About time: individual temporal orientation, time succession, and cognitive capacities

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List of abbreviations

ACC	Anterior cingulate cortex
MWT	Mehrfachwahl Wortschatztest (Multiple Choice Vocabulary Test)
RAPM	Raven’s Advanced Progressive Matrices test

Abstract

Time is a fundamental aspect of human experience. Whilst most research investigated major aspects of psychological time - time duration, time succession, individual temporal orientation - in isolation, this dissertation investigates interrelations between individual temporal orientation and time succession. Since psychological time is bound to cognitive abstraction processes that rely on cognitive resources and functions, interrelations between individual temporal orientation and cognitive capacities were also investigated. Study 1 explored how different levels of individuals' temporal orientation may be interrelated, and how interrelations may be influenced by age and sex. Interrelations between individual temporal orientation and time succession were explored in a task predominantly requiring crystallized intelligence (Study 2) and in a semantic analogy task requiring crystallized and fluid intelligence (Study 3a). Study 3b investigated interrelations between individual temporal orientation and higher-level fluid intelligence measures by applying a geometric analogy task. Interrelations between time perspective and chronotype as well as between chronotype and temporal depth are reported. Further, both future time perspective and temporal depth are interrelated with time succession. A testable global working memory model of time perception integrating all three aspects of psychological time is proposed. Further, interrelations between individual temporal orientation and cognitive capacities are reported. Future time perspective was related to fluid intelligence, chronotype to verbal intelligence. Behavioral as well as pupillary data suggest that individual temporal orientation is related to analogical reasoning, executive functions and goal management. Whereas future time perspective and morningness appear interrelated with conflict detection, temporal depth appears interrelated with inhibitory control.

Key words: time perspective, morningness, eveningness, temporal depth, analogical reasoning, fluid intelligence, executive functions, pupil dilation

Zusammenfassung

Zeit ist ein fundamentaler Aspekt menschlichen Verhaltens. Während Untersuchungen bislang meist nur auf einem der drei Hauptaspekte der Zeit: Dauer, Zeitfolge und individuelle zeitliche Orientierung fokussierten, untersucht diese Dissertation Zusammenhänge zwischen der individuellen zeitlichen Orientierung und der Zeitfolge. Zeit ist nicht direkt wahrnehmbar, sondern an kognitive Abstraktionsprozesse gebunden. Diese benötigen kognitive Ressourcen und werden kognitiven Fähigkeiten beeinflusst. Daher wurden Zusammenhänge zwischen individueller zeitlicher Orientierung und allgemeinen kognitiven Fähigkeiten ebenfalls untersucht. Studie 1 analysiert, wie verschiedene Aspekte individueller zeitlicher Orientierung korreliert sind, und diese Korrelationen von Alter und Geschlecht beeinflusst sind. Studien 2 und 3a analysieren Zusammenhänge zwischen individueller zeitlicher Orientierung und der Zeitfolge. Studie 3b untersucht mittels einer geometrischen Analogieanforderung Korrelationen zwischen individueller zeitlicher Orientierung und höheren fluiden Intelligenzleistungen. Befunde zu Zeitperspektive-Chronotyp- Relationen sowie Zeithorizont-Chronotyp-Relationen werden berichtet, ebenso Zusammenhänge zwischen Zeitperspektive, Zeithorizont und der Zeitfolge. Ausgehend von diesen und früheren Befunden wird ein kognitives Modell vorgestellt, welches alle drei Aspekte psychologischer Zeit (Zeitdauer; Zeitfolge; individuelle zeitliche Orientierung) integriert. Ferner werden als Ergebnis der Studien Zusammenhänge zwischen der Zukunftsperspektive und fluider Intelligenz sowie Chronotyp und verbaler Intelligenz berichtet. Verhaltensdaten und psychophysiologische Daten (Pupillendilation) zeigen ferner Zusammenhänge zwischen individueller zeitlicher Orientierung, analogem Denken, exekutiven Funktionen und Konfliktverarbeitung. So scheinen Zukunftsperspektive und Morgentyp eng mit Konfliktverarbeitung verbunden, der Zeithorizont hingegen eng mit inhibierenden Kontrollprozessen.

Schlagwörter: Zeitperspektive, Chronotyp, Zeithorizont, Analoges Schließen, fluide Intelligenz, exekutive Funktionen, Pupillendilation

1 Introduction

"… Since there exists in this four dimensional structure [space-time] no longer any sections which represent "now" objectively, the concepts of happening and becoming are indeed not completely suspended, but yet complicated. It appears therefore more natural to think of physical reality as a four dimensional existence, instead of, as hitherto, the evolution of a three dimensional existence..."

Albert Einstein (1961)

Time impacts upon our daily routines, our general outlook on life as well as on how we define ourselves. Albert Einstein's belief that „the separation between past, present, and future is only a stubbornly persistent illusion" (Goldsmith & Bartusiak, 2006, p.187) demonstrates the difficulty of studying psychological time. Even though Einstein proved that time is relative, and not absolute as claimed by Newton, our psychological reality of time is different. Time is a phenomenon that cannot be directly perceived. Instead, it is always connected to events in the past, the here and now, or the anticipated future that we experience, cause or influence (Block & Zakay, 2001; Gibson, 1975).

This dissertation is based on four peer-reviewed publications concerning the relationship between different levels of temporal orientation that constitute one important aspect of psychological time as well as interrelations with different cognitive capacities that can be defined as aspects of fluid or crystallized intelligence measures. These four articles will be referred to as *Study 1* (Nowack & van der Meer, 2013), *Study 2* (Nowack & van der Meer, 2014), *Study 3a* (Nowack & van der Meer, 2015a submitted) and *Study 3b* (Nowack & van der Meer, 2015b submitted). This synopsis will begin by presenting a brief introduction to the concepts of psychological time and individual temporal orientation, which will be explored on the three levels of a) time perspective, b) chronotype, and c) temporal depth. Then, the concepts of fluid intelligence and crystallized intelligence as well as associated cognitive capacities will be shortly presented. A short introduction of the psychophysiological measure of pupil dilation will be followed by an outline of the research questions and hypotheses. After presenting and integrating the main results from this dissertation project, some future directions will be outlined.

1.1 Psychological time

Psychological time virtually influences all areas of human life. Three major aspects of psychological time have been at the focus of scientific research: time duration, time succession, and individual temporal orientation (Block, 1990).

Time duration relates to the way people experience the persistence of events, or an interval between events such as experiences of time standing still or of passing very slowly versus experiences of time seeming to fly. Factors impacting upon duration estimation include cognitive load and, whether duration estimation has to be made with (i.e., prospective time estimation involving attentional processes) or without (i.e., retrospective time estimation involving memory processes) prior notice. Whereas high cognitive load increases duration estimation in retrospective judgments, high cognitive load in prospective judgments appears to lead to shorter duration estimation (e.g., Block et al., 2010). Duration estimation should, thus, be influenced by cognitive capacities such as mental speed and working memory capacity (e.g., Fink & Neubauer, 2005). In line with this, the evidence suggests that fluid intelligence impacts upon duration estimation with higher fluid intelligence scores being linked to more accurate subjective time estimation compared to lower fluid intelligence scores (Fink & Neubauer, 2001, 2005). There are various models of time duration such as those favoring one common timing mechanism (e.g., internal pacemaker models, e.g., Church, 1984) or models that propose a timing ability based on neural activation and memory decay (e.g., fading-Gaussian (neural) activation-based model of interval timing: French, Addyman, Mareschal, & Thomas, 2014; Temporal context model: Shankar & Howard, 2010).

Time succession refers to the perceived sequential occurrence of events that can be categorized into an *Earlier* (Past), a *Now* (Present) or an anticipated *Later* (Future) (Block, 1990; Friedman, 1990). How time succession is mentally coded appears to depend on the typicality of event sequences (e.g., Krüger, 2000). In highly typical event sequences, time succession appears coded by higher association strengths between sub-events (e.g., order code model; Friedman, 1993; Hintzman, Summers, & Block, 1975). Recalling time succession for highly typical event sequences further entails fast and automatic retrieval processes (e.g., Friedman, 1993). In less typical event sequences, time succession appears coded in contextual information about the environment (e.g., snow versus sunshine) or internal states (e.g. feeling cold) along with a specific sub-event (reconstructive theory; Friedman, 1993). Recalling time succession in less typical event sequences entails more controlled reconstruction processes that combine aspects of memory with internalized knowledge about personal, social and natural time patterns (Friedman, 1993).

The third major aspect, and at the focus of this dissertation, is individuals' temporal orientation. Whilst psychological studies generally focus on the concept of time perspective referring to a person's experiences and conceptions of past, present and future time, biological approaches tend to focus on annual and diurnal patterns such as the chronotype to investigate the impact of time on human and animal behaviour (e.g., Gonzales & Zimbardo, 1985; Keough, Zimbardo & Boyd, 1999; Nowack, Milfont & van der Meer, 2013; Roenneberg and Aschofs, 1990; Roenneberg et al., 2003). A third measurement of temporal perspective with a background in organizational psychology is that of temporal depth referring to the temporal distances individuals typically consider when they remember past events or anticipate future events (e.g., Bluedorn, 2002). These three levels of individual temporal orientation, time perspective, chronotype and temporal depth, will be described in more detail in the next section.

1.1.1 Time Perspective

The construct of time perspective denotes individuals' preference to rely on a particular temporal frame (i.e., past, present or future) for decision-making processes and behaviour. Individuals differ in the extent to which they overemphasize one particular time perspective (Zimbardo et al., 1997). For instance, present-oriented people tend to base their decisions and actions on the immediate rewards a present situation offers. Future-oriented people focus on expected consequences that a present behavior may have for the future. Past-oriented people mainly base their present actions on previous outcomes and events they recollect from their past.

On a cognitive level, time perspective is thought to emerge from cognitive segmentation processes that organize the continual flow of human experience into a past, a present and a future (e.g., Zimbardo & Boyd, 1999). On a biological level, future time perspective is thought to develop in stable and predictable environments, whereas environments characterized by resource instability and unpredictability of the future will support the development of more present-oriented behaviors (*Life History Theory*; e.g., MacArthur and Wilson 1967). Even though socio-economic and cultural conditions as well as personal life events impacting on the perceived stability of first five to seven years of life (e.g., absence of one parent) influence the extent to which humans exhibit present-oriented or future-oriented behaviors, these social strategies are thought to emerge from a common hereditary life history factor called the K-factor (e.g., Figueredo et al., 2006; Belsky, Steinberg, & Draper, 1991). A low K-factor appears linked to a present-oriented focus on short-term gains at the expense of long-term costs such as high mating effort coupled with low parental effort. A high K-factor appears linked to a future-oriented focus on long-term benefits such as selective mating with high parental effort (e.g., Figueredo et al., 2006; Heath & Hadley, 1998). On neuropsychological level, this K-factor is thought to relate to frontal brain regions such as the frontal cortex that is associated with planning behaviour, delay of gratification and impulse control as well as with executive functions and, hence, fluid intelligence (e.g., Miyake et al., 2000; Figueredo et al., 2006; Schacter & Addis, 2009). Nevertheless, to the author's knowledge, there has only been one investigation into possible influences of time perspective on cognitive performance before this dissertation (Nowack, Milfont, & van der Meer, 2013).

Individuals' time perspective was measured in this dissertation project by administering the Zimbardo Time Perspective Inventory (ZTPI; Milfont & Bieniok, 2008; Zimbardo & Boyd, 1999). The ZTPI is a self-report scale characterized by high retest-reliability and a well-established validity in various languages (Brandler & Rammsayer, 2002; Milfont, Andrade, Belo, & Pessoa, 2008; Milfont & Bieniok, 2008; Zimbardo & Boyd, 1999). The ZTPI consists of 54 items measuring time-related attitudes and behaviors on a 5-point Likert scale ranging from 1 (*very uncharacteristic of me*) to 5 (*very characteristic of me*) to distinguish between five time perspective dimensions: *Past Negative, Past Positive, Present Fatalistic, Present Hedonistic* and *Future*. However, in many past and present ZTPI-items the time dimension is highly confounded with valence (e.g., *I've taken my share of abuse and rejection in the past.*). The same rational as in Nowack et al. (2013) was followed in an attempt to overcome this by excluding highly emotional items. This led to 13 items for each, the past and the present dimension in addition to the 13 original future ZTPI items. In addition, points of mid-sleep on free days were calculated as a more objective measure of chronotype following the same procedure as in Roenneberg et al. (2003).

1.1.2 Chronotype

Every single cell of the body underlies a circadian rhythm (i.e., circa 24 hours long; Abraham et al., 2010). For instance, concentration and release of hormones such as cortisol or melantonin display circadian changes in activity (e.g., Keller et al., 2009). Therefore, circadian rhythms are important for many physiological functions vital to sustain and promote performance and health. The nucleus suprachiasmaticus (SCN) of the hypothalamus is the main circadian pacemaker. Via the optic nerve, the SCN is connected to the cycle of light and darkness, which is the most important external zeitgeber (Roenneberg et al., 2007).

However, there are individual differences in circadian rhythms based on circadian preferences. These individual differences in circadian preference are referred to as chronotype, which differentiates between morning types and evening types. People with a great tendency towards morningness are characterized by early rise and bed times whilst people with a great tendency towards eveningness prefer late rise and bed times (Roenneberg et al., 2003; Adan et al., 2012). The chronotype exerts an influence on physiological as well as cognitive functions underlying a circadian rhythm. For instance, cortisol levels typically peak in the waking hours gradually decreasing thereafter (e.g., Bailey & Heitkemper, 2001). In morning types, cortisol levels do not only peak earlier but are also characterized by higher amplitudes than in evening types (Kudielka et al., 2007). Regarding cognitive functions, performance such as in working memory generally peaks about midday (Folkard, 1975). However, morning types typically reach their peak performance levels in the morning hours, evening types reach their peak performance levels in the afternoon or early evening hours (e.g., Hasher, Goldstein, & May, 2005).

Being partly genetic in origin, differences in circadian preferences as well as influenced by biologic processes such as serotonergic functioning (e.g., Duffy & Czeisler, 2002; Ebisawa et al., 2001, Hur, 2007; Vink et al., 2001). For instance, higher levels of serotonergic function have been linked to a greater tendency towards morningness (DeYoung et al., 2007). Individual differences in chronotype are further influenced by sex as well as underlie changes with age. Young children display a greater tendency towards morningness, until circadian preference shifts towards eveningness in adolescence (Roenneberg et al., 2004; Werner, LeBourgeois, Geiger, & Jenni, 2009). In later adulthood, circadian preference shifts towards morningness again (Roenneberg et al., 2004; Díaz-Morales & Randler, 2008). Evidence for an impact of sex is mixed (Borisenkov et al., 2010; Figueiredo De Martino et al., 2010). However, females generally show a stronger tendency towards morningness, males a stronger tendency towards eveningness (Adan & Natale, 2002; Randler, 2007; Tonetti, Fabbri, & Natale, 2008; Adan et al., 2012).

Generally, morningness appears associated with better school leaving exams, which might be due to early school start times that more beneficial to morning types (Randler & Frech, 2006; Preckel et al., 2011). Sparse evidence further suggests that evening types demonstrate a superior working memory capacity, processing speed and, albeit in females only, verbal intelligence compared to morning types (e.g., Roberts & Kyllonen, 1999; Killgore & Killgore, 2007). However, Roberts and Kyllonen (1999) investigated working memory and processing speed by applying the Armed Services Vocational Aptitude Battery, which is not a standardized and psychometrically validated measure of cognitive ability (e.g., Killgore & Killgore, 2007). Furthermore, there has not been any study that combined behavioural data with physiological data to investigate more thoroughly interrelations between chronotype and cognitive performance.

Likewise, first evidence involving a small sample of polish students (Stolarski et al., 2012) suggests that future time perspective may be associated with greater morningness and present time perspective with greater eveningness. However, the robustness of this finding and the extent to which these interrelations may be influenced by age and sex have not been explored yet.

To this end, this dissertation project administered two questionnaires to measure participants' chronotype, namely the the Morningness–Eveningness Questionnaire (MEQ; Griefahn et al., 2001; Horne & Östberg, 1976) and the Munich Chronotype Questionnaire (MCTQ; Roenneberg et al., 2003). The MEQ is a widely used self-report measure of chronotype that is well validated against a range of physiological responses (Ishihara, Saitoh, Inoue, & Miyata, 1984). The MEQ contains 19 Items that measure circadian preference either as multiple choice questions or on a 4-

point Likert scale. Items are summed to yield scores ranging from 16 (extreme eveningness) to 86 (extreme morningness).

The MCTQ which is another widely used self-report measure of the chronotype and was used to calculate of the point of mid-sleep on free days, which appears to be a more objective measure of diurnal preference than other self-report measures (Roenneberg et al., 2004). The MCTQ is well validated against the MEQ (Horne & Östberg, 1976) as well as against a range of physiological responses and measures of the activity and rest cycle (Roenneberg et al., 2007). The MCTQ asks participants to simply state separately for work and free days, when they go to bed, how long they need to fall asleep, and when they tend to wake up (Roenneberg et al., 2003).

1.1.3 Temporal depth

Temporal depth or time horizon is conceptually distinct from and unrelated to time perspective (Bluedorn, 2002). Whilst time perspective refers to the relative importance given to the past, present or future, temporal depth refers to the temporal distances that individuals typically mentally travel when remembering past or anticipating future events (e.g., Bluedorn, 2002). Whereas time perspective (e.g., Zimbardo & Boyd, 1985) appears unrelated to temporal depth, future and past temporal depth are correlated (Bluedorn, 2002). In general, the farther the distance one typically considers when thinking of past events, the farther is the distance into the future he or she contemplates when planning future events (Bluedorn, 2002). This is in line with the *constructive episodic simulation hypothesis* and various positron emission tomography (PET) and functional neuroimaging studies emphasizing that aspects of retrieved personal memories are utilized to construct mental representations of the personal future (e.g., Schacter & Addis, 2009; Schacter, Addis & Buckner, 2007). Remembering the past and anticipating the future not only lead to overlapping brain activation. Frontal lobe damage also disrupts both the ability to recall the personal past as well as the ability to plan ahead (Addis, Wong & Schacter, 2007; Okuda et al., 2003; Schacter & Addis, 2009; Schacter et al., 2007; Tulving, 2002; Worthington, 1999).

Similar to circadian rhythms being mainly influenced by light (Roenneberg et al., 2007), temporal depths at the social level (i.e., in organizations) appear influenced by social zeitgebers entraining organizational rhythms such as the time span between managerial decisions and feedback about their consequences (e.g., Lawrence & Lorsch, 1967). Longer time spans of feedback appear related to a wider future temporal depth (e.g., Lawrence & Borsch, 1967). Similarly, individuals' temporal depth may also be influenced by the most powerful zeitgeber of light (e.g., Roenneberg et al., 2007) and, thus, by circadian rhythms. However, interrelations between temporal depth and chronotype have not been investigated yet.

In this dissertation project, participants' temporal depth was assessed by the Temporal Depth Index (TDI; Bluedon, 2002). The TDI measures participants' temporal distances into both the past and future directions. It consists of six items in a Likert style format asking participants to state the temporal distance they typically think of when contemplating events in the short-term, mid-term, and long-term future as well as when remembering events in the recent, middling or long- ago past. There are 15 response options that vary between one day and 25 years as well as more than 25 years (Bluedorn, 2002). Temporal depths for the past and the future can further be used to calculate a general temporal depth (Bluedorn, 2002).

1.1.4 Integrating aspects of psychological time and cognitive capacity

According to Block (1990), time duration, succession and individual orientation should be interrelated. For instance, recall of time succession for highly typical event sequences from long-term memory should also always entail the recall of time duration (e.g., Molet & Miller, 2013). One simply knows that taking a seat in a restaurant is not only taking place *before* studying the menu, but also that taking the seat requires *less* time than studying the menu.

However, this dissertation project not only aims at investigating interrelations between different aspects of psychological time. In line with K-factor theories (e.g., Figueredo et al., 2006), time is a fundamental aspect of human experience and behavior. Successful adaption to the cyclic patterns of time (e.g., daily rhythms of day and night; yearly rhythms of the seasons) is critical to ensure survival. Furthermore, time is inferred from perceived changes in the environment because it cannot be directly perceived (e.g., Gibson, 1975). Thus, psychological time is bound to cognitive abstraction processes that require cognitive resources and, presumably, depend on basal cognitive abilities. In line with this, the evidence suggests interrelations between psychological time (time duration; time succession), cognitive load and ability (e.g., Fink & Neubauer, 2001, 2005; Nuthmann & van der Meer, 2005; Krüger, 2000). Therefore, interrelations between individual temporal orientation and basal cognitive capacities were also to be explored in this dissertation project.

Regarding cognitive ability, the concept of human intelligence involves a variety of mental abilities necessary to learn, understand as well as to deal effectively with the environment (e.g., Wechsler, 1944). One model of the structure of human intelligence that has been dominating in the psychometric tradition is the theory of fluid and crystallized intelligence (Cattell, 1963; Horn & Cattell, 1966). In the following sections, the concepts of crystallized and fluid intelligence as well as associated cognitive capacities will be introduced.

1.2 Crystallized intelligence and script knowledge

Crystallized intelligence is the ability to use acquired skills and entails learned knowledge such as vocabulary (e.g., Cattell, 1963; Friedman et al., 2006). Given that crystallized intelligence is acquired throughout the entire lifespan, it remains stable, or even demonstrates a little increase with age (e.g., Harwood & Naylor, 1971; Ackerman, 2000).

Script knowledge is another aspect of crystallized intelligence. It refers to the mental representations of everyday events containing typical agents, instruments, activities, location as well as temporal information encoded and stored in semantic memory as people experience these events like *getting ready for work* (Barsalou, 1999; Freyd, 1987, 1992; McRae et al., 2001). Since sub-events naturally unfold in a chronological ("go forward") direction, they are also stored in that typical temporal order, and script knowledge refers to chronologically represented event sequences in memory (Schank and Abelson, 1977). In line with this, the extant literature shows that this mentally coded natural "forward" temporal progression of real-life events, also referred to as cognitive arrow of time, is entailed in visually presented gravity stimuli, in routine event sequences, event pairs as well as single events (e.g., Friedman, 2002; Krüger, 2000; Nuthmann & van der Meer, 2005; Raisig, Welke, Hagendorf, & van der Meer, 2007; van der Meer, Beyer, Heinze, & Badel, 2002). Here, processing sub-events that are presented in reverse order, thus, violating the cognitive arrow of time, leads to an increase in reaction time, error rates and cognitive load (e.g., Nuthmann & van der Meer, 2005; Krüger, 2000). Acquisition and recall of learned, crystallized information, however, is also dependent from fluid intelligence.

1.3 Fluid intelligence, analogical reasoning and executive functions

Fluid intelligence has been defined as the ability to reason logically, to solve novel problems and to draw inferences independently from prior knowledge using adaptive problem-solving strategies (e.g., Cattell, 1963; Horn & Cattell, 1966). It entails executive functions such as updating, shifting and inhibition, which are processes necessary to "control and regulate thought and action" (e.g., Friedman et al., 2006, S. 172; Miyake et al., 2000). Contrary to crystallized intelligence, fluid intelligence increases throughout young adulthood. After the age of about 25, there is a decline in fluid intelligence (e.g., Kaufman, Johnson, & Liu, 2008).

One higher-order cognitive process that is closely related to fluid intelligence is analogical reasoning which is the transfer of relational information from one domain with known relations onto another domain with unknown relations (e.g., Chuderska & Chuderski, 2009; Miyake et al., 2001; Richland & Burchinal, 2013; van der Meer et al., 2010). Analogical reasoning is a core component of human reasoning by discovery of new insights and by understanding new concepts by means of familiar ones (e.g.; Gentner, 1983; Hofstadter, 2001; French, 2002). In line with this, individuals with high fluid intelligence have a good command of analogical reasoning (Hofstadter, 2001; Geake & Hansen, 2005; Holyoak & Morrison, 2005).

The ability to recognize an analogy is highly dependent on executive functions (Miyake et al., 2001). Specifically, analogical reasoning requires the selective activation of relevant features whilst inhibiting irrelevant features, maintenance and manipulation of mental representations (i.e., updating mental representations held in working memory) to identify and map correspondences between two different pairs of elements (e.g., Sternberg, 1977; see also Klix & van der Meer, 1980). Whereas the literature typically refers to executive functions being prototypical for fluid intelligence, Friedman, Miyake, Corley, Young, & Hewitt (2006) demonstrated that not all executive functions are related to fluid intelligence as measured by psychometric tests. Specifically, only updating was related to fluid intelligence scores, shifting between mental sets and the inhibition of irrelevant features do not (e.g., Friedman et al., 2006). Therefore, investigations into analogical reasoning should also entail measurements of fluid intelligence to analyze for interrelations with cognitive performance over and above fluid intelligence (i.e., controlling for fluid intelligence scores).

In addition to updating, shifting and inhibition, executive functions also entail a fourth function according to some taxonomies, namely goal management involving goal maintenance and conflict management (e.g., McCabe et al., 2010). One brain area that is frequently associated with conflict detection and management is the anterior cingular cortex (ACC). For instance, the ACC is typically strongly activated during interference tasks that require the inhibition of pre-potent responses and under conditions that are characterized by high conflict (e.g., MacDonald et al., 2000; Botvinick, 2007). Conflict not only increases the demand for cognitive resources (Rushworth et al., 2004). ACC responses to conflict have also been linked to adjustments in arousal and, consequently, pupil dilation (e.g., Cohen et al., 2000; Ebitz & Platt, 2015).

1.4 Pupil dilation

In addition to behavioural parameters indicating speed and accuracy of task performance, studies 2, 3a and 3b also measured the pupillary response as reliable indicator of the cognitive resources that are allocated to a task (Granholm, Asarnow, Sarkin, & Dykes, 1996; Beatty & Lucero-Wagoner, 2000; Just, Carpenter & Miyake, 2003; Verney, Granholm, & Marshall, 2004; Nowack et al., 2013; Nowack & van der Meer, 2014).

There are two modes of pupil dilation that can serve to identify individual differences in cognitive resource allocation. The pre-experimental *tonic* pupil baseline diameter appears linked to alertness and wakefulness as well as activation and task-independent exploration of the environment for new sources of reward (e.g., Aston-Jones & Cohen, 2005; Gilzenrat et al., 2010, van der Meer et al., 2010; Lee, Ojha, Kang and Lee 2015). Task-evoked *phasic* peak dilation is linked to exploitation of available sources of reward and high task-engagement (Ahern & Beatty, 1979; Gilzenrat, Cohen, Rajkowski, & Aston-Jones, 2003; van der Meer et al., 2010). Generally, the more difficult a task, the more the pupil dilates. Whilst more difficult tasks generally lead to an increase in pupil dilation for all individuals, task-evoked pupillary responses associated with task-engagement may further serve to identify individual differences in cognitive resource allocation (Ahern & Beatty, 1979; Gilzenrat, Cohen, Rajkowski, & Aston-Jones, 2003; van der Meer et al., 2010).

In particular, *phasic* and *tonic* pupil dilation appear related to *fluid intelligence*. Especially for new and demanding tasks, superior fluid intelligent individuals seem to generally allocate more cognitive resources independently of the task difficulty compared to average fluid intelligent individuals, at least in complex linguistic and visuo-spatial tasks (i.e., *effort hypothesis*; cf. Ahern & Beatty, 1979; van der Meer et al., 2010; Dix et al., 2012; Lee, Ojha, Kang, & Lee, 2015). Further, participants with superior fluid intelligence show a greater pre-experimental *tonic* pupil baseline diameter than participants with average fluid intelligence (van der Meer et al., 2010). This suggests that participants with high fluid intelligence invested more cognitive resources to successfully master difficult and demanding tasks as well as a greater tendency for task-independent exploration (van der Meer et al., 2010).

1.5 Goals of the dissertation and hypotheses

The extant literature has generally focused on both the different levels of individuals' temporal orientation (i.e., time perspective; chronotype; temporal depth) as well as on the different major aspects of psychological time (i.e., time duration; time succession; temporal orientation) in isolation (e.g., Bluedorn, 2002; Loftus, Schooler, Boone, & Kline, 1987; van der Meer, 2007; Zimbardo & Boyd, 1999). Relationships between these aspects have received surprisingly little attention. Even though the literature cited above suggests that individuals' temporal orientation may be interrelated with specific cognitive capacities, to the authors' knowledge, such relationships have not been investigated yet.

Therefore, this dissertation project aimed at exploring more thoroughly how different levels of individuals' temporal orientation may be interrelated, and how these interrelations may be influenced by age and sex (Study 1). Further, interrelations between individuals' temporal orientation and time succession as another aspect of psychological time in a task predominantly requiring crystallized intelligence (Study 2) as well as in a semantic analogy task requiring both crystallized and fluid intelligence (Study 3a) were explored. Finally, interrelations between individuals' temporal orientation and higher level fluid intelligence measures were explored by applying a geometric analogy task (Study 3b).

Based on the literature cited above, the following hypotheses were postulated.

(1) Interrelations between the three aspects of individual temporal orientation were expected. Future time perspective was expected to be linked to morningness and present time perspective to eveningness. These interrelations should be influenced by age and sex. Temporal depth was expected to be interrelated with chronotype.

(2) Regarding time succession, correlations with time perspective, chronotype and temporal depth were expected. Future time perspective and morningness were expected to be linked to better performance in matching chronological and future-oriented conditions. Violations of time succession were expected to impede performances associated with future time perspective and morningness more strongly compared to present time perspective and eveningness. A wider temporal depth was expected to relate to better cognitive performance compared to shorter temporal depth.

(3) Interrelations between individual temporal orientation (time perspective; chronotype; temporal depth) and crystallized as well as fluid intelligence measures were expected with future time perspective, eveningness and wider temporal depths being associated with a better cognitive performance compared to present time perspective, morningness and shorter temporal depths.

2 Experimental approaches: Summary of the three studies

In this chapter, a brief summary of the objectives, methods, and main findings of each study will be presented. A comprehensive discussion of the results of all studies will be provided in chapter 3.

2.1 Study 1: Are larks future-oriented and owls present-oriented? Age- and sex-related shifts in chronotype–time perspective associations

Nowack, K., van der Meer, E., 2013. Are larks future-oriented and owls present-oriented? Age-and gender-related shifts in chronotype-time perspective associations. *Chronobiol. Int. 30 (10)*, 1240–1250.

2.1.1 Background and aim of the study

Stolarski et al. (2012) suggest that morningness may be associated with future time perspective and eveningness with present time perspective. However, little was known about how chronotype–time perspective relationships may alter over the life span. Study 1 aimed at investigating these links between chronotype and time perspective more thoroughly by taking age and sex into account as well. Study 1 laid the groundwork for further investigations into the impact of both levels of temporal orientation on crystallized and fluid intelligence measures.

2.1.2 Methods

In this study, 706 German adults (209 men, 497 women; mean age: 25.1 years, *SD* = 6.74) between 17 and 74 years of age completed German adaptations of the MEQ (Griefahn et al., 2001; Horne and Östberg, 1976) and the ZTPI (Milfont & Bieniok, 2008; Zimbardo & Boyd, 1999).

To examine the impact of age on the chronotype-time perspective relationship, participants were grouped according to their age into three age groups (see also Roenneberg et al., 2003): adolescents (between 17 and 21 years of age), young adults (between 21 and 30 years of age) as well as adults (over 30 years of age).

To analyze how time perspective relates to morningness/eveningness (i.e., MEQ scores), a series of correlational analyses and multiple regression analyses was conducted. Please refer to the original manuscript for a more detailed description of the methods.

2.1.3 Main results and interpretation

Study 1 generated the following main findings. First, morning types were more future-oriented, and evening types more present-oriented when controlling for age and gender. Second, this was supported by times of mid-sleep on free days with higher future time perspective scores being linked to earlier times of mid-sleep and higher present time perspective scores being linked to later times of mid-sleep. When controlling for age and gender, findings of a morningness-future relationship and an eveningness-present relationship in the German sample, thus, replicated previous findings from Stolarski et al. (2012) . This suggests that this is a robust phenomenon in the younger population and that both measures of temporal orientation are indeed related. Regression analyses further suggested that circadian preference partly predicts time perspective.

Third, an impact of both age and gender on chronotype-time perspective relationships was demonstrated. In females above the age of thirty, the relationship between morningness and future time perspective ceased to exist. On the contrary, the relationship between eveningness and present time perspective was also found in both males and females above thirty. Whilst no relationship between chronotype and past time perspective was found in individuals under the age of thirty, higher eveningness scores were related to higher past time perspective scores (and higher morningness scores were related to lower past time perspective scores) in females above thirty.

Finally, future and present time perspective scores were negatively correlated with a higher future time perspective being related to lower present time perspective and vice versa. This suggests that present and future time perspective could be dichotomous ends on a same continuum similar to the operationalization of the morningness – eveningness continuum. The more an individual was present-oriented the less he or she scored on the future time perspective scale and vice versa.

To summarize this study, owls are more present-oriented and larks more future-oriented but only in the younger population under the age of thirty. Findings of study 1 further showed that age and gender impact upon chronotype-time perspective associations, and that both need to be taken into account when examining links between both temporal orientation measures.

2.2 Study 2: Impact of chronotype and time perspective on the processing of scripts

Nowack, K., van der Meer, E., 2014. Impact of chronotype and time perspective on the processing of scripts. *International Journal of Psychophysiology, 92*, 49–58.

2.2.1 Background and aim of the study

There was very limited knowledge about how different aspects of psychological time may be interrelated as well as related to differences in cognitive capacities. Adopting a psychophysiological approach, study 2 applied a temporal judgment task to investigate interrelations between temporal orientation (chronotype; time perspective) and time succession (i.e., sequential occurrence of events as reflected by their temporal order) that is not only another aspect of psychological time entailed within script knowledge but also an aspect strongly reliant on crystallized intelligence.

2.2.2 Methods

Thirty female German Psychology students (mean age: 25.1 years, *SD* = 7.57) of Humboldt University Berlin participated in this experiment[1]. Chronotype and time perspective were measured by German adaptations of the MEQ and ZTPI respectively (Griefahn et al., 2001; Horne and Östberg, 1976; Milfont & Bieniok, 2008; Zimbardo & Boyd, 1999). To control for any influence of valence, highly emotional items of the ZTPI were excluded resulting in one present and one future scale already successfully applied in previous studies (Nowack et al., 2013; Nowack & van der Meer, 2013).

In a temporal judgment task, participants had to decide which of the two presented sub-events (e.g., *get new batteries – set right time on alarm clock*) comes earlier (or later) within a given script (e.g., *changing batteries in an alarm clock*) whilst response times (indexing processing speed), accuracy rates (indexing quality of processing), pre-experimental *tonic* pupil baseline diameter and task-evoked peak dilation (reflecting cognitive resources allocated to a task) were measured. Please refer to the original manuscript for a more detailed description of the methods.

2.2.3 Main results and interpretation

Regarding individuals' temporal orientation, study 2 generated the following main results[2]. First, higher future time perspective scores were linked to higher error rates when identifying earlier sub-events and lower task-dependent pupil dilation when identifying later sub-events compared to lower future time perspective scores. Second, eveningness led to smaller error rates for reverse items as well as to greater pre-experimental pupil baseline diameters and greater peak dilations across all conditions in comparison to morningness. Third, morning types were more future-oriented

1Gender influences chronotype (men have a stronger tendency towards eveningness; Roenneberg et al., 2007) and time perspective (men are more present-oriented, women more future- oriented; Keough et al., 1999). Chronotype also appears to affect verbal intelligence only in females (Killgore & Killgore, 2007). To control for this impact of gender, only females participated in this investigation.

2There were also main effects for instruction (earlier vs later sub-events) and temporal orientation of items (chronological vs reverse). Here, both the processing of earlier sub-events and the processing of chronologically sub-events was easier than the processing of later sub-events or reversely presented sub-events regardless of individual temporal orientation. Please refer to the original manuscript for a more detailed discussion of these main effects.

and evening types more present-oriented, whilst future and present time perspective scores were negatively correlated.

Regarding interrelations between aspects of individual temporal orientation, negative correlations between future and present time perspective in study 1 were replicated, as was the finding that morning types are more future oriented, evening types more present oriented.

Regarding time perspective, future time perspective scores appeared to interact with the temporality of instruction (earlier, later). Specifically, study 2 suggests an impact of a match or mismatch between the strong focus on future consequences of events that is associated with future time perspective and the task of identifying later sub-events versus the task of identifying earlier sub-events (Joireman et al., 2006; Zimbardo & Boyd, 1999). In matching conditions, task difficulty of identifying later (i.e., future-oriented) sub-events decreased with increasing future time perspective scores. The more a participant was future-oriented, the less cognitive resources were required to identify later sub-events correctly. In the mismatch conditions, task difficulty of identifying earlier (i.e., past-oriented) sub-events appears to increase with increasing future time perspective scores. The more a participant was future-oriented, the less accurately earlier sub-events were identified.

Regarding the chronotype, performance patterns associated with eveningness in comparison to morningness displayed remarkable similarities to those found in individuals with superior fluid intelligence compared to individuals with average fluid intelligence (e.g., Dix et al., 2012). Evening types responded more accurately than morning types but only in the more difficult reverse conditions. As indexed by greater pre-experimental pupil baseline diameters, evening types appeared to display greater pre-task alertness compared to morning types. Indexed by greater peak dilation, evening types also generally invested more cognitive resources to the task than morning types. Thus, the psychophysiological evidence from study 2 could help to explain better performances of evening types compared to morning types in previous studies (e.g., Killgore &

Killgore, 2007; Preckel et al., 2011; Roberts & Kyllonen, 1999). They may simply invest more cognitive resources.

2.3 Study 3: Impact of Time perspective, Chronotype, and Temporal Depth on processing semantic and geometric analogies

Nowack, K., & van der Meer, E. (2016, submitted). Future Time perspective and analogical reasoning. Submitted for publication to *Wiley Cognitive Sciences*.

2.3.1 Background and aim of the study

Study 2 and previous evidence (Nowack et al., 2013) suggests that temporal orientation may not only be linked to the processing of time succession but also to more general cognitive abilities with consequences for higher-level cognitive functioning (Nowack & van der Meer, 2014). To investigate this, study 3 applied two analogy tasks that are highly dependent on executive functions auch as the process of inhibiting irrelevant features, which iscrucial for the successful detection of an analogy (e.g., Chuderska & Chuderski, 2009; Miyake et al., 2000; Richland & Burchinal, 2013). In an analogy, the relational structure binding the source pair is resembled in the relationship binding the target pair. The semantic analogy task presented in study 3a entailed crystallized intelligence measures (i.e., the recall of vocabulary and event knowledge). In order to differentiate between fluid and crystallized intelligence measures investigating for interrelations between temporal orientation and intelligence, a geometric analogy task that does not require any prior knowledge being, hence, prototypical for fluid intelligence was applied in study 3b (e.g., van der Meer et al., 2010). Furthermore, temporal depth as a third dimension of individual temporal orientation was investigated in addition to chronotype and time perspective.

2.3.2 Methods

Twenty four students (10 men, 14 women; mean age: 27.1 years, *SD* = 5.73) of Humboldt University Berlin participated in the main experiment. To control for chronotype and time of testing, half of the participants were tested in the morning, the other half participated in the afternoon. To control for verbal and fluid intelligence, participants had to complete the *Mehrfachwahl Wortschatztest* Version B (German multiple choice vocabulary test; MWT-B; Lehrl, 2005) and Raven Advanced Progressive Matrices (RAPM; Heller, Kratzmeier, & Lengfelder, 1998). Chronotype, time perspective and temporal depth were measured by German adaptations of the MCTQ, ZTPI and Temporal Depth Index (TDI) respectively (Roenneberg et al., 2003; Milfont & Bieniok, 2008; Zimbardo & Boyd, 1999; Bluedorn, 2002).

In the semantic analogy task, participants were presented with two word pairs, namely with a source pair and a target pair of events (e.g., *to cook : to eat = to saddle : to ride)* and asked whether there was an analogy between both event pairs or not. The temporal orientation of the relationship between both events within each pair varied corresponding either to the chronological order of real-life events or to the reverse order. Source pair and target pair had either the same type of relation (analogy items; i.e. either both pairs of events being presented in a chronological order or in a reverse order) or different types of relation (distractor items; i.e., one pair of events being presented in a chronological order, the other in a reverse order).

In the geometric analogy task, participants were presented with quadruplets of geometric chessboard-like patterns that consisted of a source pair and a target pair. The relationship between the two patterns within both the source and the target pair was varied. Three types of relations were possible: mirroring on the vertical, horizontal or diagonal axis corresponding to different degrees of difficulty (low [vertical] < medium [horizontal] < high [diagonal]; e.g., van der Meer, 1996; van der Meer et al., 2010). Source pair and target pair either had the same type of relation (analogy items;

i.e. both pairs of quadruplets being mirrored on the same axis) or different types of relation (distractor items).

In both analogy tasks, participants were asked to decide as fast and accurately as possible whether or not there was an analogy between source and target pair. Please refer to the original manuscript for a more detailed description of the methods.

2.3.3 Interrelations between time perspective, chronotype and temporal depth: main results and interpretation

Regarding interrelations between the three aspects of individual temporal orientation study 3 yielded the following main findings. First, future and present time perspective scores were negatively correlated. Second, morningness was correlated with future time perspective, eveningness with present time perspective. Third, morningness was correlated with a wider temporal depth, eveningness was correlated with a shorter temporal depth. Fourth, time perspective was not correlated with temporal depth.

Findings of morningness-future time perspective and eveningness-present time perspective associations are in line with results from study 1 and 2 as well as from previous research (e.g., Stolarski et al., 2012) suggesting that these interrelations are a robust phenomenon. The same appears to apply to the negative correlation between future time perspective and present time perspective scores.

The finding of no relationship between time perspective and temporal depth also replicate previous research (e.g.; Bluedorn, 2002). Thus, a strong future time perspective (i.e., a focus on anticipated future goals) is not necessarily linked to a tendency to anticipate events or goals in the far away future or a tendency to recall events in the long ago past.

Interrelations between chronotype and temporal depth, however, have not been investigated yet to the author's knowledge. Here, a new key finding is that morningness is related to wider temporal depths for the past, future, and in general, whilst eveningness is related to shorter temporal depths. Morning types, thus, appear not only to be more future-oriented (and evening types more present-oriented). Morning types also appear to have the tendency to recall past and anticipate future events that are further away compared to evening types.

2.3.4 Semantic analogy task: main results and interpretation

Regarding individuals' temporal orientation, the semantic analogy task (study 3a) yielded three main results.[3][4] First, high future time perspective scores relate to faster responses in both analogy conditions and to greater peak dilation in the more difficult reverse analogy condition compared to low future time perspective scores. Furthermore, the correlation between future time perspective and smaller error rates in the chronological analogy condition just missed significance. High present fatalistic time perspective scores relate to slower responses, greater error rates for chronological analogies and smaller peak dilation for reverse analogies compared to low present fatalistic time perspective scores. Behavioral results from study 3a, thus, show a general superior behavioral performance of future oriented individuals compared to present oriented participants independently from the temporal orientation of items (i.e., chronological; reverse). This is in line with previous studies investigating the influence of time perspective on the processing of time succession entailed in the mental representations of single events (Nowack et al., 2013), in which the sequential

3 No predictions were made with regards to unrelated distractor items (i.e., no semantic analogy condition). Distractor items were analyzed for exploratory purposes only. Both future time perspective (*r*=-.49; *p*=.008) and general temporal depth (*r*=-.34; *p*=.05) correlate with response times with a greater future time perspective and wider temporal depth being linked to faster responses. Chronotype correlates with error rates (*r*=.41; *p*=.024) with morningness being associated with greater accuracy in correctly rejecting distractor items as analogies. Performances in the distractor condition were, thus, in line with performances in the analogy condition (i.e., no general strategy of simply accepting an item as analogy in favor of a fast response.)

4 There was also a main effect for the temporal orientation of analogy items (chronological vs reverse) with chronological analogies being easier to process than reversely presented analogies regardless of individual temporal orientation. Please refer to the original manuscript for a more detailed discussion of this main effect.

occurrence of events (i.e., time succession entailed in the temporal orientation of items) was not an explicit component of the task. Indexed by peak dilation, participants with increasing future time perspective scores gradually invest more cognitive resources in the reverse analogy condition, which is characterized by a mismatch between a strong focus on future outcomes in future-oriented individuals and past-oriented items. On the contrary, participants with increasing present fatalistic time perspective scores gradually invest less cognitive resources. Thus, the semantic analogy task may suggest an impact of time perspective on time succession, at least, when participants' attention is explicitly directed towards the temporal orientation of items.

Second, superior performance in this semantic analogy task was not only linked to future time perspective but also to morningness. Contrary to the hypothesis, morningness was linked to greater verbal intelligence as indexed by MWT scores. Controlled for MWT scores, morningness was also associated with faster responses, lower error rates for chronological analogies and greater peak dilation in both analogy conditions compared to eveningness. Thus, morning types outperformed evening types whilst investing more cognitive resources in all conditions (i.e., chronological, reverse) contradicting prior evidence of a superior performance coupled with a greater investment of cognitive resources by evening types compared to morning types from study 2 (Nowack & van der Meer, 2014; Killgore & Killgore, 2007). Thus, there is no one chronotype generally superior to the other. Whereas the temporal judgment task in study 2 entailed the recall of highly typical scripts from well learned event knowledge and fast automatic retrieval processes from long-term memory (e.g., Nowack & van der Meer, 2014; Hintzman et al., 1975), detecting an analogy requires additional controlled processes strongly requiring executive functions such as shifting, updating, inhibition and conflict management (e.g., McCabe et al., 2010; Miyake et al., 2000).

Third, greater future as well as greater general temporal depths relate to faster responses in the more difficult reverse analogy condition and greater peak dilations in both analogy conditions compared to shorter temporal depths. Presumably, remembering and anticipating events with a long temporal distance require more cognitive resources compared to events in a short temporal distance. Therefore, a wider temporal depth could be associated with a general tendency to invest more cognitive resources. Even though cognitive work requires time, participants with wider temporal depths were either as fast as participants with shorter temporal depths (i.e., in the chronological condition) or even faster to detect an analogy (i.e., in the reverse condition) compared to a shorter temporal depth. These findings cannot be explained by differences in verbal or fluid intelligence, since both the MWT (Lehrl, 2005) and the RAPM (Heller et al., 1998) did not yield any significant differences between participants with shorter and wider general temporal depths. Instead, the extent to which individuals can direct their attention onto relevant information to perform well might be an important factor (see also Barrouillet et al., 2008).

Finally, a greater past temporal depth is also associated with shorter response times in both the chronological (i.e., future-oriented) and reverse (i.e., past-oriented) analogy condition compared to a shorter past temporal depth. This is in line with the vast literature showing that remembering the past enhances the ability to anticipate the future, (e.g., Addis, Wong, & Schacter, 2007; Okuda et al., 2003; Schacter & Addis, 2009; Tulving, 2002; Worthington, 1999).

2.3.5 Geometric analogy task: main results and interpretation

Regarding individuals' temporal orientation, the geometric analogy task (study 3b) yielded the following main results[5]. First, high future time perspective scores relate to higher RAPM scores

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5Again, no predictions were made with regards to unrelated distractor items (i.e., no analogy condition). Distractor items were analyzed for exploratory purposes only. Future time perspective (*r*=-.33; *p*=.05), chronotype (*r*=.41; *p*=.025) and general temporal depth (*r*=-.51; *p*=.007) correlate with response times with a greater future time perspective, morningness and wider temporal depth being linked to faster responses in correctly rejecting distractor items as analogies. Future time perspective also correlates with error rates (*r*=-.35; *p*=.05) with a greater future time perspective being associated with greater accuracy. Performances in the distractor condition were in line with performances in the analogy condition (i.e., no general strategy of simply accepting an item as analogy in favor of a fast response.)

indicating greater fluid intelligence, low future time perspective scores relate to lower RAPM scores. This suggests an interrelationship between future time perspective and fluid intelligence.

Second, controlling for RAPM scores, there was no interrelation between future time perspective and response times but between future time perspective and error rates as in study 2 (e.g., Nowack & van der Meer, 2014). Furthermore, in a previous investigation applying the same geometric analogy task (e.g., van der Meer et al., 2010), effect sizes for differences in response times between participants with high fluid intelligence and participants with average fluid intelligence were much smaller after the training phase than effect sizes for error rates. This suggests that accuracy may be more sensitive to individual differences in cognitive performance than processing speed. High future time perspective scores relate to lower error rates in the most difficult analogy condition, low future time perspective scores relate to higher error rates in the most difficult analogy condition. Thus, there appears to be an interrelation between analogical reasoning and future time perspective over and above fluid intelligence.

Third, morningness relates to shorter responses and lower error rates in the most difficult diagonal analogy condition compared to eveningness. On the behavioral level, this suggests that morningness may be linked to greater behavioral performance in tasks that are more reliant on executive functions. On the psychophysiological level, there were no correlations between chronotype and pupil dilation. Morning types, thus, did not need to invest more cognitive resources to outperform evening types in the most difficult diagonal analogy condition.

Fourth, a greater general temporal depth is associated with shorter response times and greater peak dilation in the two easier (i.e., vertical and horizontal) analogy conditions compared to a shorter general temporal depth. This suggests that participants with a wider temporal depth invest more cognitive resources whilst outperforming participants with a shorter temporal depth as long as the task is not too difficult. Participants with a wider temporal depth were also faster than participants with a shorter temporal depth in a low-level cognitive task that requires the fast detection of the special position of a critical target.[6] This task has only basic demands for information storage, retrieval and processing, which may point to a more elementary cognitive capacity modulating the relationship between cognitive resource allocation and fast performance (e.g., the extent to which individuals can direct their attention onto relevant information; Barrouillet et al., 2008). In the diagonal analogy condition, no interrelations with temporal depth were found, which may have been due to floor effects on performance in this most difficult analogy condition.

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6 Participants in this present study were also presented with a low-level choice reaction task. Here, temporal depth for the future as well as the general temporal depth were negatively correlated with response times (future depth: *r*=-.36, *p*=.04; general depth: *r*=-.30, *p*=.05). Time perspective and chronotype were not correlated with performance in this choice reaction task (all *p*'s > .05).

3 General discussion

3.1 Integration of the findings

The main goals of this dissertation were, first, to investigate interrelations between different aspects of psychological time, namely between different dimensions of individual temporal orientation (i.e., time perspective, chronotype, temporal depth) as well as between individual temporal orientation and time succession.

Second, interrelations between individual temporal orientation and cognitive abilities were to be explored. To this end, the cognitive capacities involved in task performance were systematically varied between the experiments. Study 2 applied a temporal judgment task, studies 3a and b applied analogical reasoning tasks. Both paradigms in study 2 and 3a involved verbal stimuli, script knowledge as well as manipulations of time succession. However, study 2 entailed the recall of highly typical scripts from well learned and internalized event knowledge that is strongly reliant on crystallized intelligence measures and fast automatic retrieval processes from long-term memory (e.g., Hintzman et al., 1975). Detecting a semantic analogy in study 3a, however, required additional controlled processes that are strongly reliant on the executive functions of shifting, updating, inhibition and conflict management (e.g., McCabe et al., 2010; Miyake et al., 2000). Finally, the geometric analogy task in study 3b was prototypical for fluid intelligence and executive functions since no learned vocabulary, no acquired world knowledge and no script knowledge was required. Therefore, the extent to which performance relies on executive functions and fluid intelligence increases from study 2 to study 3b, whilst the influence of acquired, crystallized intelligence decreases.

In the following sections, interrelations between investigated aspects of psychological time (section 3.1.1) as well as between individual temporal orientation and cognitive capacities in terms of crystallized intelligence measures (section 3.1.2), fluid intelligence measures (section 3.1.3), executive functions and conflict management (section 3.1.4) will be discussed.

3.1.1 Interrelations between investigated aspects of psychological time

The various aspects of psychological time, namely time duration, time succession and individual temporal orientation are thought to be interrelated (e.g., Block, 1990). To clarify the existence and exact nature of such relationships, this dissertation project investigated interrelations between three aspects of individual temporal orientation and time succession. Table 1 gives an overview over interrelations found in this dissertation project between time perspective, chronotype and temporal depth.

Table 1

Correlations (*r*) between Future and Present Time Perspective, Chronotype and Temporal Depth (Future, Past, General)

Study	Future x Present Time perspective	Time Perspective x Chronotype [a]	Time Perspective x Temporal Depth	Chronotype x Temporal Depth
1	r= -.41**	Future *r*= .34** Present *r*= -.22**	-	-
2	r= -.51*	Future *r*= .39* Present *r*= -.30*	-	-
3	r= -.49*	Future *r*= .38* Present *r*= -.33*	not correlated	Future TD *r*= .44* Past TD *r*= .42* General TD *r*= .51*

(*p*<.001**; *p*</=.05*)

[a] lower scores relate to eveningness, higher scores to morningness. (Thus, eveningness relates to present time perspective, morningness to future time perspective.)

Most correlations between different aspects of individual temporal orientation are not only of medium (*r*>.30) or large (*r*>.50) effect (Bortz & Dörner, 2002), they also appear to be fairly robust. In all three investigations of the dissertation project, a higher future time perspective was related to a lower present time perspective. This suggests that, similar to the morningness-eveningness continuum, future and present time perspective may also be dichotomous ends on one continuum. Likewise, findings that morningness is associated with future time perspective and eveningness with present time perspective appear very robust. This relationship has not only been found in the German samples analysed in this dissertation project but also in previous research analyzing a Polish sample (Stolarski et al., 2012). In line with Bluedorn (2002), no interrelations between time perspective and temporal depth were found. This suggests that the distance one tends to mentally travel into the past or future is not related to the relative importance given to the past, present and future (e.g., Bluedorn, 2002; El Sawy, 1983).

However, this dissertation project not only replicates previous findings. First, it shows that chronotype-time perspective interrelations may change with age as well as depend on sex (study 1). Second, it shows for the first time that there also appear to be a chronotype-temporal depth interrelation. According to the present findings, morningness is not only associated with future time perspective but also with a wider temporal depth for the past, the future and in general. Likewise, eveningness is interrelated with both a present time perspective and shorter temporal depths. In line with social zeitgebers entraining organizational rhythms and, hence, influencing temporal depths at the level of organizations, the most powerful zeitgeber of light entraining human circadian rhythms also appears to interact with individuals' temporal depth (e.g., Roenneberg et al., 2007; Lawrence & Lorsch, 1967).

This dissertation project also aimed at investigating interrelations between individual temporal orientation and time succession, which refers to the sequential occurrence of events that can be categorized into past, present and future. To this end, time succession was manipulated in two ways. In terms of localization of sub-events in time, participants were instructed to either identify an earlier (i.e., past-oriented) sub-event or a later (i.e., future-oriented) sub-event in the temporal judgment task (study 2). In terms of a cognitive arrow of time, items were presented either chronologically (i.e., in line with naturally experienced time succession) or reversely (i.e., violating naturally experienced time succession). Table 2 reports interrelations with individual temporal orientation (i.e., time perspective, chronotype and temporal depth) and time succession.

As displayed in table 2, there is evidence of a relationship between future time perspective and time succession in terms of locating sub-events in time, which was an explicit aspect of the task (study 2).

Table 2

Interrelations between Individual Temporal Orientation (Future Time Perspective, Chronotype, Temporal Depth) and Time Succession

Study / Task	**Future Time Perspective**	**Chronotype**	**Temporal Depth (TD)**
2 - temporal judgment (earlier vs later targets)	earlier targets: higher error rates later targets: lower resource allocation	no effects	-
2 - temporal judgment (chronological vs reverse)	no effects	generally: evening types higher cognitive resource allocation reverse: evening types lower error rates	-
3 - semantic analogies (chronological vs reverse)	generally: faster chronological: lower error rates (trend) reverse: higher resource allocation	generally: morning types faster + higher cognitive resource allocation chronological: morning types lower error rates	generally: wider future and general TD higher cognitive resource allocation chronological: wider past TD faster; reverse: wider TD faster

Here, the findings suggest an impact of a match or mismatch between a strong focus on the future and identifying the later, future-oriented sub-event (i.e., matching condition) versus identifying the earlier, past-oriented sub-event (i.e., mismatch condition). Interrelations between future time perspective and violations of time succession in terms of time's arrow (i.e., presenting items in reverse order compared to the natural chronological order) appear influenced by whether or not violations of time's arrow are an explicit aspect of the task. If not an explicit part of the task (study 2), no interrelations between time perspective and cognitive performance are found. When the violation of the cognitive arrow of time is an explicit aspect of the task (study 3a), there is a trend for future-oriented participants processing chronological analogies with greater accuracy than participants with low future time perspective scores. With increasing future time perspective scores, participants gradually invest more cognitive resources in the reverse analogy condition. This may point to ACC involvement due to a mismatch or conflict between a strong focus on the future in future-oriented participants and the focus on the past in reverse analogies making the task more demanding and increasing the need for cognitive resources (e.g., MacDonald et al., 2000; Rushworth et al., 2004; Botvinick, 2007).

Regarding chronotype, there is no evidence of a systematic interrelation with time succession in terms of both localization in time (i.e., no effects) and the cognitive arrow of time. Whereas eveningness is associated with lower error rates for reverse items in the temporal judgment task in study 2, morningness is linked to faster responses in both the chronological but also the reverse semantic analogy condition in study 3a. Similarly, evening types generally invested more cognitive resources in the temporal judgment task, whilst morning types generally invested more cognitive resources in the semantic (as well as geometric) analogy task. The current findings, thus, suggest that there is no specific chronotype more adapt to process time succession. Instead, there appear to be other cognitive processes involved influencing cognitive performances in the three tasks analyses in this dissertation project. These will be discussed in the following sections.

Regarding temporal depth, interrelations with time succession were only investigated in the semantic analogy task (study 3a). Interpretations, thus, can only be made in terms of explicit violations of time's arrow. As displayed in table 2, a shorter temporal depth is associated with slower responses in the reverse analogy condition, a wider temporal depth with faster responses. This suggests an interrelation between temporal depth and time succession. When processing a typical script, the complete sequence with all its sub-events from beginning to end and, most importantly, with explicit earlier–later relations between them appears automatically retrieved from long-term memory (e.g., Landgraf et al., 2012; Collins and Loftus, 1975; Hintzman et al., 1975). Compared to a shorter temporal depth, a wider temporal depth may be associated with a faster automatic retrieval of sub-events that are also further away in time. This should facilitate the speed when processing time succession under conditions of a violated time's arrow. Since maintenance of wider horizons of sub-events entailed in scripts in working memory is a resource-consuming process, this does not come without costs as indexed by peak dilation. A wider temporal depth also appears linked to a general allocation of more cognitive resources. This suggests additional interrelations with more general cognitive abilities, which will be discussed in the following sections.

Overall, the evidence from this dissertation project confirms the first hypothesis stating that aspects of individual temporal orientation are interrelated as well as related to time succession. First, chronotype-time perspective interrelations as well as chronotype-temporal depth interrelations were found. Second, interrelations between future time perspective and time succession as well as between temporal depth and time successions were found, even though the explicit processing of time succession in terms of the cognitive arrow of time appears to be an important factor modulating these interrelations.

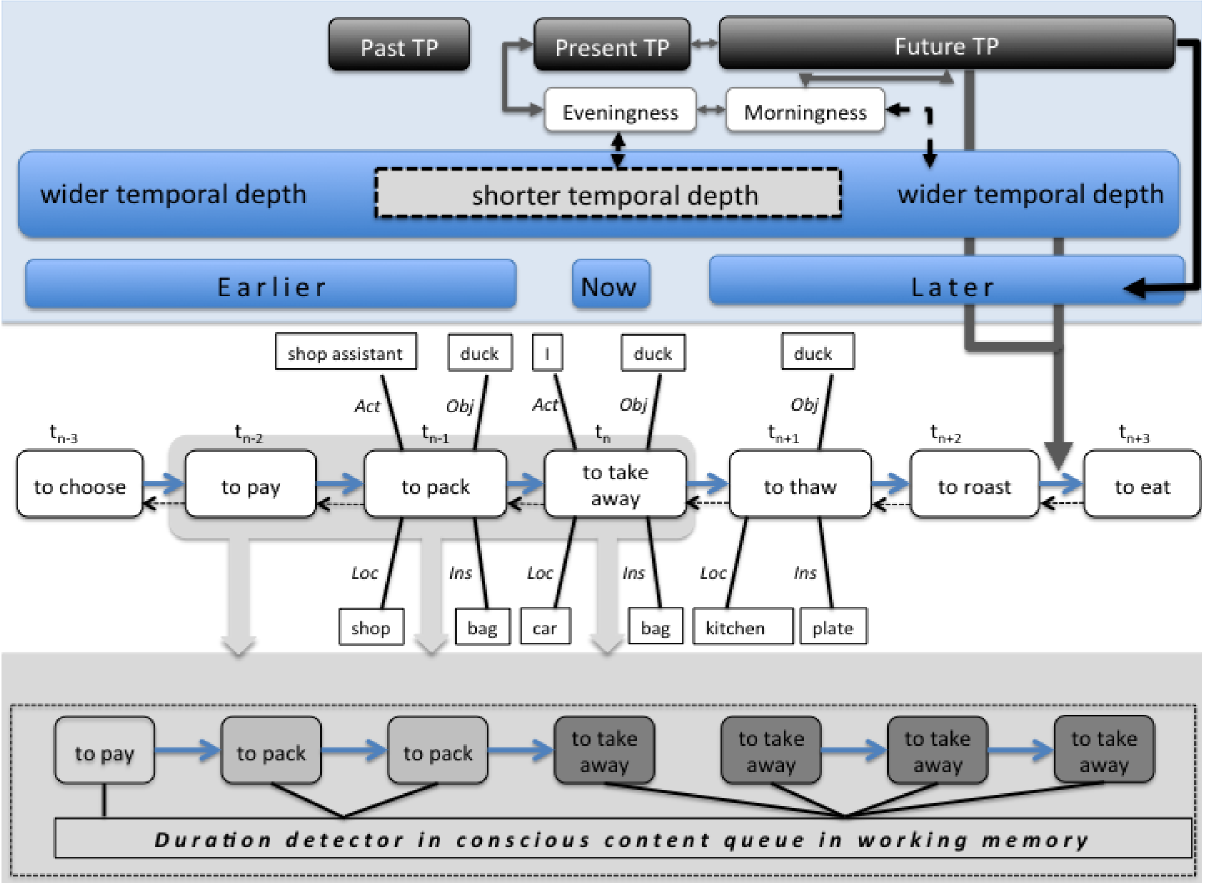
According to Block (1990), however, all three aspects of psychological time should be interrelated: individual temporal orientation, time succession and time duration. However, there have only been few attempts to integrate these into one model of psychological time (e.g., Snaider, McCall, & Franklin, 2009; Dörner, 1999). Both the LIDA model (e.g., Snaider, McCall, & Franklin, 2012) and Dörner (1999) build on the hypothesis that temporal information entailed in mental representations of events, thus, should always entail both time duration and succession (e.g., Molet & Miller, 2013). For instance, when going to the restaurant, we do not only know, that we take a seat before we study the menu. We also know that taking the seat is much shorter in duration than studying the menu. Previous evidence from relatedness judgment tasks suggests that pairs of sub-events with shorter temporal distances between them are processed faster than pairs of sub-events with longer temporal distances between them (Strauch, 2002). Here, temporal distances between sub-events appear coded on an ordinal scale (i.e., by position; see also Anderson, 1983) rather than by absolute (metric) time as suggested by Grafman (1985; Strauch, 2002).

The LIDA model (e.g., Snaider, McCall, & Franklin, 2012) builds on global workspace theory and findings that the length of the directly perceived present is limited to about 3 to 5 seconds (e.g., Block, 1990; Pöppel, 2004). The model contains a conscious content cue that entails, first, a cause-event detector coding for time succession, and, second, a duration detector that codes for repetitions of conscious, successive event segments in the queue sequence (Snaider et al., 2012).

Based on the findings of this dissertation project, the order code model of time succession (e.g., Hintzman et al., 1975; Friedman, 1993), and the duration detector of LIDA (Snaider et al., 2012), the following global working memory model of time perception integrating all three aspects of psychological time is suggested (see Figure 1).

In the duration detector (Figure 1, bottom), events are modeled by perceptual event segments. Every segment in the queue is of the same length, possibly, mirroring the minimum length of basic temporal building blocks of perception that are thought to be of around 30 ms (e.g., Pöppel, 2009).

Figure 1 Global Working memory model of temporal information in scripts integrating time duration (bottom), time succession (middle), and individual temporal orientation (top)



Perceptual segmentation of events is important for encoding processes and, thus, event memory (Sargent, Zacks, Hambrick, Zacks, Kurby, Bailey, Eisenberg & Beck, 2013; Zacks, Speer, Vettel, & Jacoby, 2006). Event Segmentation Theory (EST) stresses hat event segmentation depends on selecting important event features as well as on maintenance of these event features in working memory (e.g., Sargent et al., 2013). Duration in LIDA (Snaider et al., 2012) is modeled by the amount of repetitions of event segments with longer sub-events in event sequences (e.g., to take away) being modeled by more repetitions, and shorter sub-events (e.g., to pay) being modeled by no or less repetitions of conscious event segments (e.g., Snyder et al., 2012).

Regarding time succession (Figure 1, middle), mental representations of everyday events always contain information on typical agents, instruments, activities, location as well as temporal information (see also the five dimensions of situation models: time, space, protagonist, causality, and intentionality; Zwaan, Langston & Graesser, 1995) that are encoded and stored in semantic memory (Barsalou, 1999; Freyd, 1987, 1992; McRae et al., 2001). When a sub-event of a highly typical event sequence (e.g., from the shopping script: *to choose*) is experienced and recalled from memory, it also causes automatic retrieval of the associated sub-event (e.g., *to pay*) that is following next. This leads to the order of both sub-events being automatically stored as before-after relations in memory (e.g., order code model; Friedman, 1993; Hintzman, Summers, & Block, 1975). Since these sub-events are always experienced, recalled and encoded in the same (go forward) order, association strengths between sub-events are much higher in that chronological direction compared to the reverse direction. Therefore, processing of chronologically event sequences is typically easier than processing reversely presented event sequences regardless of individuals temporal orientation (e.g., Nowack & van der Meer, 2014; Nowack et al., 2013; Nuthmann & van der Meer, 2005). Future time perspective and temporal depth appear to modulate the cognitive arrow of time, at least, when time succession is an explicit aspect of a task (Nowack & van der Meer, 2014; 2016a). This suggests an impact of both aspects of individual temporal orientation on time succession (and vice versa) when more controlled reconstruction processes are at work. (Please note that, for future time perspective, no interrelations were found when time succession was not an explicit aspect of the task.) Future time perspective appears to increase the influence of time's arrow whilst a wider temporal depth appears to reduce its influence. Furthermore, future time perspective appears to modulate time succession in terms of localizing earlier or later sub-events in an event sequence. Here, future time perspective appears to aid the processing sub-events occurring later in a event sequence.

Regarding interrelations between different aspects of individual temporal orientation (Figure 1, top), chronotype and time perspective as well as chronotype and temporal depth are interrelated. (Please note, that Figure 1 depicts findings of morningness-future time perspective and eveningness-present time perspective relationships for the population under the age of thirty. Findings of study 1 demonstrated that both age and gender influence these chronotype-time perspective relationships.) Future time perspective is also interrelated with present time perspective. The more individuals are future-oriented, the smaller will be their present time perspective (and vice versa).

Overall, the cognitive model of time depicted in Figure 1 is a first attempt to integrate all three aspects of psychological time into one testable model. However, this dissertation project also aimed at investigating interrelations between individual temporal orientation and more general cognitive capacities. The findings regarding crystallized intelligence measures, fluid intelligence measures and executive functions will be discussed in the following sections.

3.1.2 Crystallized intelligence and its relation to individual temporal orientation

As indexed by MWT scores, time perspective was not related to verbal intelligence, which is one aspect of crystallized intelligence (e.g., Lehrl, 2005; Cattell, 1963). Regarding script or event knowledge as another aspect of crystallized intelligence, only interrelations between time perspective and time succession in terms of localizing sub-events correctly in time were found in study 2. Contradicting previous findings from a relatedness judgment task involving event knowledge (Nowack et al., 2013), there was no general superior performance linked to the future time perspective in the studies of this dissertation project. The current findings, thus, do not support the notion that time perspective may generally be related to crystallized intelligence. To the authors' knowledge, there have been no further investigations into relationships between time perspective and aspects of crystallized intelligence. However, there is indirect support for the notion that time perspective is not related to crystallized intelligence from studies investigating interrelations between personality factors and general factual knowledge (Rolfhus & Ackerman, 1999). Here, factual knowledge for instance in humanities (e.g., literature, art, music) and science (e.g., biology, chemistry, physics) was shown to be related to openness but not to conscientiousness. On the contrary, time perspective appears mainly related to conscientiousness and only weakly linked to openness (Zimbardo & Boyd, 1999).

However, chronotype is related to verbal intelligence as measured by the MWT (Lehrl, 2005) with morningness being linked to greater verbal intelligence than eveningness. This contradicts findings of superior verbal intelligence associated with eveningness, albeit, in females only (Killgore & Killgore, 2007). However, contrary to the previous notion that vocabulary tests of all formats are generally interchangeable (e.g., Carroll, 1993), Bowles and Malthouse (2008) stress that different formats in vocabulary tests (e.g., multiple choice versus producing a definition) relate to different cognitive variables. Specifically, multiple-choice tests such as the MWT applied in this dissertation project appear more strongly related to speed, whereas the task of producing a definition in Wechsler Abbreviated Scale of Intelligence (e.g., Wechsler, 1997) applied in Killgore and Killgore (2007) appears more strongly related to reasoning and memory (Bowles and Malthouse, 2008). This is in line with the findings from this dissertation project. In the temporal judgment task involving highly typical event sequences encoded in long-term memory, eveningness was associated with more accurate recall of scripts albeit in the more difficult reverse conditions only. In the semantic analogy task, morningness was generally linked to faster responses. Even though Bowles and Malthouse (2008) prefer multiple-choice tests as closest approximation for vocabulary, their findings as well as the evidence yielded in this dissertation project demonstrate the need to include multiple measures of vocabulary to investigate crystallized intelligence.

Regarding temporal depth (e.g., Bluedorn, 2002), no correlations with verbal intelligence as indexed by MWT scores (Lehrl, 2005) were found. In terms of script knowledge, temporal depth was only investigated in the semantic analogy task that is also strongly reliant on fluid intelligence and executive functions (e.g., Miyake et al., 2000). Since a wider temporal depth was associated with faster responses and the investment of more cognitive resources in both the semantic and the geometric analogy condition, the findings from this dissertation project suggest that temporal depth is not specifically related to crystallized intelligence.

To summarize, only chronotype appears related to crystallized intelligence, at least in terms of vocabulary and event knowledge. However, there is no particular chronotype generally superior to the other. Here, more research employing multiple measures of crystallized abilities is mandatory for a better understanding of the exact nature of the chronotype-crystallized intelligence relationship.

3.1.3 Fluid intelligence and its relation to individual temporal orientation

Neither chronotype nor temporal depth were related to fluid intelligence as measured by the RAPM (Heller, Kratzmeier, & Lengfelder, 1998). However, time perspective was correlated with fluid intelligence. As indexed by RAPM scores (Heller, Kratzmeier, & Lengfelder, 1998), high future time perspective scores were linked to greater fluid intelligence, low future time perspective scores to lower fluid intelligence. This suggests that fluid intelligence impacts upon individuals' ability to anticipate the future as well as on the delay of gratification and impulse control which are all necessary elements of a high future time perspective. This is in line with the literature suggesting that social strategies reflecting either a more present-oriented or more future-oriented behavior emerge from a common hereditary life history factor called the K-factor (e.g., Figueredo et al., 2006; Belsky, Steinberg, & Draper, 1991). Most importantly, this K-factor has been linked to brain regions such as the frontal cortex, which is associated with planning behavior, delay of gratification and impulse control as well as with executive functions and, hence, fluid intelligence (e.g., Miyake et al., 2000; Figueredo et al., 2006; Schacter & Addis, 2009). Furthermore, populations characterized by a higher K-factor (i.e., future-oriented behavior) also show higher general intelligence, populations characterized by a lower K-factor (i.e., present-oriented behavior) show lower general intelligence (e.g., Meisenberg & Woodley, 2013).

In line with *tonic* pupil responses reported for participants with high fluid intelligence compared to participants with average fluid intelligence (van der Meer et al., 2010), high future time perspective scores in study 3 also relate to a greater pre-experimental pupil baseline diameter (and low future time perspective scores to a smaller pre-experimental pupil baseline diameter) when controlled for RAPM scores. This suggests an interrelation between future time perspective and *tonic* activation over and above fluid intelligence (Aston-Jones & Cohen, 2005). In anticipation of the task to be presented, future-oriented participants show greater pre-task activation and exploratory behavior seeking new sources of rewards compared to participants with low future time perspective scores (e.g., Aston-Jones & Cohen, 2005; Gilzenrat et al., 2010). Possibly, pronounced exploratory behaviour is related to a high future time perspective, because it serves to supply additional important information necessary to identify possible means and options for the future as well as to predict and prepare for future events.

To summarize, future time perspective was related to fluid intelligence, whereas chronotype and temporal depth were not. However, the sample size in study 3 was too small to generalize from it stressing the need to replicate this finding with a larger sample.

3.1.3 Executive functions, conflict detection, and their relations to individual temporal orientation

Over and above fluid intelligence, a high future time perspective was related to better analogical reasoning compared to a low future time perspective. Likewise, morningness was related to better analogical reasoning compared to eveningness. Analogical reasoning is a prototypical mechanism of fluid intelligence and, thus, highly dependent from executive functions. Relevant features have to be selected; irrelevant features need to be inhibited (e.g., Chuderska & Chuderski, 2009). Maintenance and manipulation of mental representations require continuous updating processes of the mental representations held in working memory to identify and map correspondences between the different pattern pairs (e.g., Sternberg, 1977; see also Klix & van der Meer, 1980). Even though fluid intelligence and analogical reasoning are closely related, not all executive functions are related to fluid intelligence (Friedman, Miyake, Corley, Young, & Hewitt, 2006). Only updating appears to correlate with fluid intelligence scores, shifting between mental sets and the inhibition of irrelevant features do not (e.g., Friedman et al., 2006). This suggests that a higher future time perspective and morningness may also relate to the executive functions of shifting and inhibition as well as to goal maintenance. In line with this, eveningness is also associated with aggressive and impulsive behaviour, which is linked to lower serotonin levels (e.g., Brunner & Hen, 1997; Goldstein et al., 2007; Pattij & Vanderschuren, 2008). Decreased serotonic functioning also plays a crucial role in the decline of executive functioning with age (Payton et al., 2005).

However, this dissertation project did not investigate the executive functions of shifting and inhibition (as well as updating) as such. Likewise, goal management and conflict detection were not investigated in the study from Friedman et al. (2006). Conditions that are characterized by conflict (as well as tasks that require the inhibition of irrelevant features) are associated with a strong activation of the ACC (e.g., MacDonald et al., 2000; Botvinick, 2007). In addition, ACC responses to conflict appear related to adjustments in arousal and pupil dilation (e.g., Cohen et al., 2000; Ebitz & Platt, 2015). Future time perspective is associated with the maintenance of a variety of future goals and expectations; and a higher future time perspective should, presumably, be linked to more goals (e.g., Zimbardo & Boyd, 1999). The more future goals are to be maintained, the greater should be the possibility for contradicting future goals leading to conflict. Such conflicts between competing goals need to be detected and resolved. In line with this, the autonomic pupillary response in the semantic analogy task in study 3a suggests that the detected mismatch in the reverse analogy condition may have lead to adjustments in arousal and effort. Thus, future time perspective may not only be linked to more successful goal maintenance but also to better detection of and adaption to conflict. In line with evidence linking future time perspective (as well as morningness) to high levels of conscientiousness (i.e., being goal-directed, careful and impulse-controlled; Kirby & Kirby, 2006; Zimbardo & Boyd, 1999), this may suggest that future time perspective is linked to a better conflict detection ability.

In the more difficult geometric analogy task involving the search for and detection of conflict between the relationships of the source pair and the target pair, high future time perspective scores relate to a generally greater peak dilation and, possibly, stronger ACC activation than low future time perspective scores. Thus, participants with high future time perspective scores, presumably, generally invested more cognitive resources than participants with low future time perspective scores for successful conflict monitoring and resolution. These performance patterns of future-oriented participants are also in line with performance patterns of individuals with high intelligence allocating more cognitive resources than those with average intelligence across all conditions, at least for new and demanding tasks (Dix et al., 2010; Lee et al., 2015; van der Meer et al.; 2010).

Regarding temporal depth, remembering and anticipating events with a long temporal distance, presumably, requires more cognitive resources compared to events in a short temporal distance. In line with this, a wider general temporal depth appears associated with a general tendency to invest more cognitive resources. However, even though cognitive work requires time, a wider temporal depth in this dissertation project was also linked to shorter response times (e.g., reverse semantic analogies; vertical and horizontal geometric analogies) compared to a shorter temporal depth. Temporal depth was not related to verbal or fluid intelligence scores. Instead, the extent to which individuals can direct their attention onto relevant information to perform well might be an important factor (see also Barrouillet et al., 2008). Presumably, a wider temporal depth is associated with the maintenance of a variety of features that are related to distant recalled or anticipated events. Since irrelevant features associated with these events need to be inhibited, a wider temporal depth may be related to better inhibitory control. Such an elementary process should also be at work in tasks with only basic demands for information storage, retrieval and processing. In line with this, participants with a wider temporal depth were also faster than participants with a shorter temporal depth in a low-level cognitive task. Thus, temporal depth also appears to influence response times in elementary tasks that do not require any relational information. This suggests that temporal depth may be linked to the basic process of allocating attention and cognitive resources onto relevant information whilst inhibiting irrelevant features to perform fast and efficiently.

To summarize, time perspective, chronotype and temporal depth appear related to analogical reasoning and executive functions. Specifically, future time perspective and morningness could be linked to conflict detection, temporal depth to inhibitory control and the allocation of attention onto relevant information. However, executive functions, goal management and conflict detection were not specifically investigated in this dissertation project in greater detail. Therefore, more research is necessary to explore their relationships with individual temporal orientation.

3.2 Limitations of the studies and directions for future research

The evidence presented above needs to be considered along with some limitations. First, sample size and characteristics in studies 2 and 3 need to be considered when transferring the evidence to the general population. In study 2, only female students participated. However, both gender and age influence chronotype and time perspective. Men are more present-oriented with a stronger tendency towards eveningness; women are more future-oriented with a stronger tendency towards morningness (e.g., Keough et al., 1999; Roenneberg et al., 2007). Likewise, adolescents tend to be more present-oriented, whereas from early to late adulthood future time perspective is dominating. In later adulthood, there is a shift back towards present time perspective (D'Alessio et al., 2003; Gonzales & Zimbardo, 1985). Therefore, the results from study 2 might not be generalized to the male as well as elder population.

Furthermore, the sample size in study 3 is too small to generalize. Here, additional research with greater, and more representative samples is mandatory to confirm interrelations between future time perspective and fluid intelligence, between chronotype and verbal intelligence as well as between chronotype and temporal depth. Furthermore, multiple tests of vocabulary and other crystallized intelligence measures should be applied in the future to investigate more thoroughly which aspects of crystallized intelligence are linked to superior performances in evening types and which aspects are linked to superior performances in morning types.

Second, this dissertation project focused on individual temporal orientation and time succession, and no propositions regarding how individual temporal orientation may influence duration estimation can be made. For instance, future-oriented individuals are supposed to perceive events in, for example, five years time as much closer in time than present-oriented individuals according to Simons, Vansteenkiste, Lens & Lacante (2004). However, there has not been any empirical verification of such a proposed time perspective-duration relationship. Clearly, future research is mandatory to investigate interrelations between individual temporal orientation and duration estimation (as well as between duration and time succession) to verify and adapt the cognitive model of psychological time presented in this dissertation.

Finally, findings of this dissertation project elicit a variety of new hypotheses that require further investigations. For instance, interrelations between temporal depth and the basic process of allocating attention and cognitive resources onto relevant information for fast and efficient performance could be examined in future research.

3.3 Conclusion

The evidence presented in this dissertation project showed interrelations between various aspects of individual temporal orientation as well as between individual temporal orientation and time succession. A global working memory model of psychological time integrating time duration, time succession and individual temporal orientation was proposed in an attempt for a testable model for future research.

Furthermore, individual temporal orientation was shown to relate to different cognitive capacities. Future time perspective was interrelated with fluid intelligence as measured by the RAPM (Heller et al., 1998), chronotype was interrelated with verbal intelligence (i.e., one aspect of crystallized intelligence) as measured by the MWT (Lehrl, 2005). Individual temporal orientation appears further related to executive functions. Whereas future time perspective and morningness may be interrelated with conflict detection, temporal depth may relate to inhibitory control.

The current findings, thus, add to the literature by showing how individual temporal orientation as one aspect of psychological time is linked cognitive capacity. Since time cannot be directly perceived, cognitive abstraction processes are necessary to infer it from perceived changes in the environment (e.g., Gibson, 1975). In line with K-factor theories, individual temporal orientation appears to be part of the process of adapting to the cyclic patterns of time (e.g., Figueredo et al., 2006; Belsky, Steinberg, & Draper, 1991). This is critical to ensure survival, which makes time a fundamental aspect of human experience and behavior.

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Selbständigkeitserklärung

Ich erkläre hiermit, dass ich die vorliegende Dissertationsschrift selbstständig und ohne unerlaubte Hilfe angefertigt sowie nur die angegebene Literatur verwendet habe. Jede Mitwirkung von anderen mit mir zusammen arbeitenden Personen an den Forschungsergebnissen ist explizit gekennzeichnet.

Ich besitze keinen Doktorgrad und habe mich nicht bereits anderwärts um einen solchen beworben. Mir ist die Promotionsordnung der Lebenswissenschaftlichen Fakultät der Humboldt-Universität zu Berlin bekannt.

Cottbus, den 21. Januar 2016