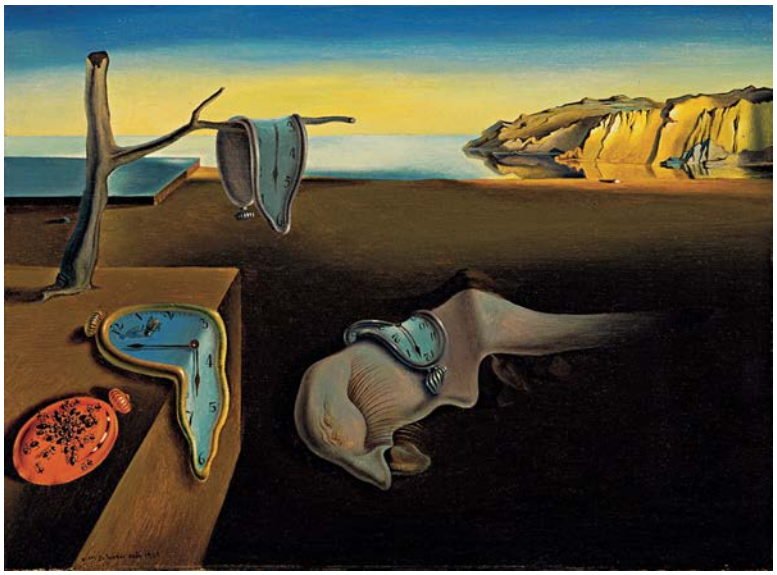

Mind the Gap

A cognitive perspective on the flow of time in physics

Master's Thesis
History and Philosophy of Science
Supervisor: Prof. dr. Dennis Dieks
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Preface

The image on the title page of my thesis is The Persistence of Memory (1931), which is the most famous painting by Salvador Dali. This painting captures many standard issues that relate to time: relativity theory, clocks, memory, and the flow of time.

This thesis is about the flow of time. As time moves on and never stops, so will the philosophical and scientific research on its flow be incomplete forever.

Never in my life has time flown by as fast as it did this last year of my master's research. So many questions remain unanswered; so much works still needs to be done, while the months were passing like weeks and the weeks were passing like days. One year is too short, to dive into the fascinating river of time. To me it feels like this thesis is a first survey of the possibilities within the field of the philosophy of time.

Time's passage has been a source of interest for quite a long time. When I was a child I kept diaries and memo-books to write down what happened each day in the hope I wouldn't forget it. Nowadays it is still a favorite game to exactly remember the date and time of special happenings and pinpoint those on my personal time line in my mind. It fascinated me why things that are in the future, become present and finally are in the past, leaving behind almost no evidence except for some physical records and memories in the mind. These traces of the past help us to find out what happened. Reconstructing the past is what historians do for a living.

Nothing illustrates the passage of time any better than the existence of history. The past is captivating. If I walk in an old castle or house, I imagine the people that walked here hundreds of years ago. They are now gone, like I will be gone a hundred years from now.

I keep looking in front of me with my eyes on the future, but from time to time, I take a look over my shoulder and think about what my world line looks like from the day I was born until 'now'. You may call it nostalgic, but I prefer to call it the fascination for the flow of time.

Years have gone by and in this fast world we are living in, I sometimes need to think about all those moments of 'now' I have experienced.

In 2002 I moved to Leiden to study history. In this first year I learned about what happened in the time between 6000 BC and 2000 AD starting with the Mesopotamian civilization and ending with the Gulf War in the nineties of the last century. What I also have learned is how difficult it is to reconstruct history. We can never know what happened for sure, unless we are able to go back in time. But we are not.

In my second year, I switched to physics and started a bachelor's in Astronomy. Many people wished me luck in the study of a much bigger history: the history of the universe.

From the start of my first year in astronomy, the science of the universe and the Big Bang when time started captivated me.

A few years ago I never thought I would write a thesis on the passage of time. It is the most fascinating subject that I have ever written about; it connects all different kinds of my interests.

'Time' and especially its flow is everyone's business every day. But if you ask yourself the question what time and its passage really are, you are stuck for an answer. It is one of the most difficult questions in the philosophy of physics.

After I took some courses in Philosophy of Mind and in Philosophy of Space and Time in the spring of 2008, I was looking for a subject to write a paper about. When I got in touch with the field of philosophy of time, I tried to write a piece about spatial metaphors we use to understand time in July and August of that year. There were so many questions lying in front of me, that I could not finish the paper. A study was needed to know more about the role of time in physics compared to the way we experience time in everyday life. The subject turned out to be too extensive to cover in 5000 words and that is how the idea for my master's thesis was born.

In this thesis I offer a cognitive perspective on the problem of the flow of time in physics. It is a relatively new kind of approach to an age-old subject. In October of last year, I got in touch with many researchers in the field of the philosophy of time from all over the world to discuss recent publications on this subject, especially on the combination of cognitive science and physics. Thanks to enthusiastic reactions of Nick Huggett, Craig Callender, Robin LePoidevin, Barry Dainton, Huw Price and Dennis Dieks, I got encouraged in the choice of my subject.

Here in front of you lies the product of a one year study on the fascinations of time's passage. It does not feel like a finished study at all. Many things that are mentioned on the surface deserve a more extensive treatment.

First of all I am grateful to Egbert Stolk for his library that has been a gold mine of references on cognitive science. He also helped me producing a part of the images in this thesis. I am also thankful to Monique van Velzen for reading pieces and her tips and suggestions for the improvement of my English.

Finally I would like to thank Dennis Dieks for supervising this project and for offering very helpful criticism to improve the scientific character of this thesis.

Annemarie Hagenaars
August, 2009

Contents

Introduction

I sit at my desk and take a sip of my tea. I feel the warmth running down my throat. I think of a first sentence and start typing on the keyboard of my laptop. It is very quiet here in the house. I hear the clock ticking, I can feel the beating of my heart and I am aware of thoughts rushing through my head. My mind is continuously making memories. Some of them exist only a few seconds or minutes; others are stored for a longer time. These memories are made at this very moment to record the past. And these same memories help us infer now what is going to happen in the future.

We learn by making explanations for ourselves of what happened in the past, decisions on what has to happen now and plans for what we want to be happening in the future. Without our memories we do not have any personal history. That is why memories are crucial for our identity. We are making plans, decisions and explanations 'now'; 'in the present'. We never directly experience what happened in the past; we know what happened if we recall our memories at the present moment. We only experience what is present and this feels as if the present is something special.

The clock is ticking the seconds, the minutes, the hours and it does not stop and cannot be returned. Every time we want to name what is present, for example it is now 10.13.55 AM, to be t_1, it is already past before you can write it down. And so it goes for 10.13.56 AM. This is the passage of time.

The ticking clock represents this passage. The moments in time that we call 'now' are never the same. The 'now' seems to be moving, and to catch this aspect of time in our language we introduced a metaphor. Imagine a long flowing river; we are in a boat on that river and we have no means to peddle; we just go with the flow and cannot stop the boat or turn it. This is the metaphor we use to talk about the passage of time. It is called 'the flow of time'.

There is a problem with the flow of time. Although we all very clearly observe and feel this flow, the laws of physics cannot capture it. The laws of physics do not contain any 'present' or 'now', but they do contain a parameter t that can take all values representing moments of time t_1, t_2, etc. Whether these points in time are past, present or future is not represented. For example, if t_1 is Wednesday April 1st, 2009 at 10.13.55 AM and t_2 is Friday April 3rd, 2009 at 11.02.23 AM, these statements are always true. However, when I write this down, t_1 is past and t_2 is future and by the time you will read this both t_1 and t_2 are past. And, as we saw above, at the moment I wrote down the sentence: 'every time we want to name the present, for example it is now...', t_1 was present.

Statements like 't_1 is present' and 't_2 is future' are not always true, while the relation between times t_1 and t_2, t_1 being earlier than t_2, is always true. The series of time that says something about points that are past, present or future is called the A-series and the one about the relations 'earlier' and 'later' is called the B-series of time.

McTaggart (1908), who argued that time could not be real, introduced these series. His paper started off the currently very extended debate between tensers and detensers, which is also known as the debate of presentists versus eternalists. The points on which they do not agree on are very subtle, and in the literature different interpretations of the debate are given. Presentists say that the picture of time in physics is not complete, because (1) it does not give a special position to the 'now' and (2) it does not contain the dynamical aspect of the flow of time. They that think the flow of time that we observe is something of nature that should be described by physics. Eternalists on the other hand argue that we do not need a special position for the 'now' and 'flow' in physics. Some eternalists say the 'now' and the flow of time are already implicit within the picture of time in physics, others argue that 'now' and 'flow' are mind-dependent: they cannot be observed in nature and therefore it is not needed in physics.

From this, we can formulate what the problem of the flow of time is. It is on two questions:

1. Is the picture of time in physics complete when the flow of time is not added explicitly?

2. Is the flow of time an objective feature of nature or is it a structure of the human mind?

My Master's thesis describes the search for the answers on these two questions. Because this introduction started with explaining the feeling of a dynamical feature of time by means of a metaphor of flow, the first chapter will discuss what metaphors and analogies are and what kind of function they have in our understanding of time. In order to have a good discussion, we need to make clear what the role of spatial analogies and metaphors is in the current debate, and question ourselves whether the problem of the flow of time is a problem at all. In the literature analogies and metaphors between space and time are often taken for granted and are often mentioned to present us with a rough sketch of the differences between space and time. The consequences of using this analogy have not been made very clear in the debate.

In the second chapter of this thesis I will discuss the picture of time in physics and I will argue, like Savitt[1] does, that there is no need to explicitly add flow of time to this picture. This chapter gives a satisfying answer to the first question that formulates the problem of the flow of time.

The second question on whether flow is mind-dependent or mind-independent is more difficult to answer. We cannot do this by using physics alone. We need to know more about how we think and how our brains work. We will shed some new light on this part of the debate on the problem of the flow of time by looking at the cognitive science and asking ourselves questions like: how is the 'now' represented in the brain and what mental mechanisms are making this representation? An answer is given in the third chapter.

[1]Steven F. Savitt, *On Absolute Becoming and the Myth of Passage*, in Craig Callender, ed., Time Reality and Experience, Cambridge University Press, 2002, pp. 153-167

To illustrate the need for a bridge crossing the river of time, between the lands of physics and cognitive sciences, I quote some philosophers of time on the subject:

> 'The most basic mistake, I shall be arguing, is that people who think about these problems - philosophers as well as physicists - often fail to pay adequate attention to the temporal character of the viewpoint which we humans have on the world. We are creatures in time, and this has a very great effect on how we think about time and the temporal aspects of reality. But it is difficult to distinguish what is genuinely an aspect of reality from what is a kind of appearance or artifact of the particular perspective from which we regard reality. Where time itself is concerned, we haven't yet managed to distinguish how the world actually is, from how it seems to be from our particular standpoint.'[2]

Price argues we first need to know how humans think about time and how they perceive it, before we can know what really is part of the external world and what is not. Will it ever be possible to see the world how it 'actually' is? In the third chapter of this thesis we will present different models that try to distinguish between time in nature and time in the mind. It will also be discussed whether they succeed or not.

> 'We seem to have an explanatory gap between time as we find it in experience and as we find it in science. Reconciling these two images of the world is the principal goal of philosophy of time.'[3]

As Callender states, the problem of the flow of time is about the gap between time as we experience it and as we find it in science. Some physicists think that it is possible to close the gap saying that time we experience is something different from time in science; others are trying to bridge the gap by giving an explanation of why we experience the flow of time and what the role of the mind is therein.

Not many physicists have sought solutions from other disciplines than physics and philosophy. Physicists seem cautious not to interfere with cognitive science, because the human mind is difficult to understand. Little is known about its workings, especially when consciousness comes in. To be able to construct good theories on how the mind works we need both disciplines of physics and cognitive science. After all, the mind is part of a physical body and therefore a physical object. The cooperation goes both ways: to be able to construct good theories in physics, we need physics but also cognitive science to understand how we think and construct those theories.

In this thesis I would like to illustrate the problem of time's flow and what interesting new insights could result from cooperating with cognitive science. In the conclusion I will recapitulate what we have learned from cognitive science to solve the problem of the flow of time and I will suggest what needs to be investigated by physicists, philosophers and cognitive scientists to work together on the problem of the flow of time.

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[2] Huw Price, *Time's Arrow & Archimedes' Point: new directions for the physics of time*, Oxford University Press, 1996 p. 3

[3] Callender, Craig, *The Common Now*, Philosophical Issues, 18, Interdisciplinary Core Philosophy 2008, p. 339

Chapter 1

'Flow of Time' is a spatial metaphor and analogy

'Had we but world enough, and time,
This coyness, lady, were no crime.
We would sit down, and think which way
To walk, and pass our long love's day.

But at my back I always hear
Time's winged chariot hurrying near:
And yonder all before us lie
Deserts of vast eternity...'
'To His Coy Mistress', by Andrew Marvell[1]

As explained in the introduction, 'flow of time' is a metaphor for the observation that an event that was future, first becomes present and then becomes past. An event is a phenomenon or occurrence located at a single point in spacetime. We have seen that 'flow of time' originates from the analogy Time is a River. A metaphor is a use of language to understand and experience one kind of thing in terms of another.[2] In our case the kind of thing we need to understand is time, and the experience of the passage of time in particular, in terms of a river. A river is a spatially extended object in which water moves from one place to the other at a certain rate. In the metaphor Time is a River, river is called the source domain and time is called the target domain. The motion of water from one place to another at a certain rate is called flow.

The concepts of time and river are not similar in their object descriptions. A concept is a mental representation of a class of objects or events that belong together, usually corresponding to a word.[3] Our representation of what a river looks like is very different from that of time. A river contains water, plants, living animals, etc., and it is spatially extended, while time is not. When seen from above it is roughly a long thin string in the landscape. While the object

[1] Jian-Shiung Shie, *Conventionality and Novelty of Time Metaphor in English Poetry* in Concentric: Studies in Linguistics, 34.2 ,July 2008, pp. 101-122

[2] Thagard, Paul, *Mind: Introduction to Cognitive Science Second Edition*, Massachusetts Institute of Technology, 2005, p. 232

[3] Thagard, *Mind*, p. 230

descriptions of time and river are totally different from each other, they are similar in the *relations* they have to other objects. You can compare a river to a one dimensional line and the tiny little boat, in which you are handed over to the water, represents the 'now' that shifts along this line. There is a relation between the boat and the river and there is a relation between the present and time. The boat flows along the river, just like the 'now' is moving in time. The river flows from north to south, like time 'flows' from past to future.

The use of the word 'flow' comes from spatial analogies we use to understand time. 'Flow' indicates motion, which is defined by distance in space divided over a time interval. That is why 'flow' often is associated with a velocity; what is the rate of the flow of time? Can time even flow at a certain rate? Dividing time over a certain time interval is either dimensionless or we need a second time axis. It does not mean anything to say that time flows at one second per second (this is 1). If we insert a second time axis, we can formulate the same problem with the second axis as we did with the first: what is the rate of its flow? And so it goes when introducing a third axis, a fourth, etc.

The question at what rate time flows, follows from the spatial metaphor we use. We can say at what rate water flows in a river, e.g. at 50 centimeters per second (or 1.8 km/h). In the metaphor we think of time as a spatial dimension, as a line. The familiar time line we use to *locate* historical events is also a spatial representation of time. It is easy to explain why we use a spatial dimension to picture time. Images, such as diagrams and drawings, in a book are always spatially extended and not temporally. We cannot picture time differently. Images are always represented visually and thus spatially.

Most cognitive scientists agree that knowledge in the mind consists of mental representations. A mental representation is a structure or process in the mind that stands for something.[4] We need to find out what structures or processes make us have a representation of time. Non-mental representations are for example a photograph, words on a piece of paper, a city map, etc. To account for many kinds of knowledge, such as knowing how to bike to the centre of the city, or knowing how to greet someone, cognitive scientists have proposed various kinds of mental representation including concepts, analogies, images, and rules. Rules can be recognized by the form If...Then: If action, then reaction. Our mental representation of a physical law, such as Newton's, is a rule. Cognitive science proposes that people have mental procedures that operate on mental representations to produce thought and action.[5]

Somehow in our mental representation of time we both use an analogy and an image. This image of time will be described in the next chapter on the picture of time in physics. When having a mental image of time, we can produce an image like a diagram or a drawing of time. In physics the image of time is contained in what is called 'the block universe', a representation of four-dimensional spacetime corresponding to the rules of physics. In this chapter we will focus on analogy as mental representation. I will first explain what analogical thinking is and I will discuss recent research that has been done on spatial analogies for our understanding of time and the implications of their use for our concept of time in physics.

[4]Thagard, *Mind*, p. 232
[5]Ibidem, p. 4

1.1 Analogical thinking and metaphoric structuring

To understand the human mind it is important to note that analogical thinking is one of the fundamental cognitive procedures. It consists of dealing with a new situation by adapting a similar familiar situation.[6] To understand the role of spatial analogies in thinking about time, we first need to examine what analogies are.

1.1.1 The analogical mind

The human mind is special in that it can identify patterns and relations between patterns, and then map these relations of patterns from one domain to another. Other animals like chimpanzees can also recognize patterns and relate them to other patterns, but only after practice. In contrast to animals the use of this skill, called analogical thinking, develops spontaneously in our children.[7] It is a critical part of the core of human cognition.

When developing his laws on the motion of the planets, Johannes Kepler considered an analogy between motive power and light.[8]

> 'Now just as it is said in optics, that light does not exist in the intermediate space between the source and the illuminable, this is equally true of the motive power'.[9]

So as light travels undetectably on its way between source and destination, so does the motive force. And Kepler even went further in the analogy: like light is spread out over a greater area as the distance grows between the source and the object, the motive power is also spread out. The luminosity per m^2 of the sun falls off quadratically with distance from the planet to the sun. Light was the source domain and he mapped the relations (quadratic fall off) between patterns (the further away the planet is the weaker the light/motive power of the sun on the planet) to the target domain of motive power. The motive power per m^2 of the sun falls off quadratically with distance. This analogical model helped Kepler to explain the mystery why outermost planets move slower than the innermost planets in our solar system.

Making analogies is not only done in science, but also in other aspects of human society: in daily life, art and literature. We all learn in secondary school during Literature classes that a basic function of analogies and metaphors is the transfer of emotions. Analogies provide a way to create specific and complex emotions for the reader of the text that cannot be described without these analogies.

Therefore, analogies are important for learning. If they can make a link to a known domain, people are able to learn something new. So we gain knowledge

[6] Ibidem, p. 77

[7] Thagard, Paul and Keith J. Holyoak, *The Analogical Mind*, in: American Psychologist January 1997, vol 52, no 1, p. 2

[8] Gentner, Dedre, & Markman, Arthur B., *Structure Mapping in Analogy and Similarity*, American Psychologist, vol 52, no 1, 1997, p. 45

[9] Kepler, *Astronomia Nova*, p. 383, in: Gentner, Markman, Structure Mapping in Analogy and Similarity, p. 46

by making analogies from a familiar domain (source domain) to a new domain (target domain).

Let us take the analogy between the mind and a computer. A computer does not look like our brains in external features, but the operations of the computer are similar to those of our brains. Within a domain like 'computer' there are relations, e.g. between the keyboard and the processor. We are familiar with this domain. If we find out something new about how the mind works and when we compare these relations between parts of the brain with relations between parts of the computer, we make relations between relations, and think analogically. We can build theories by making analogies and making inferences. This was done by Rutherford when he developed his atomic model. He made a comparison to the solar system. Later on this analogy turned out to be insufficient.

The discovery by Huygens that sounds are waves, vibrations of molecules in a medium, came from the comparison to water waves. Later on light waves were understood by the analogy of sound waves. Gaining new knowledge is making new analogies. Theoretical ideas in scientific disciplines often arise by analogies from related fields.

In the 1980s, scientists discovered the importance of analogical thinking and since then cognitive scientists, philosophers and psychologists have done structural research. Keith Holyoak and Paul Thagard are cognitive scientists who tried to find out how the human mind works by using computer models. The analogy between thinking and computing is a major source of theories of mind. Using the analogy 'a mind is a computer', Thagard and Holyoak are building computer models in which they try to capture how analogical thinking works. In one of their articles Thagard and Holyoak (1997) give an overview of analogical thinking from the perspective of the Multiconstraint theory, in which there are three basic types of constraints for making analogies.

(i) First, to some extent, the analogy is guided by a direct similarity of the involved elements (similarity of key relations between objects). In Kepler's case the similarities were involvement of sun and planets in both the target analogue (motive power) and the source analogue (light).

(ii) Second, the analogy is used to identify consistent structural parallels between the roles in the source and target domains, i.e. a pressure to establish an isomorphism (a set of consistent one-to-one correspondences). In Kepler's analogy such a consistent structural parallel was the undetectability of both light and the motive power on its way between the sun and the planet. Also the weakening of the light/motive power that falls upon the planet as its distance from the source grows, was a parallel. There are isomorphisms between light and motive power.

(iii) The third constraint in making an analogy is its purpose. Analogical thinking is guided by the reasoner's goals. Kepler wanted to explain why outer planets move more slowly around the sun than inner ones. According to him, one possibility was that the outer spirits that moved the planets were weaker than the inner ones. But there was no explanation available why these outer spirits would be weaker. Kepler came to think about one spirit, the sun that moved the planets and he made the analogy to light to explain the strength of the motive power. He also noted that each individual planet moves faster in its orbit if it is closer to the sun (Kepler's second law).

People are sensitive to all these three basic constraints. People seek and use analogies to achieve their goals. These constraints also formulate the central

features of analogies: similarity, structure and purpose.

1.1.2 Differences between metaphor and analogy

Analogies are representations in the mind, without a necessary use of language. They are comparisons that share primarily relational information. They represent and use higher order relations, i.e. relations between relations, and they share very little attributes. Analogical thinking is a mental process that establishes connections between relations in two sets of objects. When language comes in, we speak about metaphors. As we have seen at the start of this chapter, a metaphor is a use of language to understand and experience one kind of thing in terms of another. They are part of language, while analogies are part of thinking. Metaphors unlike analogies can also be based on common object attributes, e.g. 'a planet is a ball': both look like spheres. A relational metaphor is an analogy.

While analogies are often used in explanatory-predictive contexts, such as science, metaphors are used more broadly in science and literature, art, etc. in both explanatory-predictive and expressive-affective contexts.[10]

In language the words 'like' or 'as' are used in sentences called similes, such as in 'Time is like a river'. If those words are not used, we talk about a metaphor as in 'Time is a river'. The statement 'the flow of time' is a metaphor, because we use this language to represent our experience of the changing 'now' in terms of the flow of a river. 'The flow of time' is an analogy, because we make a connection between the relation of the boat to the river and the relation of the present to time. This connection involves boat = present and river = time. This is the way we seem to construct our mental representation of the dynamical feature of time.

So 'flow of time' is both a metaphor and an analogy. What are the advantages and disadvantages of using this metaphor? What is its role in the debate in the philosophy of time? We have already seen one disadvantage, i.e. the flow of time implies that time moves at a certain rate, but that rate does not exist.

Why should we use the metaphor of 'flow'? Can we use another representation of time without using this spatial analogy? Utterances like 'passage of time' and 'time goes by' still have a spatial aspect. If we carefully watch our language, we are using spatial analogies to express temporal utterances all the time: we *look forward* to a better day, propose theories *ahead of* our time, or *fall behind* schedule. Psychologists and cognitive scientists recently discovered that people understand time and think about time using spatial metaphors. This relation is asymmetric: we do not understand space in terms of temporal metaphors.

1.1.3 Novel and conventional metaphors

You probably had to think twice when I said that 'passage of time' is a metaphor just like 'flow of time'. Utterances like 'time flies' and 'the holidays are approaching' are already very common in our language, such that you do not even think about it as metaphors. These are called conventional metaphors. Novel

[10] Dedre Gentner, & Bowdle, B., & Wolff P., & Boronat, C., *Metaphor is Like Analogy*, in: The Analogical Mind: Perspectives From Cognitive Science, Massachusetts Institute of Technology, 2001, p. 240

metaphors are those that you are aware of while speaking, e.g. 'My surgeon is a butcher' or 'My job is a jail'. You almost directly know it is a metaphor, because it has not been used very often in common language. Twenty years ago the metaphor 'The mind is a computer' was a novel metaphor. Nowadays it has been used so often, that it has become conventional.

Gentner (The Analogical Mind 2001) proposes The career of Metaphor Hypothesis: novel metaphors are processed as structural alignments between the concrete or literal representations of the source (computer) and target (mind), but as repeated comparisons are made, the metaphorical meaning is gradually blended and becomes associated with the source term (computer).[11] Gentner et al. suggest that the deriving and retaining of structural abstraction is the basic mechanism by which metaphors become conventionalized.[12] In the case of 'mind is a computer', we do not compare anymore, but categorize the mind as a computer; we *associate* the mind with a computer. The base term becomes polysemous, i.e. it becomes a word that has two or more similar meanings. So if we talk about a computer, we mean either your pc at home (the literal concept), or your brains (the associated metaphoric category). In Gentner's words:

> 'Novel metaphors involve base terms that refer to a domain-specific concept, but are not (yet) associated with a domain-general category. They are interpreted as comparisons. Conventional metaphors involve base terms that refer both to a literal concept and to an associated metaphoric category.'[13]

But how exactly do conventional metaphoric meanings arise and how does the representation and processing change as a metaphor changes from novel to conventional? This question is particularly interesting in our case of the conventional metaphor 'flow of time', in which 'space' or more specific the spatial object 'river' in which 'water' flows, is evolved from novel to conventional. It turns out that space → time metaphors do not become associated metaphoric categories 'time' and 'river', but are total system mappings of 'time' and 'space'. The domains of space and time are even more deeply interconnected in our thinking than the domains of computer and mind are. Gentner writes:

> 'Hearing sentences about spatial relations primes analogous sentences in the time domain, but not the reverse. Space-time systems become conventionalized as systems, while others turn into local categories. Why? Metaphors that evolve into conventional systems are often taken from space (universal donor status) or from other well understood, highly systematic base domains like 'flowing water'[...].'[14]

In the next part of this chapter we will be discussing Gentner's research in the understanding of time through spatial metaphors. We will also see that Gentner's base domain 'flowing water' is actually the domain 'moving objects'.

[11] Gentner, *Metaphor is Like Analogy*, in The analogical Mind: Perspectives from Cognitive Science, p. 229
[12] Ibidem, p. 228
[13] Ibidem, p. 229
[14] Ibidem, p. 242

1.2 Using spatial analogies to think about time

The role that spatial analogies play in abstract thought has been investigated for years in the disciplines of psychology, linguistics, anthropology and computer science. We do not only use spatial *metaphors* to express ourselves (temperature is *rising*, *falling* in love), the domain of space turns out to be crucial for analogical thinking to understand abstract domains. The domain of time is one of these abstract domains. In section 1.2.3 we will see why these domains are abstract, when discussing research of Gilles Fauconnier and Mark Turner.

In this section I will give a short overview of the research that has been performed on spatial metaphors and spatial analogies to understand time. At the end of the 20th century research of Gentner et al. showed that in language we use a lot of conventional spatial metaphors to express ourselves in temporal relations. But only in the last few years Casasanto and Boroditsky and others have experimentally shown that we also *think* in spatial relations to understand time. Fauconnier and Turner (2008) add a richer and deeper understanding of using space → time analogies to these studies. In their book *The Way We Think*(2002), they introduce the mental process of 'conceptual blending'. They propose to 'rethink metaphor' and give plausible arguments for how conceptual mappings are constructed in the mind by integration networks and compression.

After having described these findings, I will look at what they mean for our problem of the flow of time.

1.2.1 Spatial metaphors in temporal reasoning (linguistic)

'They *moved* the meeting *forward* two hours.' 'We have had a *short* vacation.' 'We will not stay *long*.' 'I am glad that that day lies *behind* us.'

Many researchers have noted a systematic correspondence between the domains of time and space in language. Some illustrations of parallel use of spatial and temporal expressions:

- *at* the corner ⟶ *at* noon
- *from* here *to* there ⟶ *from* two o'clock *to* four o'clock
- *through* the tunnel ⟶ *through* the night.

Gentner notices some universal properties in using spatial terms to describe time, that very much remind us of the properties physicists ascribe to time to distinguish it from space.[15] First, time is conceived as one-dimensional; spatial terms used in metaphors are one-dimensional (front/back, up/down) rather than terms that suggest two or three dimensions (narrow/wide, shallow/deep). This captures the property of time *being* one-dimensional in physics. The question is then whether time is *really* one-dimensional, or are we imposing dimensionality on time because we use spatial metaphors? To answer this question we need more research on the concept of dimensionality and its origin. This however goes beyond the aims of this thesis.

Second, to capture temporal sequencing (events are future first, then become present and after that they become past), directionally ordered terms such as

[15]Dedre Gentner, *Spatial Metaphors in Temporal Reasoning*, in: Gattis, Merideth, Spatial Schemas and abstract thought, Massachusetts Institute of Technology, 2001, p.203

front/back and before/after are used, instead of symmetric terms like left/right. This captures the property of the asymmetry of time, i.e. the difference between past and future.

There are two distinct space → time metaphoric systems in English and many other languages. The first one is the ego-moving metaphor, wherein the speaker is moving along the time-line towards the future, e.g. 'I am going to do that', 'We are approaching the holidays'. The second one is the time-moving metaphor, wherein the speaker stands still and time - conceived of as a river or conveyor belt - flows by from future to past, e.g. 'The years have gone by', 'The holidays are coming fast'. According to Gentner:

> 'The two systems lead to different assignments of front/back to the time-line. In the ego-moving system, the future is normally conceived of as in front and the past as behind. In the time-moving system, the reverse is true: time moves from the future to the past, so that past (earlier) events are in front and future (later) events are behind.'[16]

In the ego-moving system we *approach* the future events that are earlier, first. Those are *in front of us* and the future events that are further in the future are further *away*. The far away future *lies in front of us*, but *behind* the earlier future events. The past lies indeed *behind* us.

Both ego- and time-moving systems can be conceived of as being in the river and on the conveyor belt. We can speak of either 'We are approaching the tree on the river side' or 'The tree on the river side is approaching us'.

Gentner means when she speaks about time-moving that we are not *in* the river or *on* the conveyor belt, but we see all events happening in the river or on the belt, and we are standing *beside* it. The events that are past are *in front of* the belt (these events passed earlier) and the events that are still future, are *at the back* of the belt (they will pass later). So we are either in the river or standing on the riverside. If we are on the river*side* we see that the tree is not approaching. Only things flowing *in* the river are approaching.

Gentner mentions examples of time-moving and ego-moving metaphors:

- Time moving: Christmas *comes before* New Year's Day. New Year's Day is *coming*.
- Ego moving: The holiday season is *before* us. We are going to have a *long* holiday season.

As you will have noticed, the first example of time-moving metaphors can be understood in two ways. Either in a tenseless way: Christmas always comes before New Year's Day, which is not referring to a position in time of the person who utters this sentence. Or it can be understood in a tensed way: Christmas is now coming and after that, New Year's Day comes. I prefer to interpret the example in the tenseless way, because the statement is not referring to any position in time of the speaker itself, e.g. that the speaker lives in the present when it is the 21st of December.

Gentner does not make any difference between a tenseless sentence like 'adulthood falls behind puberty' and a tensed sentence like 'old age is approaching us'. Both are time-moving. There is however a major difference. In the first

[16] Gentner, *Spatial Metaphors in Temporal Reasoning*, p. 204

sentence we are not talking about an event being past, present or future. Also in 'The physics exam is ahead of the English exam' we have no reference to a present, i.e. it is a description between the relations earlier and later. In the second sentence we can infer that 'we' are in the present (as we always are) and 'we being old' lies in our future. 'Here' is a reference to the present and the sentence tells us about presentness and futureness that are temporary properties of events.

In Gentner's time-moving system there is no distinction between the A-series (past, present or future) or the B-series (relational, i.e. earlier or later than). From this I infer that Gentner et al. do not seem to be aware of the debate between presentists and eternalists that I will discuss in the next chapter.

There are four kinds of possible psychological explanations of these space → time metaphors, according to Gentner. There is evidence that analogies from concrete domains are used in reasoning about abstract domains. In language we are using a concrete domain like space to express ourselves about the abstract domain of time. We see spatial representations of time across cultures in artefacts such as clocks, timelines and drawings. Gentner does not give an explanation of what makes domains concrete or abstract.[17]

(i) In the case of conceptual mapping, every time we want to express ourselves about time, we use a spatial mapping. This is called system mapping: the abstract domain of time is organized and structured in terms of systems borrowed from the more and readily observable domain of space.[18] Space and time domains are connected asymmetrically in this way.

(ii) Another possibility is cognitive archaeology. It may be that the concept of time is originally borrowed from space, but time and space are now independent concepts in our minds. The domains are not asymmetrically connected anymore, but still we have signs of this historical connection in our language.

(iii) The third possibility is structural parallelism. Space and time do share conceptual systems, but neither is derived from the other. The domains are symmetrically connected and not asymmetrically as is the case with system mapping. The domains are not depending on one another.

(iv) The last possible explanation Gentner proposes is local lexical relations: because of the same use of words, the domains of space and time seem to be related. They do *not* share the same conceptual systems. We simply use the words 'in front of' in terms of space and in terms of time, like we use the word bank in terms of 'riverbank' and 'financial bank'.

Gentner tested these four possibilities by investigating whether or not people would get confused, when reading mixed metaphors. The cost (the amount of time it takes to comprehend the metaphors) suggests that the metaphors were

[17] We experience space as something concrete, because it is directly perceived. We can grab objects that have a certain size. We view objects all at once in space, but not in time. The perception of an object is not temporally extended, but spatially. This still gives us no sense of why we experience time as something abstract and space as something concrete. Both Gentner and Boroditsky do not explain this difference. In the last part of this section research of Fauconnier and Turner (2008) is discussed. They not only give an explanation for why space is concrete and time is abstract, they also show that the two systems (ego- and time-moving) are valid but are a consequence of a full integration network. Gentner's system mapping does not account for the complex emergent structure of the integration network Fauconnier and Turner present.

[18] Gentner, *Spatial Metaphors in Temporal Reasoning*, p. 206

processed as part of system mappings. However, Gentner found this mixed mapping cost only for novel metaphors, not for highly conventional metaphors. Gentner's research method was to set up a metaphoric mapping and then present a further statement either from the same metaphor system or a different one. If the participants process the metaphors as a systematic domain mapping, then the inconsistent metaphor should take longer to comprehend.[19] Metaphors which are not mixed, but consistent:

- Anna was boiling mad when you saw her.
- Later she was doing a slow simmer.

Metaphors which are mixed and inconsistent:

- Anna was a raging beast when you saw her.
- Later she was doing a slow simmer.

What was measured was the time to read the last sentence per block.

In case of space → time metaphors you can mix from different systems such as time-moving and ego-moving in one block of metaphors. The question is what psychological status of the space → time metaphors is correct: which of the four possibilities fits the findings? Novel metaphors are processed as system mappings. Space → time metaphors however are highly conventional. It seems likely that even if the two mapping metaphors were once active in the history of language, they now are stored simply as independent different meanings of one word without any relations (local lexical relations), and they are not processed as belonging to the same conceptual systems. If this is the case, we would not expect to see a mixed metaphor effect when using space → time metaphors.[20]

Gentner observed a mixed mapping effect in switching between time-moving and ego-moving systems. The test demonstrated that lexical relations have no influence on faster processing of metaphors. The mixed mapping cost does not appear to result from local effects, but rather from a global mapping. So the fourth possibility is ruled out. If space-time event-sequencing statements are processed as coherent domain-mappings, then switching between the ego-moving and the time-moving metaphors should lead to increased processing time. A third experiment provided evidence for the psychological reality of the two metaphorical systems time-moving and ego-moving.[21] Use of time-moving metaphor (The deadline passed yesterday) turns out to be more difficult than the ego-moving metaphor (We passed the deadline yesterday). The results from Gentner's experiments suggest that the ego-moving and time-moving systems function as coherent systems of relations. The two metaphoric systems are highly conventional and are rarely noticed in every day language.

Why are time-moving metaphors more difficult than ego-moving metaphors? The fact that the time-moving metaphor is typically a three-term relation whereas the ego-moving metaphor is typically a two-term relation probably contributes to the greater processing difficulty of time-moving metaphors, according to Gentner. Another explanation is that the relative temporal location of an observer is not specified in the time-moving metaphor. The observer can

[19] Ibidem, p. 207
[20] For more details on the experiments they performed see Gentner (2001).
[21] Ibidem, p. 215

occur as a third point *anywhere* on the time-line in case of 'John arrives ahead of Mary', but not in 'the holidays are coming towards us'. Is it always the case that we need also a position of the ego in tenseless sentences? If so, this is indeed a good explanation why time-moving metaphors are more difficult to comprehend than ego-moving metaphors. If not, two-term relation against three-term relation does not count as an argument and we cannot give an answer to the question why understanding time-moving metaphors are more difficult than ego-moving ones.

Gentner's experiments are about research in language use and therefore cannot distinguish among the first three possibilities, in which the concepts of space and time are dependent on each other. In the last possibility that is solely based on language, the concepts of space and time are independent; it only looks like they are related because the same words are used in language. Therefore the last possibility, local lexical relations, is dismissed. Which of the other three accounts is correct, must be tested non-linguistically. Boroditsky argues for the strong account of system mapping, which is the first possibility. She found evidence for an asymmetry, in which people appear to understand time in terms of space, but not space in terms of time.

1.2.2 Spatial analogies to understand time (non-linguistic)

In a paper of 2008 Casasanto and Boroditsky present their findings on non-linguistic experiments between the domains of space and time. They investigated 'whether mental representations that result from physical experience underlie people's more abstract mental representations'.[22] To test this, they used the domains of space and time in which it was already shown that spatial metaphors in language were used in temporal reasoning (Boroditsky 2000, Gentner 2001, Gentner and Boroditsky 2002). If we relate this to the analogy 'flow of time', the mental representation that results from a physical experience like being in a boat on the river's flow underlies the more abstract mental representation of the passage of time. Here 'passage' is a spatial metaphor, we are hardly aware of. 'Passage of time' is, like 'flow of time', a typical example of a conventional metaphor we discussed in the last paragraph. 'Passage' even seems to be more conventional than 'flow'.

What was not yet shown, but is recently done so by Casasanto and Boroditsky, is that the metaphorical relationship between space and time observed in language also exists in our more basic representations of distance and duration. Six psychophysical experiments revealed that people are not able to ignore irrelevant spatial information when making judgments about duration. By contrast, they are able to ignore temporal information when they make judgments about distance.

Casasanto and Boroditsky asked themselves the question whether the way we think about time is dependent on space even when we are not using language at all. Previous research on experience of distance and durations has shown that the two are not independent, but little is known about whether the relationship between the two domains is asymmetrical in the way that has been observed in language.[23] What they have studied is whether the asymmetrical dependence

[22] Daniel Casasanto, & Boroditsky, Lera, *Time in the mind: Using space to think about time*, Cognition 106 (2008), p. 579

[23] Casasanto & Boroditsky, *Time in the mind: Using space to think about time*, p. 579-593

of time on space exists at a more basic level of the human conceptual system. I will summarize the six experiments they performed to get an impression of the research they have done.

In experiment 1, spatial displacement of growing lines affected estimates of duration, but duration did not affect estimates of spatial displacement, see figure 1.1.[24] If, in the case of two growing lines, the maximum length of one growing line was bigger than the other, but the duration was the same, the larger line was judged to be on the screen longer (in duration). Before they were confronted with the line, participants did not know whether they had to judge duration or distance.

In experiment 2 everything remained the same as in 1, except that participants knew beforehand what to judge: distance or duration. This experiment is done to rule out the possibility that cross-dimensional interference disappears if participants were given the opportunity to attend selectively. You would expect people to ignore length, when they had to estimate duration. They did not and the results were the same in experiment 2 as in 1: people are able to ignore duration, when estimating length, but it was not the case the other way around. While in experiment 1 the participants had to encode spatial and temporal information simultaneously, in 2 they did not have to.

In experiment 3 everything remained the same as in 1 except the duration between getting 'ready' on the screen and giving the answer was fixed. This was done to count for stability in both the spatial and temporal information. But this had no influence on the asymmetry of distance on time estimation; the results were the same as in 1 and 2.

In experiment 4 participants saw lines growing on the screen together with a tone of constant frequency that illustrated the duration of the growing line. Here was the question whether space would still influence temporal judgment, when a non-spatial stimulation like a tone was accompanied. Again the same asymmetry was noticed. So vision (spatial input) is primary to audition.

In experiment 5 Casasanto and Boroditsky used only a horizontally moving dot, instead of a full spatial extent of the line. So just like it is the case in duration, the spatial extension could not be seen directly, but it had to be imagined. Again, there was a strong and asymmetric cross-dimensional effect of space on time.

The last experiment used stationary lines. The question was whether motion is necessary to produce confusion between space and time. Therefore stationary lines with a certain length were presented for certain duration. Duration estimates were strongly and asymmetrically dependent on the spatial length of the stimulus. These findings rule out the possibility that motion or speed was principally responsible for the results of the previous experiments. Like in the other experiments, the magnitude of space-time asymmetry was significant.

There are, in principle, three possible relationships between people's mental representations of space and time.

(i) First, the two domains could be symmetrically dependent (structural parallelism).

(ii) Second, our ideas of space and time could be independent (cognitive archaeology).

[24] Casasanto, & Boroditsky, *Time in the mind: Using space to think about time*, p. 583

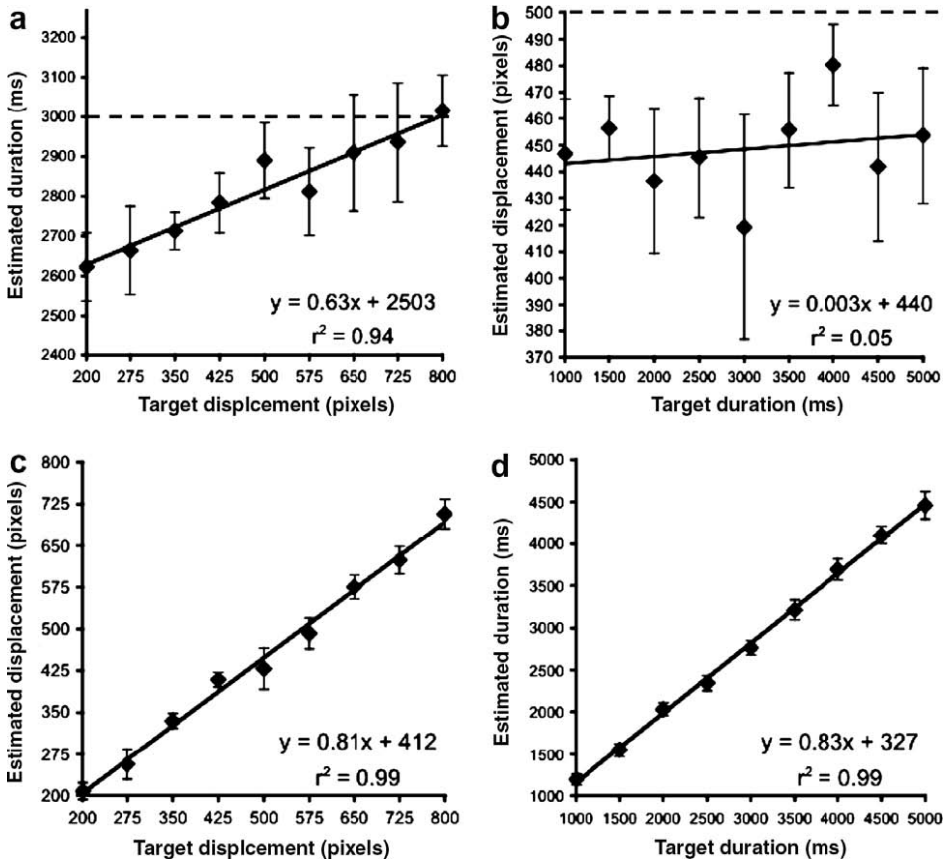

Figure 1.1: *Results from Boroditsky's Experiment 1. Top: cross-domain effects. (a) left: target displacement affects the estimated duration. The larger the displacement, the larger the estimated duration is. The actual duration was the same for all lines. (b) right: target duration does not affect the estimated displacement. There is clearly an asymmetrical relation between the influence of displacement on estimating duration and the influence of duration on estimating displacement. Below: checks. (c) left: effect of actual line displacement on estimated displacement. (d) right: effect of target duration on estimated duration. People were skilful in the estimation of displacement when only target displacement was shown and the same for duration.*

(iii) Third, time and space could be asymmetrically dependent (system mapping).

These three possible relationships predict three distinct patterns of cross-dimensional interference between space and time in the present experiments. Experiments are showing asymmetrical system mapping. This asymmetric relationship found in linguistic metaphors is also found in our more basic non-linguistic representations of distance and duration.

Casasanto et al. conclude:

> 'These findings provide evidence that the metaphorical relationship between space and time observed in language also exists in our more basic representations of distance and duration, and suggest that our mental representations of things we can never see or touch may be built, in part, out of representation of physical experiences in perception and action.'[25]

In these experiments both growing lines and stationary lines of a certain length and duration were shown on the screen and all experiments pointed towards an influence of length on duration estimation and no influence of duration on length estimation. Spatial stimuli are basically visual stimuli and temporal stimuli can be auditory stimuli.

An asymmetry between visual and auditory stimuli is also recently found by neuroscientists of the California Institute of Technology.[26] They performed research comparable to what Casasanto and Boroditsky did in the above described experiments. They found that visual perception could alter the perception of auditory stimuli, but an audio illusion had no such power over visual perception. The conclusion that vision is primary to audition, which was also drawn by Casasanto and Boroditsky.

The neuroscientists showed five gray disks that were paired with uniform half-second tones (both the disks and tones were presented with the same duration) and they asked participants whether or not the fourth tone was longer or shorter than the others. If the tone was paired with an expanding disk, the participants perceived the tone to be longer in duration than the other tones that were paired with stationary disks. But when uniform disks (all stationary or all expanding) were paired with tones of which one tone was rising in pitch, the participants correctly perceived all disks and tones as equal in duration. It remains to be seen whether the visual clock will always trump the audio clock or whether the reverse could also happen in certain situations.

Both this research and Boroditsky's are the first steps towards a psychological and neuroscientific understanding of time perception.

1.2.3 Rethinking metaphor and analogy

Above research showed that system mapping (i.e. conceptual mapping) is the way space → time metaphors are constructed. Fauconnier and Turner argue that these metaphoric mappings need to be revised, to implement them in a more complete theory of thinking. Conceptual mapping is *not* a product of one-to-one mapping. They propose an integration network for the conceptual mapping of space to time. Their theory of conceptual integration, called *conceptual blending*,

[25] Ibidem, p. 591

[26] In: *Scientific American Mind*, vol. 19 no. 2, April/May 2008

is described in their book *The Way We Think*.[27] Fauconnier and Turner argue that all learning and thinking consist of blends of metaphors based on simple bodily experiences. These blends are also continually blended together into an increasingly rich structure that makes up our mental functioning. Figure 1.2[28] shows a schema they constructed for the space → time analogy.

> 'To illustrate how metaphor has been rethought within the broader perspective of integration networks and compression, we will revisit the classic metaphor of time as space and show in some detail that much of what is going on in this metaphor has gone unnoticed and therefore unexplained. Time as space is a deep metaphor for all human beings. It is common across cultures, psychologically real productive and profoundly entrenched in thought and language.'[29]

Metaphors involve more than mappings or bindings between two domains. In the case of space → time metaphors, the domain of space is the source domain and the domain of time is the target domain. Although these domains are taken as primitives and seem rather straightforward, it does not count for why the domain of space is concrete and the domain of time abstract. We have seen that Gentner assumes they are; but she gives no further explanation. Fauconnier and Turner however seem to give a plausible theory of why space is concrete and time abstract.

The concept of time is abstract, because it is constructed from the concept of space and the concept of motion through conceptual blending. We measure duration by (static) measurement units borrowed from space and time's flowing aspect comes from moving objects (the domain of motion). The units of time can be measured by clocks and these clocks are analogical to the spatial measuring rods.

When in the beginning of the 20th century, Einstein formulated his theory of special relativity (1905), Einstein considered time to be like space by making the analogy between measuring rods and clocks. We have seen that this space → time mapping is crucial in human thinking. But time is not space; measuring rods are no clocks. It is not, in contrast to what Gentner says, a one-to-one mapping from the domain of space to the domain of time. Clocks are not only carrying the measuring units for time, like measuring rods do for space; clocks have *rotating* rods. The concept of motion is blended together with the concept of space. Both concepts are incompatible (we do not measure space by using moving measuring units) and this results into an abstract concept of time. Time is abstract, because it cannot be measured directly. Space can be measured by taking the three dimensional extension of objects we see. Without making measuring rods per se, we can use our own body as a measure for space. Our body is a spatial extension of itself. That space is such a basic concept is explicable from the view of embodied cognition, that holds that the relation between our body and the external world lies at the basis of the way we think.[30]

We cannot observe the measuring units of time directly in nature, because we do not observe temporal extension. The notion of extension is a spatial

[27] Fauconnier, Gilles, and Mark Turner, *The Way We Think: conceptual blending and the mind's hidden complexities*, New York 2002

[28] Fauconnier, Gilles, and Mark Turner, *Rethinking Metaphor*, in: Raymond W. Gibbs, Jr. The Cambridge Handbook of Metaphor and Thought, New York 2008, p. 65

[29] Fauconnier and Turner,*Rethinking Metaphor*, p. 54

[30] Thagard, *Mind*, p. 192

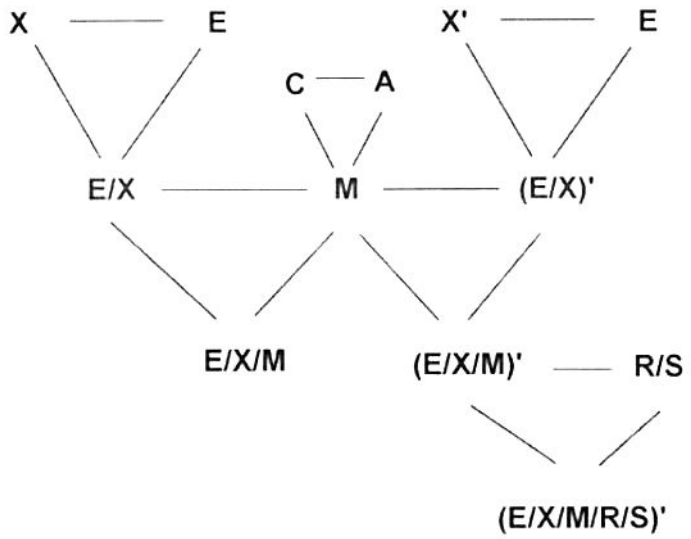

Figure 1.2: *Integration network for time as space, including dual.*

analogy itself.

We borrow the concept of static units of measurement from space to measure time. The example 'Three hours went by, and then he had dinner' shows that we have not merely projected units of measurement onto time but also turned those units into moving objects. These moving objects do not come from projecting units of measurements. 'A unit of measurement' is a different concept from 'a moving object'. Blending these gives us 'moving units of measurements', which in the domain of time becomes 'three hours that went by'. We have seen that in the domain of space, a unit of measurement is not a moving object. These concepts are incompatible sorts of elements, which are fused to construct the concept of time. In the blend, we project onto a temporal experience (i.e. the happening of an event) both unit of measurement *and* moving object from the domain of space.

Another example 'Minutes are quick, but hours are slow' shows that these emergent, moving temporal units have speed and that some have greater speed than others. Yet another example 'To me that hour went by very slowly, but to her it went by very fast' shows that not only speed can be different for different moving objects (minutes go faster than hours), but the same moving object can have different speeds (one hour can go by quickly or slowly). This is because we are also projecting our subjective experience of objects and events to the temporal units in the blend.

The example 'Time came to a halt' shows that the units of time can not only go fast or slow, but they can also stop. They can have both variable speeds as variable existence. The emergent structure that results from this blending is that time is incompatible with physical spatial input. An emergent property of a system is a property that emerges on a higher level in the network from the cooperation between lower level parts. Fauconnier and Turner made a schema, in which they illustrate the integration network of space → time analogies, see

figure 1.2.

People perceive events and objects in the external world. They can order and categorize these different events and objects as belonging to the same type or to different types.

E in figure 1.2 stands for the input of Events. These event domains can include subjective experiences of those events. An event like a pop concert is for the singer different than for the audience.

X stands for the input of experienced motion (of objects) through physical space, which is a kind of event. Therefore X is a subset of E. In this domain the use of the notion of fast versus slow is not the one used in physics but correlates with the duration of events. We can go from A to B 'faster' than from A to C, because the distance between A and B is *shorter* than the distance between A and C, even if our velocity is in physical sense the same. Distance correlates with the duration of events. This conclusion has also been drawn from the results of Casasanto's and Boroditsky's research.

E/X is a blend of event and motion, in which event is motion from one point to another. In the blend any event has length and experienced motion. An event becomes a path, like in 'we go through the hour' as we go through the landscape.

M stands for mechanism such as a watch. M does not contain subjective experience. We can compare M to physical time. The watch is a resulting blend from the concepts of the cyclic hour, day, week, month and year (C) and the motion of the mechanism such as the rotating rods of the watch (A). Both C and A themselves are results from conceptual blending. The mechanism of watches, clocks etc. are blends of the concepts of space and motion.

C is a blend because it is constructed out of analogous days experienced through observation of sun, stars, color variation etc. These days that follow linear upon each other are analogous in the sense that noon yesterday, noon today and noon tomorrow are felt to be the same noon in the blend. A single day runs its course just once, but because of the analogies of time between different days, in the blend the day runs its course and starts over again. This is the cyclic day network. See figure 1.3.[31]

A stands for mechanism, for example the rotating rods of a watch (spatial measuring units, that move cyclic) that connects every 2.00 PM to the next 2.00 PM of the other day. Since we have this concept of a cyclic day we can make watches that represent that cyclic day. It is conventional that the physical experience we have of the moving rods of the watch being in a specific position, tell us about what time it is in the cyclic day. [32]

The blend E/X/M is the conceptual mix of M (no subjective experience) and E/X (subjective experience). M has events (rotating rods for the clock) that we are all supposed to agree about, objective events that we experience to be universal. E has subjective local events. When I say that lecture went on too long: 'It was one hour and five minutes (instead of one hour)', then M dominates. If I say: 'It took centuries to go through that lecture', then E/X dominates. Those two dominations are blends with different emergent notions of time. In the blend with objective time (E/X/$\underline{\text{M}}$), all egos are constrained to move at the same rate and that is the flow of time philosophers are worrying about. Time

[31] Ibidem, p. 58

[32] Fauconnier and Turner, *The Way We Think*, p. 196

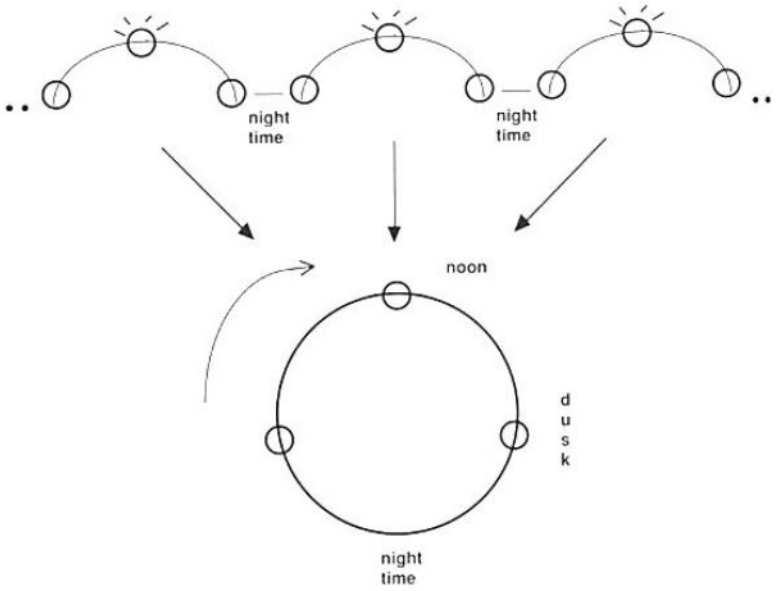

Figure 1.3: *The blended cyclic day (C).*

in this network is not a primitive input, like space is, but it rather is a notion that emerges from the full network. And once the entire network is achieved it automatically contains as a by-product the correspondences between time and physical space that Gentner's and Boroditsky's research had to postulate.

Metaphor theory recognizes that motion of an ego through time as space (ego-moving) has a dual: events in time move like objects along a path past a stationary observer (time-moving). Gentner does not explain the origin of these two systems. She just notices they exist and that people usually find it harder to think in the time moving metaphor than in the ego-moving metaphor.

Fauconnier and Turner explain why the time moving metaphor is the dual of the ego moving metaphor.[33] X contains motion along a path. Motion is relative. For any motion we experience, we can take ourselves as a point of reference, or something else as a point of reference. The dual of X in figure 1.2 is X'. E does not contain motion, so it does not have a dual. By projection, the blended space E/X has its relative motion counterpart (E/X)'. Here relative speed is preserved. If you pass something very fast, then it will pass you very fast either.

In figure 1.2 we see besides the dual of the above explained integration network, also a blend between R (memory) and S (physical space).

R/S (Recall/Space) is the blend of memory and physical distance that include 'Calling up things from the depths of your memory', 'Bringing a forgotten event to the surface'. These blends of memory and physical distance can be blended with the E/X/M networks.

We then have the new integration E/X/M/R/S that 'puts a metric on memory that uses the notion of time that is emergent in the E/X/M networks'[34]

[33]Fauconnier and Turner, *Rethinking Metaphor*, p. 60
[34]Ibidem, p. 62

and that produces items as: 'Our wedding was just yesterday (but it was 18 years ago).' 'Where have all those years disappeared?' This final integration network can be regarded as the concept of time in the human brain. We will go in more detail on the concept of the flow of time and the present in chapter 3. To conclude with words of Fauconnier and Turner:

> 'We have seen so far that analysis of metaphor requires analysis of elaborate integration networks producing what can seem like straightforward mappings between two domains taken as primitives. The ultimate conceptual correspondence between time (itself emergent) and physical space is real and especially visible, but it is a final product of emergent structures in the elaborate integration network, not something to postulate as a basic primitive of human understanding.'

Gentner sees the occurrence of space → time analogies as an example of one to one system mapping. In contrast, Fauconnier and Turner do not think that the relation between time and space is a relation between two domains being basic primitives in human understanding. Time is an emergent concept (that is why it is considered to be abstract) from the more primitive domains of space and motion.

The problem of the flow of time is created when reasoning about time in temporal units is measured in hours, minutes and seconds and seeing these same temporal units moving objects, e.g. 'the hours pass by'. Time can fly, race, drag, or come to a complete halt. In these cases there is a clash between subjective experience and objective reality, exactly what the problem of the flow of time is conceived to be.

1.3 Conclusions

This chapter gave an overview of the status of the 'flow of time' as a metaphor. Research of Gentner, Casasanto and Boroditsky shows that we not only *speak* of time by using spatial metaphors, but we also *think* about time using spatial analogies. They define two different system-mappings: ego-moving and time-moving. System mapping occurs between the domains of space and time, because one domain is considered to be concrete and the other abstract. Since space is concrete, this domain is used to understand the abstract concept of time better. However, this does not give us any explanation yet of the observations that time is abstract and space is concrete, and of the two different system-mappings.

Fauconnier and Turner however introduce *conceptual blending*, which is a theory about different base concepts, that are initially incompatible, merging together to form new more abstract concepts. They think the concept of time can be represented by an integration network of which the base concepts are space and motion.

What insight can give the research of Boroditsky, Gentner, and Fauconnier and Turner to answer the questions that define the problem of the flow of time? Is the flow of time implicitly or explicitly in the picture of time in physics? Is flow of time mind-dependent or mind-independent? The picture of time in physics is discussed in the next chapter. Therefore we cannot answer the first question

yet. To the second question no answer is given either, but especially Fauconnier and Turner point into the direction that time is a concept emerging from more basic concepts such as space and motion. The incompatibility of measuring units and moving objects is exactly what the problem of the flow of time is. Intuitively conceptual blending tells us that the flow of time is a construction of the brain merging more directly observable domains of space and motion. It goes even further: time itself seems to be derived from space and motion.

However we cannot exclude that anything physical in the external world is causing this specific merge of the domains space and motion to understand time. It turns out to be difficult to point out differences between time and space. Questions about what the differences are, why they exist and how they are related are very interesting.[35]

As we have seen it is almost impossible to avoid thinking about time as some kind of spatial dimension. Conceptual blending not only explains the existence of a problem of the flow of time, but it also explains the intuitive link between space and time. In physics, long before Einstein formulated his special theory of relativity, time is represented as a spatial dimension. From the perspective of analogical thinking we can understand why we make this spatial picture of time in physics. Both in the study of time perception and in the study of the concepts of time, it is important to notice the shortcomings of the space → time analogy.

Advantages of the analogy are:

- We can measure time using spatial objects such as clocks of all kinds: atomic clocks, water clocks, sundials, hourglasses, etc. It helps us to define time-intervals and duration analogous to space-intervals and distance.
- We can order events in time in past, present and future and put them in a one-dimensional line, in which the *here → now, there at the front → future* and *there at the back → past* analogies are used.
- By following the line of the analogy in physics, relativity theory could be developed by posing a four-dimensional space-time in which time is treated as one of the four dimensions.

Disadvantages of the analogy: where does the analogy break down?

- It causes the idea of passage of time at a certain *rate* due to domain of motion.
- It causes the 'feeling' that *travel in time*, just like in space should be possible.
- It causes 'here' and 'now' to be analogous, i.e. 'now' is just like 'here' treated as an indexical. 'Here' is a point in space, like 'now' is a point in time. Time however has no points. Because of the spatial analogy we think of the 'now' as a reference point in time.

These disadvantages are heavily debated problems in the philosophy of time and they illustrate the consequences of thinking about time in spatial analogies.

[35]Callender, Craig, *What Makes Time Special*, essay for FQXI contest on THE NATURE OF TIME, december 2008, p.1

The incompatibility of space and motion causes the shortcomings of the spatial analogy to understand time and it causes the problem of the flow of time. Can we solve this incompatibility between space and motion? This is what try to decipher in the next chapters.

Spatial analogy plays a major role in the picture of physics today, but not many physicists are aware of the fact that analogical thinking is such a basic human way of thinking. Now that we have discussed the role of the flow of time as a metaphor, we will give an overview of the status of the flow of time in today's debate in the philosophy of physics in the next chapter.

Chapter 2

The picture of time in physics

'The Present is a Point just passed'
David Russell

The solution to the problem of the flow of time lies on the border of two disciplines: (the philosophy of) physics and (the philosophy of) cognitive science. The problem can be formulated in two questions. The first question is whether flow has to be added to the picture of time in physics explicitly. This 'physics-part' of the debate is about the completeness or incompleteness of the block universe picture of spacetime.

At first sight this question is related to the second question whether the flow of time is mind-dependent or mind-independent, the 'philosophy-of-mind-part' of the debate. In most literature the two questions are believed to have a one-to-one relation: if you believe that flow does not have to be added to the block universe, you also believe that it does not exist in the physical world and is mind-dependent. If you believe that the flow of time should be added to the block picture, you also believe that flow is an objective feature of the external world and is therefore mind-independent. But these relations are not that simple.

In the first chapter it is explained that time is a concept that people understand through spatial analogies; analogies are one type of mental representation.[1] In this chapter about the picture of time in physics, we will be discussing the image of time, which is another type of mental representation. These two types of mental representation are related to each other. The picture of time in physics is developed from the mental image we have about the concept of time. The concept of time is a mixture of analogies from the domains of space and motion.

In an image-like mental representation we picture time as a one-dimensional line. In a diagram (not a mental but a physical representation) we can picture the line of time as one of the spatial dimensions.

In language but also in thought we, in the Western world, picture time

[1] Thagard, *Mind: Introduction to Cognitive Science*, p.229

linearly[2], as a straight line from left to right or from down to up: 'There is a tough week lying in front of us'. 'I am glad that that horrifying night lies behind me'. 'Time flies when you are having fun'. We have seen that we not only rely on terms from the domain of space to *talk* about time, but we also *think* about time that way.[3]

We have an experience of time's flow, when we consider an event such as a wedding scheduled at some day in the future that becomes present and is in the past when the party is over. The future is heading toward us (time-moving) or we are moving towards the future (ego-moving). We understand time by using characteristics of the concrete concept of space, but we intuitively feel that time is different from space. We can move freely in the three spatial dimensions: up-down, left-right, front-back. We have control over our position in space in contrast to the time dimension *where* we always seem to go *towards* the future, at least if we indeed picture time as a *line*. There is a *direction*, but also a *movement* that we experience, but which we cannot alter. We have no control over our *position* in time. We can only speak of something like a position in time, if we use the picture of a spatial line as time dimension. If we are at rest, we mean we are at rest in the spatial dimension. We stay at the same place, but not at the same time. We cannot be at rest in the time dimension. Here we see the influence of the domain of motion on the understanding of time.

In the literature time is roughly characterized as dynamic, one-dimensional and asymmetric, while space is static, three-dimensional and symmetric.[4] Physics pictures time like space, but not exactly. The hope was that the relativity of simultaneity in special relativity theory would give a new input to the ontological status of the present and the flow of time in physics. But as we will see in the last part of this chapter, it does not give the final convincing arguments on whether flow of time is mind-dependent.

The moving now means something special to us. It marks the difference between past, of which we have knowledge, and future, of which we do not. The metrical difference (minus sign versus plus sign for space) is often mentioned to be due to the asymmetry of time. There is free mobility in the dimensions of space, but not in the dimensions of time. Time is a measure for change and time itself seems to move (its dynamic-ness, its passage) because of the conceptual blending between space and motion. Time is not space, therefore we cannot move freely in the dimension of time. If there would not be any change, if everything remained the same, it would be impossible to measure time.

In this chapter, I will give an overview of the status of today's debate in physics and philosophy of physics to provide an answer to the first question whether flow of time is already contained in the picture of time in physics. We will also see how the first question is related to the second question. I can already give away that this relation is asymmetric: if explicitly added, flow is mind-independent. If flow is not explicitly added, flow can be either mind-dependent or -independent. So at the end of this chapter the second question will still be

[2]We can also picture time cyclic; this is a spatial analogy too, as we saw in Fauconnier's and Turner's integration network

[3]Dedre Gentner, & Mutsumi Imai, & Lera Boroditsky, *As time goes by: Evidence for two systems in processing space → time metaphors*, Language and Cognitive Processes, 2002, 17(5), p. 538

[4]Callender, *What Makes Time Special*, p. 2

unanswered.

Before we take a look at the ontological status of the flow of time, we discuss the reality of time itself. McTaggart is a well-known proponent of the 'Unreality of Time'. Today's views are building on his article from 1908. Philosophers who believe that time exists in nature are divided in two camps: tensers and detensers. Tensers say that the picture of time is not complete, for the flow of time is not captured in this image. The flow of time is mind-dependent and needs to be made explicit in the picture of time in physics. Detensers argue that the flow of time (=the moving present) is contained in the block picture, but some think that flow is part of nature and others think that it is in the mind. We will see that both views on the completeness of the picture of time in physics can be reconciled.

2.1 McTaggart and 'The Unreality of Time'

In his article The Unreality of Time[5] in 1908 J.M.E. McTaggart (1866-1925) argues that time does not exist. He starts with giving an overview of how time is treated in philosophy and religion. Almost all mysticisms deny the reality of time. In philosophy, he exposes, time is treated as unreal by Spinoza, by Kant, by Hegel and by Schopenhauer. McTaggart believes time is unreal too, but for reasons that have never been given. To explain these, he distinguishes two theories of time, the A- and the B-series.

> 'Positions in time, as time appears to us prima facie, are distinguished in two ways. Each position is Earlier than some, and Later than some, of the other positions. And each position is either Past, Present, or Future. The distinctions of the former class are permanent, while those of the latter are not.'[6]

McTaggart himself uses the word *position*, which is a spatial analogy. He also pictures time as a spatial line on which the points represent the events. This is the first series that he distinguishes, called the B-series of time, see figure 2.2. This B-series is only using *static* measurement units from the domain of space. There is no flow or motion in this picture; it is static. The A-series is represented as a line on which there is a point, the present, which is moving, as seen in figure 2.1. This moving point divides the line into points (events) that lie in the past and points that lie in the future.

The B-series might be regarded as more fundamental then the A-series (past, present, future), because of its permanency: if event N is ever earlier than O and later than M, it will always be. Event M however will not always have the property of being future, present or past. It first will be future, then present and after that it will be past. McTaggart thinks the A-series is as essential as the B-series to define time, because it accounts for change, i.e. we need both series for time to be real. If a B-series without an A-series can constitute time, change must be possible without an A-series. But there is no change in the B-series, because it is a static picture. Change is only in the A-series. If there is no real A-series, there is no real change, and thus there is no real time.

The following contradiction makes McTaggart to reject the A-series:

[5] McTaggart, J. Ellis, *The Unreality of Time*, Mind: A quarterly review of Psychology and Philosophy, New Series, vol. 17, no 68, october 1908, p. 457-474

[6] McTaggart, *The Unreality of Time*, p. 458

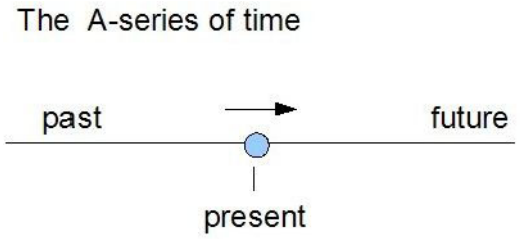

Figure 2.1: *A spatial representation of the A-series of time. The moving present is pictured as a moving point on a line, leaving the past behind and heading for the future.*

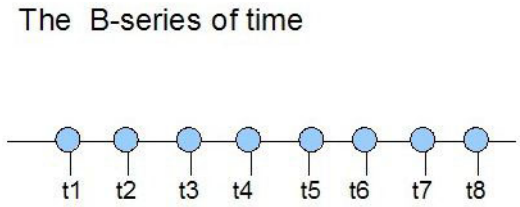

Figure 2.2: *A spatial representation of the B-series of time. The ordered events are represented as points on a line.*

> 'Thus our first statement about [event] M that it is present, will be past, and has been future - means that M is present at a moment of present time, past at some moment of future time, and future at some moment of past time. But every moment, like every event, is past, present and future. And so a similar difficulty arises. If M is present, there is no moment of past time at which it is past. But the moments of future time, in which it is past, are equally moments of past time, in which it cannot be past, Again, that M is future and will be present and past means that M is future at a moment of present time, and present and past at different moments of future time. In that case it cannot be present or past at any moments of past time. But all the moments of future time, in which M will be present or past, are equally moments of past time. And thus again we get a contradiction, since the moments at which M has any one of the three determinations of the A-series are also moments at which it cannot have that determination. If we try to avoid this by saying of these moments what had been previously said of M itself - that some moment for example is future and will be present and past - then is and will be have the same meaning as before. Our statement then means that the moment in question is future at the present moment and will be present and past at different moments of future time. This is of course is the same difficulty over again. And so on infinitely.'[7]

So there is no relation to something outside the A series! Passage is a self contradictory notion, therefore A-series is not real, therefore no change, no time, no B-series. What is wrong with McTaggart's argument?

[7] McTaggart, J.M.E., *The Unreality of Time*, in Le Poidevin, Robin, and McBeath, Murray (eds.), The Philosophy of Time, (Oxford University Press, 1993), p 33

There are several reasons why the argument is not correct. First, it goes wrong when saying that 'all the moments of future time, in which M will be present or past, are equally moments of past time'. This is not true, because for something to exist it must be defined from a point in time that is 'now'. Statements are always done from this viewpoint. We are confined to the present. Presentness, pastness and futureness are properties that cannot be universal for every point in time. Therefore these properties can not be explicitly represented in the static spatial picture of time (the B-series).

Second, McTaggart says change is only in the A-series. But what if my tea is hot a time t_1 and cold at time t_2? Then I would say a change has occurred between the times t_1 and t_2. McTaggart sees them as two events, happening at points in time. At points in time, we cannot speak about a time interval; there is no duration. If I say that at time t_1 my tea is hot, this statement is forever true. And 'at time t_2 my tea is cold' is also always true. That is why McTaggart concludes there is no change in the B-series. We will see that change is in the B-series.

What do we mean by past, present and future? They are not qualities but relations, relations to something, but to what? An A-series must depend on relations to a term outside the A-series. This reminds us of the problem of the rate discussed earlier; it might be related to a second time axis. However we do not solve the problem, we only displace it. This second time axis also has some rate for which we need a third time axis. For this third one, we need a fourth, fifth and so on. It is an infinite regress. The changing relation must be related to something, which is not in the time series. The characteristics past, present and future are incompatible. When uttering a true statement about an event like 'A ripe tomato is red', this is always true. But a statement like 'This lecture is tomorrow', it is not always true. Every event must be past, present or future at one moment in time. But every event has them all in total temporal extension. The characteristics are only incompatible when they are simultaneous.

Horwich gave a beautiful outline of McTaggart's proof:

- Events are located in a B-series (ordered with respect to later than), only if time exists.
- Time exists, only if there is genuine change, (although everything in time does not change, the now is moving.)
- There is genuine change in the world, only if events are located in a real A-series.
- Therefore: Events are ordered with respect to later than, only if they are located in a real A-series
  If events are located in a real A-series, then each event acquires the absolute properties of past, now and future.
  There is a contradiction in supposing that any event has any two of these absolute properties.
- Therefore: A real A-series cannot exist.
- Therefore: (M) Events are not ordered with respect to later than.[8]

[8]Horwich, Paul, *Asymmetries in Time: Problems in the Philosophy of Science*, Massachusetts Institute of Technology, 1988, p. 18

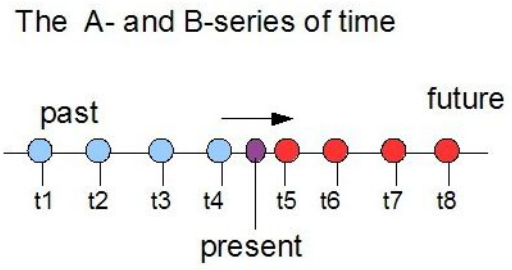

Figure 2.3: *The A- and the B-series can be merged. This is the spatial picture we have of time where the flow of time (a moving present) is explicitly drawn just like the 'static' events from the B-series. Because we picture it spatially, we need to draw both series. If we regard them as temporal, one series, the A- or the B-series is enough.*

When you say that in the A-series every event is past, present and future, this is right, but not at one moment in time. In the block Universe, every spacetime point is past, present and future, because you do not specify the moment in time. McTaggart's conclusion is very strong by saying that every event has absolute properties of past, present and future. They are properties of an event in relation to other events. The problem is that we see the spatial line of time in its full extension (past, present and future). We understand time through conceptual blending of the two incompatible domains of space and motion. This incompatibility is what causes the incompatibility between the A- (moving present=moving object) and the B-series (static points/intervals in time=static measurement units) that causes the problems.

2.2 The Reality of Time: Untensed Views vs. Tensed Views

In the picture of time in daily life, we use tenses in our language. 'Yesterday I *went* to the supermarket to buy Turkish bread. I *eat* this bread for lunch now. I *will* not eat it tomorrow.' It depends on the position of the present at the timeline, whether I speak about an event in the past tense, the present tense or the future tense. Therefore the pictures of time that refer to the relations past, present and future are called tensed theories of time. McTaggart called these theories the A-theories of time, of which he thought that they were dynamic theories of time. These kinds of theories are not used by physicists to formulate laws of nature, because the laws of nature need to be universal both in the spatial sense and in the temporal sense. Laws that are valid 'now' and 'here' you also want to be valid on the moon a thousand years ago. The viewpoint from the present is therefore not important in physics, but if things happen, they always happen in the present.

The laws of physics are based on a B-theory of time, which is static according to McTaggart. The parameter t in the laws can only be given a certain value that represents some point in time, independent of whether this value is in the past, the present or the future. Relations between two given events are the same

through time, according to B-theorists. Event 1 happening at May 21st, 2009, 11.00 AM and event 2 happening at May 23rd, 2009 at 11.00 AM are, when I write this, in the future. Event 1 however will first be present and then two days later event 2 will be present and as time passes by they will both be past. But the relation between the two events that one point in time is exactly two days after the first, was true, is true and will be true forever. It is commonly stated that no flow or passage of time follows from these tenseless theories. But I will argue in section 2.3 that it does.

Nowadays we have two basic views of philosophers who think that time does exist in nature: the tensed versus the tenseless views, or the presentists versus the eternalists, or the nowists versus the blockists. There are several names for the same debate. Often this debate is also identified with dynamic views of time and static views of time, in which the tensed view is dynamic and the tenseless view is static. We need to be careful with this, because in some literature the dynamic view vs. static view of time refers to a mind-independent vs. mind-dependent account of the flow of time. That means that flow can inhibit the dynamic character of time and if flow is mind-dependent, time is static. In other literature, dynamic and static views are identified with the debate on whether we need to add some extra factor to the picture of time in physics.

I think that the division in static and dynamic views that originates directly from McTaggart, is confusing. In this chapter I will argue that the picture of time is neither static nor dynamic. It is better to use the terms static and dynamic in the context of whether temporal passage is an ontological feature of the world. First let us focus on what the picture of time in physics is and how it developed.

2.2.1 The origin of the block Universe

When Isaac Newton formulated his laws of mechanics in Philosophiae Naturalis Principia Mathematica (1687), he wrote about space and time as if they are independently existing things: 'substances'. He assumed that an empty universe without any mass exists in itself and time goes by at a certain absolute steady rate. Time intervals are equal everywhere in the universe, seconds go by everywhere at the same rate, and they are well defined without any reference to clocks. Newton wrote about time:

> 'absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external.'[9]

Newtonian time is global, and it does not single out a 'now' or a 'present'.

What we nowadays call Newtonian spacetime is not exactly how Newton pictured it. The concepts of spacetime and of a four dimensional universe did not exist at Newton's time. These came into being at the end of the 19th century. Newton pictured space as three-dimensional and time as one-dimensional independent of each other.

In this Newtonian diagram every space and time point is absolute and an entity in itself. So if God created the universe three meters to the left, it would have been a different universe with different absolute space and time points.

[9]Dennis Dieks, *History and Foundations of spacetime theories*, 2008, course material University of Utrecht, p. 26, 27

Newton is also explicitly clear about the flow of time. This flow is an absolute feature of time itself and thus part of the external world. The now shifts as an infinite straight line orthogonal to the timeline, when you picture time as a one-dimensional line in the diagram. The moving now is absolute and global.

Physicist Tim Maudlin argues why Newton better should have written 'passes' instead of 'flows equably'. Passage is different from flow in that flow is metaphorical and passage is not. He states that rivers only flow and locomotives only move because time passes. As we have seen in the previous chapter, passage is like flow a spatial metaphor to express ourselves about a temporal feature. Passage is an ordinary spatial word, like in: 'the Indians didn't allow the passage of their domain', 'auditory passage (ear canal)', 'give someone passage'. Passage therefore has the same status as flow and is any not different from flow, the way Maudlin describes. Maudlin tries to defend the status of passage of time in this way, because he believes

> 'that it is a fundamental, irreducible fact about spatio-temporal structure of the world that time passes, and that the passage of time is an intrinsic asymmetry that has no spatial counterpart.'[10]

Indeed, passage has no spatial counterpart in the dimensions. Space does not pass, because space is static. We can pass space, e.g. a landscape. 'We' are moving spatial extended objects. Passage refers to motion, like flow refers to motion. And time is a blend between space and motion.

Maudlin is one of the unusual defenders of the block universe who does not deny any objective flow of time.

McTaggart implicitly criticizes Newton when he says: 'without relation to anything external'. According to McTaggart, time must, if it does flow, flow in relation to anything external. This plays an important role in his argument for the unreality of time. It does not flow in relation to anything external, and therefore, he concludes, it also does not flow.

During Newton's time not everyone agreed on his 'substantivalist' position about time. The philosopher Gottfried Wilhelm Leibniz believed that space and time are nothing but concepts that we use to describe relations between physical things and events, like particles and their movements. Without any mass, space and time do not exist. So opposing Newton, Leibniz assumes that an empty universe without any mass does not exist, because space and time do not exist. According to Leibniz, who embodies the position of the 'relationists', there is no independent absolute time. Time is the order in the positions of the hands of clocks, i.e. time is the order in stages of processes of change. If there is no change, if everything in the whole universe remains the same, it is not only impossible to measure time, but there simply is no time.

Leibniz proposes three famous arguments for this position. The first one is the verificationist argument: the existence of an independent space and time cannot be measured and therefore cannot be verified. The counterargument of the substantivalists is, that it is a weak premise to say that things that cannot be measured, do not exist. The second argument is Leibniz' principle of the identity of indiscernibles, which says: if two objects or systems cannot be distinguished in any way from each other, they must be one and the same object. In contrast to Newton, Leibniz thus says that two universes, of which one

[10] Tim Maudlin, *The Metaphysics Within Physics*, Oxford University Press, 2007, p. 104

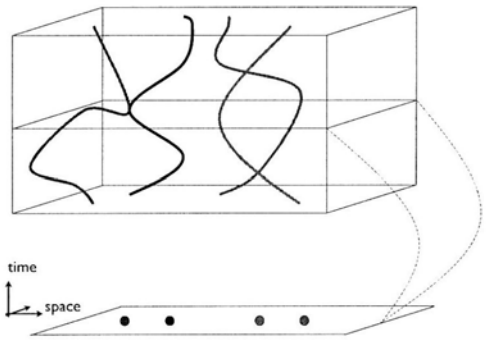

Figure 2.4: *A picture of a three-dimensional block universe. To keep it simple only two spatial dimensions are shown. Each three dimensional spatial slice contains the arrangement in space of everything that exists at one moment in time. The sequence of these three dimensional spatial slices form a four dimensional spacetime, called the block universe.*

is with constant velocity shifting three meters per second to the right in relation to the other one, are identical. Newton's laws tell us that those two universes cannot be distinguished. One cannot distinguish a particle that is at rest from a particle that travels with a uniform velocity: on both the exerted force is zero. Leibniz' third argument is the famous Principle of Sufficient Reason: every difference between two universes must have a reason or a cause. From these three arguments Leibniz drew the conclusion that absolute space and time do not exist. But if time is relative to physical things, like particles, the flow of time must also be relative to masses. We can define a relative flow of time that is local, i.e. it can have a different rate at different places depending on the distribution of masses at those places. Clocks are ticking slower at some places in the universe compared to other places, depending on spacetime curvature.

According to Isaac Newton, the universe is infinite in three symmetric spatial dimensions and infinite in one asymmetric time dimension. He thought that both space and time are absolute and that the rate at which time is flowing is equal everywhere in the universe. The usual way to picture this is by drawing a diagram with two space axes and one time axis, see figure 2.4.[11], A plane orthogonal to the time axis can be drawn to be the plane of simultaneity: at a certain time t_1 the diagram shows a two-dimensional space plane. Every event in space in this plane, happens, has happened or will happen at the same time. The plane can be regarded as the now, which moves upwards. This upward moving along the time-axis represents our experience of the flow or passage of time. The moving plane of simultaneity is the moving present. 'Above' this plane of 'now' (up) is the future and 'under' this plane is the past (down). The value of t on the time axis is increasing as we go up towards or further into the future and this value is decreasing as we go down towards the past or further into the past.

[11]Nick Huggett, *Everywhere and Everywhen*, chapter 10 and chapter 11, in press (to be published by Oxford University Press 2009), p. 87

This above describe intuitive picture makes people feel that the 'now' is something special. The feeling of a special now and a plane of simultaneity can be explained by something the historian of science, Max Jammer, calls the Visual simultaneity hypothesis[12]: it follows from the thought that light travels with infinite speed that all events that are seen at one point in time are also happening simultaneous with one another. This hypothesis can give an explanation for our intuition that there is a unique global now, and the belief that everyone you see and interact with shares your now. Thanks to our free mobility along the three spatial dimensions and because we have no spatial counterpart of the visual simultaneity hypothesis, we do not confuse our egocentric here with an objective here, according to Callender. Otherwise we would only observe one 'here', which we do not. Since we have no direct perception of temporal extension, we only experience one 'now' at a time; we see more 'heres' at one time.

What does Callender mean by an objective 'here'? If I visit a castle that is build in the 14th century, I am aware of myself walking around at the same place where many people have lived throughout the ages. It is at this place they walked around, just like I am doing now. In this sense an objective here can be a point in three-dimensional space existing along the whole time line. An objective 'now' can be a point on the time line in the whole three-dimensional space. These objective and global heres and nows are ruled out by relativity theory. But first we will expand Newton's space and time to a four-dimensional Newtonian spacetime, which contains all of the past, present and future in one four-dimensional block. This block is nothing more than a spatial analogical representation of spacetime. If we would follow Newton's line of argument, the block is infinitely large. Recently however, cosmologists have found evidence that the universe has come into being during the so-called Big Bang, which means that on one side the block is finite.

So space and time are represented in physics by the picture of the block universe, a four dimensional block in which every event that has ever happened, happens, or will happen, anywhere in the universe is included, see figure 2.4. The four-dimensional block is the whole spatial universe at every instant of time. All objects, stars, planets, human beings in this picture are extended in both space and time, i.e. what you see of a human in this representation is every step he took and every place he has been from birth until death. The line of the human being in the block is called his world line. In actual reality we cannot see objects extended in time. We only see them at a certain time, the 'now'. We know that some objects existed in the past, but we do not perceive succession of instants simultaneously. We have memories of an object at past moments, and therefore we know about its temporal extension.

The debate in the philosophy of objects, which is closely related to the debate between 'presentism vs. eternalism' or 'tensed view vs. tenseless view' or 'nowism vs. blockism', is *endurance versus perdurance.*

The central question here is whether objects are defined as a whole in one moment of time or in all of its temporality. For example, am I Annemarie in my totality at this present moment, or am I as a baby, as a toddler, as an adolescent, as an adult, as an old lady (I hope!) all together Annemarie?

[12]Callender, *The Common Now*, p. 346

Endurantism is about the first possibility: the object as a whole exists at one moment in time. So when I talk to my father now, I'm talking to him being my 'whole self'. The object's extension in time is different from its extension in space. Whereas only part of an object is present at a single point in space, the object can be wholly present at a single point in time. The object is said to endure.

The second possibility is called perdurantism: the object as a whole exists when summed over all of its temporal parts. It fills time by having one temporal part after another, just as it fills space by having one spatial part next to another. The object is said to perdure.[13] So a perdurantist would say that Annemarie is one person from birth until death. This view of perdurantism is often compared to the view of eternalism, but it is not the same. The essential point in the debate between perdurantists and endurantists is whether temporal extension makes objects complete. Endurantists believe that objects are complete entities in three-dimensional space and perdurantists only think that objects are complete in four-dimensional spacetime.

The debate between eternalists and presentists is about whether the picture of the block universe is complete when no 'present' is added. Eternalists also represent objects in their full temporal and spatial extension in the block universe as the object's worldline, but they do not claim that the object is only complete when you integrate along the world line.

2.2.2 Time and the Laws of Physics

Each of the slices of the block universe contains one instant if you cut the block somewhere along the time axis. This is all of space at one instant of time. Using the laws of physics we can say something about the position of a particle at a certain time. It seems that time in the block universe is not different from space. But if you cut along a spatial axis or along the temporal axis to get a three-dimensional 'plane'[14], there is a difference in the predictability of the position of an object in spacetime. If we cut the block along the time axis, we can pick a point t_1 in time and calculate what the position of a particle in a spatial 'plane' is somewhat later at a time t_2, given that the state of the world in the three remaining spatial dimensions x, y and z at time t_1.[15] What we need to calculate the position of a particle at time t_2, are the positions and the velocities (and accelerations) in the three spatial dimensions: x_1, y_1, z_1, v_x, v_y and v_z and t_1. But if we cut the block along the spatial dimension x and pick a point x_1 we cannot calculate what the position in spacetime is on another point x_2, given the positions and velocities in the other two spatial dimensions y and z and the temporal dimension t for point x_1. Because we do not have the velocity of the particle in the x-dimension and we do not have t_2, the particle can be anywhere in the $y - z$ plane. We have three spatial dimensions and one temporal dimension. The state of the particle depends on its phase space,

[13] Velleman, J. David, *So it Goes*, The Amherst Lectue in Philosophy 1 (2006): 1-23, p. 4, http://www.amherstlecture.org/velleman2006/
Velleman argues in this article that the enduring self is an illusion. In his view the idea of an enduring self arises from the structure of experience and experiential memory. He argues in this article that this illusion goes hand in hand with another illusion: the passage of time.

[14] A plane is usually two dimensional. In the picture of the block universe we draw two spatial dimensions, while there are three.

[15] Huggett, *Everywhere and Everywhen*, p. 87

which means that we need both the position and the velocity of a particle in three spatial dimensions at time t_1 to predict what the position will be at time t_2. It is again motion (velocity) and space (position) that we need to predict the position of an object in the future.

This example shows that also in physics we cannot treat time as just another dimension. The difference between space and time is a real physical one. What is its nature? What is so special about time? Physicist Nick Huggett gives an answer:

> 'One possibility is that the only thing singling out one of the four dimensions of the universe is the role it plays in the laws - the laws say that some dimensions will play the role described and time is just whichever dimension does. If one also thinks, as I suggested, of laws as simply descriptions of what happens, then we get the following picture: at base, the universe is composed of things arranged in four dimensions, with no distinctions among them; but the best description of the way they are distributed turns out to single out one dimension, which we call time. That is, at root, the distinction between time and space arises just from the way things are distributed across four interchangeable dimensions. Alternatively is the dimension of time distinguished from space by a special property, a basic 'temporality'? Such an idea seems plausible if one thinks that the fact that the laws single out a special dimension stands explaining: because one dimension is special, the laws treat it differently or that is why they can. [...] However, my sympathies are with the view that the distinction lies in the laws, because I am skeptical that explanations are needed here; the laws just are that way.'[16]

The two views that Huggett describes are different in whether the laws of nature are prior to what we observe in the physical world. In the first view the concepts of time and space can be deduced from the laws of nature. The laws themselves are regularities in what we observe and they seem to single out one dimension that is called time. The second view states that it is the other way around. Time and space are already there a priori and the laws of physics, that describe time and space are necessary and laid down on the physical world. From the spacetime structure the laws of physics follow.

These two views are related to the standard debate on the understanding of natural laws as regularities or necessities. The first view is a specialization of the standard Humean approach that a law of nature is nothing more than a universal generalization, a regularity. In general, the regularity approach states that laws describe the way things actually behave. The important property of laws of nature is empirical evidence. Laws of nature we can only know by observing the external world and not by the mind. The laws are the way nature shows us they are.

The second view is the necessitarian approach, which can be summarized as follows; laws are more than just regularities. This approach not only tells us how laws behave, but how they must behave.[17] This is a more platonic kind of approach. Nature is the way the laws tell her to be.

In his paper *What Makes Time Special* Craig Callender proposes a novel answer to the question of what distinguishes time from space: the temporal

[16] Ibidem, p. 88

[17] Curd, Martin, & Cover, J.A., *Philosophy of Science: The central Issues*, New York, W.W. Norton & Company, 1998, p. 805

direction is the direction on the manifold of events in which our best theories can tell the strongest, most informative 'stories'.[18] This informativeness has already been illustrated in the example at the beginning of this section that describes states of particles in spacetime with given initial conditions.

The three features of time he explains in his article are its one-dimensionality, the metrical differences in relation to space (relativistic or classical) and the free mobility we find in space, but not in time. Callender favors, like Huggett does, an empiricist account of the laws of nature:

> 'empiricist theories seek to explain the laws given the distribution of actual or observed facts, rather than going the other way round and explaining why the facts are what they are in virtue of the laws.'[19]

Space and time follow from the laws and those laws again follow from the distribution of facts across four interchangeable dimensions. This empiricist account suggests features of time are a great simplifier and a great informer. Time is a simplifier, because it makes motion look simple. However, space also is a great simplifier for the same reason. Both time and space explain motion; motion is defined as the property of something that keeps its identity through time and is at different places at different times. Simplicity alone is not enough. Time is a great informer, while space is not. The temporal dimension is special in the sense that it gives us more information, generated by less input. Callender defines informativeness as follows: the more that happens generated by small input the better and the greater the informativeness.[20]

The difference between time and space is not simply found in a metaphysical primitive feature one has and the other does not. According to Callender, the differences between space and time lay in the distribution of fundamental physical properties, such as charge, mass, etc. Time is one-dimensional, because informativeness in one set of directions is enough to be a maximally strong theory. According to Callender, we see how strength can 'find' spatial and temporal directions.

At the end of his article Callender remarks:

> 'In the end, it's a remarkable fact that laws of nature (quantum, Newtonian, relativistic) possess asymmetry in informativeness. This previously unmentioned asymmetry between time and space is in fact responsible for why we think temporal directions are special.'

Callender gives an illustration of his view that the laws of physics 'generate' the differences between time and space. Our laws are constructed in a certain way to describe what we see in nature and from these laws it turns out that in four dimensional spacetime, there is one dimension that is timelike. The distinction between time and space therefore arise from the way things and events are arranged in four dimensions. From the way we see the world around us and the way we construct laws, it follows that there is always one dimension that plays the role of time.

Both Craig Callender and Nick Huggett favor this more Leibnizian way of thinking. Space and time are *a posteriori* deduced from relations between objects and events. The other view reasons the other way around. There is already

[18] Callender, *What makes time special*, p. 1
[19] Ibidem, p. 3
[20] Ibidem

an *a priori* difference between time and space, and the laws of nature follow from this difference. In the last view we still need to answer the question why time is different from space and what exactly this 'temporality' is.

How does the above described story relate to the problem of the flow of time? Tim Maudlin writes that some people, e.g. Gödel, claim that passage of time requires some sort of spacetime structure, some objective foliation (division into space and time) of spacetime, which is forbidden by relativity theory. In relativity theory 'distance' in spacetime is absolute, but what the space and time division is, depends on the position and velocity of the observer. According to Gödel:

> 'Change becomes possible only through the lapse of time. The existence of an objective lapse of time, however means that reality consists of an infinity of layers of 'now' which come into existence successively.'

This is the Newtonian block universe view. Gödel continues:

> 'But as if simultaneity is something relative in the sense explained, reality cannot be split up into such layers in an objectively determined way. Each observer has his own set of 'nows', and none of these various systems of layers can claim the prerogative of representing the objective lapse of time.'[21]

If we really do not need any fixed or privileged foliation, then the block universe seems to be complete after all and we do not need any special 'now' that is highlighted.

While Gödel argues that the passage of time does not exist, because there is no privileged foliation, Maudlin argues that it is possible to believe both in an objective passage and in a block universe without a fixed foliation. His answer to Gödel is that for the passage of time to be objective we do not need infinite layers of 'now' that come into existence successively.

In the question whether the picture of space and time as a four-dimensional block universe is complete, the problem of the flow of time plays a crucial role. Connected to this flow is the 'now' or the present we experience. The flow of time can be represented as a continuously moving now. According to Maudlin, there are several kinds of objections against an objective passage of time.[22]

(i) The first has already been considered. Maudlin classifies Gödel's objection to the existence of flow of time, that it is not compatible with scientific theory, as a *scientific* objection. Maudlin's answer is that for an objective flow to exist we do not need a fixed foliation of spacetime. The passage of time can also exist in nature even if it is dependent on the local spacetime structure.

(ii) The present seems to highlight every instant of time at a certain rate. The pace of changes of state is the rate of processes taking place in time, motion is the change of position in space taking place in time. What about the rate of time itself? A rate of a second per second is unity, which is dimensionless and therefore of not much use. Price, according to Maudlin, states it is no rate at all.[23] Maudlin classifies this kind of objection to the flow of time as *logical*.

[21] Kurt Gödel, 1949, pp. 557-8, in: Maudlin, Tim, *The Metaphysics Within Physics*, Oxford University Press, 2007, p. 115

[22] Maudlin, *The Metaphysics Within Physics*, p. 110

[23] Ibidem, 112

Maudlin's answer to this objection is that he gives an example as counterargument to what a fair rate of exchange is: exchanging five dollars for five dollars is still a fair rate, because you get one dollar for one dollar. The rate-of-one-second-per-second story is not a very convincing argument against the objective existence of the flow of time, according to Maudlin.

(iii) The last kind of objection to the passage of time Maudlin classifies is the *epistemological* objection: if there is such a thing as passage, it would be impossible to know. From our point of view we cannot distinguish whether our experience of time flow is constructed by the mind or that it is some objective feature of the nature of time. Whether this statement is true is exactly what I try to find out in this master's thesis. This epistemological objection is not a solid argument against the existence of the flow of time in nature.

According to Maudlin, no convincing objections against the objective flow of time are brought in.

The first step in solving the problem of the flow of time is to find out whether the block universe picture in physics is complete. The block universe seems to be static and does not seem to represent time's dynamical character. However not everyone agrees. There are two mainstream philosophical positions that give an answer to the first of the two questions I have defined to be the problem of the flow of time. One argues that the picture of the block universe is not complete and the other one that argues it is.

The picture of a four-dimensional block of spacetime, which does not contain a special mark on what the plane of 'now' is, is widely used in physics and is called the block universe. The structure of Newtonian spacetime is the basis from which different views of time are developed, in most literature classified as presentism, possibilism and eternalism.

2.2.3 Views on the Reality of Time

McTaggart's article introducing the A-theory and the B-theory of time divided philosophers in two groups, the tensers and detensers respectively.

One group favored the B-theory which states that time is only about relations between events. A moving now and past, present and future are not explicit in the block universe. Some of them state that we do not need flow in physics and that a present moment is not distinguished. Others say flow does not exist, only in our minds. The division of earlier and later makes sense relative to a given event. This is the untensed view of time.

The other group, which favors the A-theory as the correct view of time, are the tensers. They divide time into the trichotomy of past, present and future and claim that this trichotomy is an objective classification. Tensed theories of time think of the present as objectively special.[24]

The terms tensed and tenseless originate from verb tenses in English grammar: 'untensed' language refers to sentences without any verb tense; 'tensed' sentences are statements about events in the past, present or future. An example of the use of future tense is: 'Five months from now I will be celebrating my 25th birthday.'

[24]Callender, *The Common Now*, p. 340

There is an endless debate going on between tensers and detensers, because both lack arguments to attack each other. Experience seems to favor the tensers, because intuitively the present is something special. Detensers think that this feeling of a common now and the flow of time is contained in the block universe and some of them even think 'flow' and the 'present' do not exist in nature. But they cannot give a satisfying explanation yet for the cause of the experience of the flow of time.

Is it really the case that experience favors the tensed view of time? According to Callender and others the argument of experience is not so solid. The feeling of the moving now might be explained by mechanisms in the brain that construct this experienced present.

If so, this 'now' is just as subjective as the indexical 'here', Callender argues.[25] An indexical is a term that always needs a point of reference to acquire a definite meaning. If 'now' really turns out to be an indexical and mind-dependent, we do not need any tensed metaphysics, i.e. a picture of time in physics that contains the present. So if we can show there is no 'now' independent of us, that our feeling that the 'now' is objective because it is constructed by our brains, the tensers can pack up and go.

By contrast, if past, present and future can be shown to be objective classifications, and we need to add a model of the flow of time into the four-dimensional picture of the universe in physics, the tensers win the debate and the detensers have to leave the stage.

Although I already explained what distinguishes these two groups, differences might be smaller than it seems. Steven Savitt even argues that the debate between eternalists and presentists can be reconciled. First I need to explain the differences between the terms used in literature that refer to this debate. Detensers think that the block universe picture of spacetime is complete; they are called 'eternalists' or 'blockists' because they picture spacetime dimensions as a whole, and do not divide these into past, present and future, like you do not divide space in 'here' and 'there'. The term 'eternalist' is a bit misleading, because it seems as if they believe past, present and future are there at one instant of time. But they do not. Detensers do not make an objective division between past, present and future in the block universe. Past was real, present is real and future will be real. They use tenses in language just like tensers do. So events are all real at their own instant of time. The block universe is a picture of this totality, containing each and every present.

Tensers are roughly divided in two groups: presentists who argue that only the present exists, and possibilists according to whom the present and the past exist, but the future not yet.

Sometimes the debate between tensers and detensers is called 'eternalists versus presentists' or 'nowism versus blockism', but it is all about whether the present moment and the flow of time need to be added to the block universe. Is the picture of time in physics complete or not? We will see that all views, both tensed and tenseless views make use of the picture of the block universe as is seen in figure 2.5.[26]

[25] Ibidem, p. 341

[26] Stanford Encyclopia of Philosophy, entry: Being and Becoming in Modern Physics, http://plato.stanford.edu/entries/spacetime-bebecome/

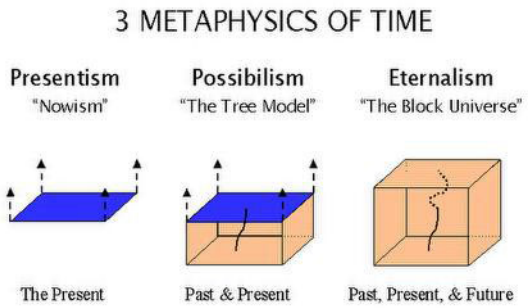

Figure 2.5: *The three different views of detensers (eternalism) and tensers (possibilism and presentism) on the reality of time.*

Eternalism (blockism) In the block universe view all of spacetime can be pictured in a four-dimensional block. All past, present and future events are in this block, without any distinction or highlighting or whatsoever of the 'present moment'. It is commonly argued that the block universe is per se static, but it is not. The picture itself is not dynamic or changeable either, because this block universe is not an entity in time. All characteristics, like the dynamical feature of time, are represented within the block. In this picture all events in past, present, future are imaged at once, but not simultaneously. Some block viewers deny that there is an objective present and any objective flow of time, others do not. Block viewers think of the past, present and future as being equally real. The present is no special instant on the time axis. According to eternalists the block view represents the view of time of contemporary physics. Physics requires no privileging of one moment as the present. The image of time according to physics is fully captured in the block.

The block is a representation of time on the metaphysical level. You can compare this picture to the book of God, in which everything that happened, happens and will happen is described. The mistake is often made that you have to be omniscient to represent past, present and future, like God is omniscient. But you cannot foresee the future. At one moment in time, you cannot find the book of God and see what is going to happen. It is just a representation of the spatio-temporal universe. We are *in* time, while the block universe that is a picture *of* time, is not.

A different view on the block universe is Storrs McCall's 'Universe Tree Model', which is a progressive decrease in sum of reality.[27] Event or time becomes actual when there is only one branch left and that is at present. Every branch is equally real. McCall's view is counterintuitive, because his block universe has a multiplicity of real futures. The moving now causes a loss in reality. McCall's view is an eternalist view in the sense that past, present and future all exist. However, the present is explicitly added in his model at the

[27]Storrs McCall, *Time flow, non-locality, and measurement in quantum mechanics*, in: Steven Savitt, Time's Arrow Today: Recent physical and philosophical work on the direction of time, Cambridge University Press, 1995, p. 156, 157

branching point of the tree. All possible futures are equally real and all, but one, become unreal when the 'present' branching point is reached. So there is a loss in reality. McCall's view can also be interpreted as a variant of possibilism.

Possibilism Eternalists use the picture of the block universe and think that past, present and future are real; the possibilist does not think that the future is real yet. The branched model is a four-dimensional spacetime model in the shape of a tree, of which each branch is a complete future containing objects and events. Only the past and the present exist, and the present is that particular part of a tree were branching begins. The unselected branches vanish so that the first branching point moves up the tree in a stochastic manner. The tree grows by losing branches. This loss and the motion upwards of the first branch point represent the moving now. This model captures the moving now; the flow of time is objective and is not related to minds and consciousness. Branch loss is instead what constitutes the flow of time.[28] An objection to possibilism lies in special relativity telling us there is no unique world-wide class of all the instants simultaneous with 'here-now' to which we come later.

Possibilism is an objective passage view and seems to capture much of the way we think about time. It reflects the asymmetries concerning past and future and the flow of time, that eternalism does not. Possibilists make use of a picture that can be called an Evolving block universe, a Growing block Model or a Universe-Tree Model. The only difference with the block universe is that in these models flow is represented explicitly.

The possibilist John Perry discusses McTaggart's argument for the unreality of time.[29] To explain his position in the discussion, Perry adds an extra series of facts to the series of McTaggart on chronological possibilities. The direction of time is the direction of decreasing possibilities. To him the future is unreal. The future is not *actual*, but *possible*.

Perry says that we cannot talk about relations in the B-series. 'Some event being earlier than N, is always earlier than N', is not a true statement. He does not agree with McTaggart that the distance between two events whether they both are future (or one of them is future and the other one present or past, or they are both past) stays the same. We cannot speak about distance. According to Perry it is a mistake to talk in terms of 'distance'. What he is actually saying is that the use of spatial analogies is a mistake and confusing the discussion. Events that are going to happen in the future are possible. Perry asks himself the question whether the B-series is dynamic. It is, because:

> 'If the B-series is an actual succession of concrete events, it does change; it grows. But if we mean by the B-series the theoretical sequence of concrete events, the whole idea of change is incoherent.'

John Perry already showed that the A- and the B-series are more look-a-likes than McTaggart made us believe they are. We will see that Perry's remarks on change in the B-series match Savitt's view on the block universe. All possible events, all events that happened and could have happened are in this B-series.

[28] George Ellis in: George Ellis, *On the Flow of Time*, essay for FQXI contest on THE NATURE OF TIME, december 2008, also argues the passage of time is something physical caused by the collapse of the wave function in Quantum mechanics

[29] John Perry, *How real are future events?*, in: Time and History, Edited by Friedrich Stadler and Michael Stoltzner

Its status may change. In concrete terms: our experience of change, and of the passage of time, is the experience of new events coming into existence, and old possibilities being eliminated. In abstract terms: it is seeing a proposition being made true or false and sequences containing false propositions ceasing to be possible B-series. Chronological possibilities change with time. We'll see this similar idea of chronological possibilities back in several possibilistic theories.

George Ellis proposes to replace the block Universe by an Evolving Block Universe (EBU).[30] He argues that time irreversibility and the flow of time are already built into quantum mechanics through the quantum measurement process. Ellis is not clear on what he means by flow of time. It seems as if he has the concept of the direction of time in mind, which is more fundamental and important for physicists to solve.

Several concepts I left unexplained. The *asymmetry* of time is the fact that the future differs from the past, in the way that past events are known and future events are not. If time would be symmetric, things would be equally predictable in past and future. No movement and no preferred direction are involved. An example of a spatial analogy will make these concepts clearer. I am standing on a road of which one direction is leading towards the sea and the other one towards the mountains. The asymmetry is that if I look towards the mountains it looks differently than when looking towards the sea. I have not yet walked one step into one direction or the other; I have not even a preferred view yet. I only observe an asymmetry in the view. But when I start to prefer the view I have on the sea over that on the mountain, I have chosen a *direction*. Processes in physics seem to favor one direction, the future, over the direction of the past. This is called the *direction* of time or the arrow of time: processes seem to prefer one way in time, but not the other way. The asymmetry and the direction of time seem to be incompatible with the time-symmetric laws of physics. The laws do not prefer a positive direction of time over a negative direction. Both directions are allowed. Often the preference of direction of time is related to the positive gradient of entropy. In time, entropy in the universe increases. Direction of time implies asymmetry, but asymmetry does not imply direction. Direction involves no 'motion', but flow does.

A special meaning is attached to the present. Flow of time implies direction of time, but direction does not imply flow. In case of our spatial example: once I have chosen a direction, I start to walk towards the sea. My walk can be compared to the flow of time (=moving present). I am the moving object in this analogy, so the present is compared to an object. An object keeps its identity through time, but does the present keep its identity? The 'moving present' and our experience suggest that it does. We use the domain of space and moving objects to understand the concept of temporal relations like pastness, presentness and futureness. The present is not really a moving object; analogical thinking makes us 'feel' that it is.

George Ellis in his article *On the flow of time* seems to be confusing the three different concepts, especially flow and direction. The key part is about the *direction* of time and not about the flow of time. Not only George Ellis, but many physicists and philosophers are confusing flow and direction. They all use spatial analogies and metaphors to present their viewpoint.

[30] Ellis, *On the Flow of Time*, p. 2

Tooley, like Ellis, is a possibilist; he calls his block model not 'evolving block universe', but 'growing block model'. The name refers to an increase in the sum of reality. The future is not real yet, but becomes real as the present moves upwards. The opposite account McCall's Universe-Tree Model has already been mentioned when discussing eternalism. He advocates a decrease in reality, because the trees branches (futures) are real. The third view on the reality of time, besides eternalist and possibilism, is presentism. As the name might suggest a presentist gives priority to the present.

Presentism (Nowism) As opposed to the eternalist position that the whole history of the universe can be represented 'at once' in the block universe and the past, present and future are equally real, is the position of 'presentism'. Presentists would like to implement a special property of presentness in the block. Some not only give the present priority, but even state that only the present is real. Past events are not real anymore; the open and unfixed future does not exist yet. Note that I am using tensed language here. Detensers will agree when you say that past events are not real anymore. They were real at the time they were present.

Presentists often object to the block universe view on grounds that it leads to fatalism: what was true in the past logically determines what will be true in the future. This is not correct. The Block View does not lead to fatalism. At one moment in time, the future does not have to be deterministic. In the Block universe picture all events are represented simultaneously, but are not happening simultaneously. The presentist misses a special moving present in the block. But just like 'here' is in the block, 'now' is also in the block. Change in the block is a matter of being in different states at different times.

According to Barry Dainton, we define a presentist to be someone who holds the dynamic view of time and who holds that reality consists of a succession of presents. Dainton[31] correctly points out that the static-dynamic dispute does not completely coincide with the tenseless-tensed views. While the tensers and detensers do not agree about whether the flow of time is needs to be added to the block universe, the static-dynamic disputes are about whether temporal passage is objective or not. Dainton however identifies the block view with the B-theorist and the static view of time, but I argue the block view is not the same as the static view. In my opinion the block view can be identified with the tenseless view of time. Tooley and McCall, according to Dainton, both support the tenseless view of time and the dynamic view of time, while speaking of a block model. A block view can be interpreted both dynamic and static.

If we define the present as the time at which events are happening; if reality consists of a succession of the happening of events according to the blockists; then reality consists of a succession of presents according to the blockists. This is exactly the way the presentists also think. Both blockists and presentists are realists about time. They want to stay as close to reality as possible. Presentists believe that our experience gives us knowledge about the nature of time. They make use of the Argument of Experience. This argument relies on the fact that we all experience the passage of time. The clock ticks away the time and we cannot stop or turn it back. This dynamical property of time must exist in nature to be experienced. Is this true? Can experiences be described by

[31] Barry Dainton, *Time and Space*, Acumen, 2001, p. 63

physics?

The argument of Experience is closely related to the Knowledge Argument. Craig Callender mentions that the

> 'actual problem [of the experience of the present] is precisely what Perry 2001 calls the Temporal Knowledge Argument. This argument is the temporal version of the Knowledge Argument in philosophy of mind, wherein colorblind Mary has an operation to recover color vision and thereby allegedly learns a new non-physical fact. Perry declares the temporal counterpart of this argument to be the 'heart' of the tensed theory. He is right. The argument comes in many forms, but the core idea is that tensed propositions give knowledge or make certain behaviours rational that tenseless propositions do not.'[32]

Callender thinks that the Temporal Knowledge Argument of the tensers is no good argument, because it reflects general features of indexicals.[33] More research is needed on indexicals and on the correct semantics for terms like 'now' and 'present'.

To illustrate the problem of the more general knowledge argument, let's take a look at the example of the blind girl Mary that is an example made famous in the debate about qualia - properties of objects such as taste, warmth, color - by Daniel Dennett and Steve Pinker. Mary is a scientist and born being color blind. She knows everything about the perception of colors: colors are waves that reach the eye; photons with energy levels that correspond to their frequencies are falling on receptors; these receptors are producing neural signals, which are processed by different parts of the brain.

The question is: will Mary gain new knowledge about the experience and perception of color if she would be able to see them for the first time in her life? Or will she, when having all knowledge about the physical workings of the brain, know nothing new at all?

This question is central in the debate between reductionists and emergentists. Both views are developed from physicalism, which holds that the mind is a physical thing in all senses.

The reductionist would answer Mary does not gain new knowledge when she can suddenly see colors. Everything that there is to know about experience and perception can be described by interaction between elementary particles. Mental states and mental processes are reduced to fundamental physical states and physical processes.

The emergentist would answer that Mary is provided new knowledge when she experiences the act of seeing colors. She now knows what it is like to be able to see.

The reductionist reacts by dividing knowledge in two types: propositional knowledge such as 'I know that a ripe tomato is red' (without ever having seen the color red) and know-how knowledge such as 'I know what it feels like to see a red tomato'. Only the first type of knowledge is objective, the reductionist says, and can be written down in books. The second kind of knowledge might be different for different persons.

The emergentist argues that know-how knowledge is not that subjective at all. Experience is maybe not explainable from the interactions between fun-

[32] Callender, *The Common Now*, p. 343

[33] An indexical is a term that always needs a point of reference to acquire a definite meaning.

damental particles, but it might be explainable from novel physical properties of the mind that can emerge above the level of fundamental properties. The emergentist states that not everything can be explained from fundamental interactions, but that our view of nature should be layered.

The reductionist thinks that the mind is a physical object that can be explained through interactions on the fundamental level.

The emergentist thinks the mind is a physical but complex system that might be explained through interactions between different levels of the system's parts out of which new mental properties emerge: the total system is more than the sum of its parts.

Mainstream cognitive scientists nowadays believe in emergentism. Marvin Minsky in his book the *Society of Mind*[34] illustrates the interaction between different layers of intelligent agents and multi agent systems in the brain and this interaction can result into new properties of the system, called emergent properties.

Presentists believe that the experience of the flow of time is not subjective. All (healthy) human beings experience the passage of time. They also do *not* say that passage is something emerging from the way the mind works: that people experience the same passage because the human brains workings are roughly the same for every person.

Instead presentists believe that it is a physical property of nature that time passes. They want to add something explicit to the block universe that represents this feeling of flow, because they think experience can add new knowledge to the understanding of the physical world. Presentists use the argument of experience to say that the flow of time is mind-independent. They agree with emergentists that know-how knowledge adds something to the picture of time in physics. Again, they do *not* think that the feeling of the flow of time is emerging from the mind, but it is emerging from the fundamental physical laws.

Physicalists in general do not make this distinction between a mind and a physical object. A mind *is* a physical object. Both in the external world and in the mind, emergent properties can come into existence.

Presentists want to add a moving now to the block universe. Let us try to explicitly plug in this moving now (=flow of time). We can picture the present as one being illuminated out of many snapshots the block contains. But picking out a single instant of the block as the present does not provide us a moving present, and does not satisfy the intuition that we are directly experiencing a dynamic passage of time. To illustrate this, imagine a particle that moves with some velocity v through space. If we take a picture of this particle at one moment of time, we cannot deduce its velocity. We cannot know how much space the particle is travelling in one unit of time. We encounter a similar problem in the case of the illuminating snapshots: one snapshot cannot contain the property of change. The changing illumination of slices is a change over time. At one instant some slice is illuminated, while at a later instant another one is. We do not know at what rate the illumination changes. This is again a try to picture the feeling that time moves spatially. We have this feeling because we think about time using spatial analogies. We've seen in the first chapter that it is exactly the problem of the flow of time that the domains of space and motion

[34]Minsky, Marvin, *Society of Mind*, New York 1985

are incompatible.

The block contains everything that happens including each instant's being the present in the presentist's sense; therefore the instant must be the present. The same goes for any instant; therefore they all must be the present. In that case the present does not move at all, leading to the apparent contradictory situation of all times being simultaneously the present. For a present to move, it must have an identity through time, like an object has an identity through time. But then we are picturing the present as a moving thing that is at different positions in space, while it is not moving in space. Understanding the present as a moving object is again a product of conceptual blending. The same holds for the picture of the block universe.

One snapshot does not represent anything that ever happens, but the stack of slices as a whole does represent everything that ever happens. McTaggart's argument assumes that the property of being the present is the same property for every instant. Although every instant is the present at some time, this does not mean that there is a moment at which all instants have the property of being present. Presentists want a new picture of time. What many of them propose is a view according to which the block does not exist; what exists is restricted to the present alone, as a series of individual slices. But the block universe is a series of individual slices represented at once. It is impossible to try to add some dynamical feature to the block universe explicitly, because we picture the time dimension in the block Universe as a spatial line. Our experience of the flow of time is already within the block universe.

Reductionists would say that flow is subjective and emergentists say that it is objective, but both think that the mind and the external world are physical systems. If experience is regarded as objective, flow of time still can be either mind-independent or mind-dependent. If it is mind-independent, the flow of time is a property of the outside world. If it is mind-dependent it is something emerging from the human brain, but it still can be called objective (or 'inter-subjective' if you like), because all human beings experience the passage of time. From this we can conclude that the flow of time is an objective feature in the sense that all humans experience a flow of time. We still do not know whether it is a feature of nature or a feature of the human brain.

Presentists take the block universe picture too literally. It is an image-like representation. Since we picture the time dimension in the Block universe as a spatial line, we tend to add a second time axis that relates the rate of passage of time to something outside the primary time axis. But a second time axis, or a third or a fourth, does not make sense. Presentists do not seem to account for the fact that time in the block Universe is not pictured as a temporal dimension, but as a spatial dimension. We cannot introduce an illumination of spatial planes that 'moves' upwards along the time dimension.

An evolving/growing block universe, or a series of individual presents or the block universe itself, it all represents the same features of time. Is it really necessary to add something to the block universe?

2.3 Untensed and Tensed Views Reconciled

In this section I will argue on the basis of Steven Savitt's article *On Absolute Becoming and the Myth of Passage* that the first part of the problem of the flow

of time can be solved. The flow of time is already contained in the block universe picture of time in physics. It turns out to be unnecessary for the presentist to come up with a new picture of time in physics. The block universe is sufficient in describing the picture of time in physics. Although the laws of physics describe time in terms of a parameter t and no notion of past, present and future is involved, in the block universe there is. An interaction between particles always happens in the *now*, when the parameter t has the value t_1. At that moment the value t_2 of parameter t is future. At time t_2 the worldline of the particle in the block universe shows us the consequences of the collision that happened at time t_1. At this moment time t_2 is present and time t_1 is past.

2.3.1 Savitt on Absolute Becoming

According to Steven Savitt tensed and tenseless views on time are not so different from each other.[35] To make his argument he uses two well-known articles each representing one view that responds to McTaggart's famous argument for the unreality of time. In C.D. Broad's chapter 'Ostensible Temporality' of his book *Examination of McTaggart's Philosophy*, it is proposed that the transitory aspect of time can be explained in terms of a dynamic aspect of time called Absolute Becoming. D.C. Williams' paper *The myth of passage*[36] is against Broad's idea that there is something active or dynamic to time. Savitt writes:

> 'there is an area of convergence, or even overlap, between these two views that might help clarify the nature of passage of time [and the aim is to] indicate the nature and the importance of this common ground'.[37]

Savitt identifies the static-dynamic debate with the detensers-tensers debate to make his argument. Williams is a detenser who believes in the static view of time and Broad is a tenser who believes in a dynamic view of time.

It is very common in the literature on the philosophy of time to think that *detensers* believe in a *static block view* where no flow of time is represented because it is *mind-dependent*, and that *tensers* have a *dynamic* world view where the flow of time should be represented, because it is *mind-independent*. This is not correct.

Detensers do not per se think that the block universe picture implies a static view of time and they also do not per se think that the flow of time is mind-dependent. It is correct that tensers, both possibilists and presentists, prefer a dynamic view of time and that they think that passage is mind-independent. Savitt shows that the static view and the dynamic view of time can be combined in one block universe view.

Many tensers think that spacetime the way it is pictured in physics misses an important extra ingredient of our world: the flow of time. Williams writes that this extra ingredient is a myth. Passage is according to him an altogether false start. It is already within the manifold. True and literal passage is the *ordered occurrence of events* in the manifold; it is the happening of things.

While detenser Williams hardly mentions McTaggart's argument, Broad deals with it in great detail. McTaggart construes flow of time as something

[35] Steven Savitt, *On absolute Becoming and the Myth of Passage*, in: Craig Callender, Time, Reality and Experience, Cambridge University Press, 2002

[36] Savitt, *On absolute Becoming and the Myth of Passage*, p. 153

[37] Ibidem, p. 154

self-contradictory, but Broad argues that there is another way of construing passage, namely in terms of Absolute Becoming. McTaggart treats passage as a kind of qualitative change, but this is a mistake. Qualitative change relates to the 'qualia' mentioned before, which are properties of objects such as taste, warmth, color. Qualitative changes are changes of taste, warmth and color that can be different for different persons. Sentences like 'this water became hot' or 'this noise became louder' record facts of qualitative change. Savitt writes that according to Broad, McTaggart treats 'being present', 'being past' and 'being future' the same as the qualia 'being red' or 'red-ness', 'being hot' and 'being loud'. To strenghten his argument, McTaggart treats past-ness, present-ness and future-ness as absolute properties of events; like red-ness is an absolute property of a ripe tomato (nobody would say that a tomato is purple). But sentences like 'this event became present' do not record facts of qualitative change, but of 'Absolute Becoming'.

> 'The route to Absolute Becoming starts in a distinction between those aspects of time in which it is like space (duration being like extension), which Broad calls *the extensive aspect of temporal facts*, and a peculiar aspect of time in which it seems very different from space, *the transitory aspect of temporal facts.*'[38]

Tensers believe only the extensive aspect of temporal facts is contained in the block universe. The transitory aspect needs to be added to make the picture of time in physics complete. The transitory aspect can be described by Absolute becoming that is, according to Broad, the happening of events; it is the *ordered occurrence of events.*

Savitt concludes that there is no difference between Broad's understanding of absolute becoming and Williams' true and literal passage. He suggests that the claimed difference is no difference at all, but merely a verbal confusion. What is left of the static/dynamic difference in the block universe? There is none. The block universe view is both static *and* dynamic. We are still left with what might be called a static/dynamic difference in the discussion whether flow is mind-dependent or mind-independent. In this case people thinking that flow is mind-dependent are called static viewers and those who think it is mind-independent are dynamic viewers.

Savitt proposes that Williams' true and literal passage and Broad's Absolute Becoming is all there is to the passage of time. Both are assuming that passage exists, when defining passage as 'becoming': the ordered occurrence of events. Becoming is not a product of the human mind, but an external physical reality. Broad and Williams only quarrel about whether this 'true and literal passage' or 'absolute becoming' is already within the block Universe. According to detenser Williams there is passage, but it is nothing extra[39] that needs to be added to the block; it is already within the block universe picture. According to tenser Broad 'becoming' is something extra that needs to be added since the block is a static picture. Broad is right in the sense that change is not literally in the block picture, because the block is a spatial representation of spacetime. But Williams is right that there is change (passage) in what the block is a picture

[38]Ibidem, p. 158
[39]Ibidem, p. 157

of.[40]

The picture itself is an analogy and must not be taken literally. The analogy of the block universe picture of time in physics breaks down on what Broad calls the transitory aspect of temporal facts. The picture itself is static, but it represents a dynamic view of time. It is possible to have a static picture of a dynamic process.

William James[41] already wrote in 1890 that, in order to have an idea of succession, we need a representation of successive ideas/events *simultaneously* in the mind. If I think about an apple, I can think about the apple I see in front of me together with the memory of the apple I ate yesterday. Thoughts about the apple I ate yesterday and thoughts about the apple I am going to eat, are at the same moment of time, at present, in my mind. Still I know that the events of me eating an apple yesterday and me eating an apple a few minutes from now, are successive events.[42]

Now if we imagine all events everywhen and everywhere in the universe, I can still think about all of them and represent them in a spatial picture like the block universe, knowing the events are successive.

We have to be aware of the implications of using (static) spatial analogies to represent time.

In Savitt's words:

> [The quarrel is all about] 'confusing a static representation with a representation of stasis. If we learn from philosophers of mind, that "we must distinguish features of representings from the features of represented"[43], if we keep in mind that one dimension of this spacetime structure is supposed to represent time, that events occur at times, and that different events occur at different times, I think we should have no trouble in understanding that this static structure can represent a dynamic or unfolding world.'[44]

What does Savitt say about the mind-dependence/mind-independence difference? In the second part of his article he refers to Adolf Grünbaums classic paper 'The Meaning of Time' where Grünbaum argued that becoming or passage is mind-dependent, but he explicitly contrasted passage with serial happening of events. Savitt agrees with Grünbaum that events occur at various serially ordered clock times, and that nowness is not a property that hops from event to event, i.e. the now does not have the same identity through time. This is again a conceptual blend. Nowness cannot jump; in fact, it cannot move either.

Savitt disagrees with Grünbaum who writes: 'becoming (passage) involves more than mere occurrence at various serially ordered clock times'.[45] Savitt, admitting that the disagreement seems close to emphasis, would drop the 'mere' and would explain the absence of nowness from the mind-independent world by treating 'now' as an indexical, like 'here'. He says the occurrence at various serially ordered clock times is all there is to passage. The only thing that

[40]Ibidem, p. 162

[41]William James, *Principles of Psychology*, 1890, p. 629

[42]In Chapter 3 I will go deeper into the argument of experience and the role of memory and perception in the experience of the present.

[43]Savitt's citation from Daniel Dennett's *Consciousness Explained*, p. 147

[44]Savitt, *On Absolute Becoming and the Myth of Passage*, p. 163

[45]Ibidem, p. 164

passage involves more is now-ness, but now-ness is easy explainable: 'now' is just an indexical expression. Therefore, according to Savitt, absolute becoming is passage and is defined as the ordered occurrence of events. I agree with both Savitt and Grünbaum on that the experienced 'now' as a moving object is absent from the occurrence of events at various serially ordered clock times. The moving of the present seems to be mind-dependent. If you define the flow of time as the moving present, the flow of time seems to be mind-dependent. But if you define flow as becoming, which is the ordered occurrence of events, then it is mind-*in*dependent. The present is not included in the definition of Savitt, but what is its status? Is the notion of the present mind-independent or mind-dependent?

Objections from opponents of passage, according to Savitt, are only about models of passage that construe it as a kind of motion or as qualitative change. Those objections cannot be applied to the conception of passage as the successive happening of events. Broad says about absolute becoming that it is 'so fundamental a notion that it cannot be explained in terms of simpler or more basic ideas'.[46] Savitt agrees with Broad.

It might be that the experience of the 'now' can be explained in terms of simpler or more basic ideas. Is our experience of the present mind-dependent? Is the notion of the present constructed by the brain? Is Savitt right when he says that the 'now' is mind-dependent? In what sense is it mind-dependent? In the next chapter we will see what answers can be given on these questions from the perspective of the philosophy of mind and cognitive science.

But first we need to take a look at whether the definition Savitt gives for 'Absolute becoming' in Newtonian spacetime also applies to Minkowski spacetime.

Both tensers and detensers will agree that the events in the future will happen and that events in the past have happened. It is a mistake to deduce that in a block the events represented in the diagram exist simultaneously. One of the purposes of the block diagram representation is exactly to represent the temporal relations between events. Therefore it distinguishes between events that are future and past with respect to any given event. Only the present exists now: the detenser would not deny that. Tensers sometimes object to the block universe picture that it cannot accommodate change: that it leads to a static conception of the universe, because the universe is there at once. But all change is already present within. In this article Savitt used Newtonian spacetime to illustrate Absolute Becoming. In his conclusion he writes:

> 'Recognizing passage as no more (or less) than absolute becoming may help to solve some problems. [...] Good solutions raise problems too. If it does turn out that absolute becoming is the best way to understand passage in the spacetime structure described, [...] then passage becomes mysterious again as soon as one turns to the spacetime of special relativity, perhaps to other more general spacetimes. Minkowski spacetime could scarcely be less hospitable to absolute becoming, since its geometry does not admit a unique partitioning into the sets of simultaneous events needed to occur successively. General relativistic spacetimes most likely do not admit any privileged partition either. Can a differentiable manifold, then, provide 'the true and literal description of what the enthusiastic

[46] Ibidem

> metaphors of passage have deceptively garbled' [...]? This question seems to be the important and puzzling question concerning passage.'[47]

Recognizing passage as absolute becoming can be a good solution. Savitt argues that absolute becoming of the tenser Broad is the same as the literal and true passage of the detenser Williams. The only difference between the two is that Williams accepts the intrinsic existence of passage in the block Universe and Broad does not. They use the same notion of absolute becoming. The way that Savitt defines the passage of time (namely as the ordered occurrence of events that, according to him, does not include the 'now') is objective and mind-independent, because change is objective and mind-independent. The 'now' according to him, is mind-dependent. We will examine the mind-dependentness of the present in the next chapter.

We can conclude that it is not per se the case that tensers believe in a mind-independent flow of time and detensers do not. Detensers can believe that passage is mind-independent too, like Maudlin, and they believe that flow is already within the block Universe. If we ask ourselves to what extent Steven Savitt has reconciled tensed and tenseless theories, he only succeeded in reconciling the status of flow in the block Universe, but he did not succeed in giving a satisfying answer on the question whether flow is mind-independent or mind-dependent. A new argument against an objective 'now' comes from special relativity. There is no such thing as objective simultaneity. In the last part of this chapter we will investigate whether absolute becoming is still the best way to understand the flow of time in the spacetime structure of relativity theory.

2.3.2 Dieks on Local Becoming

In the picture of the block universe that is a spatial representation of Newtonian spacetime, time flows at a constant rate upwards along the time axis. We can picture the 'now' as a three-dimensional plane in the four-dimensional spacetime that moves. This picture fits into Newton's view of absolute space and time: everywhere in space (in the universe), the rate of the flow of time is the same and more important, the 'now' here on earth is the same 'now' as ten thousand light years away. And by the 'same' now I mean that the point in spacetime over there is part of the same universal plane of the 'now' as this point in spacetime over here.

In the case of same 'nows' over large distances in space, we can think of cosmic nows succeeding one another. This idea of succeeding cosmic nows is called global becoming. The present comes into existence everywhere at the same moment in time as seen on an absolute global time axis. How can it be that we use this idea of cosmic nows in cosmology, while we know from special relativity theory that simultaneity is relative: observers in different inertial frames can see events happen in different temporal order.

(i) First of all, intuitively the history of the universe must have occurred in a succession of events happening on a global time scale t. This intuition stems from Newtonian physics, in which compared to our daily velocities the velocity of light seems to be infinite (the visual simultaneity hypothesis mentioned earlier). Time is a succession of cosmic nows.

[47] Ibidem, p. 166

(ii) Secondly, more specific, because all visible parts of the universe must once have been in contact; cosmologists use the Friedmann Robertson Walker metric based on the cosmological principle which says that on a large scale the universe is homogeneous and isotropic. It must once have been started with one 'now': the becoming of the Big Bang. However, maximally symmetric models like the FRW solutions to the Einstein Equations, on the local level do not give a good representation of our actual realistic universe.

Dennis Dieks' paper on *Becoming, Relativity and Locality* (2006) continues where Savitt stopped. The question that is central is to what extent absolute becoming still holds in the spacetime structure of special and general relativity. Dieks uses the same definition of passage as Savitt does (passage = becoming).

in his article, Dieks first argues that from relativity of simultaneity in special theory of relativity we cannot say anything about distant simultaneity. All we know is that events that happen on almost the same spacetime points are coinciding, in other words: happening simultaneously. But the temporal order of events occurring at different spacetime points can be different for observers in different inertial frames. In his paper of 1905, Einstein[48] defined simultaneity as follows:

> '...We have to bear in mind that all our judgments involving time are always judgments about simultaneous events. If for example I say that the train arrives here at 7 o'clock, that means more or less, the pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events.[...]but the definition is no longer satisfactory when series of events occurring at different locations have to be linked temporally...'[49]

To illustrate this, Einstein uses the example of a clock A at location A and a clock B at location B. An observer at A can evaluate the time of events nearby A by reading clock A and the same for observer B reading clock B. But as Einstein says:

> 'It is not possible to compare the time of an event at A with one at B without a further stipulation. So far we have defined only an "A-time" and a "B-time", but not a common "time" for A and B. The latter can now be determined by establishing by definition the "time" required for light to travel from A to B is equal to the "time" it requires to travel from B to A. For suppose a ray of light leaves from A for B at "A-time" t_A, is reflected from B toward A at "B-time" t_B and arrives back at A at "A-time" t'_A. The two clocks are synchronous by definition if $t_B - t_A = t'_A - t'_B$.'[50]

We can write this definition differently: $t_B = t_A + 1/2(t'_A - t_A)$. Reichenbach (1957) generalizes this equation and argues that the value $\epsilon = 1/2$ is just a matter of convention. In other words: the amount of time elapsing can differ while traveling from A to B from traveling from B to A. According to Reichenbach relativistic theories with ϵ different than $1/2$ are empirically equivalent to the one using $\epsilon = 1/2$. Dieks calls Reichenbach's theory of simultaneity an epistemological critique; relativity of simultaneity is merely conventional; the value

[48] Einstein, Albert, *On the Electrodynamics of Moving Bodies*, Annalen der Physik, 17 (1905), pp. 891-921

[49] Einstein, *Electrodynamics of Moving Bodies*, p. 125

[50] Ibidem, p. 126

of ϵ is not a property of the physical world. This is in contrast to Malament's proof:

> 'that the $\epsilon = 1/2$ relation is the only plausible equivalence relation between events that can be defined from the four-geometry of Minkowski spacetime and a given inertial world line.'[51]

Dieks calls Malament's theory an ontological critique; the value of ϵ is part of physical reality. Any other value would give us a different reality. Apart from this discussion, Dieks presents a number of arguments to show that in relativity theory we do not need the idea of cosmic nows and a global flow of time to explain our common sense of the 'now'.

(i) First he states that experiences of observers are of such short duration and occupy such a small amount of space that they can be seen as point-like, which is a spatial expression. The 'now' is local.

(ii) Second, these experiences convince observers (tensers and detensers) that time flows or passes.

(iii) Third, because of the speed of light as maximum speed of causal signals, no events that are spatially separated from each other can influence one another.

From these arguments, Dieks concludes that local observations are invariant under different choices of the value of ϵ in the same way as they are invariant under different choices of coordinate systems. From this it follows that those human experiences that suggest that time flows, are invariant under different choices of ϵ. It does not matter for the existence of the flow of time, whether the relativity of simultaneity is conventional or not, i.e. what value of ϵ is correct. However, the fact itself, that simultaneity is relative, is important for our formulation of 'becoming'. Becoming is local and relative, like the present (and simultaneity) is local and relative.

Let us examine the relativity of simultaneity more closely with an example. If we want to tell something about the galaxy today and more specific about a planetary system some 10,000 lightyears away from our planet Earth, then we immediately get into trouble. What is today? We define a day to be the time in which the earth rotates once around its axis. Okay, you say, this is about 24 x 60 x 60 seconds and a planet X some 10,000 lightyears away rotates around its star in some amount of the same seconds. Yes, I say, but is this true? Are seconds everywhere the same, is the rate at which time flows over there the same as it flows over here, if it even flows? From our point of view, we can define a 'now' at the moment we observe planet X. As seen from our 'now' here on Earth, X looks like it was approximately 10,000 years ago when the photons left its surface. But we cannot see X as it is 'now', because that would take 10,000 years in the future before we can observe it. Because of the fact that no information can travel faster than the speed of light, spaces far away from each other are not in contact and also do not have a common now. We cannot speak about distant simultaneity; it is not defined.

By choosing a plane of simultaneity in Minkowski spacetime, we cannot say that one hyperplane marks 'becoming'. There are simply too many hyperplanes if we take every inertial observer into account. Every observer has his own plane of simultaneity. The choice of one plane of simultaneity is not coherent with

[51] Dennis Dieks, *Becoming, Relativity and Locality*, Philosophy and Foundations of Physics: The ontology of Spacetime, 2006, p. 159

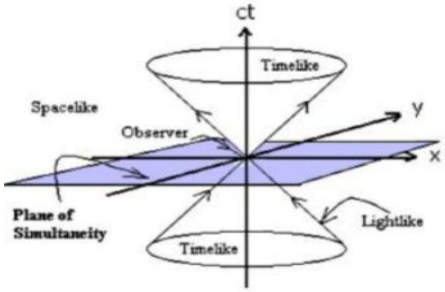

Figure 2.6: *A picture of the lightcone in Minkowski-space time. The hyperplane of simultaneity that has been drawn is a left-over of the Newtonian block universe and only correct from the view point of only one inertial observer. The hyperplane is spacelike and many hyperplanes of simultaneity can be defined different for different observers. The present or 'now' in Newtonian spacetime is a three-dimensional spatial plane, but the present is only a point in Minkowski spacetime.*

Minkowski spacetime structure. From this we can draw the conclusion that the 'now' is not one hyperplane of simultaneity. The 'now' is local and different for every inertial observer.

The example of the twin paradox shows us that time flows at different rates if you travel through space at different speeds. The faster you travel, the slower your proper time flows compared to the ones left behind on Earth. As long as you travel away from the Earth, both you and the people on Earth think that the other one's clock is ticking slower. But if you return to Earth, you definitely are younger than your twin brother who stayed at home and whose worldline followed a geodesic. The rate of the flow of time is different for different inertial observers, i.e. the rate of flow of time is local.

Another reason why we do not need only one hyperplane, is because we are no inertial observers on Earth. We cannot use the theory of special relativity and Minkowski spacetime, but we need the theory of general relativity. We live on Earth rotating around the sun that is rotating around the center of the galaxy. We are rotating observers and

> 'local einstein synchrony ($\epsilon = 1/2$) in a rotating system does not extend to a consistent global definition of simultaneity.[...] the so-defined local nows do not combine into one hypersurface. Therefore, orthogonality with respect to rotating worldlines cannot serve the purpose of defining a succession of global nows.'[52]

In contrast to what modern cosmology suggests, by defining a cosmic time, a succession of global nows cannot be defined in GTR. Solutions of the Einstein Equations exist, like the Gödel universe, where a global linear flow cannot be an essential feature. In the Gödel universe the hyperplane for an observer is crossed more than once by the temporal dimension: there are closed timelike loops. There is no global linear flow of time, only locally. The Gödel universe is a counterexample to a universe where the time objectively lapses. Whether time's flow is objective or not in our universe is the important question.

[52]Dieks, *Becoming, Relativity and Locality*, p. 161

If we exclude those exotic spacetimes like the Gödel universe from being physically possible, Dieks is going to find out whether a global now still cannot be defined.[53] In the Friedmann Robertson Walker metric it is possible to define a cosmic time t; the scalefactor a depends on t. The FRW metric is often used as a representation of our universe, but the universe is not homogeneous and isotropic; it is only by approximation. What we would like to have is a foliation of spacetime that does not assume our experience of time and our intuition of time, but explains them.[54]

The laws of nature have a local character and they do not need any notion of simultaneity. Global cosmic time t is irrelevant to our time experience.[55] Objective becoming is not a matter of top-down description; it is a bottom-up description. From processes on the small scale originates the notion of becoming, and people expand this notion to the whole universe believing intuitively in the existence of a global now.

According to Dieks (2006) it is impossible to give an unambiguous definition of global time. The definition of time t in physics is arbitrary.

> 'The bottom line is that cosmic time on any proposal is defined via a global description that has no bearing on what happens on a small scale. But it is exactly the processes on the small scale that lie at the basis of the idea that there is objective becoming. The resulting global time t is irrelevant to our time experience and the description of local processes.'[56]

From his solutions of the Einstein Equations, Gödel argued that time cannot be flowing in a physical way. He concluded that the flow of time is something 'ideal', not some property of the external physical world that exists independently of us.

> 'Change becomes possible only through the lapse of time. The existence of an objective lapse of time, however, means (or, at least, is equivalent to the fact) that reality consists of an infinity of layers of 'now' which come into existence successively. But, if simultaneity is something relative [as is implied by STR]... reality cannot be split up into such layers in an objectively determined way. Each observer has his own set of 'nows', and none of these various systems of layers can claim the prerogative of representing the objective lapse of time.'[57]

If there do not exist global nows, according to Gödel, the flow of time must be mind-dependent. But reality can also exist as an infinity of points of 'now' that form a worldline in the block universe.

Then Dieks asks himself how the denial of the objective existence of global time could lead to a picture that is at odds with our direct experience and to Gödel's conclusion that time flow is mind-dependent? To answer this he wants to find out whether there is actually something in the block universe that is in conflict with our time experience. Dieks asserts that this is hopeless, for reasons Savitt also mentions, which I have outlined above.

[53] Ibidem, p. 165

[54] See the section on Time and the Laws of Physics for the part on the debate of the status of natural laws. Callender in *What makes time special* offers an explanation by examination of the well-posed Cauchy Problem, that is not discussed in this thesis.

[55] Dieks, *Becoming, Relativity and Locality*, p. 167

[56] Ibidem, p. 167

[57] John Earman, *Bangs, Crunches, Whimpers, and Shrieks: Singularities and Acausalities in Relativistic Spacetimes*, Oxford University Press, 1995, p. 195

> 'It is the purpose of the four-dimensional spacetime picture, which the block universe is, to represent all events that actually take place in the universe, complete with all their properties and mutual relations. All actual events, experiences and intuitions must be there in the block representation. This is independent of whether or not global simultaneity exists.'[58]

So Gödel's argument for the mind-dependence of time's flow is too radical. The existence of a global now is independent of the correctness of the block representation, and gives us no argument in favor of or against the existence of the flow of time. Local becoming is contained in the block universe, but this does not say anything about its mind-independence or mind-dependence. You can place every intuition, thought, etc. in the block. The block universe contains the flow and the present, but does not explain what they exactly are. Dieks says about the 'now':

> The motion of the added 'now' is apparently a completely new concept, and we are at a loss to explain what it is.'[59]

I think that the theory of conceptual blending that is discussed in the first chapter might be able to explain what the motion of the 'now' is, and whether it is mind-dependent or not. In the next chapter we will see what other sorts of explanations can be given.

If we want to say something useful about becoming (coming into being the present, the flow of time), about whether it exists in the extern world, we should try to interpret it as something local. But what is then local becoming? According to Dieks, processes of becoming are nothing but the happening of events in their temporal order or the successive happening of events. His definition coincides with the one Savitt uses. Savitt defines Absolute becoming as, 'the happening of events; the ordered occurrence of events'. Due to the maximum speed of information, only local events can be within causal reach, so we must talk about the successive happening of local events and 'local becoming'.

2.4 Conclusions

The problem of the flow of time can be formulated into two questions: (i) Is the picture of time in physics complete without adding something extra that accounts for passage? (ii) Is the experience of the flow of time constructed in the human mind or is flow perceived through the experience of its physical (counter)part that exists in the external world?

In this chapter that discusses the picture of time in physics, I have proposed an answer to the first question: the picture of time in physics (the block universe) is complete. It contains everything: change as well as the past, present and future. The flow of time, that can be defined as the 'moving present' is contained in the block universe. We do not need to add anything, in contrast to what presentists claim.

We now have an idea of the status of the debate on the problem of the flow of time. We started with McTaggart, who advocated that time is unreal. He introduced the A- and the B-series that are foundational for todays tensed and

[58] Dieks, *Becoming, Relativity and Locality*, p. 169
[59] Ibidem, p. 174

tenseless views. Both tensers and detensers think that time is real, but they disagree with to what extent the past, present and future exist. Detensers do not attach a special meaning to the present. They think that the present is equally real as the past and the future. Tensers can be divided into two groups: presentists, according to whom only the present exists, and possibilists who think both past and present are real, but the future is not.

The tensed and tenseless views in essence boil down to the same thing. If the eternalist says that past, present and future are real, they mean that the past, present and future are in the block universe. The block is not a picture *in* time but a picture *of* time, that includes everything there *is*, *was* and *will be*. The presentists however draw a picture of what *is*, i.e. of what is *in* time. These two pictures of time are not different; they are compatible, only viewed from a different level. Often it is thought that the two views are precisely the opposite, and that is also how it is presented in the literature: presentists think only the present is real, and eternalists think all of past, present and future events are real (for simplicity, I skip the possibilist view, which is situated in between). It is not correct to state that eternalists are fatalists thinking that the future is already there at a present moment *in* time. Eternalists will not say that dinosaurs *are* real, they will say that they *were* real. As Savitt argues the difference between tensers and detensers are based on verbal confusion.

In my opinion the difference between tensers and detensers is not only based on a misunderstanding in language, but also on a misunderstanding of the role that space → time analogies play in our picture of time in physics. Analogies are not only used in language; analogical thinking is the core of human thinking. The importance is often underestimated.

The block universe is a spatial picture, and therefore the picture can impossibly be dynamic itself. It, however, does not represent a static picture, just as it does not represent something spatial; it represents a temporal picture of time, which is dynamic itself; things happen in temporal order; one event happens after the other. Picturing time by using spatial analogies does not mean that time is static and that the present is not a special moment in time.

If we picture time as a line and the points on that line represent events, then indeed we do not have a special point that tells us what the present is. And also this picture does not represent the dynamic feeling of the flow of time that we experience. It does not, because it is a spatial analogy. The concept of time in our minds is constructed from the concepts of motion and space.

I think that McTaggart when he thought of the A- and the B-series of time, precisely managed to unravel these two elements: the static measurement units (the B-series) and the moving objects (the A-series). These two series are indeed incompatible when thinking about them spatially: how can a line with permanent and static points be the same as a special moving dot at which point things come into being? Eternalists and presentists advocate exactly these two series. The 'static' B-series is used in science, because it can easily account for measurement of duration and the 'dynamic' A-series is used in experience, because it can account for our feeling that time flows.

Our concept of time is a mixture of these two series. If we step over this spatial line that represents the B-series and look beyond, we see that the B-series is a *temporal* series of events that *happen* one after the other. The B-series is an ordered series of events that occurred, are occurring and are going to occur,

like our worldline in the block universe is.

Savitt thinks that flow of time in the way he defines it, as ordered occurrence of events, does not contain the 'now', but it does contain change, of which he says it is mind-independent. Change is a feature of the physical world outside our mind.

The 'now' can be interpreted in two ways: first as the moment in time, at which events happen, and second, as the experienced present. Events occur only in the present; the occurrence of events is in the present. If we interpret the present in the first way, Savitt's definition of becoming does include the present. It does not include the experienced present, i.e. the moving now that hops from event to event.

From relativity theory we know that the 'now' in the first meaning (the moment at which events happen), cannot be globally defined. Observers can disagree on what happens 'now', because they have different hyperplanes of simultaneity. The 'now' is local, therefore the flow of time must also be local.

The question whether the block universe picture of time is complete, has been answered. The A- and the B-series represent the same concept of time. The tensed and detensed views can be reconciled in both Newtonian spacetime and relativity theory. There is no difference between the two views. The same spatial analogy we use to understand time creates the problem of the flow of time in the picture of time in physics; both the A- and the B-series are created from this analogy and show the incompatibility between the domains of space (B-series) and motion (A-series).

Now that we have solved this part of the problem of the flow of time, the question whether the flow of time (moving present) is mind-dependent or mind-independent is still open. In the next chapter we try to find an answer to this question.

Chapter 3

Perception of the flow of time in the brain

'Time present and time past
are both perhaps present in time future,
and time future contained time past.'
T.S. Eliot[1]

In the first two chapters of this thesis we handled two aspects of the problem of the flow of time.

In the first chapter, we discussed the role of analogical thinking in understanding the concept of time. We have seen that this role is often underestimated; metaphors and analogies are regarded only as a matter of language. In the first chapter it was shown that analogical thinking is not just a way to express ourselves, but that it is the way humans think. All kinds of scientific theories (physical theories, cognitive theories, etc.) are constructed by using analogical thinking. This is also true for theories of time, which are constructed from conceptual blends between the domain of space and the domain of motion. The concept 'flow of time' is a blend between the static measurement units from the domain of space and moving objects from the domain of motion. Some problems in the philosophy of time, like the problem of the flow of time, are caused by the incompatibility of these two domains. These problems can be solved if we understand the origin of the concept of time, and understand how we can solve the incompatibility.

In the second chapter, different views of time in physics were explained. We have seen that the recent debate originated from McTaggart's division in an A- and B-series of time. I argued that McTaggart already noticed the incompatibility that is described by the theory of conceptual blending when he classified the two series. The B-series of time is regarded as a static series where time points $t_1 ... t_n$ show the relations between linear ordered events $e_1 ... e_n$, e.g. e_1 is earlier than e_4, and e_n is later than e_2 and e_4. The A-series of time is regarded as a dynamic series where the moving present shows when events are past, present or future. e_1 first is future, then becomes present and after that becomes past.

[1] Minsky, *Society of Mind*, p. 60

The B-series of time shows the static measurement units from the domain of space in the blend of time. The A-series shows the moving object (=moving 'now') from the domain of motion in the blend of time. This incompatibility between the two series creates the problem of the flow of time. The picture of the four dimensional block universe is a generalization of the B-series. Both the B-series and the block universe do not show a static view of time, but contain change. Both representations might be static pictures, but they are not static *in what it is a picture of.*

The intuitive feeling that something like a moving now is not captured in the block universe can be explained by the theory of conceptual blending. Because both the B-series and the block universe show a static spatial picture of time that is incompatible with the picture of the moving now, the block universe intuitively seems incomplete.

We have seen however that the block universe is complete as long as the block is not interpreted as a static spatial picture. It also contains the flow of time, whether it is mind-dependent or mind-independent. Tensed and tenseless views on whether the flow of time is contained in the block universe can be reconciled.

In the previous chapter we have seen that the flow of time can be defined in two ways:

1. Flow of time is the 'moving present'.
2. Flow of time is 'becoming', which is defined as the 'ordered occurrence of events'.

According to Savitt change is objective and mind-independent. The 'moving now' is not contained in his definition of becoming, because the 'now' is not an objective property in nature that hops from event to event. What is 'now' depends on the point of reference of the observer and is an indexical, like 'I' and 'here'. The indexicals 'I' and 'here' are mind-dependent. Nature does not deal with the present, our minds do.

In this chapter we are going to find out whether Savitt is right when he says that the 'now' is mind-dependent and that it is not a property that hops from event to event.

I have argued in the first chapter that the block universe picture of time is not only a picture to talk about time in physics, it is also a mental picture of the way we understand time through spatial metaphors. The Argument of Experience is based on the intuitive feeling that the present is something that moves in time and that keeps the same identity through time, i.e. it hops from event to event. Presentists (tensers) use this argument to reject the block universe, because the moving present does not fit into a static block picture. The block universe is not static but seems static due to analogical thinking. Is the experience of a 'moving present' also constructed in the brain by perceptual processes like analogical thinking?

The question that is tackled in this chapter is whether the flow of time in the definition of the moving present is mind-dependent or mind-independent. Questions about the causes of the experience of a moving present that we shall address include:

- Can the experience of motion be created by the brain, without observing any motion in the outside world? If so, the 'moving' of the present might

also be mind-dependent. If not, the 'now' is a property that hops from event to event and the experience of its motion must have another cause than being constructed by the mind. The 'moving' of the present must be mind-independent. Two motion illusion effects will be discussed in section 3.2 (the Apparent Motion Effect and the Flash Lag Effect) to show whether motion can be experienced without observing real motion.

- Can the experience of the present be created by the brain without directly observing 'becoming' (the temporal order in which events happen in nature)? If so, the 'present' is mind-dependent. If not, there something in nature that might be called 'present' and is objective and mind-independent. Six models on the perception of the present will be discussed and they show the possible differences in the relation between the temporal content of perception (the representation in the brain of the temporal order of events) and the temporality of perceptual processing (the time it takes for the brain to process incoming stimuli and make a representation).

- Can the past, present and future be differently organized consistent with the laws of physics and the picture of spacetime? If so, Hartle says, the notion of the present might be a cognitive universal of Information Gathering and Utilizing Systems (IGUSs). If not, the notion of the present and the division of events into past, present and future are localized in spacetime, but they are *not* mind-dependent.

These three questions are important in this chapter to find out whether the flow of time is mind-dependent or mind-independent.

We will start with a short overview of the six different models that are based on three questions about the temporal content of perception.

1. Is the temporal content of perception an interval or an instant?

2. Is it a passive reflection or an active construction?

3. Is it purposefully delayed by the brain or not?

A delay means that the time represented as the present is delayed compared to the time at which the representation was made. This delay is purposeful, not when it is due to the processing speed in the brain, but when it is caused by mental mechanisms that alter the interpretation of the content of the stimuli. This alteration can cause illusions, e.g. motion illusions.

After briefly discussing the six models on the experience of the present in section 3.1, we shall focus on motion illusion first (section 3.2) and after that on the two versions of the doctrine of the specious present in section 3.3. Grush based two of these models on the doctrine that the experienced present (the temporal content of perception) is an interval.

While the first part of the chapter is concerned with the temporal content of perception (how the present is represented in the brain), the second part (section 3.4) is about the (temporality of the) perceptual processes themselves, especially about the mechanisms that the brain is using to construct the experienced present. Memory plays a big role in these mechanisms. We will see what different kinds of memory our mind uses to organize our experience in past, present and future. Then it is shown how information in the brain is stored in

neurons and neural networks. Further, when discussing the temporal integration window it will be explained that the brain not only represents the present as an interval, but it also uses a time interval of incoming stimuli for the construction of the present.

Finally, in section 3.5, on the basis of James Hartle's article *The Physics of Now* we will look at the possibilities of other ways we can organize our experience than in past, present and future, that are consistent with the laws of physics and the four-dimensional spacetime we live in.[2]

The chapter ends with a conclusion on what we can learn from neuroscience and cognition about the whether the moving present exists only in our minds or exists in nature.

3.1 Six models on the Perception of the Present

The six models on the perception of the present are based on six different theories examined by Rick Grush in his article *Temporal Representation and Dynamics* (2008). To classify these theories Grush distinguishes 'the time at which a representation is produced' (temporality of perceptual processes) from 'the time that the representation represents' (the temporal content of perception, i.e. the temporal order of events as it is represented in the mind).[3]

According to Grush the time that it takes for stimuli to be processed in the brain and the time at which a representation is made totally differs from the *temporal content* of that representation. Therefore the perception of the present cannot be explained by neural processes, i.e. the time it takes before neurons fire and how long they fire. Of course these neurons process the stimuli and are therefore crucial for the processing of the content of perception, but these transporting neurons do not *explain* the content, according to Grush.

What is it then that explains this content? Mechanisms other than the temporality of the neural processing, such as conceptual blending, memory and the temporal integration mechanism might construct the temporal content of the representation.

In these models, Grush only discusses the relation between the temporality of perceptual processes in the brain and the temporal content of the representation in the brain. He does not give a statement on how these are related to the temporality of the actual happening of events in nature (becoming). Therefore the domain p of temporality of the events in nature (that are represented in the brain by the representation $\hat{p}$) is not included in his models. So if $\hat{p}$ stands for the perceptual representation, then p stands for the domain that is being represented.

What is described by his models is the relation between the time that the representation $\hat{p}$ represents and the time that the representation $\hat{p}$ is produced. This relation is indicated by two subscripts separated by a slash, so that $\hat{p}_{a/d}$ is the notation for a perceptual representation produced at time d that represents what is (/was/will be) happening at time a. This notation shows the relationship between the time of the represented (a) and the time of the representing (d).

What explains this relationship?

[2] James Hartle, *The Physics of Now*, American Journal of Physics, 73 (2), Feb. 2005, p. 101

[3] Rick Grush, p.151

Imagine an event A that happens at time t_1 and an event B that happens at time t_2. We have seen in the previous chapter that, if events A and B are spatially separated, the temporal order of arrival of information of these events can be different for different observers, because the speed of light is finite. If observer X is spatially nearer to event B than to event A, information of event B reaches him before that of event A.

Therefore we imagine that both event A (a firing gun) and event B (a screaming man) happen at the same location in space. For all observers, event A physically happens before event B: firing the gun causes the screaming of the man. The information, such as electromagnetic waves and sound waves from these events, is travelling at the speed of light or slower towards the observer and the senses pick up this visual and auditory information. The visual stimuli arrive earlier at your eyes than the auditory stimuli arrive at your ears, because the speed of light is much larger than the speed of sound. The auditory stimuli catch up because they are transported quicker to the part of the brains where cognitive processing takes place. However, visual and auditory stimuli arrive at different times at this part of the brain. Let us call this the temporal order of arrival of information, $perception_1$.

Whether the brain accurately represents what really happened depends on workings of the perceptual cognitive processes. If the representation is passively made, then in the final representation (the experienced temporal order) the temporal order of the stimuli that arrived at the back part of the brain, is reproduced. If information of event B (seeing the man scream) arrived earlier than event A (hearing the gunshot), then event B is represented earlier than event A.

But if the brain uses mechanisms that can account for transportation speeds of the information and actively constructs a representation in which event A is represented as happening before event B, this processing takes time. The representation having the temporal content of t_1 and t_2 is produced at t_3. The representation is available for our consciousness and it is then that we perceive event A happening before event B. Let us call this $perception_2$. The delay of the temporal content of perception is caused by mental mechanisms that actively construct this content. It is the relation between the temporal content of $perception_2$ and at what time $perception_2$ is made that Grush describes in his models. The difference between the temporal content of $perception_1$ and the temporal content of $perception_2$, terms that I borrowed from Rebecca Roache[4], can be explained by the workings of the mechanisms in the brain discussed in section 3.4.

Grush assumes for simplicity that there is no delay in transportation and that the information that arrives at a time t_1 at the back of our brain for cognitive processing is what happened in nature at time t_1.

> 'there may be some small delay from neural processing or mechanical transmission, but those are not the subtleties I am concerned with, and I will henceforth make the simplifying assumption that there is no delay *of this sort* in perceptual processing.'[5]

[4]Rebecca Roache, *Mellor and Dennett on the perception of temporal order*, The Philosophical Quarterly, 49, 1999, p. 234

[5]Grush, p. 147

He therefore neglects the time it takes for signals to arrive at the back of our brain. This is an *un*purposeful delay.

A purposeful delay can be caused when the brain is actively processing the temporal content of perception. The brain waits for stimuli to arrive at later times than the times that are content of the representation. There are different ways to interpret the meaning of perception, as we have seen in what we called $perception_1$ and $perception_2$. Both can be described with the word 'perception', but the meaning is different. This also applies for the concept of 'experience'. 'Perception' and 'experience' are often mixed up, because the difference between the concepts is difficult to point out. Both experience and perception can be defined in two ways, in which knowledge-making plays a role in the difference between these two ways.

Experience can be defined as:

(i) Direct observational knowledge of the world. In this sense experience includes everything one has come to know or believe about the world by direct observation and without inference (no knowledge or believes from a book or from movies are included). In this version knowledge and believes are included in the definition of experience.

(ii) Only the sensory events that form the basis of knowledge and believes. The construction of knowledge and believes are part of the brain's perceptual processes and not part of experience. In this version something can be called experience at the moment information from stimuli arrives at the back of our brain for cognitive processes. This information might not become available for consciousness.

In the last definition the experience of objects or events is not epistemic, but in the first definition it is.

In the case of perception the same dichotomy splits up the different definitions. Therefore the concepts of perception and experience are often used rather loosely.

Perception can be defined as the extraction and use of information about one's environment and one's own body.[6]

If perception is defined as the information processed by the brain *prior* to the person's conscious awareness of it, it is possible that the temporal order of perceptions is different from the perceived order of events. Event B can be processed earlier than event A, because the velocity of sound and light differ and because sound in the auditory system and light in the visual system are processed differently. Still we can have a representation of event A happening before event B. This interpretation of perception is called '$perception_1$' by Rebecca Roache and matches with the second version of experience.

Perception can also be defined as only the information that is available for conscious reflection, either as it is received or as it is remembered afterwards. Although physically event B can be processed earlier in the brain than event A, cognitively event A can be perceived before event B. This sense of perception is called '$perception_2$' and matches with the first version of experience.

It is most common to refer to $perception_2$ when talking about perception, but neuroscientists often use $perception_1$. Only in $perception_2$, knowledge is provided.

[6]Ted Honderich, *The Oxford Companion to Philosophy*, Oxford University Press, 1995, p. 652

These two versions of perception later turn out to be important when discussing Grush' six models, because when ascribing his models to views of philosophers and neuroscientists he seems to be mixing up these different interpretations of perception.

The concept of *perceptual experience* that is often used in the literature on cognition and philosophy of mind, can be defined as observational knowledge based on the senses.[7] You get this concept if you blend the first version of experience with $perception_1$ and the second version of experience with $perception_2$. Perceptual experience, perception and experience can have the same meaning.

The experience of the flow of time belongs to what is being represented; the 'moving present' is content of $perception_2$. We are consciously aware of the moving present.

To summarize, the process that turns information from events into a mental representation of these events, can be divided in several steps:

1. events happen in nature;
2. transport of information through environment, body and the brain (perceptual *transportation* process);
3. $perception_1$: arrival of information at the back of the brain for cognitive processing at time(s) t_i (to t_k);
4. perceptual processes: mechanisms that can alter the content of information (takes time t_n - t_i)
5. $perception_2$: information that is available for conscious reflection = temporal content of perception that contains time(s) t_i (to t_k) produced at time t_n;
6. the representation produced in the previous step becomes conscious.

Grush' models present what happens from step 3 to 5, in which the temporal content of perception represents the temporal order of arrival of the information from events for cognitive processing. Because Grush assumes that there is no delay in steps 1 to 3, he can identify the times that events happen in nature with the times that information arrives at the back of the brain. For reasons of simplicity Grush assumes that the temporal order of arrival of signals (p), which is step 3, is the domain represented by the temporal content of perception ($\hat{p}$), which is step 5. This content is not always the same.

I will give an overview of the six models on the temporal content of perception Grush describes. For some of them a detailed discussion follows in the next sections of this chapter.

The Standard Model: punctuate, present and passive The first model is the standard view, in which the temporal content of perception is considered to be punctuated, present and passive, see figure 3.1. Because the mental mechanisms are passive and act like a mirror, $perception_1$ (step 3) is the same as $perception_2$ (step 5). The brain perceives time as a succession of instants.

If brains process stimuli instant by instant like a movie is build up out of snapshots, the perception of time has no duration. This is the first assumption

[7] Stanford Encyclopedia of philosophy, entry: *The contents of perception*, Susanna Siegel

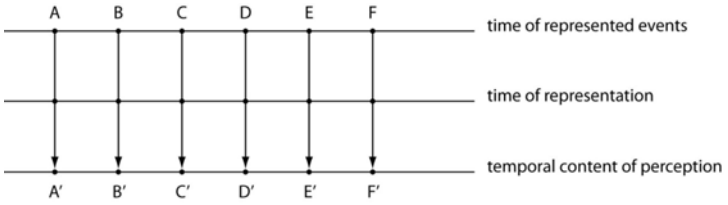

Figure 3.1: *The Standard Model of the perception of time: punctuate, present and passive ($p = \hat{p}_{t/t}$). In the figure, three time lines are shown, above: the represented events A, B, C, D, E, and F (step 1-3), in the middle: when the representations of the events are produced (step 4), under: the temporal content of the representations A', B', C', D', E', and F' of the events (step 5). In the standard model the time of the represented events p corresponds to the time when the representation $\hat{p}$ has been produced; so the making of the representation is present, and not delayed. The temporal content of perception ($perception_2$) also matches the temporal content of the represented events ($perception_1$). The mechanisms of step 4 are not active, but passive and only act like a mirror (middle time line). The events happen in successive instants of time, and the events are instant by instant represented in the brain.*

built into the standard view, Grush writes; the time represented in perception is the present instant instead of an interval ('punctuated').

Secondly, for simplicity Grush assumes that there is no delay due to neural processing or mechanical transmission. There are always delays of that kind, but they are minimal. As explained above a purposely-made delay is a delay caused by mechanisms other than neural processing or mechanical transmission. If there is no purposely-made delay, the perceptual processes map directly what enters the brain onto the mental representation. Therefore it gets the stamp 'present'.

In the standard view a purposely-made delay is not necessary, since there is no active construction either. Besides a 'present' content of perception, the standard model also has a 'passive' content of perception. This is the third assumption that is built into the standard view: the temporal content of the perception of the present instant is a reflection of the temporality of the perceptual processes themselves ('passive').

In the standard view the temporal content of perception is the same as the time at which the perception is made and the domain that is represented: $p = \hat{p}_{t/t}$, see figure 3.1.

The second model: punctuate, present and active The second model is punctuate, present and active. The temporal content of perception agrees with the time when the representation is constructed ($\hat{p}_{t/t}$), but the domain that is represented differs. Because p is not equal to $\hat{p}$, the model is active and can account for illusions. There are two types of illusions: past directed, which means that representations are made on the basis of something that happened *before* the stimulus appeared, or future directed, which means that representations are made on basis of something that happened *after* the time the stimulus has appeared. Besides information that is coming from stimuli, the

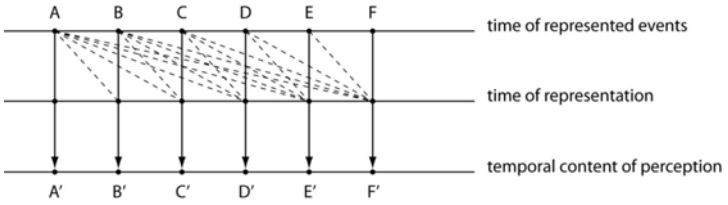

Figure 3.2: *The second model of the perception of time: punctuate, present and active ($p \neq \hat{p}_{t/t}$). The represented domain p (perception$_1$) can have a different content than the representation made of this domain $\hat{p}$ (perception$_2$). The mind adds knowledge from earlier events to this present. The time at which the representation is made however coincides with its content. The events happen in successive instants of time, and the events are instant by instant represented in the brain. This model can account for past-directed illusions (information from earlier events can be taken into account), but not for future directed illusions.*

mechanisms also process information from past events (from the memory).

In this model only past-directed illusions are possible, because what we perceive is not an interval over time, but an instant and directly in the present perceived. When perceiving the stimulus it might not be exactly the same as it is in reality. Since we assume that we do not have any delay in perception, the perception of the stimulus can only be affected by events happening before this stimulus.

Two examples of future-directed illusions, we will discuss in the next section. These illusions cannot be explained by this second model, because this model is present and punctuate and does not account for a delay or any expectations, see figure 3.2.

The third model: punctuate, delayed and passive The third model that Grush distinguishes is adding a purposeful delay to the standard picture: punctuate, delayed and passive. The representation of the temporal content $\hat{p}$ is the same as the represented domain p, but the temporal content does not match the time at which the representation is made due to purposeful delay: $\hat{p}_{t-i/t}$. Here is i the amount of time of the delay.

Adding a purposeful delay however has no function at all, when the temporal content of perception is passive and punctuate. Why does the brain need a delay, if it does not construct the experienced present any differently from the information it got from the stimuli? There is always a certain delay because of the time it takes for brains to process stimuli, but this is not the kind of delay meant here. When the temporal content of perception is passive, the brain does not have to construct anything from later sensory information. Therefore a purposeful delay has no function and this view has no proponents. This model will not be explained any further.

The fourth model: punctuate, delayed and active The fourth model is like the third, except for that it is active instead of passive. The temporal content of perception $\hat{p}$ does not exactly match with the represented domain p. Also the time at which the representation is made, is not the same as the tem-

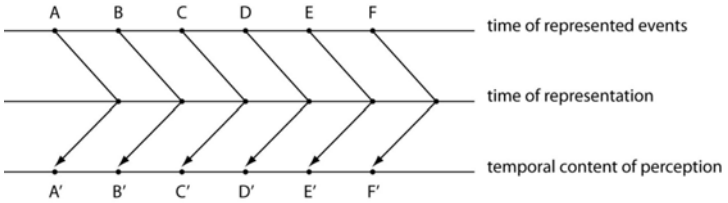

Figure 3.3: *The third model of the perception of time: punctuate, delayed and passive ($p = \hat{p}_{t-i/t}$). The represented domain p does not have a different content than the representation made of this domain $\hat{p}$, because the temporal processes (middle line) are passive. They act like a mirror. But the making of the representation is delayed. This delay has no function, because the experienced present is not constructed by the mind.*

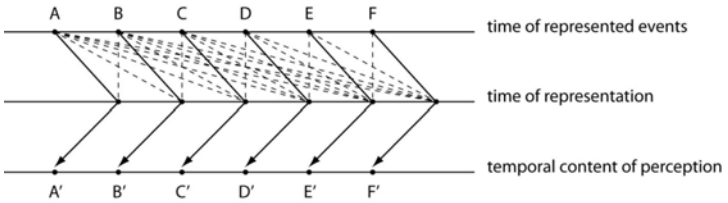

Figure 3.4: *The fourth model of the perception of time: punctuate, delayed and active ($p \neq \hat{p}_{t-i/t}$). The represented domain p and the temporal content of perception $\hat{p}_{t-i/t}$ are drawn as B-series where the points A and A', B and B', C and C', etc. are incoming stimuli from events and representations of these events respectively. The making of the representation is delayed. This is done such that the mind can correct the representation B' for event C happening after event B. The represented domain p has a different content than the representation made of this domain $\hat{p}$ and the temporal content of perception is also different from the time at which the perception is made. This model can account for both past- and future-directed illusions.*

poral content of this representation ($\hat{p}_{t-i/t}$). It seems plausible that the brain needs time for cognitive processing while producing an active representation. A reason for the brain to delay its mental representation of what is happening is to collect additional sensory information that arrives after the perceived event, in order to construct a more accurate interpretation. Grush ascribes this view to Eagleman and Sejnowski (2000). Their postdictive hypothesis can account for future-directed illusions in contrast to the second model and will be explained in 3.2.2.

The fifth model: interval and passive According to the fifth model, the temporal content of perception is an interval and passive and matches with the temporal content of the represented domain (p=$\hat{p}$). Not only the content of perception is an interval, but also the temporality of perceptual processes themselves is an interval, i.e. $\hat{p}_{[t-i,t+k]/[t-i,t+k]}$. Here, i is the amount of time before t where the relevant interval begins, and k is the amount of time after t

where the relevant interval ends.[8]

According to Grush, the fifth model reflects Barry Dainton's view if $k = 0$. Dainton claims that

> 'these intervals are superimposed, [and] that the reason that perceptual content comprehends a temporal interval is because the associated perceptual act manifests over that same interval.'[9]

We will see in the next section that Dainton indeed presents an overlap model that proposes that the temporality of perceptual processes itself is an interval. However, in my opinion, he does not cover whether the processes are active or passive and how they work. In the next section, I will argue that Grush has misinterpreted the meaning of what Dainton calls 'the phenomenal contents' as being the contents of $perception_1$ and I think Dainton refers to the phenomenal contents as the contents of '$perception_2$'.

Grush questions what actually distinguishes the fifth model from the first model. What is the difference of mapping a sequence of instants one-to-one like a mirror and mapping an interval one-to-one? A sequence of instants is an interval.

> 'A proponent of the Dainton view might respond as follows: the set $(\hat{p}_{t-4/t-4},\ \hat{p}_{t-3/t-3},\ \hat{p}_{t-2/t-2},\ \hat{p}_{t-1/t-1},\ \hat{p}_{t/t})$ contains distinct elements, whether they are called 'perceptions' or not. By contrast, the perceptual act $\hat{p}_{[t-i,t+k]/[t-i,t+k]}$ is not composed of any distinct units but is a holistic process, or something like that. I am not convinced that this would be any more than confusion, though.'[10]

The fifth model cannot account for illusions, because it is not an active model and it can be compared to the standard model. It looks like Dainton's model and it is a version of the specious present doctrine that argues that the present is an interval.

The other version of the specious present is James' model, in which the temporality of perceptual processes is an instant instead of an interval. The temporal content of perception is an interval, but the time at which the representation is made is not. This model can account for past-directed illusions, but it cannot account for future directed illusions. It does not contain a delay or an expectation. So the represented domain p has the same content as the representation $\hat{p}$, but the representation is made at time t, while the content of the interval is $[t - i, t]$.

In figure 3.6 you see that a representation of the present is produced at one moment of time in the brain, while the representation (the experienced present) is an interval: the specious present. Figure 3.5 represents the fifth model, where the present is also represented in the mind as being an interval, but the production of the representation is also made during an interval.

The sixth model: interval and active Last, Grush presents his own view where the temporal content is an interval and actively constructed by the brain. The represented domain p does not necessarily match the representation $\hat{p}$. The

[8] Grush, p. 151
[9] Ibidem
[10] Grush, p. 154

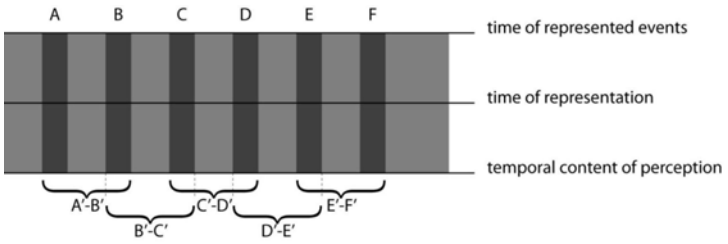

Figure 3.5: *The fifth model of the perception of time: interval and passive ($p = \hat{p}_{[t-i,t]/[t-i,t]}$) The temporal order of events is represented as overlapping intervals. The perceptual processes themselves take the same amount of time (interval $[t-i]$) as the temporal content of perception is. The represented domain p does not have a different temporal content than the representation $\hat{p}$ made of this domain, because the temporal processes (middle line) are passive. They act like a mirror. The events are directly represented in the mind, without any construction and manipulation from the mind onto this representation of the present. This model can account for the experience of motion, but not for the experience of illusions.*

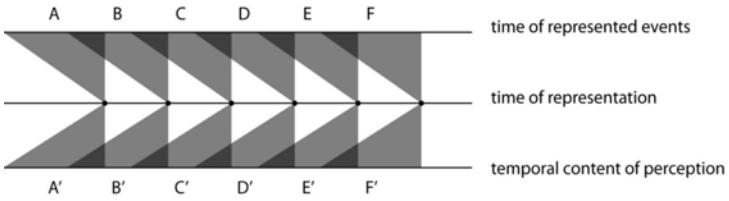

Figure 3.6: *James' model of the perception of time: interval and passive ($p = \hat{p}_{[t-i,t]/t}$). This model is the same as the fifth model, except that the perceptions are made at instants and not during an interval. Both models are different versions of the doctrines of the specious present. The experienced present (the temporal content of perception) is an interval, passively constructed from incoming stimuli that arrive in the interval of the same duration and without any delay. The information of these incoming stimuli is collected in the brain and then a representation is made at one moment of time that contains the same temporal content as the incoming stimuli. The fifth model, in contrast, acts like an intermediary, directly passing the information such that the representation as a whole of the interval is made part by part.*

temporal content of perception is not the same as the temporality of the perceptual processes. Grush model $\hat{p}_{[t-i,t+k]/t}$, is like James' model except that in James' model $k = 0$ and Grush thinks $k > 0$. He calls it the Trajectory *estimation* model, which distinguishes between two different kinds of representational state involved in experience, sensation (information picked up by sense organs) or $perception_1$ as I call it and perception itself (interpretation eventually reached) or $perception_2$ as I call it.[11] Rick Grush combines the two theories of Eagleman (active and delayed) and James (interval, but no interval in the temporality of perceptual processes) and takes the best of the two to construct a new theory of the experienced temporal content.

His model appears to be the only one out of six that can accommodate future oriented temporal illusions without positing a costly delay in the processing. The future-orientated temporal illusions that Eagleman explains by the postdictive model, Grush explains by a combination of filtering, smoothing and prediction, hence the name Trajectory Estimation Model. These cognitive processing mechanisms can produce representations $\hat{p}$ of the represented domain p as it was or will be at times other than the present.

Filtering is the process where knowledge-based expectation can be overridden by sensory information, and likewise sensory information can be overridden by expectation. When having knowledge about how the domain typically behaves, the mechanism can project ahead in time, such that a prediction $\hat{p}_{t+1/t}$ is constructed.

Smoothing involves combining the estimate that was produced at earlier times with some back-tracked versions of later times, such that the smoothed version is different and often better than the original filtered estimate. Backtracking is the process where the brain makes a new representation on the basis of new information, for example stimuli coming from the flash at place C, and infers how the earlier stimuli have to be represented. Not every estimate is available for consciousness. So what Grush suggests is that the brain uses both prediction and postdiction all the time. The brain makes an estimate and represents this estimate, but it keeps the estimate up to date with new information and even can interpret older stimuli differently through back-tracking. It literally tracks back what different interpretations of older stimuli are possible and keeps making new representations. Some of them come to the surface of consciousness.

In figure 3.7 it is shown that the content of perception involves a combination of information of incoming stimuli and estimation based on this content.

While Eagleman in the fourth model posits a delay all the time, Grush only posits this delay when necessary in the case of back-tracking. So representations are continuously made, but only of some of them we are aware. The brain decides somehow when a representation is ready for consciousness, and no further information is needed to sharpen the representation. It is not clear how the brain decides when a delay is necessary.

The next sections will describe which of the six models is most plausible by giving answers to the three questions Grush has defined. The section on the experience of motion shows that the three passive models described above are

[11] Rick Grush, *Temporal Representation and Dynamics*, New Ideas in Psychology 26 (2008), pp. 146-157

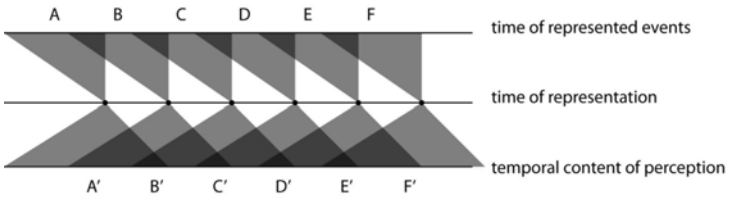

Figure 3.7: *The sixth model of the perception of time: interval and passive ($p \neq \hat{p}_{[t-i,t+k]/t}$). The content of perception involves a combination of information of incoming stimuli and estimation based on this content. Incoming stimuli that arrive in intervals are integrated and perceived ($perception_1$) as simultaneous, but the representation of the present is constructed from this $perception_1$, memory and expectations. Therefore the temporal content of perception ($perception_2$) contains backtracked and estimated information. The represented domain p, for example the interval A, has a different temporal content than the representation made of this domain $\hat{p}$, the interval A', because the temporal processes (middle line) are active. This model can account for both past directed and future directed illusions.*

incorrect. We will see that motion is not passively copied from what the brain received from the senses, but it is actively constructed by the brain even when no stimuli from moving objects arrive in the brain.

3.2 The experience of Motion

We will now discuss two illusions, the apparent motion effect and the flash lag effect, to show how the mind can manipulate the experience of motion. In some situations we perceive motion of an object, while in reality this object is not moving at all. Instead different objects that look the same are shown in different places at different times. When these places A and B and times t_1 and t_2 are close enough together, the objects are merged by the brain as being one object that moves from A to B. This is the *apparent motion effect*. How narrow the distance between places A and B is and how small the duration between t_1 and t_2 is, depends on the width of the temporal integration window. The mechanisms that can alter the width of this window will be discussed in section 3.4.3.

In situations where a moving dot and a flash are shown at the same time t and same place K, the moving dot seems to be processed quicker by the brain. The dot is perceived to be moving through K earlier than the flash is shown at K. This is the *flash lag effect*. The moving dot is not processed any quicker than the flash. The stimuli of the moving dot and the flash arrive at approximately the same time in the brain. But because the brain has already received information from the moving object at earlier times, it can make an expectation and correct for the delay in content at the time that the representation is made. It cannot correct the delay for the flash, because the brain does not have any information from earlier times that come from the flash. You would expect the brain to have some estimation of the moving object. Grush argues there is, but Eagleman and Sejnowski argue that there is no prediction but postdiction.

We have already seen in the first chapter that the concept of time is constructed from the blend of moving objects and static measurement units. The motion of the present as an object might be an illusion if we show that the experience of moving objects themselves are sometimes illusions constructed by the brain. The evidence is not conclusive, because we do not know for sure if the motion of the present is also an illusion; but it seems very plausible.

3.2.1 The Apparent Motion Effect

Nick Huggett, who is mainly a philosopher of physics dares to step into the field of cognitive science to show how the experience of dynamism can be explained as a feature of the succession of events *in* time and not of some feature *of* time. Time is not fundamental, Huggett says, but the arrangement of and relations between particles are. Huggett agrees with Savitt when he says that the succession of events (becoming) already contains the feature of 'changeyness'. According to Huggett it is not the moving present that is contained in the block universe, but the block contains the changeyness that is a feature of events. The experience of the moving present is a misinterpretation of changeyness as motion, because we think of the present as the same object at different points (places) in time. Motion is defined as having a series of experiences of something at different places. So to speak about motion, we need two conditions. First, an object or thing that keeps its identity through time and second, we need the object to be at different places through time. Because of the conceptual blend of the domains of space and motion, these condition are satified when we think about the present: we think of the present as an object that hops from event to event (spatial analogy) and that keeps its identity through time.

> 'The point is *not* that just because our experiences of motion can be wrong, they aren't reliable indicators of a moving present. The point is that we know that mechanisms in the brain detect motion, and the illusions show how those mechanisms correlate with our characteristic experience of the 'changeyness' of motion. This striking aspect of experience, which many have thought could only be of some feature of time itself, can be understood without postulating anything beyond the mechanisms.'[12]

It is changeyness that causes the experience of dynamism. Changeyness of events does not per se constitute motion. But in the apparent motion effect it will be shown that changeyness can be misinterpreted by the brain as motion. This argumentation will undermine the most important intuitive motivation for the moving present: the argument of experience.[13] If motion can be an illusion, our experience cannot teach us about the moving present. Huggett's main argument is that the experience of dynamism as a 'flow' can be actively constructed by the brain only by the observation of changeyness.

He illustrates this by a generalization of the apparent motion effect. The apparent motion effect is the illusion that an object at place A at time t_1 and another object shown at place B at time t_2 is one and the same object that *moved* from place A to place B in the temporal interval t_1 to t_2. So it is perceived as if the object is also in the intermediate places, while it is not. If the object is shown in place A again and then in place B again and so forth, it seems to

[12] Huggett, *Everywhere and Everywhen*, p. 94
[13] Ibidem, p. 93

be moving back and forth from A to B and back from B to A. But, as George Mather recently has shown, this apparent motion effect can be extended to an infinite loop of motion in one direction. All we have to include is a negative of the object at place C and show the object at place A, B and C in a loop.[14] He used a loop of pictures that show objects at different positions, instead of real sparks or objects. Huggett refers to Mather's website.[15]

When we watch a loop of two pictures from a movie of something that moves forward, we constantly see this switching of pictures forward and backward. But when we insert a negative picture or an empty frame in the loop after the second picture, we see something that is moving constantly forward, while not getting anywhere. We are in loop without recognizing immediately when going back to the first picture again. The forward motion is something we experience, but is not real.[16]

Because the color of the first two pictures in the loop contrasts with the third, the pause after the second picture is too long to detect the shift towards the first picture again. The arrival of stimuli from this event, namely the shift towards the first picture, does not fall into the interval of the temporal integration window. The temporal integration window is a mechanism that works on the stimuli that arrive at the back of the brain. If these stimuli come in an interval, which is the represented domain p represented by the brain as the experienced present $\hat{p}$, this does not mean that this representation itself, namely the experienced present $\hat{p}$, is an interval or an instant. Whether the experienced present is an interval or an instant is answered in the next section.

In the temporal content of perception $\hat{p}$, no backward motion is detected. The brain does not recognize the jump backwards of the object in the picture, because it falls in between two intervals. It only infers forward motion. It seems to take longer for the brain to process the negative or empty frame than it takes to process the two normal pictures. Something that differs from what was shown earlier seems to take longer to process. But this is not true, as we will see in the case of the flash lag effect. What was earlier shown can be inferred and therefore already represented, even when the stimuli coming from that object are not processed yet. When stimuli arrive from a totally different picture, impossible to infer by the brain, through back-tracking it will correct for this negative. The appearance of the negative 'resets' the interval and therefore the brain loses the reference between seeing picture two and then picture one (backward motion). Forward motion is inferred from constantly seeing picture two *after* picture one (forward motion) and not seeing picture two *before* picture one (backward motion), because the negative is in between.

This is a visual example, but there is also a famous auditory example: the Shepard tone. Here we have tones instead of pictures, which *appear* to be continuously higher and higher in frequency. These tones are played cyclic, like the movie that consists of three frames is played cyclic too. Every tone is a

[14] $http://www.lifesci.sussex.ac.uk/home/George\_Mather/Motion/$

[15] Huggett, *Everywhere and Everywhen*, p. 95

[16] You might say that in a sense it is no illusion at all, because there really is a forward progression of images in time. But we are talking here about motion illusion of objects and not about the motion illusion of time itself, because the last is what we indirectly want to show by using the first. There is change just as in the case with the sparks, but there is no motion of one and the same objects. That the motion of time itself is an illusion is hard to prove directly, unless as explained above, we have a theory of conceptual blending that constructs the concept of time through blending static measurement units and moving objects.

combination of a loud version of one frequency, that gets slightly quieter in the cycle of tones, and its almost inaudible partner an octave higher or lower, that gets slightly louder in the cycle of tones. The role of negative in this example is played by the last tone, that does not consist of two frequencies, but of three frequencies of the same tone. An example of an ascending Shepard scale is: the first tone could be an almost inaudible C(4) (middle C) and a loud C(5) (an octave higher). The next would be a slightly louder C#(4) and a slightly quieter C#(5); the next would be a still louder D(4) and a still quieter D(5). The two frequencies would be equally loud at the middle of the octave (F#), and the eleventh tone would be a loud B(4) and an almost inaudible B(5) with the addition of an almost inaudible B(3). The twelfth tone would then be the same as the first, and the cycle could continue indefinitely.

It is easy to suppose that to experience motion we need to have series of experiences of something at different places. According to Huggett adding a single moment (the negative frame) in the series influences the experience of motion in being uni-directional, instead of back and forth.

When dealing with an apparent motion affect, we certainly need to observe the flash at place C before constructing to have seen a motion of the flash going from A at time t_1 via B at time t_2 to C at time t_3. According to Huggett the 'changeyness' of the experience of motion leads people to propose that we have direct perception of the passage of time.

He ascribes the experience of the moving of the present to the brain's mechanisms that misinterpret the feature changeyness of events. The experience of the flow of time in contrast to (static) spatial variation is mind-dependent.

3.2.2 The Flash Lag Effect

Another well-known motion illusion, often referred to in cognitive science when discussing time perception, is the Flash Lag Effect. The flash lag effect is not creating motion from non-moving objects, but it shows that a moving object seems to be processed quicker by the brain than a flash. It is an example of the temporal integration mechanism of the brain that does not always successfully reproduce the objective temporal relations.[17]

The Flash Lag Effect is the visual illusion wherein a flash and a moving object that are presented at the same location are perceived to be displaced from one another (see figure 3.8[18]). There are a variety of explanations for the Flash Lag Effect: some say that flashed objects take longer to reach awareness than non-flashed continuously moving objects. The view that the visual system processes moving objects more quickly than flashed objects corresponds to the *latency model*. According to others the visual system uses motion extrapolation to predict the position of moving objects (predictive model). This model is also supported by Grush, but it does not seem to account for the results Eagleman and Sejnowski found.

Eagleman and Sejnowski (2000) presented a new hypothesis concerning the

[17] Eagleman, David M., & Sejnowski, Terrence J., *Motion Integration and Postdiction in Visual Awareness*, Science vol 287, march 2000, p. 2036-2038 and at http://neuro.bcm.edu/eagleman/flashlag/

[18] http://neuro.bcm.edu/eagleman/flashlag/overview.html

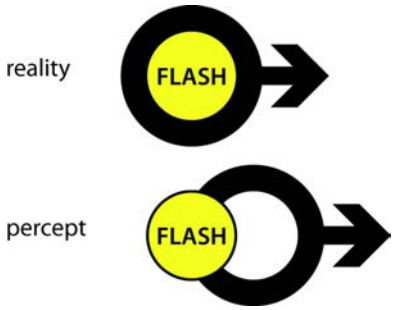

Figure 3.8: *While the flash and the moving ring are presented at the same place at the same time, the flash is perceived to be lagging behind the moving ring.*

flash lag effect.[19] Instead of two previously proposed explanations, the predictive model and the latency model (an online model), they proposed a postdictive model, which is not online, but purposefully delayed. The online processing mechanism directly perceives the present as it is in nature without any *purposeful* delay. Offline models use expectations or a purposeful delay. The latency model also deals with a delay, but that is caused by the difference in processing speed, which is an unpurposeful delay as Grush would call it. He neglects this kind of delay. The flash is delayed, but there is a passive one-to-one copy mechanism in the brain without any significant manipulation by the brain itself. Eagleman and Sejnowksi propose a postdictive model: what happens approximately 80 ms after the flash influences how the flash is perceived.

The idea in the predictive model is that the trajectory of the moving object is already extrapolated, while the flash is not. So the brain expects the moving object to follow a certain path, and takes the prediction into account, i.e. the brain anticipates on the delay that is going to be caused by the processing of the visual stimuli. The flash however suddenly appears and therefore cannot be predicted.

According to Eagleman et al. this predictive model is not correct. In psychophysical experiments they showed that participants perceived the flash to be at the opposite place when the moving object was reversed at the time of the flash, instead of following the original trajectory. This implies that not the trajectory of the object *before* the flash is used to infer the motion of the object, but the trajectory *after* the flash. This reverse in directions was never used in research on the flash lag effect before. It shows that the brains are delayed. They first sense both the flash and the motion of the object and afterwards they correct for the motion but not for the flash. This is the reason why the flash is perceived to be at a different place from the moving object, while in reality both the flash and the moving object are at the same place at the same physical time. Motion extrapolation is untenable and only events after the flash determine the perception. What does this say about the relation between the experienced present and the happening of events in reality? In the case of the flash lag effect, the experienced present is delayed and actively constructed by the brain afterwards. If objects are not moving, they can be perceived as though

[19] Eagleman and Sejnowkski, *Motion Integration and Postdiction in Visual Awareness*, p. 2036

they are. The brain is adapted to the observation of moving objects.

So there is no prediction, but postdiction. Further, Eagleman et al. discovered that this lag is appearing when there is a 67 to 80 ms of movement in one direction necessary to approach the illusory displacement. As the amount of time before the reversal is reduced the illusory displacement is lessened and when reduced with only 26 ms the flash lag effect is cancelled out. Most of available literature assumes that motion integration would occur over time before the flash, but their data indicates that the visual system integrates information after the flash. This pleads for delayed perception. This theory is also supported by the apparent motion effect where the spark is only perceived to be moving after both sparks at place A at time t_1 and at place C at time t_3 are shown. A delayed and active model accounts for future directed motion illusions, like the apparent motion effect and the flash lag effect.

To test the latency hypothesis, they gave the flash a temporal advance. These stimuli were separated by a asynchrony ranging from 0 to 53 ms. In some conditions the flash and the ring appeared at the same time (simultaneously), at others they appeared with a variable delay (13 ms $<$ t $<$ 53 ms). The flash' duration was 13 ms. But regardless of the advance of the flash, participants still saw the flash lagging behind in position compared to the starting position of the ring. The flash resets motion integration: even when the flash is given a head start, it is still perceived to be lagging behind the moving object.

The conclusion is that both the flash and motion take time to process, but the motion is postdictively corrected, while the perception of the flash is not. In addition, the delay of the brains is approximately 80 ms.

Future oriented temporal illusions, such as the moving object that seems to be predicted in contrast to the flashed object, can be explained by Eagleman's *postdictive* model. There is no prediction, there is only postdiction in combination with a purposeful delay. Eagleman's model that describes a punctuated, delayed and active present is the fourth model that was discussed above.
The existence of the apparent motion effect shows us the possibility of how the 'motion' of the present can be an experience that is created by the brain, instead of some feature of nature. Motion is experienced without receiving stimuli from moving objects. This shows that the brain makes an active representation of moving objects. Since we have seen that to understand the concept of time, moving objects are blended with static measurement units, it is plausible that the brain translates from what belongs to the experience of moving objects into the experience of the moving present. The present itself is by the brain represented as an object, and therefore it can be experienced as moving either. The existence of the apparent motion effect might point towards a mind-dependent moving of the present. If the present is not moving at all and its motion is constructed by the brain, this might give us a clue that the moving present is itself mind-dependent. Because we defined the flow of time as the moving present, the apparent motion effect points towards a mind-dependent flow of time.

The existence of the flash lag effect shows us the arguments for the fourth model that Grush describes; Eagleman and Sejnowski found that stimuli from the motion of the object *after* the flash are used to make the representation. The mind uses a purposeful delay to keep the representation of moving objects up-to-date. Information of the flash and the moving object arrives at the same time

for cognitive processing, but the moving object seems to be processed quicker, such that flash is perceived to be lagging behind spatially on the moving object. The brain actively corrects for the perception of motion.

The flash lag effect can also be explained by Grush' model of prediction and back-tracking. The brain makes estimates of future positions of the moving object and corrects this through smoothing. A flash cannot be predicted and not be backtracked. Both Eagleman's model (fourth model) and Grush' model (sixth model) can account for future-directed illusions.

These motion illusion effects show that we can perceive motion without receiving stimuli from moving objects. Both illusions show that the experience of moving objects is a default setting in the brain. The apparent motion effect shows that motion is represented while there is none. The flash lag effect shows that the brain corrects for motion, but not for the flash.

Correction is the change of the temporal content of $perception_2$ by the brain to account for the time its perceptual processes have taken. Huggett agrees with Savitt that becoming includes change and that it is mind-independent. Now that we have seen that the motion of the present is probably mind-dependent, what about the experience of the present itself. Is the present mind-dependent or mind-independent?

To find this out, let us look at another theory on which Grush based his model: the doctrine of the specious present. The temporal content of perception, according to him, can only be an interval instead of instant. Grush' interpretation of Eagleman's and Sejnowski's postdiction model is that they think of the temporal content of perception as an instant, because of the delay they introduced. But in their article they do not explicitly say whether the perception of the present is an instant or an interval.

3.3 The experience of the present: two versions of the doctrine of the Specious Present

Grush asks himself how we can perceive motion if the temporal content of perception is an instant. It depends on how we interpret the temporal content of perception. Since perception is often interpreted as either $perception_1$ or $perception_2$, you can interpret perception as either an instant or an interval. The experience of motion is a product of $perception_2$, just as the flash lag effect is. Theoretically speaking we cannot perceive motion if the content of perception is an instant. Motion occurs in an interval and not in an instant. We experience motion because motion can be actively constructed using expectations and very recent memories from the short term memory, as will be explained in the next sections of this chapter.

Transportation of information through environment, body and the brain, i.e. the perceptual *transportation* process, is what makes $perception_1$. The temporal content of $perception_1$ consists of stimuli that arrive within a certain interval: the temporal integration window. This window is also called the window of simultaneity. The width of this window depends on the transportation speed of your neurons in the brain. This transportation speed is not infinitely fast. Everything that happens within a certain distance and duration are merged together as being one event. Let us illustrate this with an example. Put your

finger in front of your face and move it up and down as fast as you can, while your hand keeps still. You do not see exactly anymore where your finger is at every moment; instead you see a spatial extension of your finger that is actually temporal. You get the same effect with the colors if you spin around a top. This is what you get when images of spatial objects at a series of instants of time are plotted on top of one another. It seems as if you see your finger up, down and in between simultaneously! The window of simultaneity thus represents what is happening in an interval as being simultaneous (an instant).

This is meant when the present is perceived as an instant. I think that Eagleman and Sejnowski did not explicitly write about whether the temporal content of perception is an instant or an interval. But if Grush reads in their model an instantaneous representation of the temporal content, I think this is because they interpret perception as being $perception_1$, the stimuli that arrive within a certain interval that are integrated as happening at one instant of time. This content of the temporal integration window can alter through mechanisms in the brain that produce a representation that contains an interval because of the mechanisms of filtering, smoothing and prediction that Grush described. This is $perception_2$.

Every event within this integration window is produced as being simultaneously, as happening at the same time. So we have the interval of the memories that we use to construct a representation and motion and we have a much smaller interval that we use to construct what seems to happen simultaneously.

The window of simultaneity is an interval that is much smaller than the interval Grush interprets as the temporal content of perception. If our temporal integration window would be very large, we would observe the world like Tralfamadorians do. The neurons in our brains would transport everything very slowly and we would observe humans who have two legs as long millipedes.

There is a difference between the processing speed of our neurons (step 2) that produce $perception_1$ being an instant and the interpretation mechanisms of our brain (step 4) that produce $perception_2$ being an interval. During step 4 the content of the temporal integration window is changed by perceptual processes such as temporal integration mechanisms. This is $perception_2$, constructed from interpretations and expectations, backtracking and memories, before it comes into consciousness. This explains the difference between Grush model and Eaglemans model.

Grush explains his argumentation against the 'punctancy' assumption, the perception of the present as an interval, by the example of the hour hand and the second hand of a clock. We do not directly perceive the motion of the hour hand; we infer from our memory that it moves very slowly, but we do perceive ($perception_2$) the second hand's motion. It turns out that we 'know' through our Long Term Memory that records the temporal order of events that the hour hand of the clock moves.

> 'The second hand's motion takes time, and so if the temporal content of my perceptual experience is merely an instant as the punctancy assumption holds, then I will not, ever, perceive motion or change.'[20]

We perceive motion using our short-term memory, in which succession of instants are remembered and merged by the brain into one perception. Such

[20] Grush, *Temporal Representation and Dynamics*, p. 147

events occurring within the interval of these series of instants are experienced as present.

The duration of the present is often related to the 'specious present'. The doctrine of the specious present can be defined as the view that a group of events experienced as being present contains successive events that span an interval.[21] The 'specious present' is the representation of the present as an interval; the experienced present is an interval. From the domain that is being present successive stimuli are used. Earlier stimuli are remembered.

The present (in the represented domain), in contrast to the experienced present, is defined as an instant. Time is composed of past and future divided by an indivisible point or instant. The experienced present is specious in that it is an interval and not a durationless instant.

We have two ways to articulate the doctrine of the specious present. The first version of the doctrine is held by William James who made the notion of 'specious present' famous in his book *The Principles of Psychology* (1890): *at each moment* the content of perceptual experience includes a temporal interval, see figure 3.6. The representation of the experienced present is made at one moment in time: $\hat{p}_{[t-i,t],t}$. Between these different moments in time at which the representations are made, there is no connection or overlap. James' model is a snapshot lapsing interval. According to Dainton, a snapshot lapsing interval still is a static configuration. This is a problem and his overlap theory proposes a solution. But both Huggett and Grush do not see these discrete moments at which representations are made as a problem: as long as the temporal *content* of the representation is not discrete. We even need these discrete moments such that we can account for future-directed temporal illusions.

Dainton's view is that perception itself is a process that takes place in time, and that the perception of the present cannot be explained by a snapshot lapsing interval. The representation in the mind occurs *not at one moment*, but is an interval too and those intervals somehow need to be connected too. One can see the second hand's motion, and this is because the act of perceiving the second hand itself takes time. This version was defended recently by Dainton (2000).[22]

Let us first take a look at the version of the specious present as James held it; after that we will discuss Dainton's view.

3.3.1 James and the Snapshot Lapsing Interval

In his *Principles of Psychology* (1890), James writes that memory is essential for our thought that something is past.[23] Events and objects that are in the past, are not 'past' because of some intrinsic quality they have, but because we experience in the present moment other events and things, that have associations to those events and things in the past. Imagine that we do not have any knowledge of things. Then, according to James, we are still able to act in a rational way at the present moment, provided that we have some mechanism that produces our observations of the present in a rational order.

He asks himself what kind of mechanism can produce this identical order. He has no answer. Later in this chapter we will see what kind of mechanisms the

[21] Robin Le Poidevin, The Stanford Encyclopedia of Philosophy, entry: *The Experience and Perception of Time*, http://plato.stanford.edu/entries/time-experience/

[22] According to Grush this view is also held by James' contemporary Stern (1897)

[23] William James, *The Principles of Psychology*, (1890), chapter 15 and 16

brain has for construction of the experienced present (=the specious present, the present as an interval). If the temporal content of perception is of ABCDEFG, the next one will be of BCDEFGH.[24] In James model there is overlap in the content of perception.

> 'What we call the present is an empirical portion of the course of time, containing at least the minimum of consciousness, in which the instant of change is the present time-point.'[25]

If we look closer to our consciousness, as James points out, we do have a minimum of consciousness and this minimum has durations. The minimum of consciousness is a difference or a change in feelings and this difference or change makes our memory, and our perception of things. The flow of time is the change of going from ABCDEFG to BCDEFGH. And the present as we define it is, according to James, an idealized abstraction and he refers to 'the specious present' that has been introduced for the first time by E.R. Clay (1882), a pseudonym for amateur philosopher E. Robert Kelly.

> 'The present to which the datum refers is really a part of the past- a recent past-delusively given as being a time that intervenes between the past and the future. Let it be named the specious present, and let the past that is given as being the past be known as the obvious past.'[26]

The specious present consists of the present and a part of the recent past, as seen in figure 3.6. We do not experience this duration of the present; we seem to feel this interval as a whole. What happens if there is no change in our thought? Do we still experience the passage of time?

These are important questions, because if we indeed also keep experiencing time when we have no change of thoughts, we have a sort of special sense of pure time. If we do not have a sense for pure time, time is constructed from changes in mental content; the conscious mind has a content that disagrees with the previous content. James concludes that we do not have a special sense for pure time; it is awareness of change that is the condition on which our experience of time's flow depends.

> 'In the experience of watching empty time flow we tell it off in pulses. We say 'now' 'now' 'now'. This composition out of units of duration is called the law of time's discrete flow. The discreteness is merely due to the fact that our successive acts of recognitions or a perception of what it is, are discrete.'[27]

Here James explains his snapshot lapsing interval. He thinks that the moments at which representations are made are discrete. In figure 3.6 you can see that the specious presents (experienced presents), the representations, are made in the mind at discrete single moments of time.

If A and B are to be represented as occurring in succession (content of perception) they must be simultaneously represented (the moment in time at

[24] James, *Principles of psychology*, p. 571
[25] Ibidem, p. 572
[26] Quote from Clay in: James, *Principles of Psychology*, p. 572
[27] Ibidem

which the representation of the interval is made); if we are to think of them as one after the other, we must think them both at once.[28]

Dainton's view on the specious present is another view of the specious present doctrine. Dainton wants to get rid of the static and discrete configuration of consciousness. He proposes an overlap theory instead of a snapshot lapsing interval, in which our perception too is a process in time and therefore takes intervals instead of instants. Not only the experienced present is an interval, but also the making of the representation itself takes time.

3.3.2 Dainton and the Overlap Theory

Dainton's overlap theory is a theory of mind. It tells us how we experience time and tries to find an explanation for this experience in the mind and not in the physical world. His approach is phenomenological. He wants to formulate a theory of experience that matches with all theories of presentism, possibilism and eternalism. The 'flow' in the flow of time, he ascribes to an 'immanent phenomenal flow' that is a feature of all experiences. There is a continuous flow of making representations. He does not give any statement about whether time really passes in the external world. His theory of mind does not tell us whether the flow of time is a feature of the mind or a feature of the external physical world. The way Dainton defines phenomenology that is at the basis of his theory, is:

> 'Phenomenology is the enterprise of describing the character of consciousness, in all its aspects, as clear and systematic way as is possible. Phenomenology is concerned only with describing how things seem to the experiencing subject and ventures no claims about the causes of the experience or what lies outside or beyond experience.'[29]

He searches within his own experiences and proposes a theory that matches with these experiences. Many phenomenologists have written about the experience of time. Although phenomenology tries to be scientific, it does not study consciousness from the perspective of clinical psychology or neurology. Dainton confirms this in his approach:

> 'Other interesting problems such as how our brains manage to perform the impressive feat of integrating the inputs from our different senses to produce a real-time representation of our usually changing surroundings (the typical time-lag between initial stimulation and experience is under half a second) will be ignored.'[30]

Dainton does not give any statements about the workings of the perceptual processes. These interesting problems will be discussed when explaining the temporal integration mechanisms of our brain. He ignores like Grush the time it takes to process the incoming stimuli. The overlap theory is a combination of various theories on time perception that are, according to Dainton, independently not sufficient to account for all features of experiences.

(i) Dainton starts off discussing memory based accounts and he criticizes the memory theorist positing a short-term memory of an experience of succession.

[28] Ibidem, 591
[29] Dainton, *Time and Space*, p. 360
[30] Ibidem, p. 93

He questions himself how memory can register the temporal distance between present and past experiences. He argues that the sort of experience, i.e. the experience of a succession that needs to be explained, is already presupposed when positing memory. What is experienced as present, e.g. motion, consists of earlier and later parts. The latest part is the real present moment and the earlier parts are already past events stored in our memory. But, Dainton remarks, temporal awareness cannot be wholly a product of 'experiental' memory (memory of experiences); it is plausible however that 'experiental' memory plays a central role. In the next section we will go deeper into the role of memory in the experience of the present, of which I think it is bigger than Dainton here supposes.

> 'Accounts of experience of time all appeal, in one way or another, to memory. Memory is however not largely or wholly responsible for our experience of time. Experiential memory provides us with a distinctive kind of knowledge of our own pasts. Memory plays a role in experience of passage. There are philosophers [e.g. Mellor] who have assumed that memory can explain the short-term awareness of time. Hearing tones CDEF: simply remembering having heard C while hearing D is not enough; that is compatible with me having heard C years ago. Somehow my memory must register the temporal distance between present and past experiences. [...] Perhaps we can appeal to a distinctive sort of memory: immediate short-term memory.'[31]

Dainton's first association with 'experiental' memory is long-term memory and especially episodic memory that accounts for personal memories of events that happened yesterday or last year. This association is clear in 'compatible with me having heard C years ago'. Only by the long-term memory that orders events, can be remembered that you have heard a sound some years ago. Tones that have been heard in the recent past (from a few seconds to approximately a minute) are stored in the STM (short-term memory). Dainton's definition of immediate short-term memory matches Harry Foundalis' definition of short-term memory.[32] Harry Foundalis and Marvin Minsky are cognitive scientists mentioned in this thesis who support a memory-based account.

(ii) The second theory Dainton discusses is the pulse theory of experience. In this theory short pulses of experience have a finite duration and they correspond to the specious present. All parts of these pulses are what he calls *co-conscious*.

In the pulse theory, successive pulses are only linked by memory and not by direct experiential relations. If this pulse theory is correct, we need to discern two distinct forms of transition: change within pulses and change between pulses. If C and D are in one pulse and E and F are in another pulse, we would experience the transition between C and D differently from the transition between D and E. In our daily life however, we seem to experience both these transitions the same. So we would like to get rid of this difference, but we should keep the binding between C and D, and E and F. Somehow we need to build a bridge in our theory between D and E.

[31] Barry Dainton, *Stream of Consciousness: Unity and continuity in conscious experience*, Routledge New York and London, 2000, p. 124

[32] Harry E. Foundalis, *Why Does Time "Flow" but Space Is? Answers in Evolution and Cognition*, www.foundalis.com, http://www.fqxi.org/community/forum/topic/276, October 2008

C and D are in one interval and E and F are in another interval, but between the intervals there is no link. The intervals are lapsing snapshots. It does not account for the dynamic feature we experience between D and E, according to Dainton. For the sake of clarity, here C, D, E, and F, etc. refer to the content of perception as an interval; C, D, E, and F are *intervals*.

(iii) Another model, that does bridge the gap between D and E, is the awareness and overlap model. However the problem with this model is that D is experienced twice, once by the act of awareness A1 and once by A2. Therefore also the awareness and overlap model is inadequate. Grush does not agree that this model is inadequate and his answer to Dainton is:

> 'Dainton claims that if perception produces, at each time a representation of what is happening over a temporal interval, then it would follow that we are perceiving things more than once. Consider two successive perceptual acts on the trajectory estimation view: $\hat{p}_{[t-i,t+k]/t}$ and $\hat{p}_{[t-i+1,t+k+1]/t+1}$. And suppose that something happens at time t that I perceive, the flash at A, say. The perception of A is part of both of these perceptual acts, the first perceiving it as happening now, the second as having just happened. Dainton claims, then that on this view A is perceived twice, at t and $t+1$. But he claims clearly we only perceive A once.'

But the fact is that we do not perceive flash A from the same point of view, the first time it is a representation made on the basis of new stimuli coming from A or even a prediction about A, the second time it is a new representation made on the basis of incoming stimuli of events happening after event A. The perspective is different. For an impression of the awareness and overlap model, see Grush model, figure 3.7.

(iv) The fourth model Dainton discusses is the two dimensional model. In this model the experience of A is fading away smoothly while having experience of B. The content of the awareness is temporally extended; it is 'two-dimensional'. Dainton comments on this model that it is ingenious and it possesses explanatory potential, but it is problematic on the following: experience would never end abruptly, but smoothly fades away. Our consciousness in this model would be full of residues of recent past experiences. And that is not how we are usually aware of experiences. They can end abruptly. So also this model does not account for our experiences.

The problem with Dainton's interpretation of this model is that is a spatial analogy to show the difference between the perception of A as happening now, and the perception of A having just happened. The experience of A is fading away when it is further in the past. This is not correct. Experiences can end abruptly. Direct after perceiving stimuli from A, the $perception_1$ of these stimuli is stored in memory before it comes to consciousness. The information of $perception_1$ can be used as most recent information, but it can also be used as older information in backtracking processes.

(v) Finally, Dainton presents solutions to the deficiencies of the models above in his own overlap theory. The key solution is to state that also the acts of awareness A1 (of perception C and D) and A2 (of perception D and E) partially overlap, as seen in figure 3.9, which they do not in the described models above. The key to continuity is temporally extended partially overlapping ex-

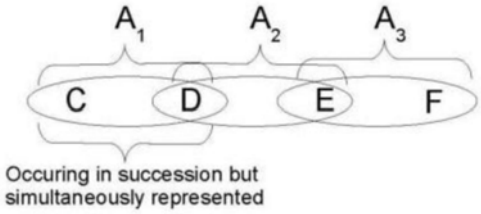

Figure 3.9: *The key of Dainton's overlap model: also the acts of awareness A1 (of perception C and D) and A2 (of perception D and E) partially overlap. The content of perception of C, D, E and F are intervals. The content of interval C partly overlaps interval D, etc. Dainton adds that also the acts of awareness A1 and A2, that makes these intervals of perception conscious, overlap, and not only the intervals. While the intervals C and D occur in succession, they are simultaneously represented in A1. So this overlap theory is not about the workings of perceptual processes, but about the workings of acts of awareness and that is not the same.*

periences.[33] If A1 and A2 partially overlap, these acts of awareness cannot be momentary, they must have some temporal extension.

He says that we must, therefore, abandon the doctrine that an awareness of change (or succession) consists of a temporal spread of content being presented to a single momentary awareness, as James did. Dainton abandons James' version of the doctrine of the specious present. The simple version of the overlap model that Dainton presented assumes no distinction between phenomenal contents and the acts of awareness that apprehend them.[34] This overlap theory is not about the workings of perceptual processes, but about the workings of acts of awareness and that is not the same. He describes what happens from step 5 to step 6, in the process of six steps that I distinguished at the beginning of this chapter.

Grush, however, reads Dainton's statement as if he means there is no distinction between the temporal order of the content of perception and the temporal order of the incoming stimuli, i.e. $perception_1$ is the same as $perception_2$. But from a citation of Dainton it became already clear that he only tries to answer questions about what comes into consciousness or not. In my opinion Dainton does not say anything about the relation between step 3 (the arrival of information for cognitive processing) and step 5 (information available for conscious reflection). It might be that Grush' conclusion that the simple overlap theory assumes a passive registration of the brain instead of an active construction, is a misinterpretation of Dainton's overlap theory. Dainton points at the relation between step 5 and step 6: what exactly that is perceived comes into consciousness. He assumes for simplicity that everything that is perceived, what he calls the phenomenal contents (and we call $perception_2$), comes into consciousness (the acts of awareness). It seems like Grush read 'phenomenal contents' as being $perception_1$ instead of $perception_2$.

[33]Dainton, *Time and Space*, p. 103
[34]Ibidem, p. 104

Dainton is *not* claiming that the external world itself contains a characteristic flow. The flow is immanent within the mind. When having an auditory experience, you are aware of a continuous and continuing flow of sound. This feature that Dainton calls *immanent phenomenal flow* is possessed by all forms of experience and is a dynamic feature of *experience*, and not of nature.

In the first chapter I argued that the experience of the passage of time is explainable by analogical thinking and conceptual blending between the domains of space and motion. Dainton warns us, and thinks that the immanent flow being a feature of experience is much more fundamental than analogical thinking:

> 'It has often been said that in thinking about time we must guard against our tendency to think in spatial terms (a tendency that may well be rooted in the dominant role that vision plays in our cognition) and no doubt there is some truth in this, but I suspect that there is a further and very different reason why thinking clearly about time can be difficult. Immanent flow is such a pervasive feature of our consciousness that it is hard to think of any thing that does not possess this feature, time included, for not only do our thoughts possess it as we think in terms of a series, but so do any mental images that we call up.'[35]

The immanent flow, Dainton says, is much more important for the experience of the flow of time than the tendency we have to think about time through spatial metaphors. He does not make a judgment about whether he believes in the block universe model and whether the flow of time is mind-dependent, but it is for sure that consciousness is a 'flowing' thing.

> 'Consciousness is not a static but a flowing thing, it is never still but always on the move [...] It is not just in perception that we directly experience change. Thinking as an activity involves a continuous succession of occurring thoughts and mental images, irrespective of whether the content or subject matter of these is continuous or fragmented. The succession of thoughts and perceptions is itself something we experience: the succession is not just a succession of experiences, it is a succession within experience.'[36]

In this section we have seen that Grush interpretations of the fourth and fifth model do not exactly coincide with the positions of Eagleman and Dainton respectively. While Eagleman focuses on the neurological workings of perceptual processes, Dainton does not focus at all at the perceptual processes but only looks at the relation between the information available for consciousness ($perception_2$) and what actually comes into consciousness. Eagleman and Sejnowski do not have uttered explicitly that they think the experienced present is an instant. I think that when talking about perception they mean $perception_1$ as most neuroscientists do.[37] Dainton does not think that the perception of the present is passively copied from the incoming. He only assumes that the phenomenal contents is the same as the acts of awareness, whatever that may mean.

The next section of this chapter is about mechanisms for time perception (the perceptual processes) in the brain that both James and Dainton did not discuss for different reasons. James did not know what mechanism is causing the

[35]Ibidem, p. 107

[36]Dainton, *Streams of Consciousness*, p. 114

[37]Roache, *Mellor and Dennett on the Perception of Temporal Order*,p. 238

perception of the present and Dainton set up his theory of mind from a phenomenological point of view, not a neuroscientific point of view. Neuroscientists are concerned with what happens when stimuli arrive at the back of the brain and are being processed to make a representation of the present.

3.4 The Mechanisms of the Brain

In this section several mechanisms are discussed. Memory plays an important role not only to record the past, but also to experience the present.

The brain consists of neurons that form neural networks. Every neuron has a different task. The connection between these networks can give rise to intelligent systems that not only process incoming stimuli from the senses, but also store knowledge and make mental representations and memories.

Incoming stimuli are not at the same physical time arriving at the systems that process these stimuli. Further these processes take for one sense longer than for the other. Therefore if both images and sounds are coming from a source, the brain somehow figures out that these stimuli come from the same source. The brain uses temporal integration mechanisms and different kinds of recalibrations, i.e. the brain has mechanisms to calculate what stimuli came from what source.

3.4.1 The role of memory

Dainton advocated against a memory based account of time perception, but thanks to our memory we can construct mental representations such as analogies. Starting with the distinction between long-term memory (LTM) and short-term memory (STM), I will argue that the LTM is important for recording the past in ordered events and that the STM is important for the experience of the flow of time.

Memory plays an important role in the way we perceive the present. When talking about memories of something in the past, we usually mean memories that are stored in the LTM. In the LTM events are stored chronologically. LTM is not like STM. Long-term memory does not cause our sense of flow.

The feeling of flow is felt in the experienced present. The experienced present turns out to be an interval that has a duration comparable to our STM. The STM plays an important role in feeling the flow of time.

In some theories short-term memory is identified with working memory. The concept of working memory replaces or includes the older concept of short-term memory. They have done this to put a stronger emphasis on the notion of manipulation of information (active construction) instead of passive reflection. This active construction of the experienced present takes place during the perceptual processes of the brain. The representation of the present is partly constructed from memory and partly from processed incoming stimuli.

According to other theories that do not identify the STM with the working memory you can store information, like a phone number, for 30 seconds to 2 minutes in the STM. But in the working memory, which is often associated with Miller's magical number 7, only 7 ± 2 elements of information can be stored, for 5 to 12 seconds. A phone number can be remembered by putting the information in chunks. When the working memory is full, this chunk is transferred to the

STM. Several chunks can be stored in the STM. Information in the short-term memory can be stored in chunks. That is why we can remember a phone number in the STM longer than 7 elements (10 numbers), and is remembered by putting these into chunks. We need approximately 10 seconds to 'transfer' these chunks from the working memory into the short-term memory. It is the working memory that is often associated with the duration of perception. If the experienced present has some sort of duration, it probably corresponds to the duration of the working memory. Foundalis identifies working memory with STM.

Long-term memory is divided in procedural and declarative memories. Procedural memory is also called implicit or unconscious memory. It refers to the long-term memory of skills, procedures, and unconscious 'know-how': riding bikes, playing music, driving cars, and crossing streets. Someone who lost his memory is still able to do these kinds of actions. Declarative memory is again divided in semantic and episodic memory.[38]

Semantic memory refers to memory of meaning, understanding and more generally to knowledge that is not related to specific events. In semantic memory we can remember facts that we did not experience ourselves, like $3 + 5 = 8$ and 'Napoleon was prisoner at the island of Elba'. Of course, the semantic memory will have arisen from some relevant experience, but it is no perceptual experience of the event itself, as opposed to hearing or reading a report of it.[39]

Episodic memory on the other hand contains information from experiences of an event from the inside. The 'rememberer' has experienced the event itself. Of these two kinds of memories, it seems to be episodic memory that links us to the past. It is not clear whether this distinction between episodic memory and semantic memory is an objective distinction or a conventional one, in the sense that there is a physical difference between these kinds of memories in the brain itself or not.[40]

It is the STM that is for the purposes of this thesis the most interesting type of memory. Harry Foundalis, a cognitive scientist, proposes that the flow of time is an artifact of a densely populated STM.[41]

> '[The] continual activation and formation of new and overlapping structures in STM [...] is what gives rise to the sense of temporal flow. An analogy is a commercial sign with a row of light bulbs that turn on and off in succession, yielding the illusion of motion. The flow appears smooth to us, because activations in STM appear and fade away very quickly, producing a dense sequence of successive, overlapping structures.'[42]

What is discrete, according to Foundalis, is the activation and fading away of the neurons. But this goes so fast that we are not aware of these discrete processes. That is why we perceive continuation. Foundalis attributes the sensation of flow to the dense sequence of successive, overlapping structures in

[38] Juval Portugali, *Self-Organisation, Cognition and Planning: Some implications to New Towns and Urban Simulation Models*, in: Egbert Stolk, Marco te Brömmelstroet (Red.), Model Town: using urban simulation in new town planning, 2009, p. 7

[39] Le Poidevin, Robin, *The Images of Time: An Essay on Temporal Representation*, Oxford University Press, 2007, p. 57

[40] Le Poidevin, *The Images of Time*, p. 58

[41] Foundalis, *Why Does Time "Flow" but Space Is? Answers in Evolution and Cognition*, p. 5

[42] Ibidem, p. 6

the STM. The passage of time, Foundalis says, is the sense of how fast we think: we are capable of comparing the number of successive mental structures that form and fade against the number of real world events that occur in a given interval of time. We end up with the illusion that our thought has a speed due to spatial analogical thinking. Foundalis uses other words than Dainton does, but they seem to mean the same: 'Thinking as an activity involves a continuous succession of occurring thoughts and mental images'.

Different authors do not agree with each other, because they misinterpret each others words. While meaning the same, they all use the term STM differently. Dainton, for example, calls the type of memory Foundalis refers to as STM, immediate short-term memory. To my opinion Foundalis means working memory, which is some sort of immediate short-term memory. It seems as if Foundalis ascribes to STM the duration that I have ascribed above to the working memory. But to keep in simple, we will talk about the STM from now on, even when we mean the working memory. So the STM seems to play a key role in the experience of the flow of time.

If we identify the content of our short-term memory with the experienced present, then the experienced present seems to have a duration and is not an instant.

The difference between the experience of time as it passes and in retrospect can be explained by the difference between the STM and the LTM. James already remarked in 1890:

> 'In general, a time filled with varied and interesting experience seems short in passing, but long as we look back. On the other hand, a tract of time empty of experiences seems long in passing, but in retrospect short.
>
> The same space of time seems shorter as we grow older. It is certain that, in great part at least, the foreshortening of the years as we grow older is due to the monotony of memory's content, and the consequent simplification of the backward-glancing view. The tracts of time shorten in passing whenever we are so fully occupied with their content as not to note the actual time itself.'[43]

If we are experiencing interesting events, time seems to go faster. Research in neuroscience and cognition has found out recently this is because the short-term memory is less aware of its own actions, but busy enough to put everything in chunks and finally transport it to the LTM. 'Time flies, when you are having fun.' We are less aware of the perceptual processes themselves.

However, if you are waiting for something and nothing happens, time crawls by and the STM makes you aware of the fact nothing happens. We are more aware of the perceptual processes.

But if you look back just a minute after the experience or some hours or weeks later, the fantastic three holidays you have had seem to have lasted for at least one week. And the time you have spent in the waiting room of the dentist that crawled by as you were experiencing it, looks in retrospect much shorter.

This is because the memories that the STM stored (into the LTM) are much denser when you have a lot of new experiences than when you have very little new experience. So when remembering events you make use of your LTM. The

[43] James, *The Principles of Psychology*, p. 587

time it took for all those experiences seems much longer than it actually was; everything in the LTM is stored chronologically and much denser. Because the brain has some standard of 'calculating' an average amount of time per experience, the densely stored experiences seemed to have lasted much longer. And the opposite is true when you waited for 30 minutes in the dentist room. The time it took in retrospect looks less.

This makes sense when you think of the STM as causing the flow of time and the LTM as making a chronological order. In other words, while we experience the present through the STM, the LTM is placing every past event in the right order making use of relations between events as if it is constructing a B-series. All theories on the experience of the flow of time and how this experience is constructed in the brain assume 'becoming': the ordered occurrence of events.

Much of what we know about time in the brain (the temporality of perceptual processes) comes from psychophysical experiments. Eagleman et al. (2008) did research on the experience that time seems to slow down in frightening situations or the mechanisms of the body speed up so that you can do a lot more in the same amount of time. To test this, they did experiments with participants who were asked to watch the ciphers on a digital clock closely while experiencing a free fall.[44] The ciphers on that clock were running fast enough such that it was impossible to read them when standing relaxed on the ground.

After the fall, they had to report whether they could read the ciphers on the watch during the fall. If they could, their eyes would report more in a shorter time, because visual processing went faster. The processing of the stimuli themselves went faster. But if they could not, their brains store memories differently and more dense such that it looks afterwards like time's passage was slowing down during the fall.

The participants could *not* read the ciphers. Therefore memories are stored differently in frightful situations. Instead of an accurate internal clock, the brain simply has access to the approximate constant rate of its own information processing. Dense memories are experienced as if happening during a longer time interval.[45]

Therefore the answer to the paradox that time seems to slow down in frightful situations, and that you could do more in less time, is that time estimation and memory are intertwined: the participants merely thought the fall took a longer time in *retrospect*, and they are not experiencing time going slower while they were falling. During their fall they are not even aware of the passage of time at all, because their brain is so busy putting every experience in the STM.

> 'It can seem as though an event has taken an unusually long time, but it doesn't mean your immediate experience of time actually expands. It simply means that when you look back on it, you believe it to have taken longer. This is related to the phenomenon that time seems to speed up as you grow older. When you're a child, you lay down rich memories for all your experiences; when you're older, you've seen it all before and lay down fewer memories. Therefore, when a child looks back at the end of a summer, it seems to have lasted forever; adults think it zoomed by.'[46]

[44] We do not have to take relativity theory into account here, because the velocities we are talking about are much less than the speed of light.

[45] David M. Eagleman et al., *Time and the Brain: How Subjective Time Relates to Neural Time*, The Journal of Neuroscience, November 9, 2005, 25(45), p. 10369-10371

[46] David Eagleman in an interview on the webpage

So both Eagleman and Foundalis agree that the sense of flow can be understood as an artifact of a densely populated short-term memory.

3.4.2 The Mind is a Society

Also Marvin Minsky in his book *Society of Mind* (1985) has developed a theory of mind and expresses himself on how the experience of the flow of time can be understood. We use certain descriptions to represent the nature of progression that of itself does not have to be smooth at all. Flow is such a description.

The feeling that what we see is 'present' in the here and now is, according to Minsky caused by agencies (neural networks) that already begin arousing memories before the work of processing stimuli is fully done.[47] The agents in your brain are already making the present before you even observed fully all events that are happening. Memories are used to make predictions.

Minsky ascribes a big role to the short-term memory concerning the experience of the flow of time. The smallest components of our short-term memory-systems he calls 'micromemory'. If we would not have had the STM then everything would seem to change and there would be nothing to hold on to: there would be no experience of the flow of time, because to experience flow other things need to remain the same. Minsky defines memories to be processes that make some of our agents act in much the same ways they did at various times in the past.[48] If agents act the same way they did in the past, we are recalling a memory. These memories can invoke the same emotions as you had at the time of experience. Recalling a memory of an event is not the same as experiencing that event; memories can change because new knowledge and experiences are added. How can memories be stored? Neural networks store information by encoding. If one neuron is 'touched' it starts to fire in a certain pattern. Together with other neurons in a network these patterns form a memory.

Minsky has become famous as a co-founder of the Artificial Intelligence Laboratory at MIT. In his book *Society of Mind*(1985) he illustrates the mind as a society consisting of all kinds of components that are separately not intelligent at all, but together they are. The mind is built out of these so-called multi-agent systems. The STM lasts only for seconds and is also composed of agents. Our various agencies selectively decide, unconsciously, to transfer only certain states into the LTM.[49] These agents that represent neural networks in AI, are unintelligent subparts of the brain. Neural networks in the brain are the areas called grey matter. Grey matter is formed by neurons and their unmyelinated fibers. Neural networks are connected through long myelinated axons, which can give rise to an intelligent system.

These neurons and groups of neurons make our mental representations.[50]

Cognitive scientist and philosopher Paul Thagard defines a multi-agent system to be an interacting collection of computers capable of intelligent action.

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http://thesciencepundit.blogspot.com/2007/12/and-then-time-slowed-to-crawl.html.

For a movie about his research, see: http://sciencestage.com/v/303/david-eagleman-time-perception-neuroscience-brain-research-free-fall.html

[47] Ibidem, p. 155

[48] Ibidem, p. 154

[49] Ibidem, p. 153

[50] Ibidem, p. 151

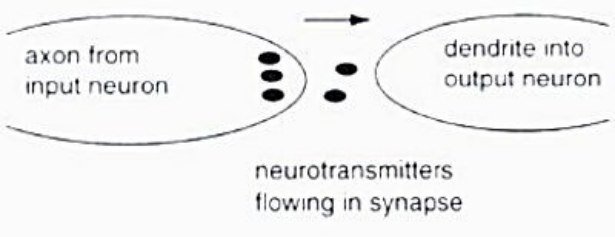

Figure 3.10: *Neurotransmitter molecules flowing from one neuron into another through synapses.*

The Mind is a Computer is an analogy often used to make new theories of mind based on computersimulations and multi-agent systems. Agents (from the domain of 'computer') and neural networks (from the domain of 'mind') are different words meaning the same.

Information between neural networks is transported by electrical pulses of neurons firing typically hundreds of times per second. We can think of this firing information as a kind of Morse code. The firing pattern of neurons is important for the making of mental representations. If we only focus on firing rates, we underestimate the representational capacity of neurons and groups of neurons. A neuron is a nerve cell that has axons and dendrites through which a neurotransmitter (a molecule) is transmitted. The neurotransmitter is transported via the axon of one neuron to the next one's dendrite through synapses (the space between axons and dendrites), see figure 3.10[51].

The spike train of a neuron is its pattern of firing and not firing over a period of time. We can represent a spike train by a sequence of 1s and 0s. The spike trains 10100 and 00011 both involve a neuron with a firing rate of 2 times out of 5, but they are different patterns. A single neuron can represent a feature of the world as the result of being tuned to fire more rapidly when that feature is presented, e.g. an apple. More powerful neural representations arise if the neuron can encode more possibilities by using the temporal properties of different spike trains, and if the neuron is part of populations of neurons that work together to represent many features. In sum, a representation in the brain is a population of neurons whose firing patterns can generate output, having input from agents that are less intelligent.

Each representation in the brain's worldline results from a complex 'negotiation' between different parts of the brain and also from different agents in the same part of the brain. An example of the first kind of negotiation is that light is processed more slowly from sense to awareness than sound is. So the brain has to make somehow a correction for this. An example of the second kind is illustrated by figure 3.11[52] where we can see how a certain mental state is produced by neural networks (agents) being in a certain state.

We normally assume that through our consciousness we know what happens in our minds right at the present time. Minsky argues that consciousness does not concern the present, but the past: it is concerned with how we think about the records of our recent thoughts. Only a small minority of our agents

[51]Thagard, *Mind*, p. 156
[52]Minsky, *Society of Mind*, p. 95

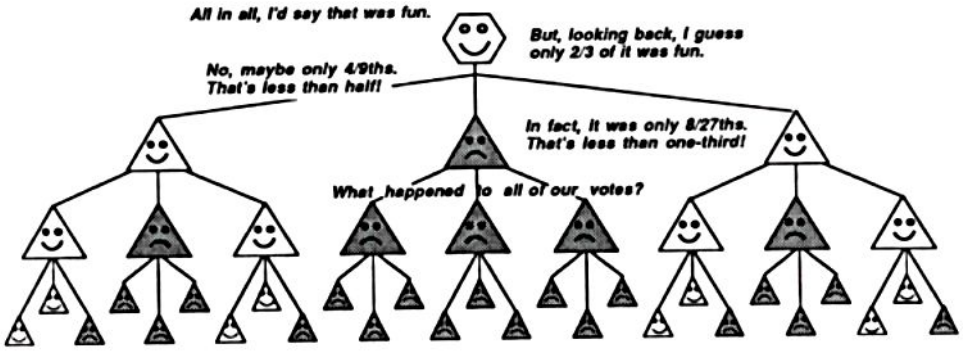

Figure 3.11: *If someone askes if you enjoyed the experience you just had, you might say that it was fun. But no such summary can say very much of what your agencies learned and liked. It might be that if the decision was based on the overall majority of agents in all kinds of layers, the experience was not very nice.*

is connected directly to sensors in the outer world, like those that send signals from the eye or skin. Most agents detect events inside the brain. Agents concerned with using and changing our most recent memories lie at the roots of consciousness.

Why do thoughts so often seem to flow in serial streams?[53] Because whenever we run out of space in our STM, the records of our recent thoughts must replace the older ones. Why are we so unaware of how we get our new ideas? Because whenever we solve hard problems, our short-term memories become so involved with doing that that they have neither time nor space for keeping detailed records of what they themselves have done.

Minsky also asks himself the question why it is so hard to talk about our present state of mind?[54] He gives two reasons.

(i) Firstly, because of time delays between different parts of a mind we cannot speak about a present state, in the sense of 'one moment in time'. The meaning of 'now' is far less clear for an agent inside a society (multi-agent system). It takes some time for changes in one part of a mind to affect the other parts. There's always some delay in the processes. Each different agent of the mind lives in a slightly different world of time. According to Minsky, our memories are *indirectly* linked to physical time. The slower an agency operates, the longer the intervals between each change of state, and the more external signals can arrive inside those intervals.[55] It sounds more plausible that the experienced present is an interval than being an instant. In such an interval all stimuli arrive at different moments of physical time of which the brain makes a representation at one moment in (physical) time.

(ii) Secondly, each attempt to try to think about our own mental state will change that state. If you are angry and try to think about how it feels to be angry, the emotion of angriness becomes less or even disappears.

[53]Ibidem, p. 151
[54]Ibidem, p. 152
[55]Ibidem, p. 61

In this subsection we have had a short overview of how the brain works. According to Minsky 'minds are simply what brains do'.[56] The mind consists of a society of neural networks, that can do all kinds of mental processes, such as 'simple' transportation through the axions and dendrites of neurons and 'complex' construction such as integration mechanisms and conceptual blending.

It is hard to define what is present in the mind. Mental processes on the content of perception happen on slightly different times than other processes. Still the mind can give us an idea of what is present. So the temporality of perceptual processes is something different than the temporal content of perception.

Minsky also says that the feeling that time flows is caused by the mind's short-term memory. The ordered occurrence of events in the external world is the sensory input for the experienced flow of time. The temporal content of the representation does not agree with the time at which the representation is made. In the next part of this section we will see what kind of mechanisms can alter the temporal integration window.

3.4.3 Present Patches, Windows of Simultaneity and Temporal Integration Mechanisms

Craig Callender in his article *The Common Now* (2008) argues, like Nick Huggett, that we need recent experiments in cognitive neuroscience and psychology to get information about time perception and time experience. He searches for a match between the present patches theory he constructed from the philosophy of physics and what he learned from philosophy of mind to argue against the Argument of Experience. The physics part of the theory uses the notion of local nows. A local now can be objective, although dependent on the frame of reference. If you glue these local nows together you get a patchwork of nows. A present patch is the spatiotemporal region over which typical observers in typical environments do not require a time stamp for communication. If we communicate by telephone for example, both speakers are in the same 'now' and do not need to talk about time stamps. A 'global common now' is built by patching together these local nows. The inter-subjective agreement leads to the idea that this 'global now' is objective. This theory is the Present Patches theory, which is a hypothesis that seeks to explain various features we associate with the present.

According to Callender the present is local, mind-dependent and constructed. The present is inter-subjective, in the sense that the experience is the same for every human being, because it is constructed by mental mechanisms that are generally the same for every person. The present patches theory does not give us an explanation for the experience of flow of time, but it does for why we feel there is an objective and global now. Callender's combines his present patches theory that is based on relativity theory with temporal mechanisms of the brain.

This is the start for the construction of a common now in physics. Now it is time to plug in the role of the brain.

Callender states that every experience is present: you cannot distinguish between an experience being past or being present or being future. Consciousness experiences are confined to the present.

[56] Ibidem, p. 287

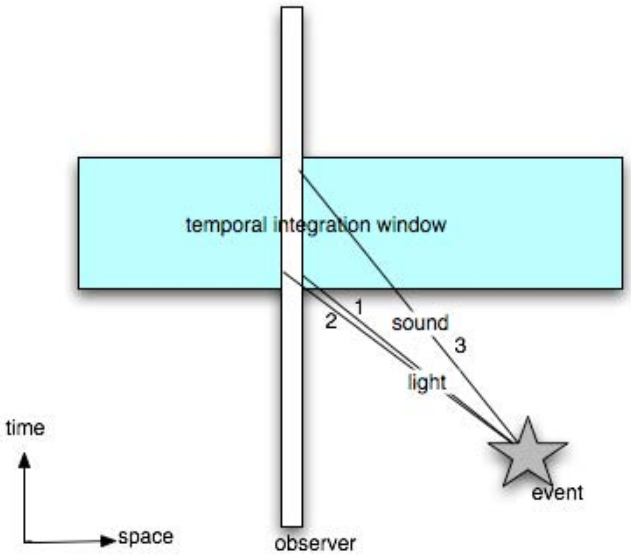

Figure 3.12: *An example of a temporal integration window where both the visual stimuli and the auditory stimuli that arrive at different physical times in the brain (perception$_1$) integrated, and represented simultaneously in the mind by altering the size shape and behavior of the integration window (perception$_2$).*

To refresh your memory and to avoid you from thumbing back to section 3.1, here a repetition of the different steps in the processing of the brain.

1. First, events happen in nature;
2. then information from these events are transported through the environment (e.g. light travels faster than sound), through your body and brain (neural *transportation* processing);
3. the perception referred to as *perception*$_1$ is constructed when the transported information arrives at the part of the brain where cognitive processing takes place;
4. through memories, conceptual blending and other mental mechanisms can alter the content of *perception*$_1$;
5. *perception*$_2$ is made, which is the content that is available for conscious reflection;
6. finally the representation that has been made in the previous step comes into consciousness.

Grünbaum already said forty years ago that the present is mind-dependent.[57] But, as Callender correctly points out, a discussion on the mind-dependentness of the present has never been focused on workings of the mind itself.

[57] Adolf Grünbaum, *The Meaning of Time*, Essay's in honour of Carl G. Hempel, Dordrecht 1969, p. 147-177

The mind is doing a lot of work in constructing present patches. The picture that emerges from recent work in cognitive neuroscience, behavioral psychology and psychophysics is one wherein the mind employs a set of temporal integration *mechanisms* that can alter the temporal information in the integration *window*, see figure 3.12[58]. Temporal integration windows integrate the stimuli from the external world, which are bombarding our senses, into temporal units. One temporal unit is what is integrated by the temporal integration window as happening simultaneously.

This integration window can be altered by integration mechanisms. Those stimuli reach us at different times, e.g. sound reaches one ear earlier than the other. From this time difference the direction where the sound comes from can be calculated. Not only the velocity of signals differ before they reach us, but also the processing that occurs within the various sensory organs takes different amounts of time. The visual stimuli take a longer route in the visual system than the auditory stimuli in the auditory system. Finally the neural processing in the brain itself takes a particular amount of time. This is all described by step 2 in the process.

There is no guarantee at all that when the stimuli reach the back of your brain (step 3: $perception_1$,) that they will correspond to the true temporal relations among events (step 1). One of the most remarkable features of the brain is that despite the non-simultaneous arrive of information (step 3: $perception_1$) from simultaneous external events (step 1), we somehow manage to get things more or less right (step 5+6: $perception_2$). What kind of mechanisms do we have that decide what events to count as simultaneous and what events to count as non-simultaneous?

What Callender aims to do is to add these temporal integration mechanisms from cognitive science into the philosophical and physical Present Patches Theory. Because for every person these mechanisms work in a similar way, each person agrees on what events are happening now and experiences a 'common now'. By merging cognitive science and philosophy of physics, and proposing an argument against the A-theorist's argument of experience, Callender hopes to defend the tenseless theory of time.

What causes in the brain the making of a present patch? Callender presents us some of the fascinating ways by which the brain creates the experienced present moment.

First we need to somehow define the present in the brain by performing experiments on when events are experienced to be simultaneous or not. One way to test this is by taking two tones with different frequencies. The interval during which events such as these two tones are fused is called the modality's 'window of simultaneity'. This window varies from person to person; from 2 ms to 5 ms. The brains fuse signals from multiple senses (hearing, seeing, tasting, feeling, smelling) coming from one object in space into a perception ($perception_1$) of the object. Then this information is processed by several mental mechanisms, such as temporal integration mechanisms discussed below that make a representation ($perception_2$). This mental representation of a known object is built from memories of that object together blended with signals from the senses. An object is very quickly represented in the brain because of earlier memories of that object. The agents are already making a construction of the object primar-

[58]Callender, *The Common Now*, p. 353

ily based on memories, without fully knowing about all signals from the senses. These signals haven't had the time to arrive yet. This representation is adapted to stimuli that arrive later, as we have seen in Minsky (1985).

A beautiful example of how the brain fuses light and sounds in a temporal integration window is by compensation of the physical differences in speed, by two processes: firstly, the mechanical sound transduction by the hair cells of the inner ear is many times faster than the chemical photo transduction in the retina, and, secondly, the neural transmission time from the visual cortex to the cerebral cortex is greater than that from the auditory cortex to the cerebral cortex. These processes belong to step 2.

It turns out that if we take these differences into account the horizon of simultaneity between light and sound intersects at about 10 m from the subject. Why then does it match when the source is even closer or further away? That is the work of the processes that belong to step 4, that actively construct the synchrony.

For large enough distances the perceptions of light and sound do not match anymore, e.g. thunder and lightning. While we see lightning almost instantaneous, sound takes about 3 seconds per kilometer. On these great distances the brain does not correct for the velocity of light and sound. Simultaneity of light and sound is as much as 250 m, before to notice the discrepancy. Why is that so? We already mentioned briefly the very wide multi-sensory temporal integration window, but there are a few mechanisms that can radically alter the size, shape and behavior of the integration window, and construct the synchrony.[59]

Temporal Ventriloquism Temporal Ventriloquism captures two stimuli and brings them closer together in time.

> 'Ventriloquism is the ancient art of making a sound appear in a spatial location that is not its source. [...] The modality appropriateness hypothesis (Welch 1986) is the thesis that the sensory modality that provides the most accurate information will dominate the percept created by the brain. [...] The interesting thing about temporal ventriloquism for us is that it is a quite dramatic mechanism whereby the brain can maintain a perception of synchrony event with asynchronous inputs; there is even evidence that the effect optimizes the chances of matching stimuli from the same event.'[60]

An example of the application of temporal ventriloquism is the play of the puppet and puppeteer. Although we know that the puppeteer is talking, our brain merges the visual stimuli of the moving mouth of the puppet with the auditory stimuli of the words spoken by the puppeteer together as the talking puppet.

Motor-Sensory Recalibration The Motor-Sensory Recalibration in the brain is not capturing one input by another as in the temporal ventriloquism mechanism, but it is the stretching and recalibration of the simultaneity windows themselves. A lot of data is supporting the claim that the experience of physical events one has depends both on one's intentions and on one's experience of synchrony. If there was introduced a lag between two things happening,

[59] Callender, *The Common Now*, p. 354
[60] Ibidem

participants reported that soon their actions and effects were felt like being simultaneous again.

A well-known experiment to investigate this mechanism is the 'computer and mouse' experiment. Participants are asked to give an indication of how long the delay is between the movement of the mouse and the reaction of a pointer on the screen. While the delay in reality kept the same duration, the participant's brain adapted and widened the integration window. After a while participants had the idea the pointer on the screen was directly reacting on their movement with the mouse; they experienced that the delay was gone, but in reality it was not.[61] The width of their temporal integration window was larger due to perceptual processes.

Multisensory Recalibration Cross-Sensory Recalibration is together with Distance-based Calibration also referred to as Multisensory Recalibration (e.g. correcting for sound and vision, or taste and smell).

In the case of Distance-based Recalibration the brain corrects for target distance. The brain probably takes sound velocity into account when judging simultaneity. Subjective simultaneity increases by about 3 milliseconds per 1 meter. Taking into account target distance would seem to be a computationally complex task, so there are probably various ways for the brain to calculate the target distance. People are more likely to report stimuli as simultaneous when they originate from the same spatial location than when they come from different spatial positions. Apparently our brains are adapted to the speed of sound in comparison to the speed of light, and it decides for itself whether events of sound and light came from the same source and are simultaneously or not.

How does this relate to the problem of the flow of time being mind-dependent or mind-independent?

According to Callender, the experience of a common now is nothing more than a construction of the brain. Therefore the argument of experience that tensers use is not valid. Tensers base the existence of the moving present also on the argument of experience. The experience of a moving present is not a good argument for the existence of a moving present in nature. Therefore the flow of time defined as the moving present might be mind-dependent and not mind-independent as tensers believe.

In this section we have seen what kind of perceptual processes the brain uses to actively construct the experienced present as an interval.

In the next and last section James Hartle suggests that the mechanisms in the brain could have developed differently such that we would have different organizations of the experience of past, present and future. According to him, these different organizations are consistent with the four-dimensional spacetime we live in, because past, present and future are not objective features of physics. What is called past, present and future depends on the observer's perspective. Hartle presents us with a schematic drawing that shows us how the brain deals with time perception.

[61] David M. Eagleman and Alex O. Holcombe, *Causality and the perception of Time*, Trends in Cognitive Sciences, vol 6 no 8, august 2002, p. 323-325

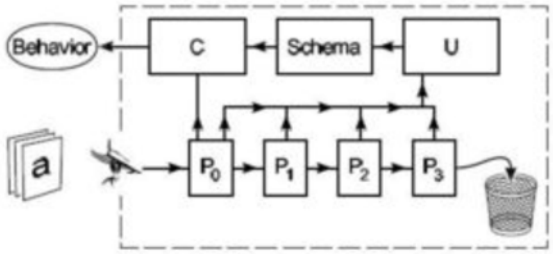

Figure 3.13: *Hartle's schema of information flow in the robot. The internal workings of the robot are within the dotted box; its external environment is without. The robot captures a visual image of a stack of cards that are labeled* a, b, c *etc. and from time to time (physical time) the top member of the stack changes. The most recent information is put in interval* P_0 *and just before the next capture the image in* P_3 *is erased and images in* P_0*,* P_1 *and* P_2 *are shifted to the right making room for the new image in* P_0*. The robot uses the images in* P_0*,* P_1*,* P_2*, and* P_3 *in two processes of computation: C ('conscious') and U ('unconscious').* P_0 *is directly used in consciousness to make predictions and decisions. In the schema, there is a simplified model of its environment, containing its history and its present state.*

3.5 IGUSs and the division into past, present and future

Physicist James Hartle, like Craig Callender, tries to combine the picture of time in physics and our experience of time in daily life in his paper *The Physics of Now*. He discusses the origin of our experience of the division into past, present and future in terms of information gathering and utilizing systems (IGUSs). These models are simplifications of the mind of human beings and can also be minds of robots of any kind.

Hartle assumes that past-ness, present-ness and future-ness are

> 'not properties of four-dimensional spacetime, but notions describing how individual IGUSs process information. [...]questions about past, present and future, are therefore most naturally in the domains of psychology, artificial intelligence, evolutionary biology and philosophy.'[62]

We have already seen in the last chapter that the notion of the present is spatio-temporally localized, and that the present can be common when IGUSs are close to each other and have relative velocities that are much less than that of light. Hartle also agrees that the division into past, present and future of an IGUS is consistent with the four-dimensional laws of physics and can also be described in four-dimensional terms. But, according to him, this division is not the only way experience can be organized. The general laws of physics are open to other ways, because past, present and future are not fixed *properties* of events in the block universe. Past, present and future only describe *relations* between events. What Hartle wants to show is that the division into past, present and future is mind-dependent; it is dependent on how the IGUS organizes experience.

[62] Hartle, *The Physics of Now*, p. 101

Different IGUSs agree on what is happening now; we have a 'common now'. There are limitations on this agreement, both from the construction of the IGUS (the time it takes to process in the brain what comes from the senses) and the limitations of defining simultaneity in special relativity (the maximum speed of light; information takes a certain time to reach us). If we want to broadcast a program 'The Galaxy Today' (see the example in the section about local becoming in chapter 2) there is no common now for all IGUSs that are citizens of the galactic empire, because there is a problem of defining a unique plane of simultaneity through the whole empire. The spacetime scales are too large compared to time scales on which human events happen.[63] The present is therefore local. We have the following contingencies:

- The timescale of perception t* is short compare to timescales on which interesting features of the environment vary (evolution). The speed of neural processing in the brains is adapted to the speed with which objects in our environments move ($t* < t_{classical}$).
- Individual IGUSs are moving relative to one another at velocities much smaller than c ($v << c$). So the light travel time is much smaller than the travel time of ordinary things such as flying birds and riding cars ($t_{light} << t_{classical}$).
- The light travel time between IGUSs in an inertial frame in which they are nearly at rest is small compared to the timescales t* ($t_{light} < t*$).

We live in a Newtonian world with 'everyday velocities' much smaller than the speed of light ($v << c$). We need to respond to our environment and if there are no dangers with velocities approaching the speed of light, we do not need to develop our brain to process with this speed ($v* < c$).[64] If we were creatures travelling at very high speeds in the universe, our brains will adapt in processing information ($v*_{new} > v*$). Our neural networks will be more adapted. Technical revolution always goes much faster than biological evolution. The amount of information our brains are processing everyday is tens of times more than our grandparents did a century ago, but we have approximately the same brain capacity.

Because the neural processing (transportation speed) is higher than the speed of the flying bird ($v* > v$), is why you can perceive the motion of a bird. But you cannot perceive exactly the position of your moving finger when it is going up and down as fast as you can in front of your eyes. The speed of your finger (or the speed of the wings of a hummingbird) is faster than the visual processing speed in your brain. The faster neural processing is the narrower the temporal integration window. The width of the temporal integration window and the speed with which memories are made, are different things. In Eagleman's experiment of the free fall, we have seen that the processing speed of the brain does not change; it is the way memories are stored that changes during a frightening experience. The processing speed of the brain belongs to step 2 in the whole process that starts with the happening of events and ends with the representation of these events in the brain. The storage of memories belongs to step 4.

[63] Ibidem, p. 104
[64] Callender, *The Common Now*, p. 348

Hartle wants to show that robots with different kinds of storage of memories will have a different organization of past, present and future. We have already seen 3.4.3 that it is also the width of the temporal integration window that can have an influence on how we perceive the present.

The kind of robot that matches our own experiences best, according to Hartle, is the robot that gets an update of the information going in and out of conscious focus again. The robot has n+1 memory locations in which it registers a time series of impressions of its external environment. It has an 'image' history of its environment. First it gathers information from its environment ($perception_1$) and then it utilizes this information stored in registers P_0 to P_n (memory) to compute predictions about its environment ($perception_2$). As seen in figure 3.13[65] the mind of the robot gathers information from the external world through the senses. It stores the most recent information in P_0 (short term memory) and at each time interval $t*$ (the specious present) it updates its schema making use of the new infomation in P_0 and old information in $P_1...P_n$, through a process of computation we denote by U (unconscious). The decisions and behavior of the robot are based primarily on the most recently acquired image in register P_0 in this computation C (conscious).

Hartle points at some similarities and dissimilarities between people and this kind of robots: The simularities are (i) that the U (unconscious) computations provide input to decision-making C (conscious) computation, (ii) that direct input to C computation only comes from the most recently acquired image in the register P_0 and (iii) information 'flows' into and out from the register P_0 directly used by C (this is the flow of time).

Dissimilarities are (i) that our information about external world is not exclusively visual, (ii) information is not stored in linear array of registers, (iii) it is not transferred from one to the other in the simple manner described, (iv) the input and records not separated by sharp time divisions (intervals t*); the duration of these intervals vary, and (v) we can consciously access memories of other than the most recent data.

Of this kind of robot can be said that it experiences the present and remembers the past and the flow of time is the 'movement' of information into the register of conscious focus and out again.

According to Hartle, the features of the physical laws of dynamics and the initial condition of the universe that are necessary for a past, present, and future organization of temporal information are consistent with other organizations of this information. Three examples of other robots than the 'past, present and future' robots are:

1. the Split Screen Robot. This robot has input from two times, such that the experienced present of the robot consists of two times. The robot also experiences two flows of time. One present is always earlier in the sequence of events than the other present. In that earlier present the robot has knowledge of the future; in the later present it has no knowledge of the future. But which of the two presents is the real local present of the robot, if there is a real present at all? The later present is the real one, because we cannot know information from the future, only from the nearby future, as we see in the case of the next robot;

[65] Hartle, *The Physics of Now*, p. 102

2. the Always Behind Robot. There is a time flow but a lag in time. He has already unconscious knowledge of events that are future events to him, because in his environment events are happening of which he is not yet aware. Since we also have a small time lag in (consciously) experiencing the present, it sometimes seems as if we can anticipate on future events, see the flash lag effect. It shows that our experienced present is lagging behind what is actually happening.

3. the No Schema Robot has no flow of time, because every past event is as vivid as a present event. He has an experienced present that looks like that of the Tralfamadorians. Tralfamadorians are typical creatures that see three-dimensional objects also spatially in their temporal extension:

   > "the Universe does not look like a lot of bright little dots to the creatures for Tralfamadore. The creatures can see where each star has been and where it is going, so that the heavens are filled with rarefied, luminous spaghetti. And Tralfamadorians don't see humans as two-legged creatures, either. They see them as great millipedes-with babies' legs at one end and old people's legs at the other" says Billy Pilgrim.'[66]

   The picture of the block universe also pictures the temporal dimension spatially.

These three kinds of robot are products of a very creative mind, but their development is not very practical and evolutionary favorable. They might be possible; they surely are not very probable. The IGUS has benefit from registering the most recent information as the experienced present and from storing the older information into memories. It is not very practical to experience two presents or to store the whole temporal sequence of events as if it is concentrated in one moment of time. We do have a time lag in processing like the AB robot has, but our time lag is small compared to the scale at which things in our universe are used to change.

It is adaptive for an IGUS of everyday size to focus mainly on the most recently acquired data as input to making decisions. But still you assume the external world has a sequence of the most recent information.

It might be possible to come up with alternative organizations, but from nature it follows that this organization is evolutionary favorable. Other organizations might be possible, but they are not probable.

It is not probable for another reason either: if we think like Tralfamadorians[67] and we can observe objects in their temporal extension directly and simultaneously, we'd see them in a spatial extension, like the example of the moving finger in the previous section. Another example: a ball would not be a round object, but would be a long snake like object with round edges. This is what happens when you picture time as space and experience temporal extension like spatial extension, and memories that, no matter how old they are, make you think everything is present.

[66] citation from: Kurt Vonnegut, *Slaughterhouse Five*, in: Huggett, *Everywhere and Everywhen*, p. 96

[67] Huggett, *Everywhere and Everywhen*, p. 96

There is the content of perception (what is in P_0) that defines the present for every instant along the world line in the block universe. That is the four-dimensional description of the present, which is a cognitive universal and thus mind-dependent, according to Hartle. The present moment does not refer to a spacelike surface in spacetime stretching over the whole universe. The present refers to relations between events from a point of reference in the block universe. Think about how our time perception will evolve, when journeys through the universe are part of everyday life. Since the 'now' is local, it will be different in different frames of reference in spacetime. We cannot compare those local nows, because it takes time for information to travel from source to observer. According to Hartle every IGUSs has its own past, present and future, and therefore the division into past, present and future is mind-dependent. What events are in the present, is mind-dependent.

The different robots Hartle presented are not all equally probable in nature. The past, present, future robot is evolutionary the most favorable. Although the division into past, present and future is not the same for every observer, it still is the only favorable way to organize experiences. This organization is the best approximation of becoming. We need the ordered occurrence of events (=becoming) that exists in nature, to experience a present. I am not convinced that the organization into past, present and future is mind-dependent and that the decision what events are in the present is mind-dependent, and not part of nature.

3.6 Conclusions

The most important question that we asked ourselves in this chapter is whether the flow of time is mind-dependent or mind-independent. We defined the flow of time as 'the moving present'. Therefore we have examined in this chapter what the status of the moving present is.

We have seen in the section on motion illusions that it is very likely that the moving of the present is mind-dependent, because the experience of motion can be created by the brain, while objects are not moving at all. We intuitively think of the present as an object that is moving, but it is very probable that it is not moving at all. Savitt is right when he says that the 'now' is not a property that hops from event to event. The combination of the apparent motion effect, in which objects that do not move, are perceived to be one moving object, and the theory of conceptual blending we discussed in the first chapter, in which it is shown that we understand time through the conceptual blend between moving objects and static measurement units, points towards a mind-dependent moving present. The 'moving' present is constructed in the brain by the process of conceptual blending.

The experience of motion is created by the brain without observing any motion in the outside world. The moving of the present is mind-dependent, but is the present itself mind-dependent? I have not found any convincing evidence that tells me that it is. The experience of the present cannot be created by the brain without observing the happening of events in nature. The stimuli that come from these events that happen in a temporal order are needed to create from this information in combination with memories an experienced present, an expected future and a remembered past. Becoming is needed for the experience

of the present.

Is there then some physical counterpart of the experienced present in nature that can be defined as an objective and mind-independent present? The most natural answer is that events happen in the present. We can define the present as the most recently acquired information from happening events. But what events are happening depends on the frame of reference of the observer. Does that make the present mind-dependent? It does, if it turns out that the organizations of past, present and future is mind-dependent. It does not, if organizations of past, present and future depend on the nature of becoming. If these relations can be differently organized consistent with the laws of physics and the picture of spacetime, the notion of the present might be a cognitive (mind-dependent) universal of Information Gathering and Utilizing Systems (IGUSs).

Although the *remembered* past, *experienced* present and *expected* future can be differently organized, this is still with reference to what *is* past, present and future at your position in spacetime. The brain is adapted to represent as accurate as possible what is happening in nature. And therefore there must be a kind of *physical* (maybe causal) division into events that are in the past, in the present and in the future.

Six models on the perception and the experience of the present have been discussed and they are distinguished on the basis of three questions about the relation between temporal content of perception and the temporality of perceptual processing with two possible answers each. Whether the temporal content of perception is an interval or an instant depends on how you define perception. We have seen that we can divide the process that makes a representation in the brain of events that happen in nature into six steps.

1. events happen in nature;
2. transport of information through environment, body and the brain (perceptual *transportation* process);
3. $perception_1$: arrival of information at the back of the brain for cognitive processing at time(s) t_i (to t_k);
4. perceptual processes: mechanisms that can alter the content of information (takes time t_n - t_i)
5. $perception_2$: information that is available for conscious reflection = temporal content of perception that contains time(s) t_i (to t_k) made at some time t_n;
6. the representation made in the previous step becomes conscious.

The temporal integration window is an interval in which stimuli are perceived as simultaneous, i.e. as an instant. If you define perception as being step 3, then the temporal content of perception is an instant. If you define perception as being step 5, then the perception is an interval. The perception of motion is an example of perceiving an interval that is constructed from information of earlier stimuli. The content of $perception_2$ is smoothed, filtered and backtracked. The experienced present can be identified with the content of $perception_2$ and therefore we experience the present as an interval, in which we can perceive motion.

The present is an active construction and the representation of the content of what is present is purposefully delayed to make backtracking possible. In this way the brain can present us with the best representation that is possible of our environment.

We have seen that Grush ascribes two of these six models to Eagleman and Sejnowski and to Dainton. The fourth model is punctuated, delayed and active. According to Grush, Eagleman and Sejnowski describe the temporal content as an instant, purposefully delayed and actively constructed. Grush is correct about the last two properties, but Eagleman and Sejnowski do not explicitly say that the content of perception is an instant. Even then I think that when talking about perception the neuroscientists mean $perception_1$, and they describe what the flash lag effect can show about the role mental mechanisms play in the construction of the representation out of the stimuli that arrive at approximately the same instant of time at the back of the brain.

The fifth model of the temporal content of perception is an interval and passive. According to Grush, Dainton thinks the perceptual processes in the brain are passively copying the temporal order of the arrived stimuli onto the representation of the content of perception. But to me it seems that Dainton does not aim to describe what happens during perceptual processing. He only says that he assumes that the phenomenal content of perception is the same as what is consciously represented. He only describes the relation between steps 5 and 6 in his overlap model. I have suggested that Grush misinterpreted Dainton's 'phenomenal contents of perception' as $perception_1$ instead of $perception_2$.

To construct his Trajectory Estimation model, Grush combines the fourth model, of which he takes the active property, and the fifth model, of which he takes the specious present.

We have described six models on the perception of the present, and every model is slightly more complicated than its predecessor: the standard model is the most simple model and the sixth model is most complicated. However, Grush made some simplifications. In the models he only describes the steps 3 to 5 of the six steps that describe the process that makes a conscious mental representation in the brain of events that happen in nature. He assumed that step 1 to step 3 could be reduced to one represented domain p. His aim was to show the relation between the temporality of perceptual processes (step 4) and the temporal content of the representation (step 5).

In the figures 3.1 to 3.7, I offered image representations of the models that Grush only describes in his article. These images capture my interpretation of Grush' descriptions. From these models on the temporal content of perception in the first part of the chapter in combination with the perceptual processes described in the second part, I have gotten an idea of what is the most plausible theory of how the present is constructed in the brain:

When event A happens in nature (step 1), information from this event arrives at multiple sense organs at different times, e.g. the eyes and the ears. Photons and sound waves are processed by electrical pulses through neurons to the part of the brain where cognitive processing can begin (step 3). Because the arrival of stimuli of the same event A does not happen simultaneously, the brain uses a temporal integration window. This window (a spatial analogy) of a certain temporal and spatial width, merges these different arrival times of stimuli to one instant, as if the stimuli arrived simultaneously in the brain for cognitive processing. This is what we have called $perception_1$. Therefore the temporal

content of $perception_1$ is an instant and not an interval. The source of its content however is an interval that has been integrated by the temporal integration window.

Now that we have arrived at the back of our brain for cognitive processing, the mental mechanisms we discussed in this chapter actively process the content of $perception_1$. Information from earlier events that is extracted from memory is taken into account; the process of backtracking corrects estimates for newly received information; temporal integration mechanisms alter the size and the content of the window; and conceptual blending helps us to understand concepts, like time, that are not directly perceivable and therefore measurable. These perceptual processes in the brain alter the content of $perception_1$ and add information in such a way that the final representation of the present ($perception_2$) that comes into consciousness is constructed from information that occurred over a temporal interval that is bigger ($> 65ms$) than the size of the temporal integration window ($< 25ms$). The minimal duration of the temporal content of $perception_2$ is the purposeful delay that Eagleman and Sejnowski have discovered. This content that is available for consciousness, is an interval (step 5). How the brain decides what comes into consciousness and what does not (step 6), is barely known and therefore not discussed in this thesis. Dainton assumed in his simple overlap model that everything that is content of $perception_2$ comes into consciousness (acts of awareness A1, A2, etc.).

The temporal content of $perception_2$ already contains predictions of what will happen in the very near future, but before this representation comes to awareness the estimates are corrected for new information from incoming stimuli through backtracking. Both prediction and postdiction are taken into account.

This model shows that the experienced present is actively constructed and that it is an interval. This argues in favor for a mind-dependent experienced present. Also motion illusions and the theory of conceptual blending plead for a mind-dependent 'moving' of the present. That does not mean, however, that there does not exist a present in nature. The robots of James Hartle are not convincing enough that the division of past, present and future, that are consistent with the laws of physics and the structure of spacetime, can have other organizations at the same point in spacetime. Therefore there are no good arguments for a mind-dependent (and a cognitive universal) organization into past, present and future.

We must conclude that there are reasons to believe that the concept of the moving present is actively constructed by the brain and thus mind-dependent. But there are no arguments convincing enough to plead for or against a present that is itself mind-dependent.

Since we defined the flow of time as the moving present, and since there exists no such thing as a moving present in nature, it follows that the flow of time is also mind-dependent.

The most important question of this chapter has an answer. Although it is unknown what the status of the present is in nature (I guess it depends on how you define the present), it is certainly not a moving object that hops from event to event and keeps its identity through time. Time does not flow or pass in nature, but it is the ordered occurrence of events in nature that might be the source of information that makes us construct the experience of the flow of time in the brain.

Conclusion: bridging the gap

In this thesis we are confronted with a lot of information about metaphor theory, philosophy of physics, and the experience and perception of time in the brain. What answers can be given to the questions that define the problem of the flow of time? Does this interdisciplinary research offer new insights in the existence of the flow of time in physics?

I offered a new perspective on the flow of time in physics. Spatial analogies to understand time play an important role in the picture of time in physics. The first chapter discusses the role of spatial analogies to understand time in general. The second chapter offers an overview of today's debate in the philosophy of physics to show that thinking in spatial analogies causes some problems in the philosophy of time, e.g. the problem of the flow of time. In the third chapter some mental mechanisms are reviewed that create our experience of the flow of time. On the basis of this experience tensers believe that the flow of time exists in nature.

How are conceptual blending and these mental mechanisms such as temporal integration mechanisms and memory related to each other? We know that the experienced present is the interval that is stored in the STM, and the flow is caused by changing the content of the STM (change of content of $perception_2$). How are conceptual blending and memory related? The answer to this question has not been investigated in this thesis, but is surely interesting enough for further research. Here is my superficial idea though.

Information is stored in both the short term memory and the long term memory, but the same information is not kept forever in the STM (reminds us of dynamic A series), while it is kept forever, theoretically speaking, in the LTM (reminds us of static B series). We picture our memory also spatially, as a bunch of boxes, of which each box is filled with memories of events. The further away a box is, the further away in time these events happened. The closest box is filled with present experiences. These are stored in the STM, while all other boxes are stored in the LTM. So the way our memories are chronologically ordered in the LTM makes us think about time as a line. And the way recent information of events are stored in the STM for a short while, put into chuncks in the LTM and refreshed in the STM again, makes us think about the present as a moving dot.

Our memories are stored this way, because it is evolutionary favorable to have the most recent information about our environment. A robot that has two experienced presents that contain information of different events at different times is not very practical. A robot that has his experiences memorized as if

they all happen in the present, sees an object extended in not only its spatial dimensions but also in its temporal dimension. The object has beside its normal three dimensional spatial extension also a visualized temporal extension: humans are seen not as 'two-legged creatures, but as great millipedes 'with babies' legs at one end and old people's legs at the other'[68]. Tralfamadorians, that see the whole timeline as if it were spatial, are a product of human fantasy that shows the tendency to think about time in spatial analogies. Hartle says these robots are consistent with spacetime. They are, because the picture of spacetime itself is a spatial analogy. This does not mean however that these kinds of robots could exist in our universe. It is hardly possible that Tralfamadorians can exist. The only way conscious creatures can order events that is favorable in evolution is by organizing them into past, present and future. This thesis has shown that the way we think about time in physics is soaked in spatial analogies. Before we can understand better the nature of time, more research on analogical thinking need to be done. The first chapter is the most important chapter of this research. It offers a new perspective on the flow of time. Other philosophers of physics like Dainton and Callender have searched for answers in the field of cognitive science to close the gap between time in physics (the second chapter) and time in experience (the third chapter), but never is metaphor theory and conceptual blending involved. This thesis sheds new light on the debate of the flow of time in physics, in that it searches for an explanation of the problem of the flow of time in conceptual blending and analogical thinking.

In the first chapter we have seen that analogical thinking is a key aspect of human thought. Fauconnier and Turner's conceptual blending theory can give an explanation of why we experience time's flow. The answer from the metaphor theory perspective is that we use our physical experience of observing space in relation to objects when thinking about time. An object has a certain size and distances between objects are measurable too. They all can be measured using static measurement units and these units are in their spatial extension visible to us. Further, we observe motion of objects, which is change of position in space. We also observe change in temperature (motion of atoms and molecules), change in pressure (force on a surface), and change in velocity. Events are happening in time and events change properties of objects. If the event 'a lecture' is occurring, and I am attending this lecture, a change in knowledge, thoughts and position (I'm in the lecture-room instead of at home), is taking place.

Events occur and change exists. Time is a measure for change. The way we measure time is through the combination of static measurement units and motion. Static measurement units come from the domain of space. And change of position in space is motion. Time is an abstract notion, because we cannot directly measure it.

We have all kinds of clocks to measure time. Sandglasses use the different heights of the pile of sand as measurement units and the motion of the grains as the motion of objects. We can also find this blend of space and motion in candles and oil lamps. People put marks on these candles and lamps as measurement units. Sundials also have spatial markings and the combination of the moving sun (the rotation of the Earth) and these markings makes a measurement apparatus for time.

[68] Huggett, *Everywhere and Everywhen*, p. 96

Water clocks use flowing water. Both the sundials and the water clocks are likely to be the oldest time measurement instruments.[69] The ancient water clocks are probably related to the age old metaphor Time is a River and the Flow of Time. But it is not clear what came first. Probably one first needs to make an analogy between River and Time, before being capable of making a water clock. Therefore I think the metaphor Flow of Time is at least as old as water clocks are.

All clocks we have discussed so far use the domain of space and motion. Even the most accurate clock on earth, the atomic clock, does not use radioactivity. It uses the microwave signal of emitting electrons in the atoms when they change energy level by jumping from one shell to another. The closer the shell is to the atom's nucleus, the higher its energy. In other words, the electron's *position* in relation to the nucleus gives it potential energy. It all comes down to the domains of space and motion again.

To measure time we need the blend of two domains that are initially incompatible, namely the static measurement units we have in space and the motion of objects (change of position in space).

From the theory of conceptual blending we can understand the origin of the problem of the flow of time. It is exactly this friction between the measurement units of duration and the continuous change of events being future then present and then past, which causes the problem of the flow of time. McTaggart already noticed this incompatibility between what he called the dynamic A-series and the static B-series.

The theory of conceptual blending and space → time metaphors makes us suppose the idea that space is a more fundamental concept in human thinking than time is. That brings up two questions:

- Where does the origin of the concept of time come from? When did humans first think about time and did they think about space earlier?
- What does the concept of time that humans have in their minds tell us about time's ontology? If we can explain the concept of time from a spatial perspective, does that mean that time in nature may not exist, that only space exists? What does the space → time analogy 'Flow of Time' that humans construct from the concepts of space and motion tells us about the ontology of time's flow? Is there something in nature that causes this particular blending between space and motion?

The answer to the question on the origin of the human concept of time has to be found in history, archeology and cultural anthropology. It even might get some help from biology and neuroscience, if we are able to locate the neural networks in the brain where the concept of space and time are produced, processed and/or kept. Questions that might give us insight in the evolution of the human concept of space and time are: when do young children develop their first concept of space and of time? Are those concepts innate or learned? If the concept of space turns out to be innate and the concept of time is not, it might provide stronger evidence for the view that space is more fundamental in human cognition than time is. If both concepts are innate or learned, we cannot say anything about whether the concept of space is more fundamental than that of

[69] Anthony J. Turner, *The Time Museum. I: Time Measuring Instruments*; Part 3: Water-clocks, Sand-glasses, Fire-clocks, Rockford 1984, IL: The Museum.

time. If the concept of time turns out to be innate and the concept of space is learned, this outcome will go against the findings of Gentner, Boroditsky and Fauconnier and Turner. They have evidence that time is understood through the use of spatial analogies.

But what light will such findings shed on the physical status of space and time? If the concept of space is more fundamental than the concept of time in human thinking, does this provide any answer to the question whether space or time is more fundamental in nature? The answer to the second question is very difficult. We can never know for sure whether something we humans all observe, such as time itself and its passage, exists in nature. However we can collect arguments that favor one of the two possible answers. If we find that the brain constructs our feelings of flow actively without relations to time in nature, we might intuitively say that the flow of time does not exist in nature but is a product of the human mind. To find this out, we need to study the theory of conceptual blending and analogical thinking more deeply. Analogical thinking and conceptual blending are theories of mind. Very little is known of how and where in the brain analogies are constructed and conceptual blends are made, which is the neuroscientific part of this research.

This last question is very much concerned with whether the flow of time is mind-dependent or mind-independent, a question that has been tackled in the third chapter. In this chapter we also discussed whether the brain constructs our feelings of flow actively without relations to time in nature. Flow is actively constructed in the brain but it does relate to the ordered occurrence of events that we have in nature. Whether we can speak about the happening of events in nature without postulating time in nature is another question that is not included in this thesis either.

Many books and articles about the problem of the flow of time and the relation between time and physics and the experience and perception of time have been written; it is impossible to cover all different points of view.

In the second chapter I have tried to examine the mainstream positions, tensed and detensed views, in the debate on the problem of the flow of time.

Due to the incompatibility between the A-series and the B-series that McTaggart noticed, he thought time is unreal. But when taking into account the theory of conceptual blending, it sounds more plausible that he only showed that the *concept of time we have in our minds* instead of time itself consists of an A-series and a B-series. McTaggart says the A-series that describes change and therefore passage is a self-contradictory notion, because there is no relation of past, present and future to something outside the time series. Since the A-series is contradictory, it does not exist. If no A-series, there is no change, if no change, no time and therefore no B-series. The B-series is according to McTaggart static. Events are located in a B-series, just like objects are located in space. The amount of distance/duration between objects/events can be measured by using static measurement units.

I think that whether time is real or not, is a belief. Time can be a concept of the mind that we humans have invented to talk about change and measure it more easily; or time can be part of nature, like space and our bodies and brains are part of nature.

Some of us will say the concept of time, which is a product of the mind, is also a product of nature, because the mind is physical. They do not make the

distinction between what is mind-dependent and mind-independent. Others do make a distinction between mind-independent and mind-dependent. A unicorn is a product of the mind, but it does not mean it exists in nature. In other words, the question is: is time a product of our fantasy or does it exist in nature?

Philosophers choose on ground of the best arguments whether they think time exists. Some, like McTaggart, think time does not exist. McTaggart does so, because of the contradiction in the A-series. Other philosophers think time exists independent of us in nature. Time existed long before humans came. Realists about time can be divided in tensers, who think the block universe is not complete and detensers, who think the block universe is complete. We have seen that the question whether the flow of time is explicitly in the block universe is not one-to-one related to the question whether the flow of time is mind-dependent or not.

Tensers, who believe the flow of time needs to be explicit in the block universe, do not only think that time is real, but also think that the flow of time is real. They can be divided in possibilists and presentists. Possibilists, like George Ellis and John Perry, believe in a growing block universe where only the past and the present are represented. The future is not, because it is not real like past and present are. Presentists, like C.D. Broad, believe only the present exists. Detensers or eternalists who believe that the flow of time is already within the block universe are divided in two camps concerned with the question whether time is mind-dependent or not. The mainstream detensers, like Callender, Huggett, Sklar, etc., think flow is mind-dependent, but some, like Maudlin, do think there is an objective flow in nature. The most important argument they use is the argument of experience. We all feel that time passes; therefore the passage of time is natural and objective.

But in chapter 1 we have seen that human thinking is analogical. All humans seem to have the same blend of time. The argument that we all feel that time passes, is no good argument for saying that passage is a feature of nature. Tensers must show the feeling of passage is not caused primarily by the brain, but that we have a sense through which we observe this passage. If we are able to show that animals also have a sense for the passage of time, or that we can ascribe a sense of passage to robots, then we might have some evidence for an objective flow of time. In 2005 a paper has been published where the authors tell about their research in designing

> 'decision-making mechanisms for an autonomous robot equipped with simple sensors, which integrates over time its perceptual experience in order to initiate a simple signalling response. [...] decision-making is uniquely controlled by the time-dependent structures of the agent controller, which in turn, are tightly linked to the mechanisms for sensory-motor coordination. The results of this work show that a single dynamic neural network, shaped by evolution, makes an autonomous agent capable of feeling time through the flow of sensations determined by its actions.'[70]

In this article the flow of time is not mind-dependent, but already presupposed in nature that can be sensed through sensory-motor coordination, in

[70]Tuci, E., Trianni, V. and Dorigo, M. (2004), *Evolving the 'Feeling' of time through sensory-motor coordination: a robot based model*, in: Proceedings of PPSN VIII - 8th International Conference on Parallel Problem Solving From Nature, Berlin Springer-Verlag, pp. 1001-1010

which we have input of sensations and output of actions. The experience can be constructed by temporal integration mechanisms. Further research has to be done on time perception and artificial intelligence before we can test which of Hartle's kinds of robots are possible. Artificial intelligence is not a subject covered in this thesis. The article of Tuci et al. (2005) might however provide an interesting point of view from the discipline of robotics. In a PhD in cooperation with the Universit Libre de Bruxelles robotics concerned with the flow of time might be further investigated.

From chapter 2 it follows that the tensers' and detensers' views on the question whether flow is contained in the picture of time in physics, the block universe, can be reconciled. Savitt's definition of flow is somewhat different from what I think that it should be. He defines flow or passage of time to be the same as (absolute) becoming. Becoming is in his words: 'the ordered occurrence of events'. We defined the flow of time as the moving present. Savitt's definition does not include the 'now'. He thinks 'now' is just an indexical like 'here'. Both Savitt and Dieks do not provide any satisfying answer to the question whether the present is mind-dependent or mind-independent from the view of physics. They do however both have important contributions to a better understanding of the flow of time. Savitt reconciles the tensed and tenseless debate on the picture of time in physics in Newtonian space time, and Dieks does the same for both special and general relativity.

In Newtonian mechanics we can speak of absolute becoming and global nows. According to relativity theory global nows do not exist in nature and need to be replaced by local nows. Every observer has his own now in which he lives, like he has his own world line in the Block Universe on which he lives. Relativity theory however does not give us an answer on whether flow is mind-dependent or not. According to Hartle who's viewpoint has been discussed in the third chapter, relativity theory does give an answer, because the division into past, present and future can be differently organized consistent with the laws of physics and spacetime. This is not a very strong argument, since these different organizations are not very probable, and the facts that the present is local and dependent on the frame of reference do not imply it is mind-dependent.

Chapter 3 was the most extensive chapter of this thesis, but it offers nothing conclusive about whether the present exists in nature. From relativity theory, we have learned that the present is local and dependent on your position in spacetime. At every point in spacetime there is a different division of the events that are past, present and future, but we have no arguments for this division being mind-dependent. At every point in spacetime there can be an objective division into past, present and future.

The three robots (the Split Screen Robot, the Always Behind robot and the No Schema Robot) Hartle introduced might offer alternative organizations of past, present and future that are consistent with the laws of physics and the structure of spacetime; but they are not very functional for the representation of what happens in nature. We can assume that the brain tries to represent the happening of events as accurate as possible. To construct an experienced present, it seems that we need incoming stimuli from ordered occurrence of events in nature.

Mind-independent becoming helps the brain to construct a present; whether

it is the necessary input we need to experience a present, might be investigated by running tests on participants who get no information from the senses. Will such a test be possible, where subjects have nothing but their internal senses and thoughts and where they have no sight, hearing, taste, smell, touch, balance and acceleration from external things and events? Would they still experience a present? Would they still experience the flow of time? If so, events outside the mind are not neccessary to construct an experienced present or a flow of time. This would give us an argument for the mind-dependence of both the flow of time and the present. If not, information from the external world is needed to experience the flow of time and the present. Observation of becoming is then necessary to have an experience of what is present.

The six models on how the present might be represented in the brain, that are described in this thesis, assume that the happening of events in our world is the fundamental sensory input for the construction of the present. Further research is needed to examine whether this is correct.

The purpose of this thesis was to give an answer to both questions that define the problem of the flow of time:

(i) Is the picture of time in physics complete without adding the flow of time explicitly?

The answer to this question is given in the second chapter and is: yes. Both the tensed and tenseless views can be reconciled from the perspective of both metaphor theory and philosophy of physics. In the picture of time in physics the temporal dimension is a static spatial representation of a temporally ordered occurrence of events. Time is a measure for change and change is contained in the block universe. Whether the flow of time is mind-dependent or not, it is contained in the block universe.

(ii) Is the flow of time an objective feature of nature or is it a structure of the human mind?

The answer to this question has been given in the third chapter. From the perspective of both metaphor theory and the apparent motion effect, the moving of the present is mind-dependent. There exists no such thing as a moving present in nature. Therefore the flow of time, that has been defined as the moving present, is a structure of the human mind.

These answers are certainly not the last word spoken about the problem of the flow of time in physics. A lot of research still needs to be done in the field of cognitive science, before we can understand:

- whether the 'now' exists in nature,
- why we think about the concept of time the way we do,
- how this concept of time in physics in constructed from the domains of space and motion,
- how conceptual blending is related to memory,
- how the concept of time relates to time's ontology, and
- the origins of the concept of time.

I end this thesis with more questions than I started with. The problem of the flow of time remains an interesting problem to work on.

I have learned that the most difficult part of the debate on the flow of time in physics is to understand the differences between the viewpoints, and to distinguish these fundamental differences from miscommunications and misinterpretations.

I hope that I have offered you an insight in today's debate on the problem of the flow of time. My goal has been to excite your interest in what the theory of conceptual blending and other mental mechanisms can mean for the understanding of the experience of the flow of time.

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