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Short Communication

Prisms to travel in time: Investigation of time-space association through prismatic adaptation effect on mental time travel

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ABSTRACT

Accumulating evidence suggests that humans process time and space in similar veins. Humans represent time along a spatial continuum, and perception of temporal durations can be altered through manipulations of spatial attention by prismatic adaptation (PA). Here, we investigated whether PA-induced manipulations of spatial attention can also influence more conceptual aspects of time, such as humans' ability to travel mentally back and forward in time (mental time travel, MTT). Before and after leftward- and rightward-PA, participants projected themselves in the past, present or future time (i.e., self-projection), and, for each condition, determined whether a series of events were located in the past or the future with respect to that specific self-location in time (i.e., self-reference). The results demonstrated that leftward and rightward shifts of spatial attention facilitated recognition of past and future events, respectively. These findings suggest that spatial attention affects the temporal processing of the human self.

1. Introduction

Space and time are tightly interwoven, as demonstrated by several investigations revealing the influence of spatial coding on time processing (Anelli, Candini, Cappelletti, Oliveri, & Frassinetti, 2015; Bonato, Zorzi, & Umiltà, 2012; Casasanto & Boroditsky, 2008; Oliveri, Koch, & Caltagirone, 2009; Lakoff & Johnson, 1999). For instance, laterality is interrelated to time processing: an association was found between short temporal durations and left-hand responses, and long temporal durations and right-hand responses (Conson, Cinque, Barbarulo, & Trojano, 2008; Ishihara, Keller, Rossetti, & Prinz, 2008; Vallesi, Binns, & Shallice, 2008). Additionally, the duration of a visual stimulus is underestimated when the stimulus is presented in the left space, and overestimated when it is presented in the right space (Vicario et al., 2008). Temporal concepts, too, may correspond with a spatial representation. For example, responses to early months of the year/days of the week are faster with a left key, and responses to late months/days are faster with a right key (Gevers, Reynvoet, & Fias, 2003, 2004). Furthermore, a processing facilitation emerges for past-related words presented in left space and for future-related words presented in right space (Kong & You, 2012; Santiago, Lupiáñez, Perez, & Funes, 2007; Torralbo, Santiago, & Lupiáñez, 2006). These findings indicate that humans represent time along a spatial continuum, where both temporal durations (short/long) and time concepts (before/after, past/future) are coded with a left-to-right spatial order on a "mental time line" (MTL; Arzy, Adi-Japha, & Blanke, 2009; Bonato et al., 2012).

Space and time are not only represented similarly, but they also appear to be processed similarly. For example, both time and space may be explored through, and influenced by, spatial attention, as demonstrated by prismatic adaptation (PA). During PA, participants repeatedly point at a visual target while wearing prismatic lenses shifting the visual field toward one side of space. To compensate for this optical displacement, participants orient their pointing movements toward the opposite direction, leading to a shift of spatial attention to that side of space (Jacquin-Courtois & et al., 2013). Frassinetti, Magnani, and Oliveri (2009) altered the perception of temporal durations through PA, showing that a PA-induced leftward attentional shift resulted in underestimation of temporal durations, whereas a PA-induced rightward attentional shift resulted in overestimation (see also Magnani, Oliveri,

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Mancuso, Galante, & Frassinetti, 2011; Magnani, Oliveri, Mangano, & Frassinetti, 2010; Oliveri, Magnani, Filipelli, Avanzi, & Frassinetti, 2013).

Since spatial attention can influence processing of physical aspect of time, it may also influence conceptual aspects of time, such as individuals' ability to project themselves in the past or the future, known as Mental Time Travel (MTT; Atance & O'Neill, 2001; Buckner & Carroll, 2007; Gilbert & Wilson, 2007; Levine, 2004; Schacter, Addis, & Buckner, 2007; Tulving, 2002). To test this hypothesis, before and after PA participants performed a task highlighting two components of MTT: self-projection and self-reference (Arzy, Collette, Ionta, Fornari, & Blanke, 2009; Arzy, Molnar-Szakacs, & Blanke, 2008). Participants projected themselves in the past, present or future time (self-projection), and, for each condition, determined whether a series of events were located in the past or the future with respect to that specific self-location in time (self-reference). In view of the abovementioned association of past time to left space and future time to right space, we predicted that a leftward shift of attention would facilitate MTT towards the past and a rightward shift of attention would facilitate MTT towards the future.

2. Method

2.1. Participants

32 healthy Italian volunteers (5 males, mean age: 22 years, age range: 19–29) participated in the experiment, which was conducted at the University of Bologna. All participants were right-handed, had normal or corrected-to-normal vision, and no history of neurological or psychiatric diseases.

Participants were randomly divided into two groups depending on the direction of the prism-induced after-effect: i.e., leftward after-effect induced by rightward PA, rightward after-effect induced by leftward PA (see below). There were no differences in age ($p > 0.25$) or educations ($p > 0.25$) between the two groups.

2.2. Ethics statement

Participants gave written consent to participate in the experiment, which was approved by the Ethical Committee of the University of Bologna, and in agreement with the 2008 World Medical Association Declaration of Helsinki.

2.3. Stimuli and procedure

Participants sat in front of a 15-in. color monitor, at a distance of about 60 cm, and listened to brief audio descriptions of personal (e.g., car license, first son) and non-personal world events (e.g., Obama's election, Chernobyl disaster) (see Anelli, Ciaramelli, Arzy, & Frassinetti, 2016; Arzy, Collette, et al., 2009; Arzy et al., 2008 for a similar procedure, and Table S1 in supplementary material for a complete list of stimuli). For each event, participants indicated if the event had already happened (relative past event) or was yet to happen (relative future event), providing a vocal response ("past" vs. "future"). Participants performed the task in three different conditions, which corresponded to three different self-locations in time (Fig. 1). In one condition, they were required to answer the questions while imagining themselves as located in the present time (present self-location), in a second condition they had to answer while imagining themselves as located in the past (10 years ago, past self-location), and in a third condition they had to answer while imagining themselves as located in the future (10 years from now, future self-location). Thus, in each self-location condition, participants had to determine whether the event being presented was located in the past or the future relative to the current location of the self in time. The three self-location conditions were counterbalanced across participants and each self-location condition included 24 stimuli, half personal and half non-personal, equally distributed between relative past and relative future events, which were presented in random order for a total of 72 trials. In a previous study using the same material, events presented at different self-locations in time did not differ in emotion or importance, as assessed by independent raters. Personal events were rated as more emotion arousing than non-personal events, but of comparable importance (Anelli et al., 2016).

Each trial started with the appearance of a cross in the center of the computer screen for 1000 ms, followed by a black screen and the acoustic presentation of the event through headphones. We recorded the vocal responses "past" and "future". The inter-stimulus interval was of 1000 ms. E-Prime 2.0 software was used for stimulus presentation and response collection. Before the experimental task, participants performed a brief practice session, with 8 stimuli randomly presented. The experimenter asked participants to self-project in time, for example focusing on their age 10 years ago/in 10 years, or on the exact year it was/will be 10 years ago/in 10 years.

Participants performed the MTT task before PA, underwent the PA procedure (for a full description of the PA procedure, see supplementary material), and then performed the MTT task again. At the end of the experiment, participants were asked to complete a questionnaire evaluating whether events in each self-location were located in the past or the future with respect to that location. This allowed determining correct responses separately for each participant.

3. Results

3.1. Prismatic adaptation (PA) effect on mental time travel

Reaction times (RTs) were calculated subtracting the duration of the acoustic presentation of the event from the overall response

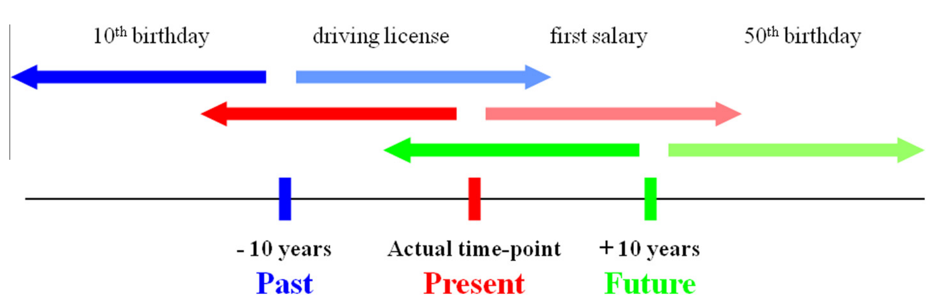

Fig. 1. Stimuli and procedure. Participants were required to project themselves in three different self-locations in time (past, present or future), and determine whether the event was located in the past or the future relative to the current self location in time.