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It's all in the past: Deconstructing the temporal Doppler effect

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ABSTRACT

A recent study reported an asymmetry between subjective estimates of future and past distances with passive estimation and virtual movement. The temporal Doppler effect refers to the contraction of future distance judgments relative to past ones. We aimed to replicate the effect using real and imagined motion in both directions as well as different temporal perspectives. To avoid the problem of subjective anchoring, we compared real- and imagined-, ego- and time-moving conditions to a control group. Generally, Doppler-like distortion was only observed in conditions in which the distance between the participant and a frontal target increased. No effects of temporal perspective were observed. The "past-directed temporal Doppler effect" presents a challenge for the current theories of temporal cognition by demonstrating absence of psychological movement into the future. The effect could open new avenues in memory research and serve as a starting point in a systematic examination of how the humans construct future.

1. Introduction

Understanding the deep connection between space and time remains one of the most exciting and difficult challenges for psychology, with accumulating evidence indicating that temporal cognition relies heavily on spatial concepts (e.g. Casasanto & Boroditsky, 2008). A relationship between space and time is a close one to the extent that one can justifiably describe human experience as being embedded in a space-time continuum. Once we attempt to treat space and time separately, we realize that time is difficult if not impossible to define independently (Boroditsky, 2000) and that describing time generally requires spatial analogies and metaphors (Matlock, Ramscar, & Boroditski, 2005). Time appears to be located on an imaginary line which stretches along the line of sight (e.g. Hartmann & Mast, 2012). In addition, despite the fact that it cannot be experienced directly, time is perceived as a dynamic medium possessing the qualities of movement and flow (Bergson, 1922). From the first-person perspective, future is conceptualized as a region which lies in front of the observer and past as a domain situated caudally, behind their back.

How far can the space/time analogy be taken? A recent study seems to indicate that the spatial metaphor is not just a figure of speech or a mode of thought, but that the subjective metric of temporal "space" is distorted by the mental movement along the imaginary time line. Inspired by a well-documented physical phenomenon, Caruso and colleagues (Caruso, Van Boven, Chin, & Ward, 2013) proposed that future- and past-duration judgments exhibit asymmetry analogous to the physical Doppler effect (Doppler, 1842). In three studies, Caruso et al. asked participants to estimate past and future distance of one month (Study 1a), one year (Study 1b) and with reference to a fixed date (Valentine's Day; Study 2). Finally, participants estimated future and past distances while being exposed to virtual motion (vection; Study 3). In all three studies, participants consistently underestimated the former relative to the latter distance. The contraction of future distances suggested a dynamic interaction between the observer and the medium of time. If the observed effect is indeed Doppler-like, the experienced movement through time should compress the subjective time line in the direction of the future and expand it in the opposite direction. This way, even though equal distances are projected onto it, the compression of future intervals leads to a relative underestimate of future distances.

In addition to the three main studies, Caruso et al. carried out three follow-up studies aimed at examining possible confounds. To test for the common assumption that different cognitive processes operate on two temporal directions (past is remembered and future is imagined), they asked participants to imagine taking part in an experiment one month away either in the past or in the future. To control for the difference in prototypicality of two mental domains, Caruso et al. asked participants to estimate past and future intervals from concrete vs. abstract target points. Finally, to examine whether the content populating the past portion of the time line could have made the past appear more distant, they prompted participants to list tasks they intended to complete

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within a three-week period. In all three cases, the results supported the temporal Doppler effect (TDE) hypothesis.[1]

Caruso et al.'s findings have potentially important implications for theories of time perception and memory. If subjective experience of time is analogous to spatial movement, other properties of the temporal medium could be investigated and charted systematically using physical analogues. For instance, one could measure the speed of temporal motion and relate it to major individual differences such as age, mood or psychopathological factors. However, before such a bold step could be taken, it is necessary to examine carefully the premises and findings underpinning Caruso et al.'s claim.

1.1. Psychophysical properties of mental time travel

If the future is contracted relative to the past, what could be causing the contraction? The model to which the authors allude can be called the TDE model. Here, temporal distance is judged from the present to an imagined or remembered event. Mental time travel distorts the temporal metric in a way that resembles the distortion of the physical medium (Fig. 1). The contraction of the frontal portion of the time line (from the observer to some future event) is accompanied by the dilation of the past portion. This causes an equidistant past event to appear further away. Although attractive, this model rests on certain assumptions. First, it requires mental time to behave in a manner similar to a physical medium (e.g. air) which allows consequences of movement to be felt and measured. Second, the TDE model presupposes a subjective time line on which experiences are ordered and which extends freely in both temporal directions. This requirement is crucial. For Caruso et al.'s claim to be true, the future portion of the time line must be real and not a projection or extrapolation of past experience (i.e. a function of "episodic future thinking", Atance & O'Neill, 2001, in which case the effect should be called "prospective memory contraction".

If future distances are contracted relative to past distances they must lie on a single time line. It follows that past and future estimates must be governed by a single metric. What kind of metric could underpin subjective time? Classical psychophysical theories of time estimation (e.g. Eisler, 1976) are not helpful here because they abstract time intervals from their experiential context (e.g. Conway & Pleydell-Pearce, 2000). The only exception could be the consistent finding that short intervals are dilated and long ones compressed relative to the linear metric (see also Ferguson & Martin, 1983). Psychological past is a continuum filled with a sequence of remembered events that fade away losing distinctiveness and relevance (e.g. Burt & Kemp, 1991). Private memories encoded within the context of public events and knowledge provide markers against which an estimate can be evaluated. In addition, several studies have revealed that temporal distance closely depends on the amount of information one possesses about a particular event. Specifically, people tend to judge as closer the events that are better memorized (Brown, Rips, & Shevell, 1985; Hinrichs, 1970). This could imply that more distant events (that are not so well memorized) are judged as being disproportionately more remote. Not surprisingly, people also experience temporally closer events as more emotionally meaningful (Bratfisch, Ekman, Lundberg, & Kruger, 1971).

The same authors observed a power law exponent (Stevens, 1975) of 0.43 for very long temporal intervals which conflicts with Eisler's report of a larger exponent (0.9) for somewhat shorter intervals. This could suggest that a different metric is used in estimating very remote past events. Alternatively, a single nonlinear (likely logarithmic) metric is progressively more compressed, with remote dates and events being crammed together and becoming indistinguishable. Overall, the above evidence is commensurate with a nonlinear (exponential or logarithmic) metric with interval size decreasing with distance and with interval contraction becoming more prominent at very long intervals. This metric is significantly modulated by mnemonic and affective factors—emotionally important or otherwise salient events can introduce additional distortion.

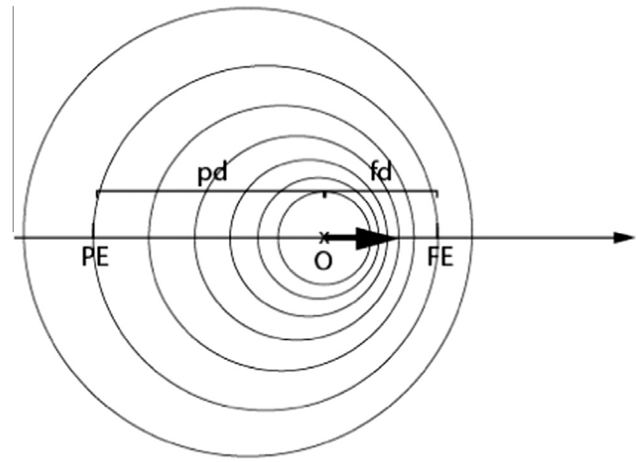

Fig. 1. Temporal Doppler effect. The motion of the observer (O) through the medium of time (or movement of time relative to the observer) compresses the frontal portion of the time line and dilates its caudal portion. As a result, the distance (fd) from a future event (FE) appears shorter than the distance (pd) from a past event (PE). The model described here assumes, in line with the standard definition of the Doppler effect, that interaction between the observer and a medium distorts the latter. Although Caruso et al. do not explicitly address this point, it logically follows from their (justified) focus on the dynamic relationship between the observer and the observed (see introductory paragraphs on p. 530).

In comparison, little is known about the metric properties of the future time line. The importance of future time perspective (FTP) has been highlighted by motivational research (Simons, Vansteenkiste, Lens, & Lacante, 2004). FTP is defined as the present anticipation of future goals. Generally, people with a long FTP experience the psychological distance from a given future goal as shorter than people with a short FTP. Although of great importance for education and social psychology, the concept is clearly subject to individual differences (e.g. age; Lang & Carstensen, 2002) to the extent that makes psychophysical measurement difficult. Furthermore, the extent of FTP must be related to experience and knowledge. The only way to populate the future portion of the psychological time line with content is to extrapolate from past events even when thinking about future ones. It is therefore difficult to see how a future metric could be created independently of experience and memory.

1.2. TDE vs. bisection model of temporal asymmetry

A closer inspection of Caruso et al.'s data revealed that their participants scaled temporal distance. In Study 1a, the target interval was one month and in Study 1b, it was one year. Yet, the proportions of the rating scale (1–10) marked off by future and past distances were almost identical (65th and 72nd and 59th and 70th percentile respectively). Study 3, which used a 9-point scale and a shorter interval (3 weeks), revealed a similar picture (64th and 67th percentile). The proportion changed somewhat (47% and 62% respectively) for a very brief interval (1 week; Study 2). The fact that two such different intervals are located at the same points

[1] All Caruso et al.'s studies were between-subjects so that each participant made only one estimate (either past or future).