). The phenomenal **v**elocity (subjective experience of speed) equals the phenomenal **s**pace divided by phenomenal **t**ime (v=s/t)[37]. Through the experiments he conducted he concluded that, firstly, when the experience of velocity of a movement increases it is either observed that the experience of distance(space) was increased as well or that the experience duration was shortened for equal space correspondingly.[38]

By majority, however, the variation in time perception was observed, and hence Brown concludes that the impression of duration gained by watching objects in visual movements is conditioned and highly dependent on the properties of the field in which the movement occurs (physical, spatial context). These variations in the "flow" of time perception (phenomenal time) are not isolated cases, he argues, which could be explained as illusions, but are continuous variations conditioned by practically any change in the structure of the movement field (again: physical context). The most important conclusion we can draw from Brown's discoveries is that time, where there is movement (filled time) is perceived longer than time felt during disparate stimuli (unfilled time) displays. However, this rate between movement and perceived time varies in accordance with the physical field in which the movement occurs.

To conclude, moving stimuli are strong reference points for the receptor to estimate the duration of events and at the same time they actively influence the estimation of their own duration through variations in speed. Hereby the perception of distance, velocity and physical context of the movement play an important role and are even indispensable to the analysis of time perception and motion. It is interesting to note that a moving stimulus opposed to a stationary stimulus is said to increase the "speed" of the perceived time. Hereby we can argue, firstly, that the change produced

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37 Noun. phenomenal world (plural phenomenal worlds) (philosophy) Especially in philosophical idealism, the world as it appears to human beings as a result of being structured by human understanding; the world as experienced, as opposed to the world of things-in-themselves.

[38]Brown, J.F., On time perception in visual movement fields, *Psychol. Forsch.*, (1931). https://doi.org/10.1007/BF00403874

through the movement is a powerful indicator for time passage and, secondly, that we associate movement of any kind with the idea of time itself. This aligns, linguistically with the thought that “standing still” is associated with a kind of “timelessness” and “moving forward” describes the thought of moving forward in time, literally. Hereby we can assume that the experience of any motion is strongly connected to our idea and experience of time. Brown takes this thought a step further and puts the experience of velocity of movement in relation to the experience of time and space into a parallel equation to the one of speed in physics. Phenomenal velocity equals phenomenal distance divided by phenomenal time. Speed of movement stays an interesting factor regarding time perception that I’d like to explorer later on.

Further, a rather general aspect we can deduce from all the researches is that change in events is the main time experience carrier. These two aspects: the effect of perceived velocity and the change model introduced by Brown I wish to explore further.

Evaluation on previous motion experiments and further research suggestion:

This brings me back to my motion dynamics experiments. What do I want to include in my experiments? As Brown explains himself: there is still room for further experimentation according to the different manners in which stimuli move. This might provide alternative ways to test the “change model”.

For example, one could compare time judgments of stimuli that move in a smooth, continuous manner with those that move in an incremental, stop-and-go fashion by jumping from point to point (such as the first simple motion experiment). Incremental movement produces more abrupt, discrete changes, which may enhance the temporal lengthening effect of motion. This aspect of unpredictable and changing dynamics I wish to explore through the nonlinear dynamics of the models I build.

Another aspect is the experience of space (distance). Brown uses screens to conduct his experiments which might limit the spatial perception. The spacial experience seems rather relevant regarding time perception and therefore I like to include in the following experiments. Lastly, the aspect of duration becomes important for the mechanic models. Since the experiment setups named above have the function to gain values and compare results they are inevitably bound to time frames, ironically. The goal during my experiments is that theses mechanic models might vary in speed and sequences, but they appear as ongoing experiments that are not bound to a specific time schedule. The aim is to create experiences that do not have a clear beginning nor end. Their experience is constant and ever changing.

2.5 'Time guides' and empathy with motion

Returning to the observation made on the spaghetti motion models earlier and the phenomenon described in story two (the moving bread bag story (2), introduction) another question arose: why do I feel empathy for- or immersed into a movement's behaviour and what does it do to the dynamics of time perception?

Research has it that our brain contains "mirror neurons" that fire both when you do something and when you watch someone else do the same thing. Because they allow us to mimic what others are doing, it is thought that these neurons may be responsible for the fact that we can feel empathy or understand others' intentions and states of mind. In the case of the plastic bag or the last experiment (2. Setup: a round board (spaghetti stool)) we could argue that anything that moves could potentially trigger the "mirror neurons" as long as the movement is "relatable" enough. By "relatable" I mean that if the movement's velocity is in the range of the human body's velocity. It seems rather self-evident since the function of "mirror neurons" is mainly to copy and learn the behaviour of other humans (a typical behaviour observed with toddlers). Empathy and learning from others are crucial for survival and thereby is, inevitably, deeply rooted in the way we perceive motion patters in a specific ranges of velocity.

Mirror neurons respond both; when perceiving an action and while executing an action. They provide a direct internal experience of another person's or object's actions or emotions and may be the neurological basis of empathy itself. We could argue that the empathy with perceived motion is a way of actively guiding the duration of the observed event through the empathy with movement. This might be quite a stretch, but I'm going for it anyway. A movement, when observed intensively could become the experience of time itself. The movement act represents a powerful "time guide" to the experience itself. As "time guide" I define a "Zeitgeber"(time indicator) that leads actively the experience of an event. For example, observing a bee trying to find a way through a glass window can have an extremely immersive effect if dressed with the right focus. The receptor becomes absorbed by the movement act. The movement becomes the experience itself and literally guides its duration through motion. Of course this statement is quite vague and is rather meant as a thought proposal as opposed to a claim. Taking into account that motion is a powerful "Zeitgeber"(time indicator) I do find the thought legitimate. To take this a step further I would need to discuss different types of attention levels which are crucial to understand the basics of sensory experiences but I will not dig that deep this time. However, the interesting part about dedicating our focus intentionally onto one movement is that it has been reported that it feels as if we become the movement itself. Brian Massumi especially writes about this effect of empathy with movement. He writes: "mirror neurons are specialized neurons which echo the movements perceived in another's body in incipient movements in one's own body, in a kind of involuntary kinesthetic empathy." He continues " Their discovery has given rise to a far-reaching reassessment in cognitive science, the arts, and the humanities of the role of empathy and the self-other relation in the constitution of the sense of self." Massumi describes a form of this empathy as a “mirror-touch synesthesia” [39]which describes the phenomenon wherein the perceived touch to another's body elicits in the perceiver the sensation of being similarly touched. He takes the mirror-touch synesthesia as a starting point to reconsider synesthesia as a whole, and in particular its relation to empathy, and the relation of empathy to movement.

To conclude, when the receptor of feels empathy with- or immerses her/himself in the development of a motion dynamic it means that the motion dynamic could be describes as an active “Zeitgeber”, namely a “time guide” that, through our own developed empathy for the perceived movement, leads the sense of duration of the event itself. This statement takes back the thought of chapter one and two that the human concept of time is closely linked to our perception of movement. Moving and experiencing movement creates, in fact, the illusion that time “flows” and is in constant motion.

What role play perceptual illusions regarding our experience of time? In the last chapter “why illusion?” I will discuss time as an illusion itself, visual and auditory illusions influencing short term duration judgements and the effect of brain oscillation entrainment on our perception of time.

3.Why time perception and illusions?

“Mr. potato head” without his ears, mouth, hands and eyes, is probably completely unaware of what is happening around him. Our brain might find itself in that predicament, too. The brain is sitting in the dark and is relying on the senses to feed it with information about the outside world. Our senses, as mediators, are complex, interconnected and limited, providing information that is only partially reliable. There are repeatedly miscommunications between the senses and the brain, and the senses themselves, leading to visual, auditory, or tactile illusions. We could argue that if our senses are so easily tricked and unreliable our experience of the world as a total could be described as an illusion. But in order to navigate, function and survive in a physical world, we rely on our senses and strongly depend on their information. Nonetheless we all encounter, from time to time, illusions that make us aware of the fact that not everything is the way we think it is. As we stated before, our perception of time is highly fragile and influenceable by many different factors inside and outside the body. Therefore, time perception seems to be the perfect candidate for perceptual illusions. It is important to note here that there are different types of illusions. There are illusions that happen between the physical world and our senses and there are illusions happening on a structural level within our body. Both are relevant regarding time perception. In the following section, I focus on physical illusions appearing through motion dynamics and light. Following that, I will discuss short term duration

[39] **Synesthesia** or synaesthesia is a perceptual phenomenon in which stimulation of one sensory or cognitive pathway leads to involuntary experiences in a second sensory or cognitive pathway. https://en.wikipedia.org/wiki/Synesthesia

judgement illusion through brain oscillation entrainment. Finally, I will elaborate on possible effects on time perception and time as an illusion itself.

3.1 Wagon Wheels and the Time-Slowing Effect

I remember the first time I experienced the wagon wheel effect[40] while observing the rims of a Porsche that drove by. As the Porsche accelerated, the rims seemingly started to rotate backwards. Even though I knew that this is a common visual illusion it created a type of cognitive dissonance momentarily. [41] The sound of the speeding Porsche wasn't matching the visual information of the slowly backwards moving rims which somehow made it difficult to estimate the actual speed of the car as it drove by.

The way the wheels rotated backwards in a slow fashion instantly made me think of the time-slowing effect in time perception. When time seemingly slows down momentarily and we can perceive more details within a short amount of time than we usually do, we speak of the time-slowing effect. The analyses of hundreds of reports after accidents revealed that 71% of people recall experiencing an altered passage of time. Most people recall that the duration of the event that occurred during the accident as much slower and detailed. [42] Many researchers have developed theories to explain this phenomenon. Because of in a situation of "fight or flight," it is important for our survival to react quickly to the encountered circumstances and thereby it is in our advantage if time momentarily slows down. What is really happening, however, is that the bodily processes are speeding up relative to the world outside, which makes us perceive the event in slow-motion. The arousal level of the body is heightened to its peak which means that the body and mind are in a physical and mental state of being highly focused and active. Because everything seems to slow down in the environment, we see and hear more details of what is happening, which then again amplifies the lengthening effect of the event (a case of filled time, as mentioned in chapter 2).

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40 **The stroboscopic** effect is a visual phenomenon caused by aliasing that occurs when continuous rotational or other cyclic motion is represented by a series of short or instantaneous samples (as opposed to a continuous view) at a sampling rate close to the period of the motion. It accounts for the "wagon-wheel effect", so-called because in video, spoked wheels (such as on horse-drawn wagons) sometimes appear to be turning backwards. https://en.wikipedia.org/wiki/Stroboscopic_effect

[41] **Cognitive dissonance** refers to a situation involving conflicting attitudes, beliefs or behaviors. This produces a feeling of mental discomfort leading to an alteration in one of the attitudes, beliefs or behaviors to reduce the discomfort and restore balance.
https://en.wikipedia.org/wiki/Cognitive_dissonance

[42] Valteri Arstila, Time slows down during accidents. Front. Psychol.,(2012)https://doi.org/10.3389/fpsyg.2012.00196

Of course, this type of temporal illusion has nothing to do with the wagon wheel effect (i.e. stroboscopic effect). However, it made me wonder: If we perceive the velocity of a movement slower than we would normally understand it, does it inevitably influence the ability to estimate the event's duration all together? Returning to Brown's hypothesis (chapter 2) that increased velocity in motion lengthens the experience of the event could mean, in this case, that visual illusions in motion could lead to a double distortion in time perception(long scale experience and short term duration judgement).

Theoretically, the fact that the Porsche's rims appear to move much slower than they actually move means that in return the experience of the movement event could appear shorter. As Brown argues, the decrease in perceived velocity equals decrease in time perception. This would be the first distortion of two. Secondly, the inaccuracy between sound and motion could lead to another interesting effect wherein two sensory information provide two different pieces of information about the duration of the event to the brain. This dissonance between auditory and optical information could at the same time signify that there are two different lengths of time experiences. Because of the lack of information and empirical data on this subject, the consequences of a plausible double distortion in time perception remains unclear. However, I like to include the factor of visual and auditory illusions in my experiments.

Further, I wish to include the idea of a double time perception distortion into further investigations. Illusions confuse and challenge our cognitive processing and make us reevaluate accuracy of our perception of the physical world. The confusion and distortion through perception could be an interesting element to look out for during experimentation.

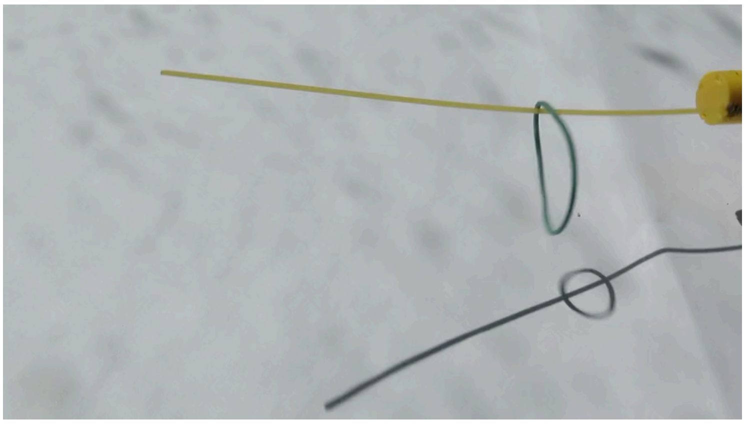
In the spirit of this hypothesis I set up the following experiment:

3.2 Experiment: The Elastic Helicopter

Returning to the wagon wheel effect (stroboscopic effect), wherein a rotary movement is distorted through it's exposure to light or also commonly known through the fragmentation of the camera I decided to spin an elastic band on an axis of a fast spinning motor. By filming its varying rotary movement with my phone (30 frames/sec) I was able to perceive two motion dynamics at the same time.

Experiment set up:

A small dc motor (500rpm), 5v battery, a piece of paper as surface, uncooked spaghetti to extend axis and one elastic band.



Scan code to watch sketch:

<u>Observation in real time:</u>

By observing the movement of the elastic band in real time (not through the camera lens) the fast movement of the rotation appeared as a blurry disc. The elastic band becomes almost invisible. It appears as a blurry disc. By slightly moving the motor downwards the elastic started to hit the paper surface which influenced the moving pattern of the elastic. Through the repetitive touching of the elastic band onto the paper the speed of the movement becomes audible.

<u>Observation through the camera lens:</u>

By observing the movement of the elastic band through the lens I can see, what appears to be three, elastic bands rotating in changing speeds in circles. Through the fragmentation of the camera the perception of rotation is reorganised. What appeared before as a blurry disc can be observed in different speeds and dynamics through the camera's lens.

<u>Conclusion:</u>

Observing the rotation in real-time, I noticed that my attention automatically shifts onto my auditory perception. As soon as I realise that I cannot perceive the speed of the rotation properly I started focusing on the sound. This also means that, in this case, the auditory perception of the rotation is more accurately (at least I perceived it that way) than the visual perception. The speed of the rotary movement is too fast to follow each rotation by rotation. The perception of velocity in movements is limited.

By observing the rotary movement through the camera lens I was able to perceive different motion patterns. Even though the movement is fragmented and behaves according to that fragmentation I had the impression to be able to follow the movement and therefore my focus relied more on the visual aspect of the movement.

Overall conclusion:

I found the combination of the view through the lens paired with the perspective in real time very interesting since the auditory effect of the real time clashed with the one through the lens. My visual illusion through the camera lens had an alienating effect but at the same time I felt visually more connected to the movement in front of me. This is an important aspect facing the motion models as active 'time-guide'. It seems that movement that reaches a certain speed becomes' 'unfollowable'. With 'unfollowable' I don't necessarily mean unpredictable but rather undefinable since the individual movements (in this case: rotations) are outside of the human perception spectrum of physical motion. This has as a consequence that the receptor's attention shifts to a different perceivable stimuli or that one loses interest in the motion event. The immersion into the event fades away and thereby the motion event's time-guiding capacity is weakened. However, the aspect of optical or auditory illusions that emerge from such ranges of speed in repetitive motion introduces the interest in the unknown as a powerful focus attractor. Perceiving a new aspect of a phenomenon or let's say a 'meta-reality' of the phenomenon, (f.ex wagon-wheel effect) the focus intensifies. Hereby we can assume that either the newly perceived motion becomes the active time-guide or the other perceivable stimuli that is usually weaker becomes intensified (the tapping sound of the elastic) and thereby becomes the dominant time guide.

Both findings are highly relevant for my further research on the effects of perceived motion on time perception.

Through this experiment another question arose: what role does optical fragmentation play in time perception?

3.3 Fragmentation of perception and entrainment of the clock?

Addressing the wagon wheel effect through the effect of a camera lens's fragmentation as described in the experiment earlier, the question of optical segregation becomes relevant.

If we think of the camera as a fragmentation tool for motion events, we should question our own perception accordingly. Since we stated before that the perception of time as a fluid phenomenon is an illusion and that a lot of our internal time keeping mechanisms are, indeed, fragmented we could ask ourselves the same about our optical perception? Is our vision as fluid and ongoing as it appears? Of course not!

I remember watching a Ted talk about brain rhythms and attention[43] when Dr. Ayelet Landau mentioned that the human optical perception is fragmented by about 8 Hertz which means a perceptual fluctuation of eight times a second. This means that, within a second, we see an object eight times better opposed to the other halves of the intervals. In this context I exclude the blink of the eye which is, self-evidently, another optical shutter by definition, a mechanical one.

In a very similar fashion to a camera, our own optical perception registers things in a fragmented way which, indeed, explains many visual illusions. These fluctuations are linked to our attention levels in the brain, usually measured in brain oscillations in the alpha range (between 8-12 Hz), explains Landau. The thought that there is a direct link between the way we perceive our environment and the fluctuations that occur in our brain made me wonder: If our visual perception fluctuates because of our brain oscillations would it be possible to entrain these oscillations through stimuli repetition in return? More specifically, is it possible to influence brain oscillations through stimuli (flashing light) in the same frequency range and thereby disrupt our attention and distort our perception of time in return?

Our ability to estimate time intervals has sometimes been attributed to a biological oscillator (pacemaker) and accumulator. As mentioned in chapter one[44], the controversial "internal clock" model (Treisman, Faulkner, Naish & Brogan, 1990) has introduced the idea of such a temporal oscillator that provides such information. This led to the argumentation that an imposed stimulus rhythm at certain frequencies could potentially interfere with this temporal oscillator to alter its frequency. This interference would cause perturbations in temporal judgements at certain frequencies of the imposed rhythm. The pattern of interference would depend on the frequency at which the temporal oscillator runs, and so would contain information about the oscillator frequency. Already some time prior to this hypothesis research has proven that brain oscillation entrainment is indeed possible through stimuli repetition (such as a flickering light). Brain oscillations can be synchronised to outer stimuli when exposed to them and allegedly maintain that rhythm for some time. However, the theories about the effects of such synchronisations are rather split and not entirely conclusive. Further, research has shown evidence for patterns found when auditory clicks at different rates were presented concurrently with time intervals whose durations subjects estimated. A study published in 1992 "Time Perception and the Internal Clock: Effects of Visual Flicker on the Temporal Oscillator"(Michel Treisman and David Brogan)[45] examines whether a similar interference pattern can be obtained when visual flicker is substituted for auditory clicks. On each trial, flicker was presented at a rate between 2.5 and 17.5 Hz (largely within and beyond alpha rhythms), together with a time interval estimation task. A pattern of increased estimates at some rates and decreased estimates at others was obtained. This pattern

[43] Dr. Ayelet Landau, Brain rhythm and attention, TEDxJerusalem https://www.youtube.com/watch?v=ktbbm7ktuAM

[44] Why time perception, fragmentation and feedback loops?

[45] Department of Experimental Psychology, (Jniversity of Oxford, Oxford, U.K.)

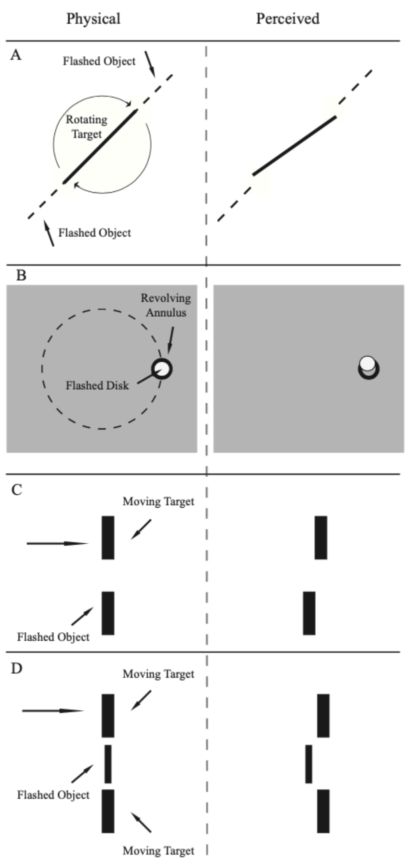
showed similarities to interference patterns obtained using auditory clicks. The presented research results supposedly provide evidence that the entrainment of the internal clock predicted by the model can also be produced by visual inputs. However, the concept of the model itself has been lacking proof over the years and the results are therefore for this experiment questionable, too. Besides these counter indications, there is merit to discuss this theories nonetheless.

To conclude, the above presented theory would mean that our internal mechanism in charge for short-term duration judgement is indeed closely connected with our senses. In the sense that our optical sense is literally fluctuating and is in return influenceable through repetitive stimuli. We could argue that our senses and our cognitive processes are in a constant feedback loop through oscillating information. The stimulus is the factor of interference, as described previously during experiments, and potentially interferes with the equilibrium between both. If indeed stimuli repetition influences the internal timing segregation, the fragmentation in visual information and illusion through perceptual segregation must be included during the motion model experiments.

On the topic of visual illusions, there is another important illusion that is bound to optical properties and cognition is the flash-lag effect which integrates the inevitable factor of space to the temporal perception. As mentioned by Brown (chapter two) the spacial context of the movement (or other stimuli) is crucial when addressing the perception of time.

3.4 Flash-lag effect and time perception

This section will detail a response to questions raised in the third story of the introduction, treating the visual illusions created through moving stimuli in contrast and direct comparison to stationary environments or objects. The flash-lag effect describes the effect when a non-moving stimulus is quickly flashed directly underneath a moving stimulus, which leads us to perceive that the stationary one as "lagging" the moving one, even though the two stimuli actually occupy the same horizontal position at the time of the flash. In example C (image: right), for instance, a rectangle moves across a screen. At the midpoint of the rectangle's journey from one side to the other, another rectangle is quickly presented (flashed) just below. Despite the fact that the two stimuli are presented at the same coordinates along the x axis, the stationary rectangle is perceived as behind the moving rectangle (as simulated in the right column of example C). The perceived lag of the flashed stationary object becomes



greater when the speed of the moving object is increased and vice versa (Nijhawan 1994). The same effect is perceivable in different motion phenomena (other examples).

A mysterious wrinkle, however, is that the effect is not present if the moving rectangle stops moving at the time the stationary rectangle is presented, with the two objects occupying the same horizontal position (Hubbard 2014, Kanai 2004).

The illusion thus appears to suggest that the later movement of the stimulus affects how the two stimuli are perceived earlier, when they appear together. We could argue that the future is influencing our later perception, against the normal direction of causation. Of course, the latter scenario is highly implausible. As a result, numerous theories have been developed to explain the phenomenon in more natural ways.

Though no consensus exists, one prominent interpretation puts the flash-lag effect in a category of temporally exotic phenomena known as postdictive effects (e.g. Eagleman and Sejnowski, 2000) and less commonly known as “backwards perceptual phenomena” (Shimojo 2014). Postdictive effects can be defined as perceptual phenomena that appear to involve later sensory input affecting the perception of earlier stimuli, though only within a timeframe of around 100-200 milliseconds (Shimojo 2014). These effects include a large group of similar illusions, each of which disrupt the ordinary temporality of perceived events in some way or another. Other examples, besides the flash-lag effect, include the cutaneous rabbit illusion, apparent motion, the color phi effect, and more.

Eagleman and Sejnowski’s postdictive interpretation of the flash-lag effect suggests that our perception of the locations of the two objects is constructed out of a process of averaging positions over time, with the relevant sampling taking place immediately after the presentation of the stationary stimulus. This act of averaging would then lead to the moving object perceived as slightly ahead of the stationary stimulus, with an increasing lag depending on the distance travelled by the moving stimulus within the sampling period. This means that when perceiving movement we constantly try to find an average point between moving and stationary stimuli around us creating a type of perceptual equilibrium of the object’s velocities in our sensory fields

Some have argued against the postdictive interpretation. One theory holds that the flash-lag effect is modulated by attention. According to this view, our attention moves from the moving object to the stationary object when it is flashed, and by the time we are able to attend again to the moving object, it has already moved past the stationary object (Baldo and Klein 1995; cf. Baldo and Klein 2010).[46]

We can conclude from the lack of consensus regarding the appropriate interpretation of the flash-lag effect, this illusion requires further study before researchers can be confident about the mechanisms

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[46] Timothy L Hubbard, The Flash-Lag Effect and Related Mislocalizations: Findings, Properties, and Theories, Psychological bulletin, (2014)
https://www.researchgate.net/publication/241696359_The_Flash-Lag_Effect_and_Related_Mislocalizations_Findings_Properties_and_Theories

involved. This flash-lag effect is interesting in reference to the topic of time perception due to the fact it indicates the temporal distortions found between perceived stationary stimuli and moving stimuli. The reference to the spatial context is crucial when analysing the effect of moving stimuli in the context of time perception theories (stated before in chapter two: the effect of motion on time perception). We could argue that most experiments done in the field of time perception that encompass the effect of moving stimuli are lacking the reference to stationary environments as reference points. On a final note, the flash-lag effect is one example of many that the perception of movement is closely relation to our perception of time and influences our ability to estimate time durations. Time, as a moving stream is an illusion that might be caused by the actual misinterpretation of moving stimuli around us.

3.5 TIME AS AN ILLUSION

Time, according to the theoretical physicist Carlo Rovelli, is an illusion. As stated before, we often compare time to something that flows. Our naive perception of it does not correspond to time's physical reality. In a final attempt to link the theories discussed on the internal clock mechanisms and time as measurement to the external physical "reality" of time itself, I argue that: Any concept of time in physics or perception are both illusory. Since we experience it as a flow and accumulate intervals in measurements and internal processes, ultimately suggests, that we inevitably see time as a continuous and linear progression of things. This means that both human concepts of time are false by default. Concerning the "stimulus", Rovelli argues in his book *"The Order of time"*, that indeed much more in the world of mathematics and physics is illusory. For instance Isaac Newton's picture of a universally ticking clock or even Albert Einstein's relativistic space-time, an elastic manifold that contorts so that local times differ depending on one's relative speed or proximity to a mass, is just an effective simplification. Rovelli posits that reality is just a complex network of events onto which we project sequences of past, present, and future. The fragmentation of time in measurement, equations and even within our cognition conceptualises time inaccurately. The apparent existence of time in our perceptions and in physical descriptions, written in the mathematical languages of Newton, Einstein, and Erwin Schrödinger comes not from knowledge, but from ignorance. Rovelli argues that the idea of 'Forward in time' is simply the direction in which entropy increases,[47] and in which we gain information. This means that the way we, as receptors, accumulate fragments, count oscillations, or perceive movement creates the feeling of progression and automatically suggests the idea of a linear progression. We can easily speak of something as being part of the past since we are convinced that it will not happen in that precise same order again. Einstein, however, showed us that time is just a

[47] **Entropy** is a scientific concept, as well as a measurable physical property that is most commonly associated with a state of disorder, randomness, or uncertainty. The term and the concept are used in diverse fields, from classical thermodynamics, where it was first recognised, to the microscopic description of nature in statistical physics, and to the principles of information theory.
https://en.wikipedia.org/wiki/Entropy

fourth dimension and that there is nothing special about 'now'; even 'past' and 'future' are not always well defined. The malleability of space and time mean that two events occurring far apart might even happen in one order when viewed by one observer, and in the opposite order when viewed by another. We can argue that the flow of time is a subjective feature of the Universe, not an objective part of the physical description. We can even take this a step further. Since, as Rovelli argues, time lays within our "inability to see the world in all its detail" (The Source of Time) every concept of it described or "consciously" perceived by humans is not accurate to the way time just is. It means that time is not a "thing". Given that we cannot know the causality between all particles of the universe we ultimately cannot describe actively what happens when it "passes.". As Rovelli notes, "A storm is not a thing, it's a collection of occurrences." At our level, each of those events appear like interactions of particles at a particular position in time; but time and space themselves really only manifest out of their interactions and the web of causality between them. "Quantum uncertainty" introduces the idea that we , as receptors, cannot know the positions and speeds of all the particles in the Universe. If we could, there would be no entropy, Rovelli concludes.

My final argument is that, if we are unable to comprehend the nature of time the next best thing we can do is observe the universe. Since the perception of the total of the universe and its dynamics are imperceivable by receptors the next best thing is to observe and investigate complex systems. The SCN and its nonlinear dynamics is probably the closest we get to "perceiving" the patterns of time. Oscillations, repetition and dynamics between atoms and planets, animals and plants are not only what describes every "stimulus" but also what describes every "receptor". This means that the physical and the internal processes are both, in fact, time itself we are only incapable of ordering it. It might in fact be more relevant to study behaviour and dynamics in systems than quantifying time as a linear succession of events

CONCLUSION:

The different statements I wish to make are shaped by the gathered information found in the fields of the 'stimulus's' research and the 'receptor's' research. As a first attempt to draw a conclusion, I present a table of short summaries about the findings discussed in each chapter. I will proceed and focus on the different aspects demonstrated by the three stories in the introduction in relation to the motion model experiments and the presented theories. Finally, I will present future research possibilities and suggestions.

MOTION MODELS/TIME PERCEPTION	Physics and physiology of the brain/"STIMULUS"	perception/"RECEPTOR"
WHY OSCILLATIONS, REPETITIONS AND FEEDBACK LOOPS?	a) Time is measured by oscillations. Every oscillator can be used as an interval generator for time measurement. b) Most, or even all, natural processes go through a type of repetition or renewal. c) Molecular circadian rhythms are generated by gene-regulatory feedback loops.	a)Brain oscillations are linked to time perception. b)Repetitive stimuli shorten the experience of time. c) The brain and the senses could be described as a feedback loop, constantly influencing one another's information about time passage.(short term timing)
WHY MOTION DYNAMICS?	a) Motion is used to measure time (sundials, water clocks, pendulums). measurement of the movement of planets. b) motion dynamics between particles in the universe are used to explain time itself in quantum mechanics and thermodynamics.	a)Research found that there are nonlinear dynamics SCN (circadian rhythms) responsible for dysregulations in the sleep wake cycle. b) Change in repetitions is THE indicator for time perception and so is the change in motion dynamics c) perceived motion has been proven to have great influence on the accuracy of duration judgement.
WHY ILLUSIONS	a)time is a human illusion.	a)time perception is an illusion. Quantum uncertainty means we cannot know the positions and speeds of all the particles in the Universe. If we could, there would be no entropy, and no unravelling of time. b) time-slowing effect is one of many temporal illusions which has an impact on duration judgements. c) the flash-lag effect is one of many visual illusion that show the illusory effect of motion as a "time guide"

Returning to the three stories presented at the beginning of the thesis, we can conclude that a repeated stimulus, such as the fire alarms beep, influences the receptor's perception of time. The anticipation of repetitions is essential regarding the receptor's planning abilities and temporal judgements and is located in the motor-areas of the brain. Another effect found through this research is that brainwaves can be entrained through stimulus repetition and cause visual and auditory illusions which are linked to spatial and temporal misjudgements. Besides that, the repetition of a stimulus has shown a time shortening effect in timing tasks (duration judgement tasks) conducted by different researchers. Concerning the idea of time, addressed in the beginning of this thesis, we can argue that the human concept of time is not only marked by the perception of motion but also by the mathematical accumulation of intervals. A general strive towards a linear order of time has been suggested and identified through the history of time measurement and models developed on timing mechanism (short term duration judgements) of the brain. Thereby the perception of stimulus repetition and fragmentation inevitably plays a role in time perception.

The next factor, as described in story three where wheel on the drill wobbles and then runs smoothly again, the change in motion heightens the interest in the motion event. Incremental movement produces more abrupt, discrete changes, which may enhance the temporal lengthening effect of the motion event. Further, through the immersion in the development of a motion dynamic the motion event becomes an active and more powerful time guide.

Another aspect discussed was the effect of perceived velocity in motion regarding time perception. As described in story three,[48] the factor of perceptual limitations regarding the speed of a movement has proven to be equally problematic concerning the ability to estimate time and spatial properties. Through the experiment conducted in chapter three (3.2 Experiment: The elastic helicopter), we can conclude that the receptor's perception of velocity in motion is indeed limited and strongly effects the perception of the motion event's duration. We can conclude that only certain speeds in motion are "followable" and thereby has time-guide potential (short duration judgement between individual motion steps). The development of the movement can be approximately estimated. However, the speeds in motion bellow or beyond a certain point (undefined), are responsible for interesting time perception distortions (illusions).

This introduces the topic of visual illusions in motion and time perception. Through the fragmentation of the camera, a different dimension of the movement became visible (3.2 Experiment: The elastic helicopter). This perspective of the speed reconnects the receptor with the stimulus on an alternative level. The focus on phenomena which indicate another dimension in perception intensifies attention levels and amplifies the motion event's time-guiding capacity. Furthermore, the fragmentation of the receptor's vision (8/sec) and the brainwave entrainment in the alpha-range through stimulus repetition strengthened the established relationship between partial feedback loops and time perception mechanisms for the experiment setups. Synthesizing the above, I can reach the understanding that visual illusions such as the wagon-wheel effect introduce another level of motion perception into the field of time perception studies. Hereby the receptor accepts the perceived stimulus as an illusion and readapts to the illusory "reality". Contemporaneously, the receptor maintains a constant awareness for the inaccuracy of the sensory experience of the event. The factor of known visual illusions (every perceptual illusion for that matter) could be an interesting aspect addressing time perception distortions in future experiments.

Further, the spatial context is an important determining factor regarding time perception and motion dynamics. We can deduct from the theories developed by Brown and other researchers that the surrounding stimuli of a physical space (story 1) actively "lead" the experience of the movement

[48]Story Three: the experience of the sound and the visual (catapulted elastic band and shattered glass) seemed disconnected

(Brown and the change model in Chapter 2). This factor also demands more attention during timing task experiments (neuroscience, time perception studies) and during motion model setups in physical spaces (artistic practice).

Furthermore, the research on emerging synchronisations (story 1) inside and outside the body (receptor) brought forth multiple interesting conclusions. First, the emerging synchronisations between partially coupled oscillators is defined by the coupling strength and phase differences (Kuramoto model) between oscillations and are crucial regarding emerging synchronisations in general. Further we can conclude that the internal time keeping hub of circadian rhythms (SCN) is a tissue of cells that generate gene-regulatory feedback loops which are partially synchronised through voltage rhythms and additionally are synchronised to external “Zeitgeber”. Hereby time, as it is processed by the receptor, is shaped by the dynamics of partially synchronised oscillations inside the body and are fed by outside oscillating stimuli (“Zeitgeber”).[49] The internal time keeping mechanisms are influenced by recurring perceived phenomena (light, temperature etc) and exhibit by themselves feedback loops that are partially synchronised across the SCN. The phase difference between voltage rhythms and calcium ion oscillations in the SCN and their effects is still not completely clear.

Another aspect is the immersive quality of- and empathy for certain types of developing movements [50] like the moving bread bag in story two. is an important factor that I have included in previous studies and has led to the conclusion that attention and emotions are guided by the perceived movement. Movements, especially followable ones are strong “time guides”.[51]

Finally, the study has revealed that the subjective experience of time (cognition) and the quantification of time (counting intervals) are both constructed by the receptor. Both are inevitably false, as Rovelli declared; the receptor is unable to perceive the complexity of the universe at once and therefore time stays a human concept. To conclude, analysing the “motion” dynamics of complex systems in physics or biology is the only way, on an empirical level, to observe objectively what happens when “time” passes. The nonlinear dynamics of recurring phenomena within “motion” systems inside and outside the body, ultimately describe how time is perceived and how time might behave[52]. There are millions of recurring phenomena entering our sensory fields and thousands of oscillations in our brain and body that channel a change in speed of perceived events and determine the way we memorise them. Time is what is created between oscillations and repetitions; a complex rhythm, an ever changing motion dynamic of the universe.

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[49] These observations are based on the longer scales in time perception such as the sleep-wake-cycles

[50] aka motion dynamics

[51] With “followable” stimuli, I mean stimuli which are within the receptor’s spectrum of perception and cognition. (not necessarily predictable)

[52] “Time” stays subjective in this sense

Further notes or research:

Two aspects that I didn't address properly was on one hand the element of emotional arousal and on the other the specific attention levels responsible for changes in time perception when perceiving motion events. Both elements are highly relevant to this research which is why I need to conduct further research in both areas.

One aspect that became relevant during the motion model experiments was "complexity". It became clear that the created mechanic feedback loops had the most immersive effect when the exhibited motion patterns were changing and almost unpredictable. The more "complex" the event the more emotionally invested and focused I was. Why is this relevant? The combination of a repetitive movement and changing overall pattern is interesting for multiple reasons. It combines a time shortening effect (repetitions) with a time lengthening effect (change model) which could result in strongly varying effects on perceived short-term durations. Further, the immersion in the development of a movement is clearly more present with a heightened variety in movement; not identically repetitive and predictable. This describes the reason for utilising partial feedback loops that are strongly influenced by a third or fourth factor.

A note on time perception studies : I realised that the paradox of timed timing tasks in time perception studies might cause strongly varying research results. I realised that a common problem of most research experiment setups is the fact that they are limited in time scales. It appeared that especially on timing experiments (short term duration judgements) the timing tasks usually didn't exceed 1 minute. There seemed to be quite some controversy in the findings regarding perceived movement and time perception studies. Brown indeed concluded at the end of his paper that longer scales were needed and different movement patterns for further conclusions in this regard.

Finally, the aspect of spatial context was lacking in most experiments. It is an important factor and nonetheless is little explored. It appeared that most timing tasks with movement are displayed on screens or with flashing lights. I'm sure that with technology developed (VR for instance) the research has further developed. However, the analysed experiments were often lacking a physical spacial dimension. Through the motion models in my final presentation, I hope to integrate and elaborate the factor of the physical spatial context.

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