The Passage of Years:
Enhancing the Understanding of Passage of Time Judgments by Investigating the Role of Autobiographical Memories

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Contributions

Article 1: The Passage of Years: Not a Matter of Covert Retrieval of Autobiographical Memories.

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Article 2: Time passes too fast? Then recall the past! - Evidence for a reminiscence heuristic in passage of time judgments.

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Article 3: Reminiscing and the Passage of Years: Investigating the Role of Affective Autobiographical Memories in Passage of Time Judgments.

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Preface

At least in Western societies, every adult person has certainly either complained him/herself or, at least, heard others complaining about how fast time passed, mostly in a regretful manner. When I was a child and then adolescent, I heard these complaints from the adults surrounding me and starting at about my mid-twenties, I started hearing these very same sentences from friends and acquaintances as well. Fortunately, I could hardly relate to this phenomenon and so I started wondering what might lead all these people around me to this conclusion.

Soon, I had developed my own everyday-theories, mainly focussing on the frequency of changes I experienced compared to my complaining fellows (in my twenties alone, I moved 9 times both between and within four different cities). It was already in my late twenties when I took part in an empirical psychology-class at the Ludwig-Maximilians-University in Munich, where we happened to investigate the experience of time. By and large, I found my own theories confirmed within the literature on which our own research-project was based: the more changes one experienced, the longer the respective interval seems to be (Avni-Babad & Ritov, 2003). However, in this course, we designed an experiment focussing on differing levels of reward for different stimuli but investigated an interval of about only two minutes. Although, some of the six studies presented in the aforementioned paper (Avni-Babad & Ritov; 2003) did cover longer intervals (up to a couple of days), this paper did also not report evidence regarding the multiannual intervals, which the people around me proclaimed to be elapsing so very fast.

After all, this class, held in winter 2011/12 by Dr. Kuhbandner, had put me on the trace of psychological time-research and thus was the starting point for the work presented in this thesis. To my surprise, I soon realized that the overwhelming majority of research conducted in this field investigated only short timeframes in the range of milliseconds to minutes while little studies tried to target the question that I wanted to answer: Are changes in life relevant for the experience of life-time passing by? And this despite – how I assumed back then – having the appropriate theories right at hand. Consequently, Prof. Kuhbandner and I decided to set up the studies that were aiming to fill this gap, based on the theories we subsumed under the term of memory-based approaches. These studies and their results will be presented in this thesis.

However, before presenting our own empirical studies, I want to (a) briefly portray some cornerstones that have been developed through the history of psychological work on time-perception before (b) providing an overview of theoretical and empirical accounts that have been established in this course. The latter helps to sort what research-questions can be targeted with which paradigms. Interestingly, the preceding retrospective of psychological research on time-perception unveils an interesting fact, namely that the fundamental deliberations of modern approaches actually root back to the 19th century.

1. Introduction to the Psychology of Time

1.1 The Beginning of Research on Subjective Timing

German Physiologist Karl Vierordt and some of his disciples were presumably the first reporting experimental evidence on the experience of time (see Lejeune & Wearden, 2009), most notably in the then influential book 'Der Zeitsinn nach Versuchen' ('The sense of time based on experiments') in 1868. As a physiologist, his starting point was to specify the sense of time, which he, together with the spatial sense, described as a general sense ('Generalsinne'). He distinguished these two categorically from what he called specific senses ('Specialsinne'), namely tactile, visual, olfactory, gustatory, and auditory senses. The sensations from the specific senses, he noted, are not comparable with the "objective nature of the stimuli" (p.13) in contrast to the perception of both time and space, which supposedly "have reality" in the sense of representing the objective character of the perceived space and interval. He justified this dichotomization by the observation that, in contrast to general senses, specific senses can be neither reproduced nor expressed in multiples. That is, one can reproduce duration but not taste or smell, one can express the length of two spatial sizes in terms of "one is twice the first", while one can only judge one stimulus as louder than the other but not quantify the relation[1].

[1] This typology seems plausible to some degree but certainly lacks consistency. For example, loudness can be roughly reproduced and temperature (as Vierordt himself acknowledged with reference to an exercised pool attendant) can be roughly quantified. Some of these considerations seem to be a result of the then not-yet established typologies regarding different levels of measurements. Discussing senses along these levels might provide a more appropriate typology but is beyond the scope of this work.

With regard to these intuitively possible quantifications, he considered general senses as mathematical senses, although explicitly alluding to the fact that these quantifications and representations contain errors. This led him to considering the mechanisms explaining these errors as a matter of psychology and saw his contribution in providing a first attempt in exploring systematic errors in human time perception.

He also described three possible dimensions, in which a quantification of time perception is possible: reproduction of intervals, judgments of the duration in time units and the judgment of an interval as having passed at a certain subjective velocity (Vierordt, 1868), which are basically the dimensions psychological research on time perception follows until today (see chapter 1.2.3.2).

The studies concerning time-perception[2] reported in 'Der Zeitsinn nach Versuchen' are – with one exception - limited to the range of about 6 milliseconds to 90 seconds and apply mainly methods of production and reproduction (i.e., reproducing a given or self-produced and reproduced interval) and comparative methods (comparing the length of different intervals). Vierordt himself and two of his disciples served as subjects in all of the presented studies. The main finding, which became renown under the term of 'Vierordts Gesetz' (Vierordt's Law) is that short durations are reproduced as longer than they actually are, while longer durations are underproduced, both separated by an indifference-point where reproduction and the original interval have to be identical. Based on his studies, Vierordt described this point to lie somewhere between 500 ms and 5 s, depending on different sensory modalities addressed with different designs, whether pauses have been implemented between presentation and reproduction, but just as well inter- and intraindividual (i.e., different test series on different dates) variations.

This law is supposedly reproduced in the only 'experiment'[3] targeting longer time-spans. Here, Vierordt himself simply estimated time-spans during which he was caught up with simple

[2] The last three studies focus on the perception of velocity, all other studies targeted duration judgments.

[3] Vierordts understanding differs from what is now established under the term of experiment since no manipulations take place in all of the studies.

work (namely preparation of his experimental devices) and calculated the mean deviation from the true duration. However, while the number of experiments and trials in the experiments discussed above might, due to an astonishingly high number of trials, allow some limited generalisability, the comparatively low number of trials on one participant combined with the relatively high error-variation evokes some caution in interpreting this result as confirmative for his law.

Vierordt also assumed different cognitive mechanisms regarding time perception of short and long intervals. Although he did neither provide studies nor in-depth explanations, he distinguished 'sensation' ('Empfindung') as mechanism for short durations from 'deliberate perception' ('überlegte Wahrnehmung') for long durations. While he asserted the basic principles concerning his law would attribute to both long and short durations, even explicitly transmitting this to intervals of months and longer, he did unfortunately not outline any thoughts on what might be the cognitive differences regarding sensations and deliberate perception for short and long intervals respectively.

Another matter of Vierordts interest was the sensitivity to discrimination of the duration of stimuli, which he studied in detail for different senses as well. Here, he observed a tendency of later intervals being often falsely identified as being longer. This can be seen as an early version of studies investigating the so-called time-order-error, which has been addressed in research decades later (e.g. Block, 1978; see chapter 1.2.2).

Vierordts contemporary and fellow physicist Wilhelm Wundt also touched on the perception of time in his field-defining 'Die Grundzüge der Physiologischen Psychologie' (1872, 1893 published in English as 'Principles of physiological psychology').

Other than Vierordt, whose work was in particular investigating differences in the perception of duration, Wundt focused primarily on psycho-physiological processes regarding the perception of time. He described the process of time-perception as consisting of (1) a nervous transmission to the sensorial modality, (2) the perception (i.e., entering awareness), (3) apperception (i.e., deploying attention), (4) the time it takes to shape a will ('Willenszeit') to trigger a central-nervous in order to achieve a physical reaction, and (5) the transmission of this

information to the respective muscle. Wundt discussed whether perception, apperception and 'Willenszeit' or only apperception ought to be considered as psychological processes. However, his main focus was to determine the sensitivity threshold of tactile, auditive and visual senses. His studies suggested this physiological time to be in the range of 70 to 350 ms and being shorter with increasing strength of the stimulus (e.g., the loudness of signals).

However, serving his ambition in establishing psychology, he also discussed the cognitive mechanisms defining time. According to his deliberations, perception of time is the consciousness of representation of a succession of stimuli (see, Deng, 2019, for a current representation of this idea). To come to a representation of time, a first stimulus has to be processed (e.g., a sound) and a second stimulus has to define the interval, which is similar to ideas outlined in some later internal-clock-models (see chapter 1.2.1). Wundt also highlights that the mere representation of these two stimuli is not sufficient and argues that between these two, the representation of the first stimulus has to be mentally present ('Phantasiebild'). By having these three elements present in the conscious mind, a representation of time comes into being. This conceptualization of time is consequently limited to short intervals and arguably describes roughly the same phenomenon as Vierordts 'sensation' but not the 'deliberate perception' of time.

In the late 19th century, William James made another influential contribution to the field of time-perception. In a more philosophical tradition but under consideration of the empirical results that Vierordt, Wundt, and others provided, he outlined fundamental ideas informing and influencing psychological research until present times. In fact, defining this very concept, present, and discriminating it from past and future, was part of the principles of psychology (James, 1890,). He described that something like a past exists for humans due to the fact that we memorize things in delimitation from sensory experiences, which constitute the experience of a present. He outlined the present as something that is cursory but still hast some extent or, as Wearden (2016, p. 8) put it, is "non-zero". This is in contrast to the perspective of his contemporary Guyau, who considered present as being "a moment of transition between the past and future, […] which cannot but be conceived of as infinitely small" (1890, p. 30). James, arguing for present having tangible duration, considered duration as "[t]he unit of composition

of our perception of time" (p. 611). Studying and discussing in-depth experimental results of his time, James tried to define the lower and upper limits of intervals that people perceive as entities, but also came to the conclusion that these subdivisions are not "essential to our perception of its [i.e., times] flow" (p. 619). Instead, he ascribed our perception of time to the "filling of the time, and to a memory of a content" and already pointed out that "[a]wareness of change is […] the condition on which our perception of time's flow depends" (p. 619f.). The underlying concept of time here is more psychological as Wundts physiological approach and might be closer to Vierordts 'deliberate perception'.

This fundamental thought of later time-perception-theories (in particular contextual change hypothesis, see chapter 1.2.2) can still be considered as the basis of a huge part of modern empirical research on time-perception using retrospective paradigms. While James believed in some physiological sense allowing the perception of time for short durations, he claimed that there is no such sense for empty time consequently building his theory of time perception on cognitions. More specifically, the duration of long intervals is supposedly based on the reproduction of memories. In his words, variations in the experienced duration (note that duration and passage are not formally distinguished here) "may possibly be explained by alterations in the rate of fading in the images [in the sense of memories from that interval], producing changes in the complication of superposed processes, to which changed states of consciousness may correspond." (p. 638). That is, experiencing an overlap of memories from the interval in question in the very moment of thinking about this interval supposedly shapes the perceived length of the interval. This, additionally, points out that there is no feeling of past time, tapering these considerations as "the feeling of past time is a present feeling" (p. 638).

Wundt and James both already share the idea that mental representation of stimuli is a key variable in explaining the experience of time. In the 1920ies and 30ies, however, another important line of timing-research came up, focusing on the idea of a physiological sense for the experience of time. François and Hoagland published empirical studies showing evidence for what the latter called the "chemical clock" (see Wearden, 2016, for a detailed discussion). Following a daily-life observation where the neuroscientist Hoagland realized that his wife perceived time very differently while suffering from fever, he as well as François reported data

showing that an increase in temperature is associated with slower production of seconds or rhythms (Wearden, 2016), a finding that has been repeatedly replicated (see Wearden and Penton-Voak, 1995). The assumption of the sense of time having a neurological basis in terms of a chemical clock mirrors Vierordts idea who secondarily noted that the sense of time in terms of bringing the experience of one stimulus after another to consciousness is supposedly present in all conceiving nerves in the human body.

1.2 Established theoretical and empirical Approaches

Overall, however, the era of Behaviorism implied a renunciation of research on psychological time, particularly regarding the explanation of actual cognitive processes. With the cognitive revolution and particularly in the 1960s, psychological research on time-perception came to a new high. In this period, more elaborated theories trying to explain mental processes emerged. These are, by and large, still the theoretical instruments of modern psychological research on time perception. The most important approaches are discussed in the following chapters.

1.2.1 Internal Clock Models

While François and Hoagland (as well as Vierordt) believed in some sort of a neural chronometer, the understanding of an internal clock evolved into a mainly psychological one in the 1960s. Treisman (1963) might be the founding figure for the modern internal-clock or pacemaker-accumulator-models, explicitly drawing from Hoagland but repulsing a “neural identity of the components of the model” (p. 19). These components are a pacemaker, producing pulses, which travel along a pathway to a counter, which records the number of pulses produced and – in these early versions – transfers them to a store. Parallel to the store, the verbal selective mechanism is a long-term memory-repository for conventional time-units such as seconds and minutes. So, the pulses entering the store get attached with a verbal label for conventional time-units. An extra comparator is used to align intervals of the present (from the counter) with stored ones from the past (lacking any other unit, the model implies that the comparator also retrieves these). Consequently, the comparator informs a response. The rate, at which the pacemaker acts, depends on the specific arousal center, which is supposedly constant under stable conditions but varies between individuals and situations (Treisman,

1963).

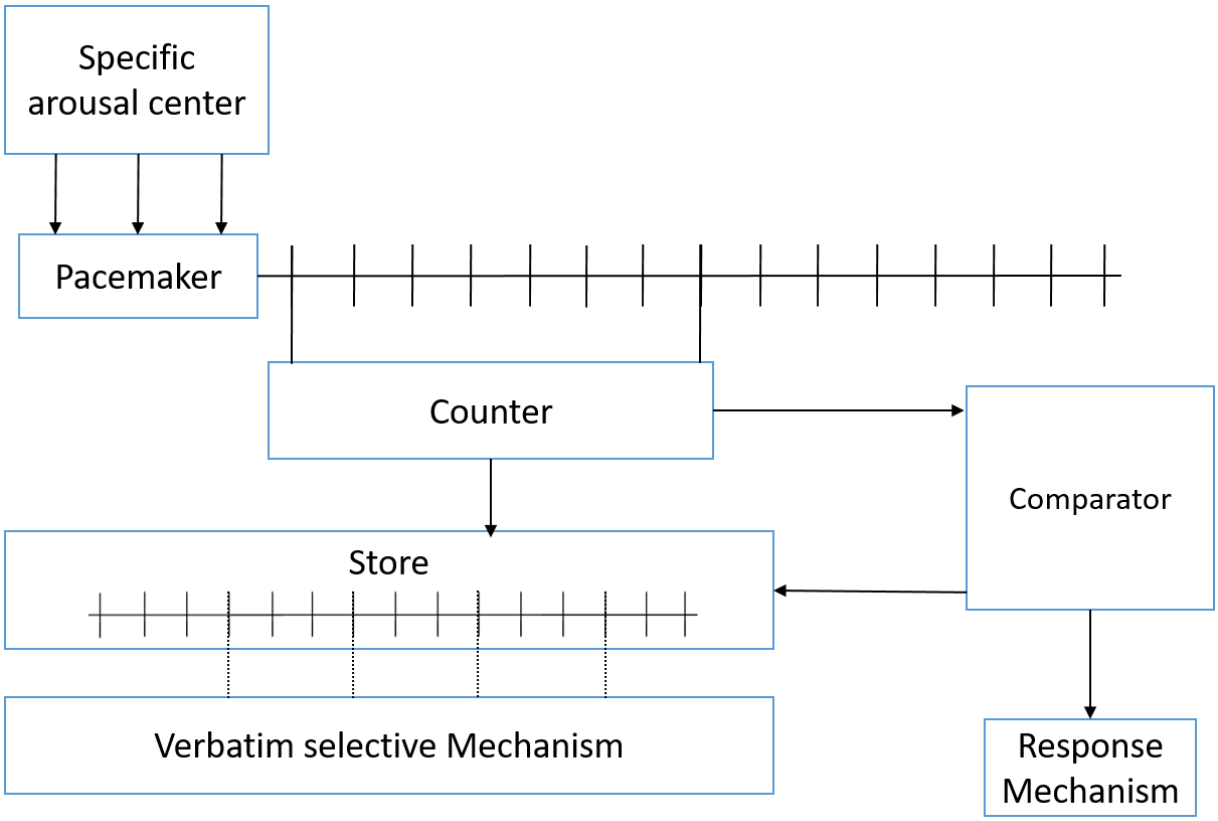

Figure 1, Internal-Clock-Model as suggested by Treisman (1963).

Scalar-Expectancy-Theory, based on work investigating animal timing (Gibbon, 1971, 1972; Gibbon et al., 1984), in later stages informed by Treisman's preceding work, was a similar theoretical approach. The emerging model resembled Treisman's but subsumed the processes in three different qualitative levels, namely a clock-, a memory- and a decision-stage. Maybe even more importantly, Gibbon and colleagues introduced what they called a 'switch' into the model. In their take, this switch ensured that the beginning (as well as the end) of an interval was marked, enabling that pulses were gated into the accumulator, which, in turn, allows the comparative memory processes. However, later this switch was considered to first and foremost allocate attention, which was considered to decide whether and how many pulses are to be available at the memory and decision stage and thus for the whole experience of time (Droit-Volet & Meck, 2007).

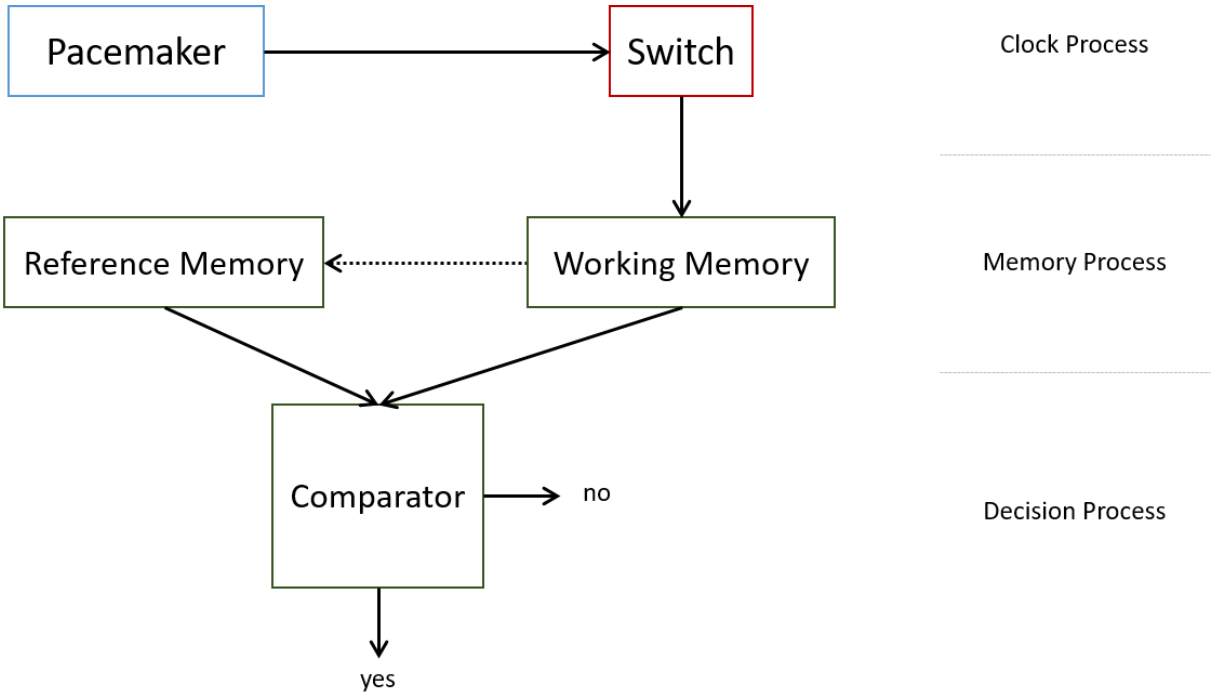

Figure 2. Internal-Clock-Modell following the proposal of Gibbon and colleagues' Scalar Expectancy Theory (1984).

This somewhat unspecific rendering of allocation led to another amendment of these sort of Models. Zakay and Block (1994), mainly known for their work on contextual change in retrospective timing, explicitly added an attentional gate to the model, which exclusively describes whether attention is allocated to the passage of time or not. This limited the function of the switch to opening or closing the counter depending on whether temporal meaning is assigned to incoming information.

Summed up, these models, which describe an internal timing mechanism based on pulses and a comparative process with working and reference memory, have been very influential on psychological research on time-perception (Wearden, 2001). They provide, in particular, the theoretical foundation for most modern research regarding prospective time perception for short durations (Wearden, 2003). Interestingly, most of the work examining potential mechanisms is solely focused on mechanisms on the clock-stage, in particular investigating the effect of different stimuli on pacemaker and attention. A body of research highlights the importance of both attentional and arousal-effects on the experience of time

(e.g. Droit-Volet et al., 2004; Noulhiane et al., 2007; Tamm et al., 2014). Neither theoretical work nor empirical studies, however, approach questions regarding the memory-processes these models rely on (e.g., when and how are prototypical time-units built? Are cognitive processes such as the retrieval of or the comparison with these stored time-units subject to any distortion?).

1.2.2 Memory Based Approaches

Memory is the domain of another string of research regarding the perception of time. These approaches conceptualize the perception of time as a function of information and/or memories and their interdependencies. As Deng (2019) recently put it, time is succession, the perception of one thing after another, highlighting the meaning of events and the remaining memories as the fundament of how humans can conceptualize time at all. This mirrors not only Wundts idea that time *is* the representation of stored information, but also a central argument in another influential book regarding the perception of time. In the 1960s Fraisse (1963) outlined his concept of time along the experience of succession and duration. Experiencing succession means to notice that all experiences are "becoming past" and realizing this to be irreversible, that is, "the impossibility of a recurrence of what has been to the level of perception" (p. 285, translated by the author). Due to memory, this experience enables humans to have time perspectives, to distinguish between one's past and to anticipate a future present. Duration, the second kind of time-experience according to Fraisse, is based on the memory of succession and is supposedly shaped by the distance of memories with the quantity of memories between two points in time. He concludes that neither of these dimensions (succession and duration) *is* the experience of time as such but suggests these two as the symbolic representations of time. Thus, he describes time as "a product of each person him/herself, who tries to reconstruct the changes, she/he takes part in." (p. 289).

At about the same time, Ornstein published his doctoral thesis 'On the experience of time' (1969), which provided both a more elaborated theoretical approach as well as experimental evidence regarding the interplay of perceived information and the experience of time. His postulated storage size metaphor, which is still very influential for present research, explains the experience of time with regard to stimuli and the remaining memories. However,

it is noteworthy that Ornstein differentiated the experience of time in four dimensions, namely (a) short time (subdivided in rhythm and immediate apprehension of brief intervals), (b) duration, (c) temporal perspective and (d) simultaneity and succession. In his empirical works, however, he focused on duration only. He rejected the idea of an inner sense for the experience of time, which he considered as "the major reason for the confusion in [research investigating] time experience" (p.102), and presented twelve experiments in which he mainly varied quantity of information and the conditions, which led to different encoding-processes. The results led him to the postulate that the experience of time was a result of the size of stored information from a given interval. Importantly, the storage size, in turn, is neither only the information given nor the sheer quantity of information encoded, but also depends on what information from "the interval […] reach[es] awareness and the way in which that information was 'chunked' and stored." (p. 105).

Ornstein himself described his work explicitly as tentative, suggesting it as starting point for future research. In particular, Block pursued the idea of memory-content being relevant for the experience of time and continued working with similar research paradigms (manipulation of content of short intervals and measuring the experience of time by indicating duration as relative length on different lines) in a number of experimental studies (1974; 1978; Block & Reed, 1978). Block, however, presented findings that, as he concluded, described limitations of the Storage-Size-Metaphor. First, the experienced duration of intervals did not change despite different levels of processing (shallow vs. deep). More precisely: despite deep processing of presented information resulting in more memories available from the respective interval, the experienced durations did not differ between the respective conditions. He also observed a positive Time-Order-Error[4] , that is, the phenomenon that the second of two (largely) identical intervals (regarding both duration and content) is mostly perceived as shorter, which, according

[4] Ornstein himself introduced the Time-Order-Effect, but in the opposite direction, explaining that the duration of an interval containing (auditory) stimuli is perceived as shorter when judged directly after the interval compared to a later duration judgment. Controlling for content in memory also revealed that this is due to this content, since both postponed judgments were shorter and memory of the content was lower in a condition where encoding was aggravated. Block discussed this as negative Time-Order-Error.

to Block, cannot be explained by the Storage Size Metaphor[5]. Instead, Block and colleagues were able to show that the perception of cognitive change (which can refer to changes in stimulus-patterns as well as to changing locations between judging identical intervals with identical material), leads to an extended (or at least not a shortened) perception of duration. These findings led to an amendment of memory-based-approaches highlighting that "remembered duration is mediated by the remembered amount of change in cognitive context during an interval." (Block & Reed, 1978, p. 657), coined as contextual change hypothesis.

Together with internal-clock-models, this theory provides the theoretical foundation for most research regarding the perception of time. While the first are particularly important regarding the prospective experience of time (see next chapter), the latter is the most-established choice to explain the retrospective experience of time. Additionally, most of the (relatively rare) research conducted regarding long intervals (i.e., intervals ranging from days to years) refers to contextual change hypothesis as well as to Ornsteins storage size metaphor when explaining differences in findings – despite the fact that the fundamental mechanisms of these have been investigated only with lab-research covering short durations in the range of seconds to minutes.

1.2.3 Different Research Paradigms to Investigate the Subjective Experience of Time

1.2.3.1 Perspective of Judgment: Prospective vs. Retrospective

Prospective and retrospective time-perception, as mentioned before, are one crucial differentiation when investigating the phenomenon of time-perception. This distinction is the fundament for the scientific validation of the common belief that time is experienced as short and/or passing by fast when experiencing a lot during this time but feels rather long/having passed slow in hindsight and vice versa for intervals with little information.

As Wearden (2016) outlined, this principle has already been described by William James. Block (1974) used the terms remembered duration and experienced duration to distinguish

[5] One might disagree, since a second interval with the same duration and content might evoke a more shallow encoding resulting in less stored stimuli and thus storage size metaphoar might explain the positive Time-Order-Error as well.

between the two phenomena, which point towards two different mechanisms for time-perception: The first describes a situation, where peoples' attention is (at least partially) aligned towards time, while the latter is a post-hoc evaluation of the subjective experience of time. Hicks and colleagues (1976) coined these disjunct phenomena with the terms prospective and retrospective timing and presented evidence that subjective duration is shorter the more information is processed in the prospective paradigm[6]. Since then, whenever subjects are aware of time as matter of the investigation in advance, the respective paradigms are called prospective while targeting the experience of time with initially naïve subjects (concerning time as matter of investigation) is considered as retrospective paradigm.

1.2.3.2 Type of Judgment: Duration Judgments vs. Passage of Time Judgments

As aforementioned, e.g., with Ornstein's (1969), Fraisse's (1963) as well as Vierordt's (1868) and Wundt's (1872) dimensions, time and its perception can comprise a number of different phenomena. In empirical research regarding subjective timing, subjects are primarily asked to estimate the duration of intervals, typically referred to as duration judgments since the 1960s (see e.g., Hawkes & Worsham, 1970; Warm et al., 1967 for early uses of the term). There is, of course, a variety of methods, with which duration can be assessed, including direct verbal estimations of time-units, productions and reproductions (e.g., estimating a predefined time-span by indicating the start and end of it, or reproducing a time span, that has been presented to the subjects), psychophysical measurements (e.g., indicating the relative length of an interval by marking a length in comparison to a line, indicating a previously experienced baseline-interval), or dual-bisection-tasks (comparing and judging the duration of stimuli-presentation as closer to short or long predefined anchor-intervals; for an introduction see Kopec & Brody, 2010). All of these paradigms are primarily used to assess the experience of time in short intervals, i.e., in the range of milliseconds up to minutes, and rarely hours (e.g., Vierordt, 1868). Duration judgments regarding extensive intervals up to several years are, by contrast, very rare. To my knowledge, the only works applying a paradigm which can be considered as duration judgment for multiannual intervals have recently been published by Ogden (2020; 2021). In these studies, participants were asked about the experienced duration

[6] Avni-Babad & Ritov (2003) later presented evidence showing the opposite effect for retrospective duration judgments as well.

of the lockdown during the Covid19-Pandemic, that is, whether the last 8 months were perceived as having passed longer or shorter than usual 8 months (5-point-likert-scale ranging from “a lot shorter” to “a lot longer than 8 months”). Given that participants seem to have an intuitive take on how to answer the question (only a minority chose the center-value indicating a perception of 8 months being experienced as “about 8 months”), this might be a valid measure targeting a certain aspect in the experience of time.

Commonly, however, the time-perception for intervals of such length are assessed by asking about the experienced velocity with which they are perceived to have passed by (e.g., Friedmann & Janssen, 2010; Wittmann & Lehnhoff, 2005). Wearden (2005) suggested to consider this as a separate paradigm in addition to prospective and retrospective duration judgments and labelled these Passage of Time Judgments. However, while Wearden (2016) seems to imply that passage of time judgments can be of retrospective nature only, nothing actually prevents researchers from applying questions regarding the velocity of time in a prospective paradigm, where subjects would be aware of the phenomenon for the respective interval. Additionally, evidence suggests that the perception of velocity is not just a mirrored duration judgment with the same interval being potentially experienced as long and having passed fast, and vice versa (Wearden, 2005), and also that passage of time and duration judgments of daily activities are rather independent (Droit-Volet & Wearden, 2016). This suggests that both paradigms, duration and passage of time judgments, approach different dimensions of the human experience of time.

Taken together, there are two dominating dimensions in current psychological research on the experience of timing, which I want to caption as Type of Judgment (passage of time vs. duration judgment) and Perspective of Judgment (prospective vs. retrospective, see Figure 1 in chapter 2.3).

Summed up, a large number of psychological studies on time-perception makes use of duration judgments in prospective paradigms, since these are rather easy to set up and to interpret. As aforementioned, in particular internal-clock-models have provided a helpful theoretical foundation for this realm of research, leading to many insights, in particular regarding the role

of attention as well as the influence of psychophysical processes for subjective duration. Although not to the same extent, retrospective duration judgments have been studied widely as well. This string of research is mainly based on theoretical ideas previously described as memory-based approaches, of which the contextual-change-hypothesis has become the dominant one. Surprisingly, throughout the history of psychological research on the perception of time, little research was published that was aiming at understanding how people perceive life as a whole (or, as a proxy, multiannual intervals) to pass. This might be due to two interlinked reasons: First, in current psychology, experimental paradigms are clearly the predominant method, even explicitly recommended by the American Psychological Association (VandenBos, 2015). However, perception of time for long intervals cannot be accessed using experimental methods. Additionally, the lack of research might also originate in a belief that the perception of long-intervals is simply an extension of the experience for short intervals, as suggested in some studies (e.g., Espinoza-Fernandez et al., 2003). However, this presumption, which has not been explicitly investigated, is unlikely to be true (see Block et al., 1998 and chapter 2.1 for a detailed discussion).

In the last 20 years, research targeting the understanding of multiannual intervals has become more frequent, often but not solely aiming at the phenomenon of a perception of time passing by faster with aging (e.g., Friedman & Janssen, 2010, Wittmann & Lehnhoff, 2005). As outlined before, in these works, the subjective experience of time has hardly ever been approached via estimations of duration, but by asking people to judge the passage of time, i.e., the velocitiy, with which they perceived time to have passed.

Given the lack of research on time-perception of multiannual intervals, there is, however, no research that provides a distinct and specific theoretical framework for that matter. Memory-based approaches, which suggest that the information stored and retrievable from the intervals in question, provide a theoretical anchor that seems plausible for the perception of time regarding multiannual intervals as well. Consequently, authors investigating the experience of time for longer intervals often refer to these (e.g., Avni-Babad & Ritov, 2003; Wittmann & Lehnhoff, 2005), but the fundamental claims of these theories have been verified only in lab research covering intervals in the range of seconds to minutes. Thus, the studies

presented in this thesis aimed to close this gap by investigating whether or under which circumstances autobiographical memories are relevant for the perception of multiannual intervals.

1.3. Outline of the Current Research Endeavour

As outlined before, in some of the few studies, which investigated the experience of time for long intervals, results were interpreted in the context of contextual change hypothesis. The according authors argued that variations in life-events (e.g., Wittmann & Lehnhoff, 2005) or variations in memories (Avni-Babad & Ritov, 2003) would account for differences in the reported experience of time. This fundamental assumption, however, was neither targeted in these studies, nor are there, to the best of my knowledge, any other studies that investigated whether variations in the reported experience of time for long intervals are in fact associated with variations of the respective life-events or accessible memories thereof.

The first two studies (Study 1a and b) presented in the first of the following three articles[7] were initially set up to provide evidence for the fundamental claim of more variation in life leading to a perception of time passing slower. Additionally, we investigated this not only by approaching the actual variation of life-events but also by surveying the most meaningful memories that participants could spontaneously recall.

Additionally, memory-based approaches apparently presume a covert retrieval meaning that memories from the relevant time interval do not have to be actively recalled in order to being relevant for the respective experience of time (e.g,, Block & Reed, 1978; Ornstein, 1968). This idea, which is plausible for short intervals, has been implicitly transferred to studies regarding the perception of long time intervals as well when authors attribute differences in POTJs for long intervals to variations in life-events or potentially accessible memories of these, This assumption seems in contrast to James' idea that the perception of

[7] The order of the articles in this thesis does not depict the chronology of the publication of these articles (article 2 was published first). However, the order presented in this thesis depicts the succession in which the studies were conducted.

duration of the past is a result of the succession of images from that past (1890), which is similar to Fraisse' (1963) and Dengs' (2019) conceptualizations. All these deliberations seem to imply that memories have to be present to shape a subjective perception of time. Premising that a comprehensive activation of memories happens automatically when judging the experience of time for multiannual intervals (as done in, e.g., Wittmann & Lehnhoff, 2005) is potentially premature. Instead, research from other domains suggests that information that is present at the current moment is crucial for the respective judgments (e.g., Kahnemann, 2011) and whether and/or which memories are present at the current moment when judging the passage of time for years is certainly rather arbitrary given the plethora of potential memories from multiannual intervals. Therefore, it seems necessary to clarify whether POTJs are different after a conscious activation of memories.

To this end, we compared Passage of Time Judgments (POTJs) for multiannual intervals given before or after having actively recalled memories from the interval to be judged. The results of this experiment are reported in the second article.

After clarifying whether and how autobiographical memories affect POTJs in general, we aimed to investigate whether the emotional valence of these memories is a crucial factor regarding these judgments. Previous research, in particular regarding shorter time-intervals, shows that affect is associated with the subjective experience of time (e.g., (e.g. Droit-Volet & Meck, 2007; Gable & Poole, 2012; Vogel et al., 2018). This means that, if activation of memories is relevant for subsequent POTJs, the valence of these might matter as well. Therefore, in the study presented in the third article, subjects were asked to recall either only positive or only negative autobiographical memories from the last five years before judging the passage of time for these years.

In all of the present studies, we basically followed the paradigm used in the most influential study regarding time-experience for long intervals published by Wittmann and Lehnhoff (2005), which has subsequently been applied in studies by Janssen and colleagues (e.g. Friedman & Janssen, 2010; Jansen et al., 2013; Lee & Janssen, 2019). In this paradigm, subjects indicate their experience regarding the passage of time on a Likert-scale ranging from

"very slow" to "very fast"[8]. In the course of our studies, however, we changed the question asked to our participants from "How fast did the previous five years pass for you?" to "How did the previous five years pass for you?" to delimit its suggestive character. Furthermore, In all of our studies, we targeted an interval of five years, while in previous studies the only multiannual period targeted was 10 years. We cut this period because charging a comprehensive review of life-events or recall of important memories from our participants seems reasonable for the last 5 years. This should have enabled our participants to capture most of the relevant life-events or important memories and thus provide a solid data quality and low drop-out-rates. Thus, we considered the five-year-interval the best compromise between long duration and reasonableness to our subjects.[9]

[8] Earlier studies such as Wittmann and Lehnhoff (2005) and Friedman and Janssen (2010) offered 5-point-scales while in later studies (e.g., Janssen, 2016) 7-point-scales were applied. We followed the latter since this enabled to differentiate between fast/slow and rather fast/slow whereas in the initial version there was no intermediate step to choose between fast/slow and neither fast nor slow.

[9] Additionally, we always surveyed the passage of time for the last year as well so we were able to monitor whether our data contained comparable judgments as found in the previous studies such as Wittmann & Lehnhoff (2005) and the studies from Janssen and colleagues (e.g. Friedman & Janssen, 2010; Jansen et al., 2013; Lee & Janssen, 2019) .

2. Peer-Reviewed Articles: Investigating the Relation of Passage of Time Judgments and Autobiographical Memories

2.1 Article 1: Covert Retrieval of Memories and the Passage of Time

This is a pre-copy-editing, author-produced version of an article published 2021 in Frontiers in Psychology (Cognitive Science) following peer review. The official citation that should be used in referencing this material is Kosak, F. & Hilbert, S. (2021); The Passage of Years: Not a Matter of Covert Retrieval of Autobiographical Memories. *Frontiers in Psycholgy. 12:744551.*

Abstract

In current research, variations in retrospective passage of time judgments for long intervals are commonly attributed to differences regarding the number of experiences in these intervals or the accessibility of the respective memories. This seems to imply the assumption of a covert retrieval, where authors presume that memories from the respective interval influence the experience of time without these memories being explicitly activated when judging. However, no studies have systematically investigated the relation between the experience of time and the respective experiences and memories. To this end, we analysed data from three studies in which participants judged the passage of the last five years either before being asked to select outstanding life events from a list (Studies 1a and b; N = 293 and 263) or before recalling as many meaningful personal memories as were spontaneously accessible (Study 2; N = 262). Despite applying a statistically powerful trial-by-trial mixed-effects modeling approach, neither in the separate datasets nor in the combined dataset, passage of time judgments were predicted by the number of reported events or memories. This suggests that people's spontaneous judgments of the passage of multiannual intervals are not necessarily affected by a covert retrieval of memories from the respective period.

Keywords: passage of time judgments, subjective experience of time, contextual change hypothesis, storage size metaphor, autobiographical memory, covert retrieval

Introduction.

The velocity with which humans perceive time to pass by is a common matter of discussion in both daily life, where people often seem to complain about time flying, as well as in academics, where researchers try to validate and explain this phenomenon. In fact, when asking participants about their experience of time passing for intervals ranging from days up to a decade, responses predominantly indicate an experience of time passing rather fast (Flaherty & Meer, 1994; Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005). In attempting to explain the subjective experience of time, different theoretical and empirical approaches have emerged.

Ratio-Theory

Already in the 19th century, Janet and James (1877; 1890; as cited in Block et al. 1998) brought up the idea of a ratio-theory: given that the ratio of time units to life gets smaller with every unit, they argued that the relative length of these units compared to our lives constantly decreases. Assuming that our perception of duration has to be in relation to some reference, and considering life as a whole as a potential all-embracing reference frame, the process of aging could evoke the impression of time passing faster than in the past at every single point in our lives. Implying that humans set a prototypical concept of the felt duration/velocity of the established time units early in their lives, this still seems a plausible and valuable approach to explain why time seems to pass fast in adulthood. An approach, however, that is hardly accessible for empirical research and consequently lacks such support.

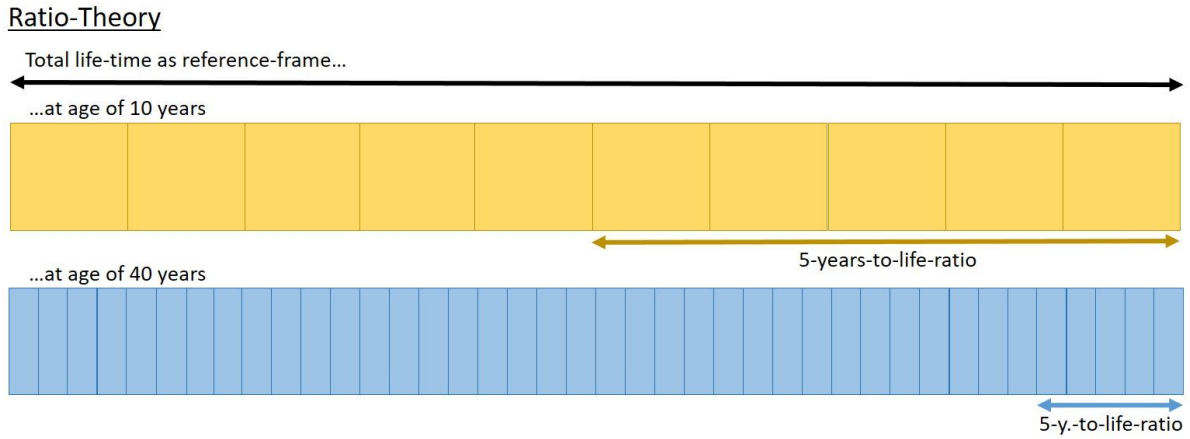

Figure 1: Illustration of ratio-theory suggesting that perception of time-units is affected by the relative length of these units compared to the age of a person. This depicts that an interval of five years covers 50% of the aggregated life-time for a 10 year old person but only 12.5% for a 40 year old person.

Internal-Clock Models

By contrast, the idea of an internal clock has become one cornerstone of modern empirical studies on time-perception. These models imply a process in which pulses are produced, stored in working memory, and compared to a reference memory. The pulses serve as time-units and the comparison to protoypical time-units retrieved from a reference memory results in an experience of duration (see Figure 2). These models have proven valuable for explaining the experience of time in short invervals (ranging from ms to s), in particular for prospective timing (i.e., where participants are aware of their experience of time being the matter of the investigation; e.g., Droit-Volet & Meck, 2007).

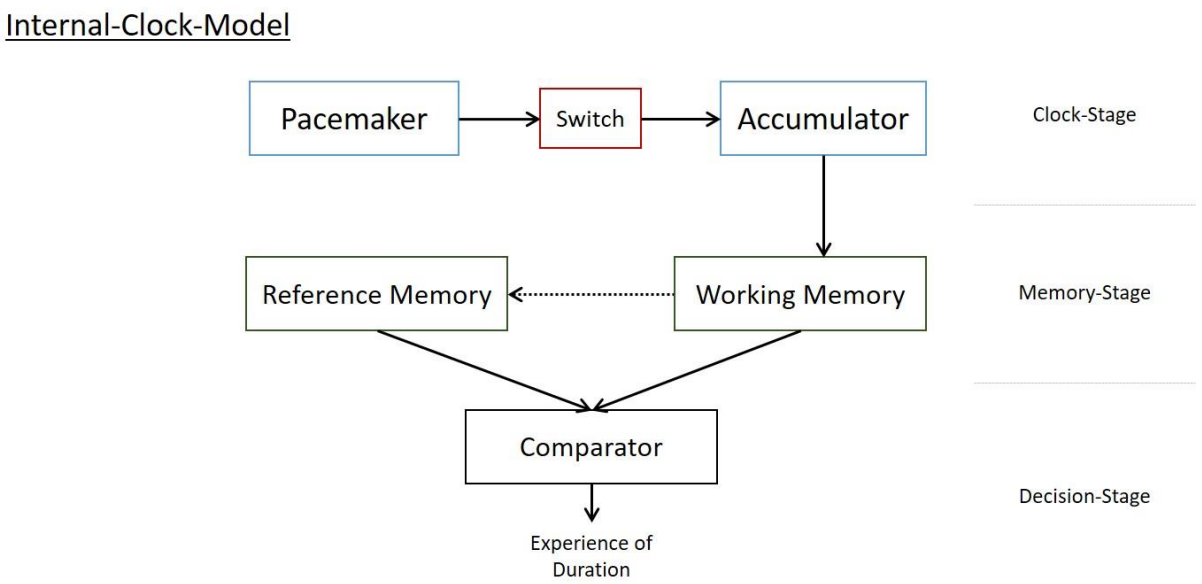

Figure 2: Illustrative example of an internal clock model. Note that many versions with minor and major differences have been suggested, e.g., by Treisman (1963), Gibbon and colleagues (1984), Zakay and Block (1994) or Droit-Volet and Meck (2007). This depiction tries to capture the most common components without arguing in favour of or against any of the models suggested. For a detailed discussion regarding the development of internal-clock-models see Wearden (2016).

However, they are hardly used to explain retrospective time perception (i.e., where participants report their time perception after the interval in question and without knowing about time as matter of investigation during the interval; for a comprehensive view of different paradigms used in psychological research, see figure 1 in chapter 2.3). Robust findings show a slowing down of the internal clock with aging, indicated, for instance, by increasingly longer productions of given intervals (e.g., Craik & Hay, 1999; Espinoza-Fernandez et. al. 2003). This is sometimes discussed as a possible explanation for time speeding up with age. However, this interpretation seems inplausible as evidence shows that passage of time judgments (POTJs, i.e.,

the velocity of time having passed; for an introduction to POTJs, see Wearden, 2005 or Wearden, 2016) differ between older and younger adults only for intervals of five years and longer, but not for a variety of intervals ranging from one hour up to one year (e.g., Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005; chapter 2.2). This suggests that the velocity with which we perceive long intervals to pass by is a different phenomenon than the estimation of duration for short intervals (see also Droit-Volet & Wearden, 2016, for an empirical approach showing that duration judgments, explicable by internal-clock models, are often incompatible with POTJs for the same intervals).

Time-Pressure

Thus, most work covering retrospective passage of time judgments relates in one way or another to memories. In recent years, for example, some studies have investigated the relation between passage of time judgments and perceived time pressure (Friedman & Janssen, 2010; Janssen, 2017). These studies were based on the idea that the perception of time pressure leads to the impression of time having passed fast (Janssen, 2017). Although the exact mechanisms linking perceived time pressure to the experience of time passing fast could benefit from a more detailed explanation, a set of studies supports this association in general (e.g. Friedman & Janssen, 2010; Janssen et al., 2013). It seems particularly interesting that participants of all cohorts perceive high levels of time pressure at the present time while recalling to having had less time pressure in the past (Janssen, 2017). This suggests a possible explanation for the phenomenon that adults across different age groups report time to be passing fast: when currently perceiving high levels of time pressure while – at the same time – being under the (presumably) wrong impression of having had less time pressure in the past, the present perception of time passing fast might be nothing but an illusion resulting from the fading of memories from the past (Janssen, 2017). In this case particularly memories of the experience of time pressure.

Telescoping

The misdating of memories, discussed as telescoping, is another theoretical approach that has repeatedly gained attention from researchers investigating the passage of time. Telescoping happens in two directions: While forward telescoping describes the tendency of

dating past events too close to the present, backward telescoping describes the opposite effect, that is, dating past events too far to the past (e.g., El Haj et al., 2017). Forward telescoping has been shown to happen in particular for events from the remote past, while there is an overall tendency of backward telescoping for recent events (Janssen et al., 2006; El Haj et al., 2017, Thompson et al., 1988). The latter has also been discussed as time expansion (see Figure 3), emphasizing that this dating error potentially has impact on the experience of time: Crawley and Pring (2000) found that older people generally date events farther to the past than younger people. They interpret this decrease in time expansion as a potential mechanism explaining the perceived acceleration with aging. They seem to suggest that older people's' systematic impression of past events being more distant compared to when they were younger might leave them under the impression of subjectively more time having passed than actually did. However, no studies have systematically investigated the interplay of telescoping with any measure of the subjective experience of time.

Time Expansion / Backward Telescoping

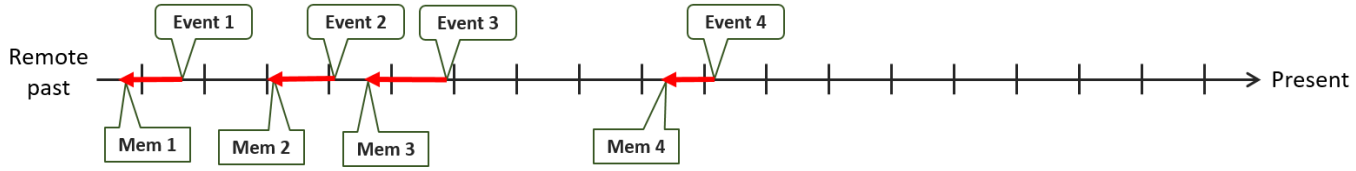

Figure 3: Illustration of Time Expansion due to backward telescoping of events from the remote past. Event-markers ('Event') illustrate the factual date of an event while memories of these events ('Mem') might be systematically dated back too far. The time between now and the wrongly remembered date is therefore expanded.

Storage-Size and Contextual-Change Hypothesis

When trying to explain the retrospective experience of time, the most established theoretical approaches highlight the importance of memories that are retrievable from the respective time-intervals. Ornstein´s work (1969) is often mentioned as having provided fundamental theory and research for this account. He suggested that the sum of content stored from an interval, resulting from the number of events encoded as well as from the complexity of the encoding-process (investigated by using auditive and visual materials), is decisive for the experience of duration of the respective interval. Ornstein himself considered his model as tentative and a starting point for further research. Consequently, other researchers, in particular Block and colleagues (1974; 1978; Block & Reed, 1978), showed limitations of

Ornstein's theory in a number of experiments. For example, they presented evidence showing that manipulating the level of processing only (shallow vs. deep) did not necessarily lead to longer duration judgments despite deep processing in fact leading to more information being stored. Furthermore, they reported findings depicting the so-called positive time-order-error (the same interval is perceived as shorter when experienced twice), which they claimed to be inexplicable using Ornstein's Storage-Size-Metaphor. They concluded that not all information is equally relevant but that "the remembered amount of change in cognitive context during an interval" is the key-variable in explaining perceived duration of these intervals (Block & Reed, 1978, p. 657).

The development of the contextual-change-hypothesis is based on work investigating retrospective duration judgments for short intervals ranging from seconds to minutes, often operationalized by indicating duration on lines in relation to reference-intervals (e.g., Block & Reed, 1974; 1978). However, this theoretical approach has been transferred to studies investigating longer intervals (from days up to decades) as well. In these studies, differences in passage of time judgments are typically explained by having different numbers of memories available from (a) intervals characterized by a high versus a low level of routine (Avni-Babad & Ritov, 2003) and (b) from young versus old age (Wittmann & Lehnhoff, 2005). The differences regarding the availability of memories from remote and recent past are sometimes attributed to a more detailed encoding process of somehow new and interesting information compared to information from stiuations one has experienced regularly. This leads to more memories being available from periods with experiences of novelty (e.g. Eagleman & Pariyadath, 2009, Tulving & Kroll, 1995)[10]. Independently from the exact mechanism, researchers using the contextual-change-hypothesis when studying the experience of long time-intervals, interpret memories as the source that indicates contextual changes throughout the interval in question. Thus, living a life that provides a multitude of experiences and avoiding routine are considered

[10] Research covering the so-called reminiscence bump, i.e., the phenomenon that most important autobiographical memories from elderly stem from their youth/young adulthood, makes use of a number of additional approaches explaining the lack of memories from recent years (see Ece & Gülgöz, 2014, for an overview).

as remedies to the experience of years fleeting away by researchers, that transfer these deliberations to the experience of long intervals (Bastam, 2018).

However, to our knowledge, no studies have systematically investigated whether the velocitiy, with which time in the range of several years is judged to have passed, is in fact associated with the number of remarkable events that happened in these years. Given both the notion of non-routine-experiences being encoded and stored better as well as the idea that particularly contextual change-indicating events should be crucial for the experience of time, having experienced more of these notable events should be associated with slower passage of time judgments (POTJs). To examine this, we asked participants to rate their experience of passage of time for the last five years (a) before they were presented with a list of outstanding life events, from which participants had to select those that they had experienced within the last five years (objective memories, Studies 1a and 1b) or (b) before they were asked to recall their subjectively most meaningful autobiographical memories from the last five years (subjective memories, Study 2).

Studies 1a and b.

These studies were designed to investigate whether the number of particularly meaningful objective life-events that typically indicate change in life (e.g., change of jobs, ending or start of romantic relationships) is associated with passage of time judgments for the interval in which the respective events happened in people´s lives. Following the contextual change hypothesis, a larger number of change-indicating events should be associated with slower POTJs for the respective interval. If, however, this association is not present in our data, this suggests that presuming a covert retrieval of memories from particularly meaningful events might not take place when judging the passage of time for multiannual intervals.

The studies were largely alike, differing mainly in adjustments necessary due to the different media used for the surveys: Study 1a was a paper-pencil version, while Study 1b was a replication using an online-survey-tool (www.sosci-survey.com, Leiner, 2014).

Study 1a

Methods.

Participants and Analyses. In April/May 2014, data from 293 participants were collected by using a paper and pencil questionnaire. The participants were mainly recruited in lectures for prospective teachers at the University of Regensburg as well as via private networks, which resulted in 89.0% teacher trainees, 9.9% psychology-students and 1.0% other participants. Data from all participants was used for data analysis, however, missing data (e.g., some participants did not fill out questions regarding valence) led to a variation in cases for some analyses. Age ranged from 18 to 34 (M = 21.80, SD = 2.46), 69.18% of the participants identified as female and 1.71% did not disclose their gender, the rest reported to be male.

All analyses were conducted using the statistical software R (R Core Team, 2021). The associations between the variables were quantified using mixed linear and logistic regression models with the individual responses nested within the subjects (see, Hilbert et al., 2019). For the analyses, the POTJs were associated by modelling them as predictor variable in the regressions with the overall number of events, the number of positive events, and the number of negative events, as dependent variables in the respective models. The regression intercepts were allowed for random variation, as nested within the subjects, and the type-1-error probabilities were corrected for threefold multiple testing via the Bonferroni method. The threefold correction was applied, because the four models were all estimated three times in studies 1a, 1b, and 2. The reported p-values are therefore multiplied by three, so that the reference value is still $p < .05$.

Procedure and Materials. On the first page, participants were introduced to the questionnaire including a detailed instruction illustrating how to answer the subsequent questionnaire (see figure 4).

	Event	*experienced within the last*					*extremly negative*	*negative*	*slightly negative*	*neutral*	*slightly positive*	*positive*	*extremly positive*	*still relevant*
		5 years	*4 years*	*3 years*	*2 years*	*12 months*								
1	Marriage	o	~~o~~	o	o	o	- - -	- -	-	o	+	++	~~+~~+	o
17	Loss of job	o	o	o	o	~~o~~	- - -	-~~-~~	-	o	+	++	+++	~~o~~

Figure 4: Inductory illustrative examples for the subsequently presented list of life-events.

After turning pages, participants were asked to judge their passage of time assessed with one item ("Looking back: how fast did the last five years pass by for you personally?"), answers were given on a 7-point Likert scale ranging from 'very slow' to 'very fast'. Additionally, we asked participants to rate their satisfaction with their current life, their life three and five years ago as well as with the last five years taken together. Answers were given on a seven-point Likert scale ranging from 'very slow' to 'very fast' and 'very unsatisfied' to 'very satisfied', respectively. On the next page, a total of 26 Life Events (e.g., marriage, death of close person, loss of a job; based on Brugha & Cragg, 1990 and Sarason et al.; 1978) was presented. Participants had to indicate each event they had experienced in the last five years by selecting the according year (radio buttons to select between '12 months' up to '5 years') and indicate the valence on another 7-point Likert scale (ranging from 'extremely negative' to 'extremely positive') as well as whether it was still a matter for the person at the time taking part in the survey ('current relevance').

After turning pages, participants found two sets of spare lines for (a) adding events that had happened more than once and (b) adding personal events, which had not been covered by the list presented on the previous page. Ultimately, the study was completed by reporting demographic information (age, gender, occupation and education), five items covering the ease of recall (e.g., "How easy did you find recalling personal events?") and an open question offering space for any remarks regarding the study.

Results and Discussion.

Participants judged the five years to have passed *M* = 5.62 (*SD* = 1.00) and selected *M* = 7.88 (*SD* = 3.31) events presented on the list. 26.5% were considered as negative (ratings ranging from 1 = very negative to 3 = slightly negative), 66.8% as positive (5 = slightly positive to 7 = very positive), the rest as neutral (4 = neutral). The reported events were *M* = 2.30 (*SD* = .68) years in the past. The POTJs were not significantly associated with neither the overall number of objective events reported (γ = -.03; p = .85) nor with the number of events reported as positive (γ = -.05; p = .30) or negative (γ = .02; p = 1). Additionally, we analysed whether the

variance of the years since the reported events was related with the POTJs, but found no association between the two variables ($\gamma = .01$; p = 1). All analyses codes and data can be accessed at https://osf.io/7z3yj/?view_only=db7f67c245354c4ba529c36cad0f3259. Given that the events presented on the list are likely to have a significant impact on people's lives and thus indicate change, and given the assumptions of the contextual change hypothesis (Block & Reed, 1978), a higher number of such events should be associated with slower POTJ´s. However, the results from this study do not support this prediction.

Study 1b

Methods.

Participants. In January/February 2015, 263 participants filled out the online-version of the study on SoSciSurvey (Leiner, 2014). Participants were recruited through private and university email distribution as well as via social media. Age ranged from 18 to 72 (*M* = 28.45, *SD* = 10.64), 69.11% of the participants identified as female, the rest of the sample as male. 50.2% of the participants were students, 47.1% working population and 2.7% spread among other categories such as job-seeking, attending school or in retirement.

Procedure and Materials. The procedure and materials were the same as used in Study 1a with some methodical improvements enabled by and some adjustments necessary due to using the online-platform. After a short introduction, participants were instructed how to answer the subsequent questions. Then, participants judged the passage of the last five years as well as their well-being. The Life Events subsequently presented were displayed on separate Pages for each event. Once people indicated that they had experienced the respective event throughout the last five years, the information regarding the year of the event (radio buttons ranging from 'last 12 months' to '5 years'), the valence (7-point Likert scale ranging from 'extremely negative' to 'extremely positive') as well as the current relevance were inquired on the next page. Finally, the participants were asked, whether the same event had taken place more than once during the last five years, allowing to specify additional events of the same nature on subsequent pages after selecting 'yes' or continuing to the next event by selecting 'no'. After having answered the questions regarding all 26 events, participants had the option to report further personal events, which had happened throughout the last five years. Then, the ease of recall

was enquired before a number of additional questionnaires for research questions addressed for a different project were presented[11]. The survey ended with collecting demographical data and an open question for potential remarks. The statistical analyses were conducted analogously to Study 1a.

Results and Discussion.

In the online-version, the five year interval was judged to have passed with *M* = 5.39 (*SD* = 1.21) and participants reported to have experienced *M* = 9.70 (*SD* = 3.71) of the events from the list. 32.0% of the events were rated as negative, 60.2% as positive, the rest as neutral. The reported events were *M* = 2.47 (*SD* = .70) years in the past. The POTJs were not significantly associated with neither the overall number of objective events experienced ($\gamma = $-.03; p = .46) nor with the number of events rated as positive ($\gamma = $-.05; p = .14), as negative ($\gamma = .03$; p = 1), or the variance of the ages of the events ($\gamma = .07$; p = 1), thus replicating the findings of the paper and pencil version (Study 1a).

Study 2

Studies 1a and b investigated whether POTJs are associated with the number of experienced objective events. In these studies, participants were provided with a list of experiences that are likely to be memorable as well as indicative for changes in the participants' lives. However, the items presented are limited and do not necessarily depict the events that actually were the most important and change-indicating for individuals. To address this limitation, we also investigated the association of POTJs with the number of subjectively meaningful memories from the last five years. These were inquired in a free-recall paradigm where participants were asked to report as many personally meaningful autobiographical memories as they could spontaneously recall. Following memory based approaches, such as storage size metaphoar and contextual change hypothesis, a higher number of these memories should be associated with slower POTJs for the respective interval. Failing to detect such an

[11] Additionally, the experience of control regarding the respective event was surveyed here as well, using one item asking "Did you have the impression, that you were able to control the situation?", answered on another 7-point Likert scale ranging from "The situation was not controlable at all" to "The situation was very controllable". These measures were used for a different research question, addressed in Kugler et al. (2021).

association might suggest that a covert retrieval of important memories, which supposedly affects POTJs for multiannual intervals, cannot be presumed.

Methods.

Participants and Analyses. Between August and December 2015, 262 persons[12] completed a questionnaire, in which they reported a POTJ before activating subjective memories. The study was carried out on SoSciSurvey (Leiner, 2014) as well and participants were recruited via the website of the German version of Psychology Today ('Psychologie Heute'), the website of our research institute, and private sources. In this sample, age ranged from 14 to 66 (M = 32.26, SD = 11.65), 74.0% identified themselves as female, 20.2% as male, the rest did not disclose its gender. 31.7% were students, 47.8% employees and 9.8% self-employed, 27.6% spread among other options (e.g., vocational training, household, retired; the selection of multiple options was possible).

As in Studies 1a and 1b, regression models were used to relate the POTJs as predictor variable for the overall number of events, the number of positive events, and the number of negative events, which served as dependent variables in the respective models. Because in this study, the individuals did not select from a pre-defined set of events but reported varying numbers of their individual memories, mixed regression models could not be applied. Therefore, the number of overall, positive, and negative events as well as the mean vanlence (all per subject) served as dependent variables in ordinary least squares regressions. Again, the type-1-error probabilities were corrected for threefold multiple testing via the Bonferroni method, due to the three times, each model was estimated, namely in studies 1a and 1b, and 2, and the reported p-values therefore multiplied by three.

Procedure and Materials. Participants started by filling out the Satisfaction With Life Scale (Glaesmer et al., 2011) and the Positive and Negative Affect Schedule (Krohne et al., 1996) and then judged the passage of time for the last five years as well as for the last year (7-point Likert scales ranging from "very slow" to "very fast"). Then they were asked to remember as many

[12] This is a subsample taken from Kosak et al., 2019, where about the same number of persons did activate their experiences before judging the passage of time.

important autobiographical events from the past five years as were spontaneously available, no time limit was given. Each event was entered on a separate page, which depicted an input line allowing a short description of the event. Additionally, each page offered a check box, which could be ticked once the participant wanted to end the input-segment after running out of important autobiographical memories. Events perceived as positive and negative were asked for in separate blocks to avoid state-dependent memory effects (see, e.g., Bower, 1981), the order of these blocks was counterbalanced. Next, each event entered was separately presented to the participants with added questions regarding valence and the time the event took place as well some other information (importance, subjectively experienced impact on the subsequent life, overcoming of negative events). Finally, demographical information was collected.

Results and Discussion.

Participants in this study rated the five year interval as having passed by with *M* = 5.46 (*SD* = 1.23) and recalled an average of *M* = 7.16 (*SD* = 3.71) subjectively meaningful memories, that were *M* = 2.45 (*SD* = .79) years in the past. 30.2% of the events were rated as negative, 57.7% as positive, the rest as neutral. The POTJs were neither related to the overall number of objective events reported ($\beta = .00$; p = 1) nor to the number of events rated as negative ($\beta = -.06$; p = 1), as positive ($\beta = .10$; p = 1) or to the variance of the ages of the events ($\beta = .12$; p = .22). This result suggests that neither the number nor the temporal cluster of subjectively meaningful events that someone experienced in a given interval is associated with the velocity, with which the according interval is perceived.

General results and discussion.

In data from three surveys, we found no evidence for an association between spontaneously given POTJs for the last five years and the number or the dispersion of outstanding personal life events that happened during these years (see Figure 5). Given that each sample is large enough to provide a power higher than 95% to detect a small effect of $r_P = .2$[13] (based on

[13] Pooling the samples leads to a correlation of $r_P(816) = -.04$, $p = .14$ between the number of events/memories and the POTJs. This implies a power of 99.99% to detect an effect of $r_P = 2$. Note that due to the varying numbers of memories per participant in Study 2, no multilevel analysis was conducted for the pooled sample.

calculations in G*Power 3.1.9.7, Faul et al., 2009) and considering that the presented mixed-effect models in Studies 1a and 1b are statistically far more powerful than correlations based on sum scores, it seems likely that an unintended or covert retrieval of meaningful life events as basis for these judgments can be excluded.

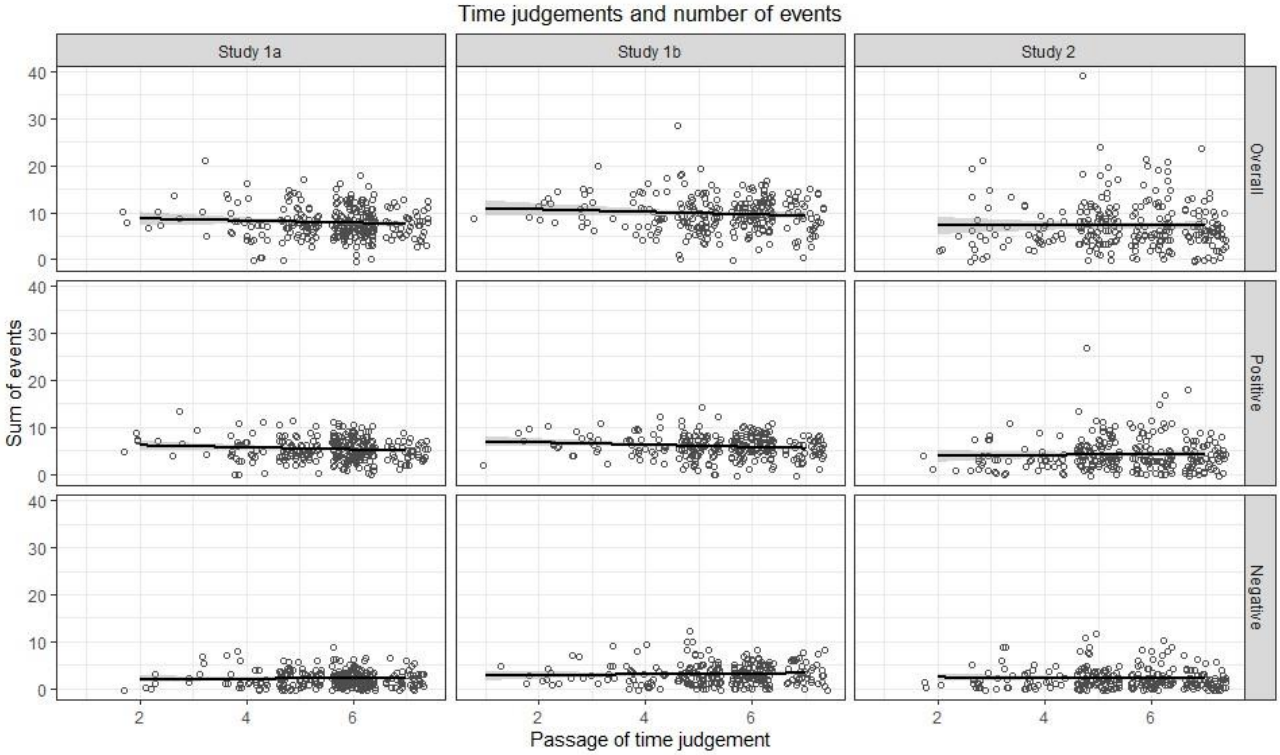

Figure 5. Associations between the total number of events/memories as well as the number of positive and negative events/memories with Passage of Time Judgments for the last five years.

Such a covert retrieval has been discussed regarding memory-based approaches and duration judgments for intervals in the range of seconds to few minutes (Block & Reed, 1978). In fact, for these short intervals, a covert retrieval seems plausible: Due to the immediacy between encoding and the judging of duration, the information from the interval in question is likely to be still easily accessible.

However, the idea of a covert retrieval has been implicitly transferred to studies investigating passage of time judgments for long intervals, for example, in Wittmann and Lehnhoff´s (2005) influential study, differences in POTJs for 10 years are attributed to "variations of activities, life events" (p.933), directly referring to the contextual change hypothesis. Since data regarding these autobiographical events (or memories thereof) or other

changes are not assessed in these studies, the covert retrieval of these memories seems to be premised. Given our results, however, it might be hasty to explain differences in POTJs for multiannual intervals without these memories and/or life-events actually having been assessed in the regarding study.

Two other studies covering longer intervals, where this idea has been implicitly presupposed as well, can be found in Avni-Babad and Ritovs (2003): Here, vacationers were asked to split their holidays in three parts and to compare the experienced duration of these (Study 5). Moreover, inhabitants of a kibbutz (a rural community in Israel with inhabitants collaboratively living and working together) were asked to judge the passage of time for their regular job and one they did work exceptionally (Study 6). Results showed that duration was judged as shorter for the last part of the holiday and passage of time was judged faster for the regular job. These findings were interpreted as a consequence of "fewer stimuli to remember" (p. 549) due to higher levels of routine. Again, this would imply that a (potentially covert) retrieval has to take place when judging the passage of time. Although this retrieval was not an explicit part of the design, in this case, the instructions direct their participants attention to reasonable intervals (one or two days of a 3-4 day-vacation) and concrete experiences (the regular and exceptional job), potentially directly inducing a retrieval of memories. That is, when asking explicitly for the experience of time of certain days/situations, memories from these instances could have been activated and a comparison of spontaneously recalled memories between the respective timeframes might have led to the different judgments. Summed up, both the presumed activation of memories and the direct comparison between different intervals are likely to have affected the reported experience of time since both processes are potentially crucial for these judgments. Evidence from our previous study supports this interpretation, since we were able to show that activating a crucial number of autobiographical memories before judging the passage of time led to judgments of these years as having passed slower compared to having activated very little or no memories (chapter 2.2).

In the light of this prior finding, it seems that memories still play a crucial role for the perceived velocity of years passing. Presumably, however, spontaneous judgments of the passage of time for multiannual intervals are not systematically affected by the mere amount

of experienced remarkable life-events as long as memories from these are not directly activated prior to judging (Kosak et al., 2019). Other factors, such as perceived stress (e.g., Janssen, 2017) or the ratio of time-units (in this case of years) to life-time (as discussed in Block et al., 1998) might be important too when trying to understand spontaneous judgments of time for multiannual intervals.

However, we have to acknowledge that interpreting null-findings is generally a challenging task because these can result from a variety of causes. Nevertheless, the fact that we found a consistent pattern in three independent datasets using highly powered analyses gives the results credibility. But of course, our approach comes with methodological limitations that might restrain the generalizabilty of the presented findings. First, we investigated only one particular interval, namely five years. Although it seems likely that this null-result is transferable to other multiannual intervals, it is possible that investigating intervals in the range of days or even several months (both still 'long' compared to most of the research conducted in this field) with this approach leads to different results. The content of such intervals might be more comprehensible and/or salient memories from the past might subconsciously affect the experience of time since, in such a case, these are less far in the past at the moment of judging the passage of time. Regarding intervals of several days, the studies presented by Avni-Babad and Ritov (2003) might be interpreted as preliminary evidence for such an assumption.

Second, the list of events used in Studies 1a and 1b covered only a limited number of life-events and thus might not have depicted all potentially crucial events. However, we tried to fill this blind spot by applying the free-recall-paradigm in Study 2, which did not reveal different results. However, Study 2 has its own limitations: Although we consciously decided to set no time limit for the recall in order to avoid any pressure for our participants, we cannot exclude that this has led to an inflation of recalled memories. Possibly, a limitation of time for the recall-stage of the study would lead to a retrieval of fewer memories and this reduced number might be a better representation of potentially change-indicating events.

Despite these limitations, the current studies are an important first approach in trying to verify the common presumption that the number of important and/or change-indicating

memories affect the experienced passage of longer time-intervals. Our results provide no support for this presumption. This suggests that explaining the experience of time for multiannual intervals by applying insights from memory-based theories, which have been validated only with duration judgments for short intervals, is potentially premature.

After all, when investigating POTJs for long intervals, it might be important to incorporate a recent finding: Lee and Janssen (2019) were able to show that personal believes about the passage of time affect the judgments of these. Given that a majority of people in industrialized countries believes that time goes faster with aging (Lee & Janssen, 2019), presumably with different underlying theories explaining this phenomenon, spontaneous POTJs regarding long intervals might also reflect conclusions individuals draw from their personal believes about the passage of time. Simply put, spontaneous and decontextualized POTJs might – from a researcher's perspective – evoke relatively arbitrary ratings, which do not necessarily reflect an actual experience of time, but rather believes people have about the passage of time. A study investigating POTJs and its relation to laypersons theories and concepts regarding the passage of time would be necessary to clarify these assumptions. For the time being, we must conclude that a covert retrieval of remarkable, change-indicating memories seems not to be a decisive mechanism explaining differences in Passage of Time Judgments for multiannual intervals.

2.2 Article 2: Activated Memories and the Passage of Time

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Abstract

Memory-based approaches suggest that retrospective judgments concerning the passage of lifetime are based on available meaningful experiences. However, an open question is whether passage of time judgments reflect the objective amount of important experiences or rather the amount of memories that are currently activated in the moment of judging. To examine this issue, we asked 473 participants to judge the passage of the last five years either before or after recalling as many important autobiographical events as possible from the last five years. Activating memories before the judgement slowed the experienced passage of time, but only if participants recalled at least four or more memories. For participants recalling less than four memories, the opposite effect was found: few activated memories had even an accelerating effect. Interestingly, the experienced speed of time did not continuously decrease with a rising number of memories activated: Below and above the threshold of four memories, passage of time judgments were unrelated to the number of activated memories. These results indicate that passage of time judgments are based on currently activated memories, suggesting that the common phenomenon of time flying reflects the effect of a reminiscence heuristic.

Keywords*:* Passage of Time Judgments, Subjective Experience of Time, Contextual Change Hypothesis, Storage Size Metaphor, Autobiographical Memory

Introduction

Almost on a daily basis, one can overhear people saying things like “The marriage of my daughter? Oh boy, yet five years ago! How time flies!”, mostly accompanied by a sorrowful sigh. This suggests not only that time has an objective (physical time) as well as a subjective (experienced pace) dimension, but additionally, and maybe more importantly, it implies that the feeling of lifetime slipping away is mainly considered as a negative experience since it reflects a perceived scarceness of a valuable resource (e.g., Rosa, 2005). Unfortunately, the phenomenon of experiencing time as passing too fast seems in fact common: when asked to judge longer intervals ranging from days to years retrospectively, people generally rate these as having passed rather fast (Janssen, 2017; Wittmann & Lehnhoff, 2005). In this study, we aim to shed some light on how judgments for the passage of lifetime are made, and whether these judgments are stable, or rather depend on momentary factors. If the latter was true, the common experience of time flying by might be attenuated with adequate strategies.

In psychological research, experience of time typically is studied from either a duration perspective, asking participants to judge their estimated duration for intervals (duration judgments), or from a pace perspective, asking participants to judge how fast they perceive intervals to pass by (passage of time judgments). Both, duration judgments as well as passage of time judgments can be studied prospectively, which means that people are aware of time as the subject of investigation, or retrospectively, meaning that during the interval in question people are not aware of time as the matter of investigation (see Wearden et al., 2014, for a broader discussion). In previous research, the experience of time has mainly been examined by measuring prospective duration judgments of relatively short time intervals typically ranging from milliseconds to a few minutes, revealing that these judgments are influenced by a number of factors such as emotions (e.g., Droit-Volet et al., 2004; 2011), gender (e.g., Espinosa-Fernandez et al., 2003; Rammsayer & Rammstedt, 2000), or age (e.g., Craik & Hay, 1999; Espinosa-Fernandez et al., 2003). Studies using prospective paradigms often refer to Pacemaker-accumulator models to explain these findings. Pacemaker-accumulator models suggest a mechanism where time units produced by an internal pacemaker are stored in an accumulator during a physical time period, the sum of which is then compared with prototypical reference time periods stored in long-term memory (e.g., Droit-Volet & Meck,

2007; Treisman et al., 1990).

However, while pacemaker-accumulator models may explain findings concerning duration judgments of short time intervals, they seem to be inapplicable to explain judgments of the passage of longer time intervals in real life (Droit-Volet et al., 2017; 2018). Beyond the difference in the length of time, judgments of the passage of time intervals in real life situations, that exceed a range of just a few minutes to hours, necessarily require a retrospective judgment, meaning that people judge their time experience without being aware of judging time in advance. Furthermore, the experienced passage of lifetime cannot be assessed by duration judgments ('How long was the interval?') because people rationally know when specific events such as 'the marriage of my daughter' had taken place in their past ('five years ago!'). Instead, the retrospectively experienced passage of lifetime is assessed by passage of time judgments ('How fast did the interval pass?'). These do not consistently reflect the actual physical or subjectively estimated duration of a time interval but the feeling about how slow or fast the passage of the time interval was experienced (Droit-Volet et al., 2018, Wearden, 2015). In fact, research has shown that duration judgments and passage of time judgments seem to be largely independent phenomena (Droit-Volet & Wearden, 2016). For instance, in a study by Wearden (2005), it was shown that the duration of one particular film clip was overestimated in length but experienced as having passed fast at the same time – a contradictory result if passage of time judgments simply would reflect duration judgments.

In order to explain both retrospective duration judgments as well as retrospective passage of time judgments, so-called memory-based approaches have been proposed. (Block & Gruber, 2014; Block & Zakay, 1997; Friedman & Janssen, 2010; Sahakyan & Smith, 2014). These share the basic idea that the subjective experience of time depends on memories available from a specific time interval. However, different assumptions have been made about which specific characteristics of the stored memories may be crucial. According to storage size metaphor (e.g., Ornstein, 1969; Block, 1974), the retrospectively experienced passage of time reflects the number of stored events. When judging time retrospectively, the stored events for a time interval are covertly retrieved, with the passage of time being experienced the slower the more content is stored in memory.

While existing empirical evidence generally supported such an account (Ornstein, 1969), subsequent accounts have suggested that it may actually not be just the amount stored in memory that affects the experience of time, but a specific quality of these memories. According to the contextual-change hypotheses (Fraisse, 1963; Block & Reed, 1978), only stored events that indicate contextual change are crucial for the experienced passage of time or duration judgments respectively. However, while such a hypothesis has been supported by empirical findings for the retrospective judgment of shorter time intervals in the range of minutes (Avni-Babad & Ritov, 2003; Sahakyan & Smith, 2014), direct evidence for longer time intervals such as months or years is largely missing in existing literature. At least preliminary indirect evidence comes from a set of studies by Avni-Babad and Ritov (2003), showing that time periods in real life that were filled with non-routine activities are experienced as having passed by slower than periods filled with routine activities. Assuming that due to a higher degree of perceived change in novel situations more memories are stored for non-routine periods, this finding supports contextual-change accounts. Additionally, recent findings suggest that further characteristics of memories may affect retrospective passage of time judgments. In particular affective state has been shown to have an impact on prospective passage of time judgments (Droit-Volet et al., 2017; 2018), thus, it may be that retrospective judgments on the passage of lifetime depend not only on the number but additionally on the affective quality of the events stored for a time interval.

However, while a covert retrieval (Block & Reed, 1978) of stored memories might be a plausible assumption for relatively short intervals due to the immediacy between encoding and the subsequent judging of duration or passage of time respectively, for a lifetime perspective, such an assumption may not hold true. In fact, research in the domain of long-term memory has shown, that a critical distinction has to be made between the number of memories that is overall stored for a time period and the number of these memories that is currently activated (e.g., Bjork & Bjork 1992). Thus, it may not be the overall amount of meaningful memories one has accumulated for a time period that drives passage of time judgments but instead the amount of memories that are currently activated in the moment of judging. If so, passage of time judgments would reflect the effect of a reminiscing heuristic, meaning that two persons

may actually have stored equal numbers of meaningful memories for a time period, but if one of them activates some of her/his meaningful memories in the current situation while the other does not, their passage of time judgments would differ. Indeed, it in the domain of judgment and decision making, it is a well proven fact that people often form their judgments based on currently activated information (e.g., Tversky & Kahnemann, 1974). For instance, it has been shown that judgments of one's life satisfaction do not reflect the sum of all positive and negative events stored in memory but vary depending on whether positive or negative event memories have been activated before (Schwarz & Strack, 1999). However, to our knowledge, research on the existence of similar heuristics in the domain of passage of time judgments is still lacking.

The aim of the present study was to examine the role of autobiographical memories in retrospective real-life passage of time judgments, and the specific effect of activating such memories by recalling them from long term memory before judging the passage of time. Participants were asked to judge how fast the last five years had passed either before or after recalling as many important autobiographical events as possible from that particular period. If passage of time judgments depend on the number of memories currently activated, the attempt to retrieve as many personally important events from their past as possible should lead people to rate time as having passed slower, and this effect should be stronger if more events from the past are activated.

Method

Participants. The sample size was based on a power analysis (G*Power 3.1.7; Faul et al., 2007) to have sufficient power (.80, alpha = .05) in order to detect small-to-medium sized effects (d = 0.3), suggesting a minimum required sample size of N = 352. Participants were recruited via the website of the German version of Psychology Today ('Psychologie Heute'), the website of our research institute and private sources. In total, 524 participants voluntarily completed the questionnaire on SoSci Survey (soscisurvey.com). Participants who did not report any autobiographical event at all (n = 26) as well as participants who reported a number of autobiographical events higher than 2 standard deviations above the mean number of reported

events (≥ 17 events; *n* = 24) were excluded from further analysis.[14] In addition, one participant who constantly selected the center-value on each scale was excluded. The final sample consisted of 473 participants, on average it took them 22.15 minutes to complete the questionnaire (*SD* = 7.74). Age ranged from 14 to 67 (*M* = 31.51; *SD* = 11.32), 72.5% identified themselves as female, 21.4% as male, 6.1% did not disclose their gender. All data and analysis scripts are provided online on https://osf.io/xbq6w/?view_only=dcba9f9440a5483f8559e840be02b9e9 via an Open Science Framework online repository and may be downloaded by the interested reader.

Design and Procedure

The study was conducted in accordance with the Helsinki declaration and University Research Ethics Standards of the University of Regensburg.

Participants were randomly assigned to two experimental conditions where they were asked to judge how fast the last five years had passed either before (judgment-before-retrieval condition; *n* = 232) or after (judgment-after-retrieval; *n* = 241) recalling as many important autobiographical events as possible from that particular period. All data exclusions, all manipulations, and all measures in the study are reported.

In both experimental conditions, participants first filled out the Satisfaction With Life Scale (Glaesmer et al., 2011) and the Positive and Negative Affect Schedule (Krohne et al., 1996).[2] Next, in the judgment-after-retrieval condition, participants were asked to remember as many important autobiographical events from the past five years as one could spontaneously recall without any time limit. A length of five years was chosen in order to capture a relatively long period of time on the one hand and to ensure that the activated autobiographical memories are relatively reliable regarding the correct date of the events on the other hand. A new page appeared on the screen for each remembered event, depicting an input line to type in a short description of the event. Additionally, a check box was offered to be ticked in case the participant wanted to end the input-segment when running out of important

[14] Including these participants did not change the pattern of any of the observed results.

autobiographical memories. Events considered positive and negative were asked for in two separate blocks to control for state-dependent memory effects (see, e.g., Bower, 1981); the order of blocks was counterbalanced.

After completion of the autobiographical memory task, each of the reported autobiographical events was presented again in order to collect additional information (year of the event, importance, subjectively experienced impact, emotional valence at the time when the event took place and today, overcoming for negative events; Table 1 shows these specifications according to experimental condition). In the next step, passage-of-time judgments were asked for the past five years and additionally for the last year (seven-point-Likert scales ranging from 1 = very slow to 7 = very fast). The procedure in the judgment-before-retrieval condition was identical with the only exception that participants were asked to provide the passage of time judgments before retrieving and specifying autobiographical memories.

Results

In both the judgment-before-retrieval condition (M = 6.72, SD = 3.36) and the judgment-after-retrieval condition (M = 6.58, SD = 3.35), about the same number of autobiographical events was reported, $t(473) = 0.478$, $p = .633$, $d = .044$. Overall, there was a significant correlation between passage of time judgments and age, $r_s(443) = .21$, $p < .001$, and passage of time judgments did not vary with gender, $t(442) = 1.37$, $p = .17$, $d = .15$; the experimental judgment groups did not significantly differ in mean age of participants, $t(441) = 1.40$, $p = .163$, $d = .13$, and distribution of gender, $\Phi = .02$, $p = .839$. Furthermore, the reported events did not differ between experimental judgment groups with respect to all collected specifications (see Table 1).

Passage of time judgments did not vary between the judgment-before-retrieval condition and the judgment-after-retrieval condition ($M_{\text{Judgment-Before-Retrieval}} = 5.45$, $SD = 1.22$; $M_{\text{Judgment-After-Retrieval}} = 5.30$, $SD = 1.22$), $t(471) = 1.37$, $p = .17$, $d = .126$. Furthermore, the number of activated autobiographical events was unrelated to the passage of time judgment, both when analysed overall, $r_s(473) = -.02$, $p = .740$, and when analysed separately for the two experimental conditions (judgment-before-retrieval condition: $r_s(232) = .06$, $p = .353$; judgment-after-

retrieval condition: $r_s(241) = -.09$, $p = .171$. Thus, at first glance, the results seem to suggest that the number of autobiographical events is unrelated to passage of time judgments, independently of whether they are activated before or after judging the passage of time.

Table 1

Mean ratings for the specifications of autobiographical memories reported by participants depending on experimental condition.

	Judgment Before Retrieval		Judgment After Retrieval	
Ratings of Memory Characteristics	*M*	*SD*	*M*	*SD*
Years since event	2.45	0.80	2.44	0.85
Impact on subsequent life	4.94	1.01	4.99	1.06
Personal importance	5.04	1.21	5.07	1.10
Initial Emotional Valence	4.11	1.14	4.23	1.22
Current Emotional Valence	4.72	1.08	4.79	1.07
Overcoming of negative Events	4.61	1.65	4.58	1.50

Note. *Years since event* were selected from a dropdown-menu, offering options from 1 = less than 1 year ago to 5 = between 4 or 5 years ago. All other items were rated on 7-point-Likert-Scales: *impact on subsequent life* (1 = very negative impact, 7 = very positive impact), *personal importance* (1 = one among many important events, 7 = one of the most important events at all), *initial emotional valence* (i.e., "How did you feel at the time the event had happened?"; 1 = very negative, 7 = very positive), current emotional valence (i.e., "How do you feel now thinking back to that event?"; 1 = very negative, 7 = very positive), overcoming of negative events (i.e., "At this point in my life I experience the event as…" …1 = acute burden, …7 = overcome/outlived).

Passage of time judgments did not vary between the judgment-before-retrieval condition and the judgment-after-retrieval condition ($M_{\text{Judgment-Before-Retrieval}} = 5.45$, $SD = 1.22$; $M_{\text{Judgment-After-Retrieval}} = 5.30$, $SD = 1.22$), $t(471) = 1.37$, $p = .17$, $d = .126$. Furthermore, the number of activated autobiographical events was unrelated to the passage of time judgment, both when analysed overall, $r_s(473) = -.02$, $p = .740$, and when analysed separately for the two experimental conditions (judgment-before-retrieval condition: $r_s(232) = .06$, $p = .353$; judgment-after-retrieval condition: $r_s(241) = -.09$, $p = .171$. Thus, at first glance, the results seem to suggest that

the number of autobiographical events is unrelated to passage of time judgments, independently of whether they are activated before or after judging the passage of time.

However, fitting regression models with local second-order polynomials revealed an interesting pattern: Participants in the judgment-after-retrieval condition remembering three and less memories reported time to have passed faster than participants in the judgment-after-retrieval condition, and vice versa for participants reporting four events and more. The intersection point, situated between three and four memories (3.414), was detected using numerical approximation. Figure 1 illustrates the passage of time judgments for both condition as well the values predicted by the polynomials. Above and below of the intersection point there were no correlations in neither of the conditions, all r_s´s < |.06|, all p´s > .414.

As depicted in Table 2, a dummy-coded linear regression analysis confirms the visual inspection with an interaction between condition (0 = judgment-after-retrieval condition; 1 = judgment-before-retrieval condition) and memory (0 = less than four events recalled; 1 = four or more events recalled) when predicting the passage of time judgement for five years: The significant negative regression coefficient for “Condition” shows that, when having activated less than four memories, participants in the judgment-after-retrieval condition, on average, judge the time as having passed faster compared to the judgment-before-retrieval condition if all other variables are held constant. The significant positive regression coefficient for the interaction term, on the other hand, shows that this pattern is reversed when four or more memories are recalled. Moreover, persons in the judgment-before-retrieval condition, recalling four or more memories, on average, judged time as having passed faster, as indicated by the negative regression coefficient for “Memory total”. To rule out possible confounding effects of age of participants, age was added as covariate; to examine the role of the valence of retrieved events, the proportion of positive events was included as a covariate. . Notably, the depicted Type-I-Error probabilities are not corrected for multiple testing but remain significant even when corrected according to *Bonferroni*.

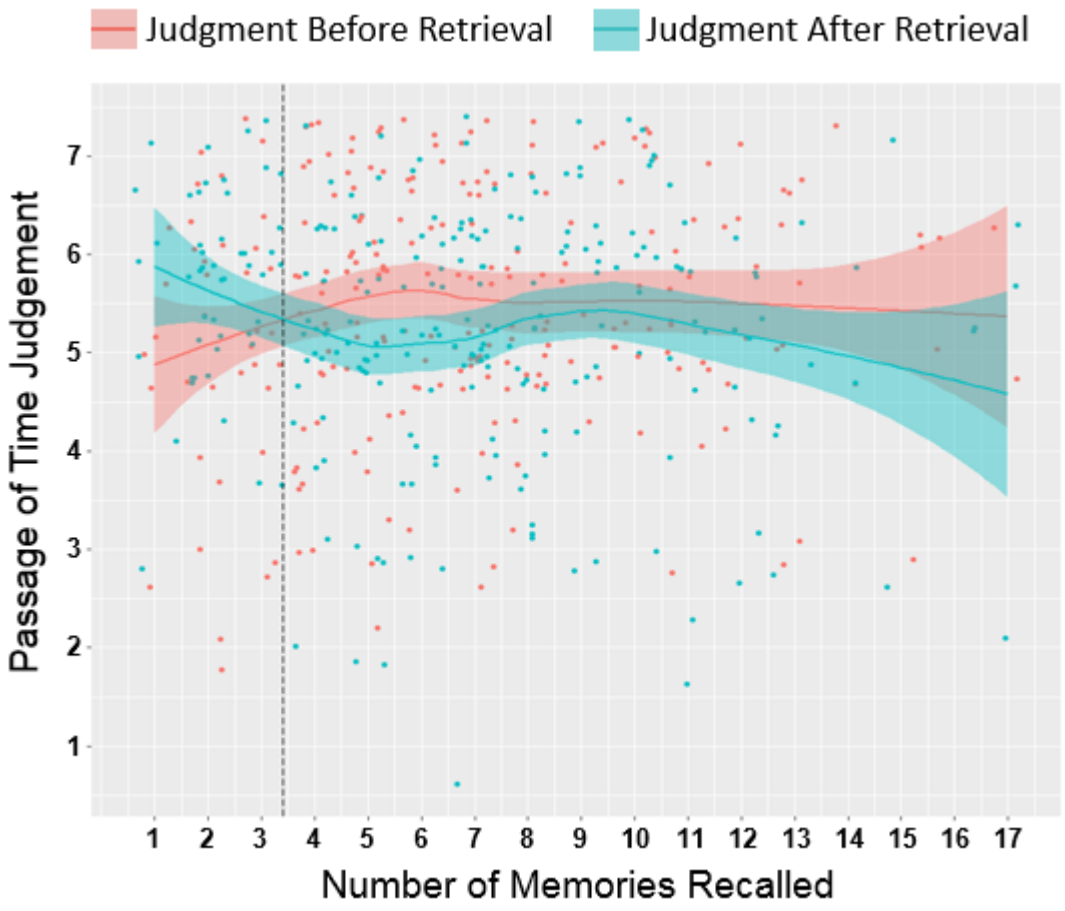

Figure 1: Illustration of local polynomial regression fits for the judgment-before-retrieval and the judgment-after-retrieval conditions showing the passage of time judgments for the past five years (ranging from 1 = "very slow" to 7 = "very fast") depending on the number of memories activated. Random jitter was added to the position of the data points for the sake of a more informative illustration.

Planned comparisons (see Figure 2 for an illustration) confirmed that participants in the judgment-after-retrieval judgment condition who recalled four or more memories (M = 5.18, SD = 1.25) judged time to have passed slower compared to both participants in the judgment-after-retrieval condition who recalled three or less memories (M = 5.76, SD = .97), $t(239) = 2.99$, $p_{uncorrected} = .003$, $d = .49$), and to participants in the judgment-before-retrieval condition who recalled also four or more memories (M = 5.52, SD = 1.18), $t(384) = 2.74$, $p_{uncorrected} = .007$, d = .28). Participants in the judgment-before-retrieval condition who recalled three or less memories (M = 5.11, SD = 1.35) did neither differ significantly from participants in the judgment-before-retrieval condition who recalled four or more memories, $t(230) = -1.93$, $p_{uncorrected} = .055$, $d = .34$, nor from participants in the judgment-after-retrieval condition who recalled four or more memories, $t(228) = -0.34$, $p_{uncorrected} = .732$, $d = 0.05$.

Table 2

Passage of time judgment: confirming the interaction between number of events recalled and condition

	Estimate	*SE*	*t*	*p*
Intercept	4.84	.25	19.48	< .01
Condition	-.32	.12	-2.58	.01
Memory total	-.49	.22	-2.22	.03
Proportion positive events	.13	.27	.49	.63
Age	.02	< .01	3.90	< .01
Condition x Memory total	1.03	.30	3.45	< .01

Note. Estimate = Regression coefficient; *SE* = Standard error of the regression coefficient; *t* = *t*-value; *p* = Probability of committing a Type-I-Error; Condition = Experimental condition (0 = judgment before retrieval; 1 = judgment after retrieval); Memory total = Dummy-coded high or low number of recalled memories (0 = less than four events recalled; 1 = four or more events recalled); Proportion positive events = Proportion of positive recalled events compared to the number of total recalled events; Age = Age of Participants; Condition x Memory total = Interaction effect between experimental condition and dummy-coded memory variable; adjusted R^2 = .05 (p < .001).

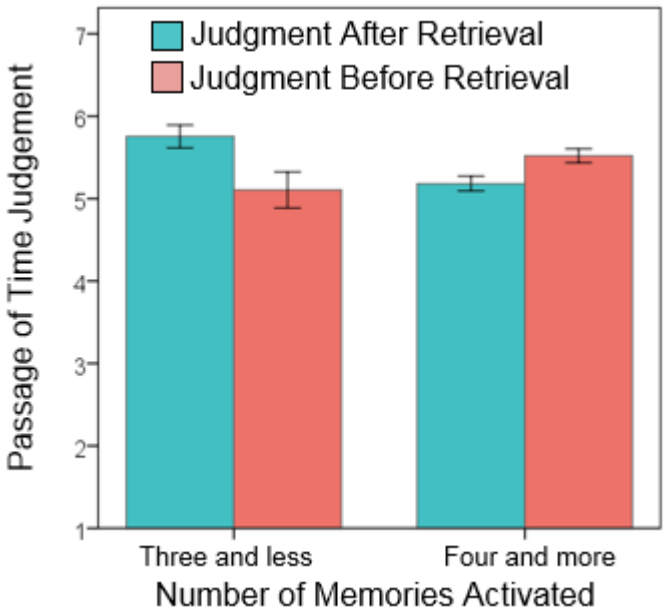

Figure 2: Passage of time judgments (ranging from 1 = "very slow" to 7 = "very fast") for the last five years for participants recalling three and less (left bars) or four and more (right bars) memories as a function of the time point of judgment (judgment before retrieval condition, judgment after retrieval condition). Error bars show standard errors.

Table 3

Passage of time judgments and number of events activated with high ratings of valence

	Estimate	*SE*	*t*	*P*
Intercept	4.89	.25	19.36	< .01
Condition	-.36	.13	-2.71	.01
Memory high valence	-.26	.22	-1.19	.24
Memory total	-.32	.26	-1.23	.22
Age	.02	.01	3.93	< .01
Proportion positive events	.1	.27	.35	.73
Condition x Memory val	.23	.33	.69	.49
Condition x Memory total	.88	.38	2.33	.02

Note. Estimate = Regression coefficient; *SE* = Standard error of the regression coefficient; *t* = *t*-value; *p* = Probability of committing a Type-I-Error; Condition = Experimental condition (0 = judgment before retrieval; 1 = judgment after retrieval); Memory High Valence = Dummy-coded high or low number of recalled memories with high valence (0 = less than three events recalled; 1 = three or more events recalled); Memory total = Dummy-coded high or low number of recalled memories (0 = less than four events recalled; 1 = four or more events recalled); Age = Age of Participants; Proportion positive events = Proportion of positive recalled events compared to the number of total recalled events; Condition x Memory val = Interaction effect between experimental condition and dummy-coded memory valence variable; Condition x Memory total = Interaction effect between experimental condition and dummy-coded memory variable adjusted R^2 = .05 (p < .001).

To further examine the role of affective quality of the activated autobiographical events, the sum of retrieved events rated as particularly emotional, regardless of the direction (events with ratings <=2 and >=6 on a 7-point-likert-scale ranging from '1 = very negative' to '7 = very positive'), was determined for each participant,. Again, an intersection point (2.12) was visually identified and detected using numerical approximation. After splitting the dataset, another dummy variable coded was computed according to the intersection point of the regression splines of the judgment before retrieval and judgment after retrieval conditions for the variable sum of high valence events. (1 = three or more memories with high valence, 0 = two or less memories with high valence). Subsequently, a linear regression analysis including this variable and judgment condition (0 = judgment-before-retrieval; 1 = judgment-after-retrieval) as

predictors was estimated. It showed no interaction between condition and sum of high valence events (see table 3). The total number of memories as well as age and the proportion of positive events have been added as covariates to control for the respective effects.[15]

Table 4

Passage of time judgments and number of events with high impact activated

	Estimate	*SE*	*t*	*P*
Intercept	4.84	.26	18.79	< .01
Condition	-.3	.14	-2.15	.03
Memory High Impact	.02	.2	.12	.91
Memory total	-.51	.26	-1.93	.05
Age	.02	.01	3.93	< .01
Proportion positive events	.11	.27	.42	.68
Condition x Memory HI	-.15	.3	-.51	.61
Condition x Memory total	1.13	.36	3.12	< .01

Note. Estimate = Regression coefficient; *SE* = Standard error of the regression coefficient; *t* = *t*-value; *p* = Probability of committing a Type-I-Error; Condition = Experimental condition (0 = judgment before retrieval; 1 = judgment after retrieval); Memory High Impact = Dummy-coded high or low number of recalled high impact memories (0 = less than three events recalled; 1 = three or more events recalled); Age = Age of Participants; Proportion positive events = Proportion of positive recalled events compared to the number of total recalled events; Condition x Memory HI = Interaction effect between experimental condition and dummy-coded memory high impact variable; Condition x Memory total = Interaction effect between experimental condition and dummy-coded memory variable; adjusted R^2 = .04 (p < .001).

Finally, to examine the role of the subjective impact of retrieved autobiographical memories on one's life, a similar analysis was conducted concerning passage of time judgments

[15] Since for both, number of high impact and number of highly emotional events, the intersection point was between two and three memories, the analyses have been adjusted. However, splitting the dataset between three and four memories, as in our first analysis concerning the overall number of events, did not lead to different results.

and the number of memories that participants rated as particularly influential for their subsequent life (events with ratings <= 2 and >= 6 on a 7-point-likert-scale ranging from 'very negative impact' to 'very positive impact'). The intersection point of the regression splines for the judgment before and the judgment after retrieval condition was located at 2.20, based on which another dummy coded variable regarding high-impact was derived (0 = two or less high-impact-memories, 1 = three or more high-impact-memories). The respective linear regression analysis did not show an interaction between judgment condition and memory of high impact events (see table 4).[3]

Discussion

When being reminded of outstanding autobiographical events from our past, we are often overwhelmed by the feeling of lifetime having passed rather fast since. By examining the dependence of such retrospective passage of time judgments on the active retrieval of autobiographical memories, the present study suggests that the experience of time flying reflects the effect of a reminiscing heuristic. Compared to a control condition where participants were asked to retrieve autobiographical memories after judging the passage of time, passage of time judgments varied depending on how many autobiographical memories were retrieved before. When recalling less than four autobiographical events from the past, time was experienced as having passed faster, while after recalling four or more autobiographical events, time was experienced as having passed slower. Thus, the everyday experience of time flying when being reminded of an outstanding autobiographical event (such as the marriage in our introductory example) may actually stem from the fact that it is the *only* memory activated in such a situation.

The present findings are basically in line with memory-based approaches, proposing that retrospective passage of time judgments depend on the amount of memories available for a specific time interval (e.g., Block & Gruber, 2014; Block & Reed, 1978; Block & Zakay, 1997; Friedman & Janssen, 2010; Ornstein, 1969; Wittmann & Lehnhoff, 2005). However, our findings reveal several specifications concerning a life-time perspective. First, a decelerating effect of stored memories was only found, when these were activated before judging the passage of time. When passage of time judgments were made without activating stored memories before

(judgment-before-retrieval condition), a higher number of memories was not accompanied by slower passage of time judgments. Thus, the assumption of a "covert retrieval" of stored memories (Block & Reed, 1978, p. 657), which is discussed for the experience of time for short intervals (Block & Reed, 1978), cannot be confirmed for a lifetime perspective. Instead, rather than on the amount of stored memories, passage of time judgments seem to be based on the amount of stored memories that is currently activated, a phenomenon that is well known in other domains of judgments such as, for instance, judgments of subjective well-being (Schwarz & Strack, 1999).

Second, other than one may derive from both storage size metaphor and contextual change hypothesis, the experienced speed of time having passed seems not to decrease continuously with an increasing number of memories activated. Instead, the relationship between passage of time judgments and the amount of recalled memories seems to follow a step function with a tipping point. In the judgment-after-retrieval condition, when recalling four or more memories before judgment, the experienced speed of time having passed was suddenly slowed. However, below and above that tipping point (i.e., three or less and four and more memories recalled), passage of time judgments were unrelated to the number of retrieved memories.

In the previous literature, it has been discussed whether specific qualities of stored events for a time interval may affect the experienced passage of time beyond the mere number of stored events. In particular, contextual change hypothesis suggests that mainly events indicating change are relevant for the experience of time. (Block & Reed, 1978). Additionally, affective state has been shown to impact passage of time judgements (Droit-Voletet al., 2017; 2018), thus it is a plausible assumption that the valence of the events activated might be relevant as well. Interestingly, in the present study, neither participants' ratings of the influence of the recalled events for their subsequent life nor the emotional quality of the recalled events was associated with passage of time judgments. At first glance, such a finding seems to suggest that it is not a certain quality but the mere number of the recalled events that mitigates the phenomenon of time flying. However, although this would be in line with the original Storage-Size-Metaphor (Ornstein, 1969), such a conclusion is premature since participants were

explicitly instructed to activate personally meaningful emotional events. Consequently, the range of variability in the importance and affective intensity of the retrieved events may have been restricted, which may have masked potential effects of the respective factors. Thus, to clarify the role of factors such as importance or affective quality in experienced passage of lifetime, further research is needed.

Finally, the present study may be used as a starting point for several interesting lines of future research. First, since the present study only investigated passage of time judgments for an interval of five years, the question arises whether the observed relationship between autobiographical memories and passage of time judgments generalizes across other time intervals both in terms of the form of the relationship (step function with a tipping point) and in terms of specific parameters (position of the tipping point). Second, an interesting question would be whether reminiscing is the default strategy when judging the passage of lifetime intervals. While the present results clearly show that a reminiscence heuristic is at work when one actively retrieves memories of the past before judging the passage of lifetime, the fact that no decelerating effects of increased numbers of retrieved events was found in the judgment-before-retrieval condition suggests that this is at least not the only strategy people are using when judging the passage of lifetime. In fact, a number of other factors may play a role such as, for instance, general beliefs in time flying (see Friedman & Janssen, 2010, for a brief discussion), subjectively experienced time pressure (Janssen et al., 2013; Janssen, 2017) or the individual time perspective (Wittmann, Rudolph, Linares Gutierrez, & Winkler, 2015). Thus, an examination of the actual mental processes participants are applying when asked to judge passage of time may be an interesting avenue for future research. Third, the existence of a reminiscence heuristic in retrospective judgments of passage of time may be relevant for other phenomena such as the finding that the passage of time is judged as faster with increasing age. This finding was particularly found for intervals of 10 years (e.g., Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005), now we can confirm about the same correlation regarding the last five years. Furthermore our results imply the possibility that actively reminiscing might be a potential strategy to compensate the experience of time acceleration with aging. However, since our database does not include enough older participants to answer such a questions, these aspects have to be examined in future research as well.

In conclusion, the present findings suggest that filling up long intervals of life time by recalling autobiographical memories leads people to judge time as having passed slower. Thus, whenever a conversation brings up a single outstanding autobiographical memory ("the marriage of my daughter!") and one is on the brink of complaining about time flying, it might be helpful to recall some more autobiographical memories. This may lead to the experience of time having passed slower than initially thought.

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2.3 Article 3: Valence of Activated Memories and the Passage of Time

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Abstract

Previous research has shown that judgements of the experienced velocity of recent years passing by vary depending on the number of autobiographical memories being activated in the moment of judging. While a body of evidence shows affect to have an impact on both prospective and retrospective judgments on the experience of time for short periods, the effect of valence of memories on the experience of the passage of long intervals has not been examined yet. Thus, we asked 282 people to retrieve five either emotionally positive or negative memories from the last five years before judging the subjectively experienced passage of time of these years. However, positive and negative events differ in some ways beyond valence, e.g. the ascribed impact on the participants' subsequent lives as well as the stability of ascribed affective intensity: the latter decreased over time for negative but not for positive memories while ascribed impact was markedly higher for positive memories. Results indicate no significant differences between the two conditions, even after controlling for the aforementioned differences. However, exploratory analyses show that participants rate time to have passed faster, the longer the activated memories dated back on average, a result that seems in line with contextual change hypothesis.

Keywords: Passage of Time Judgments, Subjective Experience of Time, Contextual Change Hypothesis, Storage Size Metaphor, Autobiographical Memory, Fading Affect Bias

Introduction

Autobiographical Memory and the Experience of Time

A famous quote of Benjamin Franklin suggests that one should not squander time since it "is the stuff life is made of" (e.g., Leo-Lemay, 2006, p. 194). Although one could repulse the implicated utility-imperative, the simple truth of time being life's basic commodity may explain why the perceived velocity of time is a phenomenon of high significance to humans. In fact, at least inhabitants of western countries seem to regularly claim that time flies by in everyday conversations.

This anecdotal observation gets evidential support by studies looking at passage of time judgments (POTJs) for longer intervals (ranging from days to 10 years): when asked to judge the experienced velocity of these intervals, reported mean-ratings consensually indicate a perception of time passing fast (e.g. Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005, chapter 2.2).

Since the passage of years is obviously no sensorial experience, such judgments are necessarily based on derivations from other information. One possibility is that these reflect something like a cultural 'meme' (see Lee & Janssen, 2019 for everyday-theories concerning time-experience) suggesting time to fly and the judgment itself being made without individuals actually examining their inner mental processes. If this was the only source, asking for POTJs could evoke nothing but the belief in this meme, and the complaint about time flying was just an empty phrase. However, ending the debate here would ignore the possibility that people might in fact be able to evaluate their experience of time-passage: It has been argued that passage of time is actually the perception of succession, of one event happening after another (Deng, 2019). This can be read as a reflection of Franklin's idea: in hindsight, life is the accumulation of time, which is mentally represented as succession of events. This view suggests that the information we use to both access and define time in the past are actually the memories of events from this exact past. Following these thoughts, trying to sense a subjective velocity of passed intervals means examining the succession and accumulation of accessible memories and – in order to be able to come to a judgment – compare the result with one's individual conception of a prototypical interval.

These considerations are compatible with established theories explaining differences in retrospective timing (i.e., naïve reporting of time-experience after an interval, see Figure 1 for a comprehensive view), namely the storage-size-metaphor (Ornstein, 1969) and the contextual-change hypothesis (Block, 1985). The first claims that the higher the amount of information stored for the time interval in question, the longer it´s subjective experience of time. This storage size, in turn, results from i) the number of informational units encoded and ii) the complexity of the encoding-process. The contextual-change hypothesis, by contrast, rejects the idea that the amount of stored information itself is decisive. Instead, it proposes that not all information is equally relevant and identifies the degree to which experienced information is perceived as indicating change as crucial (Block, 1985). This shifted the focus from the intervals content to the subjective interpretation of the information.

<table>
<tr><th>Type of Judgment

Perspective of Judgment</th><th></th><th>Duration Judgments
i.e., estimates of the duration of intervals</th><th>Passage of Time Judgments
i.e., judgments of the perceived velocitiy of intervals</th></tr>
<tr><td rowspan="2">Retrospective
Participants in the according studies are naive regarding time as matter of the investigation, i.e. attention has not been directed to time in advance.
Only one rating/judgment can be provided.</td><td>Long Intervals
i.e., from days to several years (not accessible for reseach in laboratory settings)</td><td>Indications of longer/shorter subjective durations of objectively quantified intervals via perceived differing time-units, e.g., “It is 8 months since the UK first went into lockdown. It feels like…”
Answers on 5-point-likert-scale ranging from “A lot longer…” to “A lot shorter than 8 months.” (e.g., Ogden, 2021)</td><td>Indicating that an objective time-interval has been perceived as having passed at a certain velocity, e.g., „How did the last 5 years pass for you?“ – Answers on likert-scales ranging from „very slow“ to „very fast“
(e.g., Kosak et al., 2019)</td></tr>
<tr><td rowspan="2">Short Intervals
i.e., ranging from ms to hours (accessible for research in laboratories)</td><td><u>Duration in time-units</u>
Estimation of the length of an interval in time-units, e.g., „[…]estimate the number of seconds elapsed[…]. (Hicks et al., 1976)
<u>Duration in relation to some reference</u>
Psychophysical measurement:
the duration of the interval in question has to be indicated on a line in comparison to a reference line representing the length of a previously experienced baseline-interval (e.g., music, a training trial) (e.g., Ornstein, 1969; Block, 1974)</td><td rowspan="2">Judgments of the perception of the velocitiy with which short intervals (e.g., film-clips) pass/ed by, answers ranging from (very) slow to (very) fast.
(e.g., Wearden, 2016)</td></tr>
<tr><td>Prospective
Attention has been directed to time in advance, participants in the according studies are instructed to focus on their experience of time.
Multiple trials are possible.</td><td><u>Duration in time-units (see above)</u>
<u>Duration in relation to some reference</u>
a) Psychophysical measurement (see above)
b) Temporal bisection tasks:
Presented stimuli have to be identified as (rather) short or long, the anchordurations for long and short are predefined using reference stimuli. (e.g., Kopec & Brody, 2010)
<u>Production and Reproduction</u>
a) Production:
A target time has to be estimated by signalling the end of the interval (e.g., Espinoza-Fernandez et al., 2003).
b) Reproduction:
An interval is presented and has to be reproduced by subjects (e.g., Eisler & Eilser, 1994)</td></tr>
</table>

Note. Without claiming completeness, this comprehensive view captures and depicts some of the most common paradigms applied in psychological research investigating the experience of time. The differentiation between long and short intervals is a suggestion based on what length of intervals can or cannot be assessed in laboratories and therefore with the according paradigms.

Experimental studies investigating short intervals have confirmed this idea showing that i) the level of processing (shallow vs. deep) leads to different memory content but not different estimates for duration and ii) given the same quantity of content, an experience of an irregular pattern indicates more contextual change and therefore an extended experience of time compared to pattern with higher levels of routine (see, e.g., Block, 1985, Block & Reed, 1978).

Despite the differences regarding content itself or its perception being crucial, both approaches are based on the assumption that the information presented and stored from intervals are fundamental for the perception of time. Furthermore, this implies a "covert retrieval" (Block & Reed, 1978, p. 657), i.e., in the moment of judging time people are not necessarily aware of this judgment being influenced by the information from the interval in question. This seems plausible for short intervals, typically investigated by using retrospective paradigms in laboratory-settings, but assigning this hypothesis to longer intervals might be hasty. The retrieval of relevant memories – covert or not – to judge extensive parts of a life is obviously more complex than retrieving memories from a preceding interval ranging from seconds to minutes. In fact, due to the sheer amount of potential memories, a comprehensive evaluation of relevant information from long intervals is impossible. Thus, it seems reasonable to expect these judgements might depend on what is present in the moment of judging. This was confirmed in our previous study, where POTJs for the last five years varied depending on the number of actively recalled memories from this interval: with a certain amount of memories being surpassed, POTJs were slower compared to a control condition with no explicit request to retrieve memories before providing POTJs. On the other hand, retrieving only few memories led to even faster POTJs compared to the control condition (chapter 2.2).

The impact of activated information on evaluations of life

That salient information can affect supposedly extensive evaluations of life has been shown in another field of research, namely well-being: a set of studies presented evidence showing that overall subjective well-being was rated higher after having recalled positive compared to negative autobiographical life-events (Borg, 1987; Schwarz & Clore, 1983; Schwarz & Strack, 1999), although recent evidence suggests that effect-sizes might have been overestimated in earlier studies (Yap et. al., 2017). Similarly, having recalled one's latest dating

record (Strack, et al., 1988) or verbally addressing the result of a preceding football-game (Schwarz, et. al., 1987) had likewise consequences. In these studies, the direction of the shift in well-being depends on the affective valence of the salient information: overall life-satisfaction was lower if negative information was activated, and vice versa regarding positive information. While this impact seems plausible given the coherence between the valence of memories and subjective well-being, a similar role of valence for the subjective experience of time seems not as obvious.

However, from an everyday-perspective, common claims of time flying when one is having fun but dragging when experiencing boredom and/or discomfort suggest a possible importance of affect for the experience of time. The hereby-assumed mechanism seems plausible: since situations perceived as negative are typically aversive, which implys a desire for the current situation to end or to improve, time has been suggested to be explicit in these situations. By contrast, in situations considered as positive, e.g., flow-experiences, one's awareness is usually led away from time so that time gets implicit (Fuchs, 2005). Thus, positive situations might often feel like having gone by (too) fast while experiencing something unpleasant or waiting in a boring situation is likely to feel dragging. This, however, applies primarily to prospective (i.e., participants being aware of time-perception as matter of investigation, see Figure 1) judgments for a short-time perspective.

The role of valence in time perception

In fact, a body of research covering prospective time perception for short intervals suggests that emotion has a significant impact on the experience of time (see Droit-Volet, 2019, for an overview) with some studies supporting the described association of valence and time perception. For instance, the presentation of positive stimuli was perceived as shorter than negative stimuli (e.g. Gable & Poole, 2012), and high levels of boredom lead to a relatively longer time perception (Danckert & Allman, 2005). Other studies show that stimuli of any valence can extend the subjective experience of time highlighting that the reason for differing results is a complex interplay of attention and arousal effects (e.g. Droit-Volet et al., 2004; Kliegl et al., 2015; Lambrechts et al., 2011; Noulhiane et al., 2007).

Little research covers the impact of emotional material and/or mood on retrospective judgments for longer intervals. One study reported no impact of film-induced affective states on the felt duration of a subsequent waiting-line-situation (Chebat et al., 1995), while another reported that a wait with positive music was judged as longer than one with negative music, the duration of which was still overestimated compared to a no-music condition (Hui et al., 1997). Similarly, an entertaining situation (watching a movie) was judged as having lasted longer than a particularly boring task (waiting in an empty room, Wearden, 2005). Both experiments suggest not only that valence but also the content of the intervals in question matters, supporting the memory-based approaches' main claim that the existence of more encoded and retrievable information leads to a lengthened experience of time in retrospect.

For the experienced passage of years, however, the role of affect has not been investigated yet. As mentioned before: a comprehensive retrieval of all potentially relevant information is obviously impossible, what explains the relevance of currently activated memories on POTJs (chapter 2.2). However, whether the emotional valence of these memories is crucial remains an open question. From a theoretical perspective, the direction of a potential effect seems unclear: One plausible assumption suggests that the activation of negative events evokes and/or mirrors the experience of time dragging through the interval in question, potentially resulting in time being experienced as slow. At the same time, research has shown that negative memories are typically remembered in less detail and are less vivid compared to positive ones (D'Argembeau & Van der Linden, 2008; Sedikides & Skrowronski, 2020). Thus, considering memory-based approaches, recalling positive memories could lead to more mental content compared to recalling the same number of negative events too. This would suggest that activating only negative memories should result in judging time as having passed faster compared to activating positive memories. To investigate whether POTJs differ depending on the valence of previously activated autobiographical memories, participants in the present study recalled either positive or negative personal memories from the last five years before judging how fast these have passed for them.

Methods

Participants. Based on a power analysis (G*Power; Faul et al., 2007), aiming for 80% power for small to medium effects of d = .35 (p < .05), we targeted a minimum sample size of 260 participants. All data exclusions, manipulations, and measures used in the study are reported. Participants were recruited via Prolific (www.prolific.co), the website of the German edition of 'Psychology Today', and private sources. Participants on Prolific were compensated with 1,90£, students of the Regensburg university received course credit, all other participants received no compensation. 282 participants (149 via Prolific, 133 via other sources) recalled the required memories before providing POTJs and were included in the final sample. Mean Age was 27.32 years (SD = 9.56), 33.3% were male, 62.8% female, 3.9% did not disclose their gender. 52.4% of the participants were students, 37.3% employed, 7.4% self-employed (the rest spread among other categories, e.g., household-work, unemployed or vocational training (multiple options could be selected).

Design and Procedure. The study was realized using the online-platform SoSci-Survey (Leiner, 2019), participants spent M = 15.96 minutes (SD = 5.56) to complete the questionnaire. When opening the survey, participants were introduced to the study without any information regarding time as a matter in its course. Instead, the study was presented as investigating the relation between subjective well-being and autobiographical memories. Additionally, participants were asked whether they had been diagnosed with post-traumatic stress disorder throughout the last five years, suffer from flashbacks, intrusions or dissociations or have experienced things, of which the recall might cause strong and burdening emotional reactions. Answering yes to at least one of these questions ended the study, advising against taking part due to a potential confrontation with burdening memories. Otherwise, the next page provided detailed information about the survey and the use of data and finally participants had to provide informed consent by ticking a checkbox.

The actual survey started with the Satisfaction with Life Scale (Glaesmer et al., 2011) and the Positive and Negative Affect Scale (Krohne et al., 1996). Then, participants were randomly assigned to one of two experimental conditions and had to recall either five negative (N = 137) or positive autobiographically relevant events (N = 145) from the last five years. The

instruction was presented on a separate page, asking participants to look back on the past five years and recall five positive/negative events from these years, which one has personally experienced as meaningful (German: 'bedeutsam') or defining (German: 'prägend'). It was emphasized that what is meaningful or defining is a matter of each individual's notion, and that a keyword with a significant meaning only for the participant was sufficient. Each event was provided on a separate page with an input line. On the next two separate pages, subjects were asked to judge the passage of time (POTJ) for the last five years and the last year (7-point likert-scales ranging from 1 = very slow to 7 = very fast). Subsequently, subjects were asked to briefly describe their thoughts when judging the passage of time before they had to recall another five memories of the opposite valence (this was done to avoid that participants of one group end the study with in depth exposure to negative and burdening memories only). Then, all memories were presented to the subjects again asking them for some additional information, namely the year of the event, emotional valence (i) at the time when the event took place (from here on referred to as 'initial valence') and (ii) at the moment of retrieval ('current valence'), as well as impact on the subsequent life. Following these ratings, participants were asked to fill out a modified version of the Protestant Work Ethics Scale (McHoskey, 1994) and a scale measuring Time Pressure (Friedmann & Janssen, 2010). Finally, demographical information and a short evaluation of the questionnaire were requested.

Qualitative Data

The qualitative data generated by asking participants about their thoughts when judging the passage of time was manually coded into the variable "thoughts while judging" using MAXQDA 2020 (Verbi Software, 2019). All participants referring explicitly to their past (e.g. "The events from the last years feel like being long ago but somehow still like yesterday", Case 2628) were coded with "memories" while participants whose statements did not at all touch on memories (e.g. "Sometimes time goes by fast, sometimes slow, on average neither fast nor slow", Case 2472) were coded as "other". Answers referring to high levels of routine and/or answers explicitly stating an absence of memories (e.g. "every day is just the same and eventless", Case 2727) were coded as "memories" as well, since these imply an attempt to recall memories.

Ethics, Preregistration and Repository

The study was conducted in accordance with the declaration of Helsinki and the ethical guidelines of our university. In Germany, psychological studies of these type do not require ethical approval of an Ethics Committee (see https://www.dfg.de/foerderung/faq/geistes_sozialwissenschaften/). The study was preregistered using open science framework (https://osf.io/v2ujc). All data and measurements including verbatim instructions regarding POTJs and the recall of autobiographical memories are accessible in a repository (https://osf.io/habrz/).

Results

79.9% of participants' thoughts while judging the passage of time referred to memories (excluding participants that did not refer to memories did not lead to different results in the subsequently reported analyses). The two experimental conditions did not differ significantly regarding age, subjective well-being, time pressure, their values on the protestant work ethics scale (all *d*s < |.13|, *p*s >.31, see table 1), or their thoughts while judging ($\chi 2$ (1, *N* = 275) = 1.31, *p* = .25, *d* = .14). The average POTJs across experimental conditions were *M* = 5.33 (*SD* = 1.18) for the last five years and *M* = 5.78 (*SD* = 1.33) for the last year.

Comparing the POTJs for the last five years between the experimental conditions (positive vs. negative memories activated) revealed no significant overall differences, (*t*(280) = 1.17, *p* = .241; *d* = .136). We further investigated the absence of a statistically significant mean difference in the frequentist framework by calculating a Bayes factor to relate evidence in favor of a null-effect to evidence in favor of a non-null-effect. The resulting Bayes factor of BF_{10} = .26 indicated moderate evidence in favor of the null (although relatively close to the range considered as weak, see, van Doorn et al., 2020). For the model, we used default Cauchy prior distributions with a scaling parameter of *r* = .71. POTJs for the last year did not differ between conditions as well (*t*(280) = -.50, *p* = .616; *d* = -.06).

Table 1

Mean ratings on several variables reported by participants depending on experimental condition.

	Positive before POTJ		Negative before POTJ	
Variables	*M*	*SD*	*M*	*SD*
Age	27.63	9.79	27.01	9.33
SWLS	4.75	1.28	4.75	1.23
PANAS Balance	1.06	1.18	1.05	1.14
POTJ last five years	5.41	1.27	5.25	1.08
POTJ last year	5.74	1.39	5.82	1.27
Time Pressure	4.95	1.33	4.79	1.30
Protestant Work Ethic	2.74	.51	2.75	.52

Note. *SWLS* refers to the Satisfaction with life Scale (Glaesmer, Grande, Braehler, & Roth, 2011). *PANAS Balance* reports the mean rating on negative items subtracted from the mean rating on positive items of the Positive And Negative Affect Scale (Krohne et al., 1996). *POTJ* refers to the Passage of Time Judgments for the last five years and the last year, respectively, measured with a 7-point-likert-scale ranging from "very slow" to "very fast". *Time Pressure* is measured by a four item-scale (7-point-likert) taken from Friedman & Janssen (2010). *Protestant Work Ethic* (19 items, 5-point-likert) reports the average on a slightly modified version of the according scale, taken from McHoske, (1994).

With reference to potentially interacting variables, an interesting observation was that while the initially experienced affective intensity (i.e., valence ratings without direction, thus, ranging from 0 = neutral to 3 = very negative/positive) of the recalled events did not differ between conditions ($M_{positive}$ = 1.97, *SD* = .95, $M_{negative}$ = 1.99, *SD* = .69; *t*(253.06) = -.17, *p* = .87; *d* = .02), the currently experienced affective intensity differed markedly ($M_{positive}$ = 2.01, *SD* = .72, $M_{negative}$ = .74, *SD* = .84; *t*(264.70) = 13.37, *p* < .001; *d* = 1.62). A mixed ANOVA with time (initial vs. current) and condition revealed both a significant effect of condition (*F*(1, 273) = 53.65, *p* < .001, *d* = .91) as well as an interaction of condition and time (*F*(1, 273) = 141.44, *p* < .001, *d* = 1.44), indicating that the affective intensity reported for the memories varied between 'initial' and 'current' depending on experimental condition. Thus, participants reported a strong decline of affective intensity for negative memories while intensity of positive memories did

not change with time.

Furthermore, experimental conditions did not differ concerning the average time passed since the events ($M_{positive}$ = 2.56, *SD* = .70, $M_{negative}$ = 2.64, *SD* = .72; *t*(273) = .26, *p* = .35; *d* = .11), while they varied markedly regarding the ascribed impact on the subsequent life ($M_{positiveMeM}$ = 5.92, *SD* = .76, $M_{negativeMeM}$ = 3.78, *SD* = .89; *t*(273) = 21.30, *p* < .001; *d* = 2.57).

Regarding the specifications of the memories recalled (mean years since event, mean impact on subsequent life, mean initial and current valence) before judging the passage of time a linear regression reveals that two of these have a small but significant impact on POTJs for five years: these were faster with a higher average of impact ascribed to the memories as well as with a longer average time passed since the events (see table 2). Neither current nor initial affective intensity, however, were associated with POTJs.

Table 2

Linear model of memory-specifications predicting POTJs for 5 years.

Model	*b*	*SE B*	ß	*p*
Constant	4.22	0.41		<.001
Avg. years since event	0.27	0.10	0.16	<.01
Impact on subsequent life	0.14	0.06	0.17	.01
Current affective intensity	-0.03	0.08	-0.04	.63
Initial affective intensity	-0.11	0.09	-0.08	.21

Note. R^2 = .05, corrected R^2 = .04, *p* = .005. *Avg. years since event:* for each event the time passed since was selected from a dropdown-menu, offering options from 1 = less than 1 year ago to 5 = between 4 or 5 years ago. All other items were rated on 7-point-Likert-Scales: *impact on subsequent life* (1 = very negative impact, 7 = very positive impact), *initial affective intensity / current affective intensity*: the emotional intensity at the time of the event taking place (initial i.e., "How did you feel at the time the event had happened?") and at the moment of filling out the questionnaire (current i.e., "How do you feel now thinking back to that event?"). The original scales regarding valence were ranging from 1 = very negative to 7 = very positive. To compare the intensity, we transformed the scale into a unidirectional scale ranging from 0 = not intensive at all to 3 = very intense. Note that only specifications of memories activated before judging the passage of time had been included in the analysis.

Since impact on subsequent life does both differ between the experimental conditions and is associated with POTJs, we decided to control for potential interaction-effects. Thus, we applied a linear mixed model including experimental condition, impact, and the interaction of condition and impact to predict POTJs for five years (see, Hilbert et al., 2019). However, the overall model did not significantly explain variance of POTJs for five years, $F(271,3) = 2.46$, $p = .07$, corrected $R^2 = .015$ and neither condition nor impact nor the interaction of impact and condition did predict POTJs, all p-values > .24. Additionally, we applied the same procedure to control for a potential impact of the fading of affective intensity on POTJs (e.g., the difference between the absolute values of initial and current intensity) but the model including condition, decline in affective intensity and the interaction of both did not explain any variance in POTJs; $F(271,3) = .56$, $p = .64$, corrected $R^2 < .01$. These analyses show that none of the observed differences between positive and negative memories cover up a potential effect of valence on the experienced passage of time.

Discussion

The main goal of this work was to investigate whether the emotional valence of currently activated memories has an impact on subsequent POTJs for intervals of several years. While the present study is the first investigating the impact of valence on retrospective POTJs for multiannual intervals, numerous studies have shown that emotional factors have a significant impact on prospective experience of time for short intervals (e.g., Droit-Volet et al., 2004; Kliegl et al., 2014; Lambrechts et al., 2011; Noulhiane et al., 2007), and some studies show an effect of emotional factors on the retrospective experience of time for periods up to some minutes (e.g., Hui et al., 1997; Wearden, 2005). However, our results show no differences in POTJs depending on the different emotional valence of currently activated memories, and this holds true after controlling for specifications that differ between positive and negative memories, such as currently experienced affective intensity, the fading of affective intensity or the perceived impact of the memories on one's subsequent life.

The last two aspects seem worth a closer look: our results show that the relatively long intervals between the time the events took place and the recall lead to a lower affective intensity of retrieved negative compared to positive memories. This replicates the fading affect

bias, i.e., the decline of affective intensity for negative but not positive memories (e.g., Skowronski et al., 2014). Consequently, negative memories are judged as less negative in the present than by the time the events took place. Other than, in studies investigating shorter intervals (i.e. the wait in Hui et al., 1997 or the movie-excerpt in Wearden, 2005), by the time of judging the passage of time, the affective intensity of negative memories is systematically lower compared to positive ones. However, since the decline of intensity has no significant impact on POTJs and controlling for this decline does not uncover any differences between the experimental conditions regarding POTJs, it seems that valence of activated autobiographical memories simply does not affect POTJs for long intervals.

Another aspect that differs remarkably between positive and negative memories is the impact, people ascribed to the memories: negative ones are reported to have had considerably less impact on the participants' subsequent lives than positive memories. In the light of contextual change hypothesis, which identified the perception of change as crucial for the subjective experience of time (Block & Reed, 1978), this would suggest that participants, which activated negative events before judging POTJs, should have rated time as having passed faster. However, across both conditions, a higher ascribed impact of the reported memories on subsequent life is associated with slightly faster POTJs. This seems surprising, but before voiding contextual change hypothesis as an explanation for the perceived passage of years, one should note that participants had to recall specifically personally meaningful events. Presumably, this prompts the recall of memories that have had impact on participants' lives so that the true variability of impact of past events might be considerably underestimated in our data. Additionally, the markedly lower impact-ratings for negative compared to positive memories seem somewhat peculiar. In fact, it is difficult to come up with plausible explanations why negative life events such as, for instance, severe illnesses or death of close persons should have less impact on the subsequent life than positive events. One interpretation might come from literature discussing the Pollyanna-Principle, describing a positivity bias in a range of cognitive phenomena including memory and judgment (Matlin, 2004). Drawing from these findings, a plausible mechanism seems that people tend to reduce the ascribed impact of negative events just in the way they leave behind negative affect while savoring positive affect (Walker et al., 2003). This cushioning of negative experiences may help staying mentally equipped for the

challenges of life. However, confirmatory studies investigating both a lower ascribed impact of negative life events on the subsequent life itself or its interplay with the subjective experience of time would be necessary to support this interpretation.

In contrast, an exploratory finding in this study provides preliminary support for contextual change in experiences of long time intervals: the longer the reported memories dated back on average, the faster time was judged as having passed. In terms of contextual change, this might suggest that under the impression of little contextual changes in recent years, the time since is perceived as having passed comparatively fast. Given that the activation of memories has been shown to mitigate the experience of time passing fast (see chapter 2.2), prevention of time flying might be particularly effective when reminiscing in one´s recent past.

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3. General Discussion

3.1 Summary of Findings

The present work aimed to clarify the role of autobiographical memories for Judgments of the passage of time for multiannual intervals. In the relatively rare works investigating longer intervals, memory-based approaches such as the storage size metaphor and the contextual change hypothesis have been regularly addressed to explain differing experiences of time (Avni-Babad & Ritov, 2003; Wittmann & Lehnhoff, 2005). The respective authors state that higher levels of different experiences (or less routine) would be associated with a higher number of memories available, which supposedly leads to a slower or longer experience of time, respectively (Bastam, 2018; Sußebach, 2021). However, evidence for such a relation only exists for short intervals in the range of milliseconds to several minutes (e.g. Block, 1974, Ornstein, 1969), and, up until now, no studies have actually verified these claims concerning longer intervals. In this thesis, I present studies that partially closed this gap by investigating whether (a) a higher number of autobiographical memories and/or remarkable life events are in fact associated with the experience of time, whether (b) these memories have to be salient at the time of judging and (c) whether the emotional valence of these memories plays a role.

The first research-question was addressed using two different approaches: In order to capture both objective events as well as subjectively meaningful memories, we created surveys targeting life-events with a questionnaire offering typical important life-events, that ought to be selected when these have been experienced through the respective interval and subjective meaningful memories in separate studies (studies 1 and 2 in the 1st article). These events and memories were collected right before the passage of time was judged in order to investigate whether the mere existence of differences in the level of important life-events or memories is decisive for these judgments. Despite applying statistically powerful trial-by-trial analyses to detect even small effects, we found neither an association between the number of objective life-events nor subjectively meaningful memories and judgments of the passage of time. This means that our data do not support the widespread claim that more variety in experiences or more personally meaningful memories directly result in a slower passage of years. Since, at least to my knowledge, no other studies exist that directly approach the interplay of life-events or memories and the passage of time for longer intervals, this suggests that researchers should

refrain from publicly spreading these explanations (Bastam, 2018; Sußebach, 2021).

This seemingly wrong presumption that a life rich of events and experiences and therefore rich of (potential) memories directly leads to a perception of a slower pace of life (or, to be more precise, slower judgments of the passage of years), additionally implies that this judgment is in some way subtly informed by memories, without any conscious effort. This has been discussed as covert retrieval (e.g. Block, 1979). For short and explicitly delimited time-intervals, where attention is aligned to the content of these intervals and where the judgment regarding its duration is given right after the presentation, this seems plausible. However, as outlined in our first article, transferring this assumption to the passage of years is somewhat bold since a comprehensive evaluation of memories for these intervals is simply not possible. Therefore, regarding the passage of long intervals, it seems reasonable to assume that not the variability of life or the number of remarkable memories itself are crucial for judgments, but the memories that are present at the very moment of judging the passage of time.

Study 2 was designed to test this hypothesis with half of the subjects actively retrieving autobiographical memories before judging the passage of time while a control group provided spontaneous POTJs. The results confirmed our expectations, showing that above a certain number of memories recalled (five or more) from the last five years, these were rated as having passed slower compared to the control group but just as well compared to participants that recalled only very few memories from this time. Although we did not hypothesize the latter in advance, this is highly plausible when assuming that the fundamental mechanisms of memory-based approaches are true: Recalling very little information from the interval in question is likely to leave people under the impression of a particularly empty time-interval that has gone by in a blink.

Combined, the studies presented in article 1 and 2 suggest that autobiographical memories do in fact play a role regarding the passage of multiannual intervals, but that the assumptions (a) of a covert retrieval of memories and (b) that a life rich in experiences automatically corresponds with judgments of years having gone by slower is premature. Instead, and similar to what has been shown regarding well-being (Schwarz & Clore, 1983;

Schwarz & Strack, 1999), these judgments are formed on the spot and influenced by information that is currently accessible. Consequently, these judgments can be affected by salient memories but, potentially, might often be made without any memories having been approached at all, too. In this case (and maybe in general), it seems possible that the beliefs people have about the passage of time explain the respective judgments (see, Lee & Janssen, 2019). Thus, the common claim about time flying, that comes up so often in conversations circling around past events (e.g., "My brother's wedding was five years ago. Ah, how quickly time passes!"), might result from two different reasons: a) that only one outstanding event addressed in a conversation is salient when judging the experience of time, and b) that people simply belief that time passes by fast – without actually referring to any experiences.

Since we were able to provide evidence showing that activated autobiographical memories have an impact on POTJs for multiannual intervals, a natural next step was investigating whether certain qualities of these memories are more relevant for the time-experience than others. One particularly important quality of memories is their emotional valence. However, research has repeatedly shown that this valence is not stable but fluctuates over time. In particular, negative but not positive affect associated with memories has been shown to fade over time (see literature concerning the so-called fading affect bias, e.g., Walker et al., 2003). Similarly, literature concerning the pollyanna-principle suggests that positive events are encoded and remembered in more detail (e.g., Matlin, 2004). In the light of memory-based-approaches, this suggests that activating positive memories should lead to more content in memory and thus to an experience of time having gone by slower. Additionally, factors such as the time passed since the events or the impact that people ascribe to these events seem also potentially relevant when transferring the idea of memory-based approaches to the time-experience in multiannual intervals. For example, the ascribed impact on peoples' subsequent life should indicate changes suggesting that more impact ascribed to activated events might signal a mental representation of more change, and thus a perception of time having passed slower. Regarding the time passed since the events, a long stretch without anything that seems to stand out when recalling memories might suggest that little happened throughout the last years and could lead to the conclusion of little changes/content and, consequently, to an experience of time having passed fast.

However, we found no significant evidence regarding the main hypothesis of valence of memories from the last five years being relevant for POTJs for the last five years. A Bayes-Analysis showed moderate support for the null hypothesis, namely that the valence of previously activated memories does not matter for subsequent POTJs. This differs from research investigating mainly duration judgments but also POTJs for short intervals where affect in general and valence in particular have been repeatedly associated with different experiences of time (Droit-Volet et al., 2004; Noulhiane et al., 2007; Wearden, 2005). Additional analyses showed a fading of negative affect, but the latter was not associated with the POTJ, meaning that the experience of time does not differ depending on the affective intensity at the time of judging the passage of time. After all, the average time since the events took place and ascribed impact have shown to be slightly associated with POTJs: while the average time passed since the events is in line with memory-based-approaches (more time passed on average is associated with judgments of time having gone by faster), a higher impact correlates with a faster passage of time, reversing what contextual-change-hypothesis would suggest. However, since this preliminary evidence is only the result of exploratory analyses, confirmatory studies would be necessary to validate these findings.

Taken together, the results of our studies emphasize that the experience of time for long intervals in the range of several years is probably a different phenomenon than the experience for short intervals. Thus, a direct transmission of theories and evidence from short intervals to a multiannual perspective is hasty. At the same time, our results suggest that memories nevertheless are an important factor when it comes to understanding the retrospective experience of time for long intervals. However, the mere accumulation of memories seems not to be decisive for the respective judgments, but rather the question which memories are salient when judging.

3.2 Limitations

Of course, the current work has a number of limitations, some of which I want to discuss on the following pages.

One first aspect is that we did only include autobiographical memories and events in order to explain the retrospective experience of time for multiannual intervals. Of course, this is not the only plausible approach to this research question. Non-personal or public events such as natural disasters, sports-events, meaningful political events, or festivities may serve as the content through which people access their past as well (Deng, 2019). Since it seems unlikely that memories of public events differ from autobiographical ones regarding a covert retrieval, it is plausible to assume that these might serve as content and/or indicators of contextual change as well. Thus, an activation of a certain number of public events might have the same effect on passage of time judgments as the activation of autobiographical memories. After all, examining only autobiographical memories might lead to an underestimation of the role of memories altogether since people might differ regarding what they memorize: It seems possible that some people are more prone to (implicitly or explicitly) refer to public events when accessing their experience of time. Therefore, investigating autobiographical memories only might lead to a systematical underestimation of the association of memories and the subjective experience of time for long intervals.

Regarding our aspirations to investigate the experience of time for multiannual intervals, we have to acknowledge that we only applied POTJ for one time frame, namely five years. This particular length was selected because, on the one hand, it covers a range that seems long enough to approximate the phenomenon of life being experienced as flying by. On the other hand, it was not too long to enable subjects to perform a comprehensive review of their meaningful memories. Note that, except from the objective events in study 1 (chapter 2.1), the aim was not completeness but rather capturing what seems spontaneously meaningful for the subjects. Using an interval of 10 years (as used in preceding studies by e.g., Wittmann & Lehnhoff, 2005 or Friedman & Janssen, 2010, without any activation of memories) would have meant that the subjects' reminiscing-phase would have been rather extensive. Given that the participation in the surveys regularly exceeded 30 minutes in its current form, this would have probably led to poorer quality of data and higher drop-out-rates. Although it seems likely that our findings can be transferred to longer intervals as well, this cannot be confirmed with the data from the current studies. Likewise, it seems plausible that the activation of memories but not their mere accumulation is relevant for the experience of time for shorter time frames

(e.g., days, weeks or months), but we cannot exclude the possibility that for these time frames a covert retrieval of memories does indeed take place.

Finally, it seems necessary to critically discuss the POTJ-paradigm we used in our studies in general. As noted repeatedly, the perception of time in daily life mainly comes up in everyday-conversations circling around a topic (e.g., certain events or the time people have last seen each other), often with the notion of its fast passage. In the present studies as well as in preceding studies (e.g. , Friedman & Janssen, 2010; Wittmann & Lehnhoff, 2005) participants were (a) asked to judge the velocity by giving answers on (b) a Likert scale and (c) for an interval of a certain length, all of which might be perceived as artificial by the participating subjects. Asking someone about their perceived velocity of past time is a question that presumably hardly ever comes up in natural conversations. Instead, as outlined above, these typically address an event, accompanied by realizing its place on a timeline first (e.g., "Ah, the feast was already five years ago"), and in response the time since this event is judged. In the present studies, this natural way of a conversation was dissolved, and instead, a judgment had to be given without a direct reference to a certain event. Similarly, in contrast to the mundane judging of the passage of time since an event, subjects had to judge the passage of a numerously defined interval of time. Finally, a Likert-scale with a particular wording (such as the option time has gone by neither fast nor slow) offers answers that might initiate an up-weighing that never takes place in a natural situation. This might lead people to think about time in a new and certain way (e.g., asking oneself what could be meant by 'neither fast nor slow', wondering about a reference time, etc.) that differs from ways of thinking about the passage of time in everyday situations. Taken together, it seems important to bear in mind that asking for POTJs might initiate cognitive processes that could lead to certain judgments that are influenced by the way we address the topic, and which might not directly reflect the everyday experience of the passage of time.

3.3 Open Questions

The preceding deliberations already pointed to a number of open questions that future research might address in order to gain a better understanding of the experience of time for long intervals. Here it is particularly important to note that other theoretical accounts than the

ones that served as basis for the studies presented in this work may be important as well. Some of these and their respective benefit for research investigating the subjective experience of time for long intervals shall be briefly discussed in this chapter.

As already discussed regarding the limitations of this work, the role of public events for the understanding of the experience of time for multiannual intervals seems very relevant. Beyond their potential relevance as memory-content, public events provide a quality that might be particularly interesting regarding potential research targeting the retrospective time-experience: they come with a verifiable date. This might be specifically relevant regarding the investigation of the interplay of time-experience for long intervals and the phenomenon of telescoping. In short, telescoping describes that peoples' estimates of dates of historical public events are to some degree systematically biased. These biases exist in two opposing directions: forward telescoping means the tendency of underestimating the time passed since an event, backward telescoping (also discussed as time expansion) describes that events are misdated too far into the past (e.g., El Haj et al., 2017). Events from a remote past are typically dated to close to the present while events from a relatively recent past (about up to 7 years) have been repeatedly shown to be affected by backward telescoping (e.g., El Haj et al., 2017; Janssen et al., 2006; Thompson et al., 1988). This time expansion has been discussed as a potential reason for a subjective acceleration with aging, since some evidence allegedly suggested that older people date events further towards the past than younger people (Crawley & Pring, 2003). However, the evidence presented in the respective study is based on a very small sample and differences between the age groups are solely of descriptive nature. Thus, this far-reaching interpretation seems relatively bold. Furthermore, the interpretation presented, presumedly suggesting that the relative decrease in time expansion with aging might contribute to a perception of intervals passing faster with aging, is relatively sketchy. In fact, the opposite interpretation, that forward telescoping could contribute to an experience of acceleration, seems plausible as well: Misdating an event to close to the present and realizing the event is actually longer ago might yield the impression that the time since has passed rapidly (see Draaisma, 2009). Unfortunately, no further research regarding telescoping, age-effects, and its potential interplay with time perception has been presented. Since a systematic bias in dating events might in fact be important for the subjective experience of time passing, this could be a

very interesting line for future research.

Another theoretical approach that seeks to explain the understanding of retrospective time-perception of long intervals and particularly the phenomenon of a perceived acceleration of life with aging, which has not been considered in this work, is a classic approach that Block called ratio-theory (Block et al., 1998). The French philosopher Paul Janet brought up the example of a ten-year-old pupil, for whom one year equals the tenth part of his/her life, compared to a 50 year old person, where the last year represents only 2% of her/his life (Janet, 1877). He interprets this implication rather strict, suggesting that a man of fifty years experiences time to pass by five times as fast as the ten year old since "[e]ach of them, in fact, unconsciously compares their partial life span to the total life span." (p. 498, translated using deepl.com). Although that narrow interpretation seems inept, the underlying concept is still plausible and might be valuable when taking a slightly different view that follows the basic principle: It seems highly plausible that both the perception and the concept of temporal units evolve, at least to some degree, in childhood. By describing years (such as every other conventional time-unit) as passing by fast[16], people have to refer to some conceptual reference frame, where their prototypical idea of a year is deposited and to which a seemingly slow or fast present year is compared. Such a comparative process has been explicitly discussed in internal clock models regarding prospective time perception (e.g., Gibbon et al., 1984) but has been neglected in work regarding POTJs. Future approaches, both theoretical and empirical, should try to clarify to which subjective norm this comparison refers.

These reference intervals (i.e., a prototypical concept of time-intervals) might be developed in childhood[17] during acquiring general concepts of time. Following the ratio-to-life-

[16] As described above, only intervals of five years or longer seem to be affected by an acceleration-effect with aging (see Wittmann & Lehnhoff, 2005 or the data presented in article 2). James, who embraced the ratio-theory as well, believed this not to be true for short intervals (in his case shorter than a day), implicitly suggesting that the perception of short and long intervals might reflect different cognitive processes (Block et al., 1998).

[17] The fundamental perception of time as well as behavioural and neurological reactions to short durations of children have been shown to be rather similar to that of adults even (see Droit-Volet, 2013). Estimations of short durations improve around the age children attend elementary school (Fraisse, 1963). However, to the best of my knowledge, the development of prototypical concepts of long time-units has not been empirically investigated yet.

mechanism (as suggested by Janet, 1877), which suggests that the subjective length of an interval is judged in comparison to life as a whole, this would make the experience of a year being a very long interval during childhood, whereas comparing the experience of a year as adult to these prototypical years from childhood might then plausibly explain why these feel as passing fast.

Additionally, one could argue, that children and adolescents might have a different perspective towards time compared to adults. As Joubert (1984) outlined, life is structured differently in different periods of life[18]. It seems plausible to assume that the life of adults is typically characterized by a higher level of demands as it is for children and adolescents, which results in higher levels of time-pressure for adults. Time pressure implies that time is a scarce resource, which has to be contained. On the other hand, for children and adolescents, time (and particularly long intervals) might very often be perceived as an obstacle, that stands between now and a wistful state/experience in a future (e.g., the next Christmas, birthday, being old enough to make a drivers license, to enter clubs, etc.). Thus, one might infer that during the period in life, where prototypical concepts of long time-intervals have to be developed, time is predominantly perceived as obstacle and therefore as passing too slow, while in adulthood, time is often perceived as increasingly scarce and as passing too fast. Evidence showing that the perception of higher levels of time pressure (e.g., Janssen et al., 2013) respectively of life being more demanding (Joubert, 1984) preliminarily support this idea. Future research might address this question by approaching (a) whether different perceptions of long time-intervals (e.g., longing for time to pass vs. to persist) exist between younger and older age groups and (b) whether time pressure and/or demands are perceived to be systematically lower in young age groups.

Finally, two further theoretical accounts, which imply a potential explanation for the perception of how multiannual intervals pass by, shall be briefly outlined: Time Styles and Scheduling Styles. The first describes a “nonconscious personal attitude that each of us holds towards time” (Zimbardo & Boyd, 2008, p. 51). Time Perspective basically describes the degree

[18] A discussion of what differences appear between which different age-groups, is missing in this brief study.

to which someone's cognitive processes are directed towards past, present or future[19], which is considered as crucial for a plethora of cognitive processes (e.g., encoding, storing, and recalling events, forming expectations, individual goals and imaginations as well as influencing decision processes; Zimbardo & Boyd, 1999). Presuming that the dominance of, for instance, a future-time-perspective compared to a dominant past-orientation might in fact be associated with the perception of time, it seems natural to expect researchers having addressed such questions in the past. However, no studies have investigated this systematically and only a couple of studies have touched on these associations peripherally. The according results show almost no relation between the subjective experience of time and different Times Styles, in particular for long intervals (Droit-Volet & Heros, 2017, Wittmann et al., 2015). However, this might be due to a lack of construct-validity of the most widespread scale measuring Time Perspective, the Zimbardo Time Perspective Inventory (ZTPI; Shipp et al., 2009). Although not only the original scale (Keough et al., 1997, Worrel & Mello, 2007) but also short forms (Košťál et al., 2016) and a large number of translations (e.g., German: Reuschenbach et al., 2013; Polish: Przepiorka & Sobol-Kwapinska, 2016; Spanish: Usart & Romero, 2014; Swedish: Carelli et al., 2011) have been validated, the items themselves provide a rather narrow understanding of the time-styles, confounded with a relatively random selection of other concepts. For example, the items supposed to measure a future-perspective target primarily how to organize and structure the near future in order to be somehow successful in work, studying or meeting other demands (e.g., "I complete projects on time by making steady progress"; "I am able to resist temptations when I know there is work to be done"). Items from other scales measure numerous arbitrary concepts such as risk-aversion, nostalgia or believe in faith (see Shipp et al., 2009, for a detailed critique of the ZTPI). Given the fundamental idea of time perspective, namely that different dominant temporal cognitions might be important to a plethora of other cognitions, these might in fact play a role in the experience of time for long intervals. Studies investigating this experience that would apply a measure conceptualizing the tempi in a more valid way (e.g., the Temporal Focus Scale with items such as "I think about things from my past" or "I focus on my future"; Shipp et al., 2009), might indeed unveil these associations.

[19] Zimbardo and Boyd distinguish between a past-negative, past-positive, present-hedonistic, present-fatalistic and a future perspective (1999), others have suggested to distinguish between future-positive and future-negative as well (e.g., Worrell & Mello, 2007).

On a more mundane level, people might differ how they structure their time and how they locate themselves in time. The concept of scheduling styles captures this by claiming that this happens following either inner senses ("event-time") or calendars and clocks ("clock-time"; e.g., Levine, 1997; Sellier & Avnet, 2018). Clock-timing implies that one structures life mainly by calendar and clock (e.g., returning to office from lunch-break at 1 pm) while event-time covers a reference to inner senses (returning to office from lunch-break when one feels ready to go back to work) as well as happenings in the surrounding world (returning to office from lunch-break as soon as the boss does the same), although the latter distinction is missing in the respective literature (Avnet & Sellier, 2011; Sellier & Avnet, 2014; 2018, for a detailed discussion see, Kosak et al., 2022). It has been argued that variations in dominating scheduling styles represent different temporal cultures from different regions of the world (Levine, 1997), but, of course, there are both inter- and intranindividual differences within different countries, too: People presumably have different overall propensities regarding their scheduling styles but also adapt it to circumstances (Kosak et al., 2022). The individual overall-tendencies regarding clock- or event-timing, however, might in fact be relevant for the experience of time. Living a life strictly by clock and calendar seems likely to be associated with a different perception of time passing by than structuring life along ones inner needs. Ultimately, this might yield a different experience of time than following external cues other than the clock. However, no research has targeted the association of time-perception and scheduling styles yet.

In addition to these theoretical accounts, I want to include two further aspects, that should get more attention from future research regarding the experience of long intervals. Firstly, the aforementioned role of laypersons theories regarding the passage of time, where only a first step has been provided by investigating the interplay of believing in the phenomenon of acceleration with aging and POTJs (Lee & Janssen, 2019), might be a very important avenue. Since people certainly have more theories concerning the perception of time, allegedly sometimes similar to theories developed by researchers (e.g., regarding emotions as well as memories), it seems likely that the belief in these theories shapes POTJs as well. Finally, recent evidence for the experience of time during the COVID19-Pandemic suggests

that emotional factors and well-being in general might play a role. Consistently, studies from different countries reported that higher levels of negative emotions were associated with a slower passage of time (e.g., Cellini et al., 2020, Kosak & Wittmann, 2021; Ogden, 2020, 2021) what is in line with patterns we find in our data from the studies reported in our studies. Previous research in clinical settings, although targeting short intervals only, comes to similar results with depressed patients reporting time to pass slower (Vogel et al., 2018; similarly Wittmann et al., 2006). For long intervals, the role of well-being (both affective and cognitive) regarding the experience of long time intervals should be investigated using empirical methods but also providing conclusive theoretical deliberations, since the latter are still missing.

Summed up, we have to constitute that memory-based approaches, which are dominant regarding explaining retrospective timing for short intervals, are only of limited help for explaining the time experience regarding the past years. However, one has to constitute that there are no elaborate theories available, which specifically try to explain the experience of time for long intervals[20]. This is insufficient since from a psychological perspective, the experience of long intervals seems to be not just the accumulation of short ones. Therefore, it is obvious that future research on long intervals should be targeted with a variety of different theoretical approaches.

These deliberations point out that there is no simple path to understand the passage of time judgments for long intervals. On the contrary, the different approaches seem to suggest that the spontaneous judgments targeted in empirical studies might actually measure rather heterogeneous phenomena, depending partially on individual notions regarding the passage of time as well as subtle processes, of which participants may be hardly aware. This is not necessarily problematic, it might rather reflect how people judge their experience of time in their daily life too: partially depending on what is present in the moment of judging, no matter whether this is a personal theory regarding the passage of time or particular memories but additionally reflecting underlying mechanisms (e.g., comparisons to prototypical time-units) of

[20] This is surprising since pioneers such as Wundt (1872) and James (1890) already provided first deliberations regarding that matter over a hundred years ago.

which one is hardly aware of. However, the systematic shift in passage of time judgments during the COVID19-pandemic, a situation everyone was affected by, compared to the time before (Kosak & Wittmann, 2021) suggests that POTJs are, after all, not just arbitrary ratings.

3.4 Conclusion

Several years ago, when I started this work on the perception of time for multiannual intervals, the original aim of this task was to provide the missing evidence showing that a life rich in contextual changes and the according memories is experienced as passing slower. I was confident to find support for these – as we subsumed them – memory-based-approaches.

However, on this path, I had to realize that this idea did not sufficiently depict the complexity of the respective judgments. The missing evidence presented in article 1 (more precisely from the studies 1a and 1b; see chapter 2.1) led us to considering not the variability of people's lives but the memories that are salient when judging the passage of the respective years. The evidence we found for this relation between activated memories when judging and POTJs is the empirical cornerstone of this work. Taken together, these two articles suggest that a transfer from theoretical ideas, which have been developed and empirically validated solely by investigating short intervals, to multiannual intervals is premature. In more detail, I want to highlight that a covert retrieval of autobiographical memories, as plausibly presumed in both the storage size metaphor (Ornstein, 1969) and contextual change hypothesis (Block, 1974), seems not to take place when judging the velocity with which the preceding years have passed by. Instead, it seems reasonable to conclude that a heuristic similar to Kahneman's (2011) famous WYSIATI-rule ('What You See Is All There Is') applies here as well, and the widespread impression of time flying might be partially due to the little memories that are present at the time of judging.

This implies that the time-experience for long intervals is, at least to some degree, a different phenomenon than the experience of time for short durations. Therefore, it might come as no surprise that we could find no evidence showing that POTJs differ regarding the emotional valence of memories recalled. Simply put: it has no effect on subsequent passage of time judgments whether one recalls negative or positive events from the past. In contrast, for

short durations, a plethora of articles presented evidence showing that affective qualities of relevant stimuli influence the experience of time (e.g., Droit-Volet & Meck, 2007).

However, when considering the effect sizes and the variance explained respectively, one has to acknowledge that even active reminiscing has just a minor effect on POTJs for multiannual intervals. This might be partially due to the vagueness of the POTJ-paradigm: one should be aware that two people with the 'same' experience might still select very different values on the scale offered. Additionally, variations in the experience of time for long intervals are likely due to many different and potentially interindividually varying notions and the according different cognitive processes (e.g., different believes of people regarding the passage of time or different information that people use to derive a judgment). Thus, I provided both a discussion of limitations of our unidimensional approach using only autobiographical memories as well as other theoretical approaches amended with some new deliberations, all of which might be potentially relevant regarding future research on the passage of time for long intervals. This includes the (up to this point neglected) question regarding to what people compare their experience of present time, the role of people's presuppositions concerning time but also theories such as the classic and in recent literature hardly discussed theory considering the time-unit to life ratio (Janet, 1877).

After all, the path I travelled down these years did not lead to a simple answer but rather to more open questions that are yet to be investigated to understand the experience of time for long intervals. Therefore, my hope regarding this thesis is that we, my co-authors in the according chapters and I, provide solid reasons for rejecting simple answers, as well as some theoretical deliberations that might inspire future research targeting the experience of time for long intervals. Providing this small stepping-stone is the humble contribution that I want to offer to the field of psychological time-research.

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