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Impact of chronotype and time perspective on the processing of scripts

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ABSTRACT

Little is known about the impact of temporal orientation (chronotype; time perspective) on cognitive performance. This study adopted a psychophysiological approach to explore how chronotype (morningness–eveningness) and time perspective (present; future) influence time succession as another aspect of psychological time that is entailed within script knowledge. In a temporal judgment task, participants decided 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*). Behavioral and pupillary data suggest a differential impact of chronotype and time perspective on script knowledge and cognitive performance. The impact of time perspective on the processing of temporal information entailed in script knowledge appears linked to match or mismatch conditions between a strong focus on future outcomes associated with future time perspective and the task of identifying either the later (future-oriented) or the earlier (past-oriented) sub-event. Concerning the chronotype, evening types process items in which chronological time succession is violated (i.e., reversely presented items) more accurately than morning types. Indexed by pupillary data, the impact of chronotype may relate to more general cognitive abilities. The psychophysiological data derived in this study suggests that evening types typically outperform morning types in various measures such working memory capacity and verbal intelligence simply because they invest more cognitive resources than morning types.

1. Introduction

Even though time is a phenomenon that cannot be directly perceived (Gibson, 1975), over the past decades, great scientific interest has been devoted to the investigation of psychological time. Three major aspects of psychological time have been distinguished: time duration (persistence of events, or the interval between events), time succession (sequential occurrence of events as reflected by their temporal order), and temporal orientation (Block, 1990). Despite ongoing efforts in analyzing the three major aspects of psychological time, the interrelation of these aspects has received surprisingly little attention. Therefore, we aimed at examining the impact of temporal orientation on the retrieval of time succession of everyday events. In regard to individual temporal orientation, biological approaches traditionally focus on diurnal (i.e., chronotype) and annual patterns to investigate the impact of time on human behavior (e.g., Roenneberg and Aschoff, 1990; Roenneberg et al., 2003). Conversely, psychological approaches tend to focus on the concept of time perspective referring to a person's experiences and conceptions of past, present and future times. This study combined biological and psychological approaches to investigate how these two measures of temporal orientation, chronotype (morningness–eveningness) and time perspective (e.g., present; future), may influence time succession as another aspect of psychological time that is entailed in script knowledge and stored in semantic memory.

1.1. Chronotype and time perspective

The chronotype (morningness–eveningness) relates to individual differences in circadian preferences. Evening types prefer later bed times and rise times, morning types tend to wake up and go to bed earlier (Roenneberg et al., 2003; Adan et al., 2012). Although the exact genetics behind morningness and eveningness are not fully understood yet, there appears to be a genetic base of individual differences in chronotype (e.g., Duffy and Czeisler, 2002; Ebisawa et al., 2001; Hur, 2007; Vink et al., 2001). The central pacemaker of the circadian rhythm is located in the suprachiasmatic nucleus (SCN) of the hypothalamus. Via the optic nerve the SCN is connected to the cycle of light and darkness, which acts as the most important external zeitgeber (Roenneberg et al., 2007).

Morningness appears associated with better school leaving exams (Randler and Frech, 2006; Preckel et al., 2011; Vollmer et al., 2013). This might be due to early school start times which are more beneficial to morning types. Evening types demonstrate a superior working memory capacity, processing speed and, albeit for females only, verbal intelligence than morning types (e.g., Roberts and Kyllonen, 1999; Killgore

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and Killgore, 2007). However, to the authors' knowledge, there has not been any field study at school that tested the impact of chronotype on both intelligence and performance parallel in a representative sample.

Time perspective denotes the preference to rely on a particular temporal frame (e.g., present or future) for decision-making and behavior, and individuals differ in the extent to which they overemphasize one particular time perspective (Zimbardo et al., 1997). Present-oriented individuals tend to base their decisions and actions on the immediate rewards available in a present situation. Future-oriented participants tend to rely on the expected consequences that a present behavior may have for their future.[1]

Like morningness, future time perspective has been linked to better grade point averages in college students (Mello and Worrell, 2006). In line with this, morning types tend to be more future-oriented and evening types more present-oriented (Stolarski et al., 2012; Nowack and van der Meer, 2013).

To investigate how the individual chronotype and time perspective may influence another aspect of psychological time, namely time succession, a temporal judgment task on script knowledge was applied.

1.2. Script knowledge

Everyday events experienced like *getting ready for work* are encoded and stored as mental representations that contain typical agents, instruments, activities, location as well as a temporal dimension (Barsalou, 1999; Freyd, 1987, 1992; McRae et al., 2001). These event components naturally unfold in a chronological ("go forward") direction and are stored in that typical (i.e., chronological) temporal order in scripts in semantic memory (Schank and Abelson, 1977). Script knowledge thus refers to chronologically represented knowledge structures or event sequences in memory, and retrieval of a script from memory entails a chronological activation of associated sub-events.

Event sequences (i.e., scripts) are processed more easily when the temporal order in which events are presented matches the temporal order of these events in real life and, thus, memory (e.g., Landgraf et al., 2012; Raisig et al., 2007). Reading the header of a script (e.g.; *getting ready for work*) appears to trigger the retrieval of the complete sequence from the beginning to the end from memory (Collins and Loftus, 1975; Landgraf et al., 2012). In a temporal judgment task that implicitly entailed the accessing of temporal position within scripts (early or late), pairs of events occurring early within a given script were processed more easily than pairs of events occurring later within a given script (Landgraf, Raisig and van der Meer, 2012).

Typicality and frequency of everyday events influence storage of temporal information and its retrieval from memory. When highly typical scripts (e.g. *going to the supermarket*) are encoded, the relative temporal relationships between sub-events (e.g., *drive to supermarket–put groceries in trolley–pay for*) are explicitly stored in semantic memory as "old–new relations" (see also van der Meer and Kolbe, 1997). Retrieval of a particular sub-event also triggers the retrieval of temporally associated sub-events as well as the stored "old–new relations". These relations are retrieved automatically and enable the identification of earlier–later relationships between sub-events (*Reminding Model*; e.g., Hintzman et al., 1975). For less typical scripts (e.g. *going parachuting*), temporal information is not explicitly stored. Instead, retrieval of temporal information from semantic memory is based on controlled cognitive processes involving the retrieval of contextual information (e.g., snow on trees) and inferring temporal information from general knowledge of temporal patterns (e.g. snow in winter; *Reconstructive location-based processes*; Friedman, 1993; Curran and Friedman, 2003).

At present, there is no research that has addressed whether and how one aspect of psychological time, namely temporal orientation, that is, individual chronotype and time perspective may impact another aspect of psychological time, namely the retrieval of temporal succession of events from semantic memory. To answer this question empirically, a temporal judgment task was administered. Participants were presented with a sub-event (e.g., *get new batteries*) from a script (e.g., *changing batteries in an alarm clock*) on the left of the center of the screen, which was followed by a second sub-event (e.g., *set right time on alarm clock*) on the right of the center of the screen. Each pair of sub-events was presented either in a chronological or in a reverse temporal order. Participants had to decide, which sub-event comes *earlier* or *later* within the script. Depending variables included behavioral parameters (response times and error rates) as well as pupil dilation as an indicator of resource allocation (Just et al., 2003).

1.3. Cognitive resource allocation and pupil dilation

The pupillary response is a reliable indicator of the cognitive resources allocated to a task (Granholm et al., 1996; Beatty and Lucero-Wagoner, 2000; Just et al., 2003; Verney et al., 2004). In general, the more difficult the task, the more the pupil dilates.

Arousal and cognitive load lead to an activation of the sympathetic dilator muscle and a concomitant inhibition of the parasympathetic sphincter that is mediated by the Edinger–Westphal center, which stimulates the pupil to dilate (Steinhauer et al., 2004). An important role in the inhibition of the Edinger–Westphal nucleus, and, thus, in parasympathetic inhibition plays the Locus coeruleus (LC). Involved in the regulation of arousal and autonomic function, the LC is situated in the dorsal pons with ascending norepinephric projections throughout the forebrain (Samuels and Szabadi, 2008). In line with the LC-mediated activity of the Edinger–Westphal center, correlations have been reported between pupil diameter and LC activity (Loewenfeld, 1993; Aston-Jones and Cohen, 2005; Gilzenrat et al., 2010). Two modes of LC function can be distinguished: *phasic* and *tonic* activities (Aston-Jones and Cohen, 2005; Gilzenrat et al., 2010). Task-evoked *phasic* activity is linked to the exploitation of available sources of reward and high task-engagement (Gilzenrat et al., 2003). *Tonic* activity is linked to disengagement from a task and task-independent exploration of the environment for new sources of reward.

Task-evoked *phasic* pupillary responses reflect individual differences in cognitive resource allocation based on cognitive abilities (Ahern and Beatty, 1979; van der Meer et al., 2010). For instance, individuals with superior fluid intelligence outperformed individuals with average fluid intelligence by allocating more cognitive resources in a mathematical test independent of task difficulty (Dix, 2011). In line with the *effort hypothesis*, participants with superior cognitive abilities may thus generally invest more cognitive resources indicated by higher peak dilation across *all* tasks (Ahern and Beatty, 1979; see also Nowack et al., 2013). In addition, higher pre-experimental *tonic* pupil dilation that is associated with a greater task-independent tendency to scan the environment for sources of reward has been demonstrated for participants with superior fluid intelligence compared to participants with average fluid intelligence (van der Meer et al., 2010). Likewise, eveningness and higher future time perspective scores may be associated with greater pre-experimental and task-evoked pupil dilation.

Based on the literature cited above, we assumed

1. *Processing pairs of sub-events from scripts depending on instruction and temporal orientation of items*: Earlier sub-events as well as chronologically presented pairs of sub-events were expected to be identified more easily (i.e., faster, lower error rates and lower task-dependent pupil dilation) than later sub-events and reversely presented pairs of sub-events (Landgraf et al., 2012).
2. *Processing pairs of sub-events from scripts depending on individual time perspective*: Due to a strong focus on future outcomes (Zimbardo

[1] According to Gonzales and Zimbardo (1985), only one percent of the population in industrialized, Western societies is predominantly past-oriented. Therefore, we will only report on future and present time perspective scores in this paper. Analyses have, however, also been computed for the past time perspective scores (all yielding no significant results), which can be obtained from the authors.