Mental Time-Lines Follow Writing Direction: Comparing English and Hebrew Speakers

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Abstract

Across cultures people construct spatial representations of time. However, the particular spatial layout created to represent time differs across cultures. Previous work suggests that writing direction (e.g., left to right as in English, or right to left as in Arabic) can have an effect on how people mentally lay out time. The purpose of this paper is twofold: 1. Our study examines whether people automatically access spatial representations when they reason about temporal order, and 2. whether culturo-linguistic artifacts such as writing direction affect which spatial representations are likely to be automatically accessed. We asked Hebrew and English speakers to make temporal order judgments about pairs of pictures (i.e., to decide whether a picture represented an event 'earlier' or 'later' than the one depicted in another picture). Subjects made a response using two adjacent keyboard keys. English speakers were faster to make "earlier" judgments when the "earlier" response needed to be made with the left response key than with the right response key. Hebrew speakers (who read from right to left) showed exactly the reverse pattern. It appears that people do automatically access spatial information when making temporal order judgments, and the kind of spatial layout people mentally create for time differs depending on culturo-linguistic artifacts.

Keywords: reading directionality, space, time, SNARC.

Introduction

Spatial representations of time are ubiquitous around the world. People use graphs and spatial time-lines, clocks, sundials, hourglasses, and calendars to represent time. In language, time is also heavily related to space, with spatial terms often used to describe the order and duration of events (Clark, 1973; Lakoff & Johnson, 1980; Lehrer, 1990; Traugott, 1978). In English, for example, we might move a meeting *forward,* push a deadline *back,* attend a *long* concert or go on a *short* break. Further, people also represent time spatially in spontaneous co-speech gesture (e.g., Casasanto & Lozano, 2006; Núñez & Sweetser, 2006). Further, people appear to access spatial representations when processing temporal language (e.g., Boroditsky, 2000; Boroditsky & Ramscar, 2002; Torralbo, Santiago , et al., 2006; Núñez, R., Motz, B., & U. Teuscher, U., 2006). Even simple temporal judgments like reproducing short durations are affected by spatial information (e.g., Casasanto and Boroditsky, 2007).

While it may be a universal that spatial representations are used for time, languages and cultures differ in terms of how time is laid out in space. For example, Núñez & Sweetser (2006) observed that the Aymara talk about the future as being behind them and the past as being ahead of them, and gesture accordingly. English and Mandarin differ in terms of how often they talk about time vertically, with Mandarin speakers being much more likely to use vertical metaphors for time than do English speakers (Chun, 1997a; Chun, 1997b; Scott, 1989).

Another way in which languages and cultures differ is in terms of writing direction. Previous studies have found that writing direction affects the way people graphically lay out time (Tversky, Kugelmass, and Winter, 1991). English speaking participants (who read from left to right) spontaneously mapped a sequence of events (such as the meals of the day) onto a horizontal line directed rightward, placing earlier events to the left and later events to the right. In contrast, Arabic speakers (who read from right to left) showed the reverse pattern, placing earlier events further to the right, and later events further to the left.

Recently, Casasanto & Lozano (2006) have shown that even when not confined to a two-dimensional surface like a computer screen or a tabletop, English speakers use the horizontal left to right axis when they tell stories, by spontaneously gesturing to the left when referring to the past, and to the right when talking about the future.

Beyond reasoning about time, people show a directional bias congruent with the writing direction of their language in perceptual exploration, drawing, and aesthetic preferences (e.g., Nachshon, 1985; Nachshon, Argaman, & Luria, 1999; Tversky, Kugelmass, & Winter, 1991). Imagery and sentence representation also seem to be modulated by writing direction; For example, Maass and Russo (2003), showed that while Italian speakers represent sentences in drawing from left-to-write, positioning the subject of the sentence to the left of the object, Arabic speakers show a reversal of this directional bias, representing the subject of the sentence to the right of the object.

Writing direction has also been found to affect numerical reasoning. Speakers of languages like English and French that are written from left to right have been shown to represent numbers spatially on a 'mental number line' along which numbers are positioned from left to right according to their increasing magnitude (Dehaene, Bossini, & Giraux, 1993). Accordingly, speakers of languages written left-right show spatial compatibility effects when responding to numbers, with faster reaction times to small numbers using the left hand and faster reaction times to large numbers using the right hand (Dehaene et al., 1993; Bachtold, Baumuller, & Brugger, 1998).

Dehaene and his colleagues termed this phenomenon the SNARC effect (Spatial Numerical Association of Response Codes), and it has since been replicated across a wide range of experimental manipulations and participant groups, as well as with non-numerical ordinal sequences like the alphabet and names of the months (Gevers, Reynoveot , & Fias, 2003). Since the effect is observed even when number magnitude is irrelevant to the task, as in parity judgments (Dehaene et al., 1993) or without semantic processing of the numbers at all (Fias, Lauwereyns, & Lammertyn, 2001), it was attributed to an automatic access to spatial codes.

Handedness and hemispheric specialization do not account for directional bias presented in the SNARC experiments; the effect does not reverse for left handed participants, or when participants perform the task with the hands crossed (Dehaene et al., 1995). On the other hand, spatial scanning habits formed during learning how to read and write may account for the SNARC effect. For example, Berch, Foley, Hill, & Ryan (1999) showed that the SNARC effect as found in parity judgments does not appear in children before the third grade (although this may be due to the specific task demands, for discussion see Fias & Fischer, 2005).

Moreover, cross-cultural evidence suggests that directionality of different writing systems influences the properties of the mental number line: Dahaene found a change in the left-to-right SNARC effect in Farsi speaking French participants, who use the right-to-left writing system (1993), and Zebian has recently demonstrated a reverse-SNARC effect with right-left directionality in Arabic speaking monoliterates, a weakened reverse-SNARC effect in Arabic-English biliterates and no effect in illiterate Arabic speakers (Zebian, 2005). In addition, Ito and Hatta (2004) have replicated the SNARC effect (left-to-right) in Japanese participants, but have also observed a vertical SNARC effect in the same participants; subjects responded faster to large numbers with the top choice than with the bottom choice, whereas the reverse pattern was found for small numbers.

The aim of the present study is twofold. First, we investigate the hypothesis that people use spatial coordinates when they reason about temporal order, in a similar way to the automatic stimulus-response compatibility effects observed in numerical reasoning (the SNARC effect). We predict a systematic compatibility effect between response side (left or right) and temporal order (earlier or later), one that could be named the STARC effect (Spatial-temporal association of response codes). According to this prediction, English speakers will consistently react faster to earlier events when using the left response-side, and to later events when using the right response-side.

Previous studies have extended the SNARC effect found in numerical reasoning to other ordinal sequences, such as letters of the alphabet and months of the year (Gevers, Reynoveot , & Fias, 2003). In our study, the stimuli were pictures showing different temporal stages of everyday actions and events (see Table 1). We were interested in whether people would automatically access spatial information even when making on-the-fly judgments about these novel and purely non-linguistic stimuli. Ordinal sequences like numbers, letters of the alphabet, and months of the year are overlearned sequences in our culture and are often presented in left-to-right orders in graphs, time-lines, and other diagrams. Would participants automatically form left-to-right representations even for these new sequences of events that they have not necessarily seen laid out from left to right?

Second, and maybe more importantly, we explore the possibility that this effect is influenced by the cultural artifact of writing direction. Hebrew, as other Semitic languages, is written from right to left. Thus, we predict a reverse-STARC effect for native Hebrew speakers, with consistently faster temporal order judgments when the response to an earlier event is made with the right side key than when it is made with the left side key.

Methods

Participants 38 Stanford University undergraduate students participated in the experiment in exchange for course credit or payment (20 Males, $\underline{M}_{age}$= 21.03, $\underline{SD}_{age}$=1.16). They were all native English speakers, and none of them were proficient in a language with a right to left writing direction (according to self report in a language experience questionnaire). 37 Tel-Aviv University students were paid to participate in the experiment (18 Males, $\underline{M}_{age}$= 24.95, $\underline{SD}_{age}$=2.58). They were all native Hebrew speakers, though they all reported a proficiency level in English of above 3 on a 1-5 scale. However, none of the participants in the Hebrew speaking group learned English before the age of 8, or lived in a foreign country before that age. All the participants were right handed.

Materials and Design Materials used in this study consisted of 18 triplets of pictures depicting an object, person, animal or plant in three stages in time: 'early', 'middle' and 'late'. For example, one triplet represented a banana being eaten, such that the 'early' picture depicted a whole banana, the 'middle' picture a half-peeled banana, and the 'late' picture – just the peel. The pictures were chosen to represent a range of temporal intervals: 9 of the 18 picture triplets depicted short intervals, i.e actions that take a short time to complete, and the other 9 picture triplets represented actions that take a number of hours, days, months or even years to complete (see Table 1 for examples of the two categories).

Table 1: Stimuli examples

	Short intervals	Long intervals
Early		
middle		
Late		

Procedure Participants were tested individually in a quiet experiment room, where they were seated in front of an IBM ThinkPad T43 laptop computer (15″). Both English and Hebrew speakers completed the same experimental task, but read instructions in their native language at the beginning of each block.

Participants were presented with 2 testing blocks, each consisting of 72 trials. Overall, each of the 'earlier' and 'later' pictures appeared twice in every block. Each block started with 10 randomized practice trials; the participants received feedback about their performance during the practice block, but not during the rest of the experiment. The items used in the practice trials were not used subsequently in the testing blocks.

At the beginning of each experimental test trial, the reference (midpoint) picture of each triplet appeared at the center of the screen for 2 seconds, and was then replaced by one of the target pictures (either the 'earlier' or the 'later' picture). Participants were instructed to decide as quickly and as accurately as possible whether the event depicted in the second picture happened earlier or later than the event in the first picture. Participants made their responses by pressing one of two adjacent keys that were labeled with stickers marked as 'earlier' and 'later'. The target picture remained on the screen until a response was made. In one block, the left key was marked as "earlier" and the right key as "later", and in another block this mapping was reversed. Each subject completed both blocks, and the order in which the blocks appeared was counterbalanced across subjects.

Data Analysis and Results

The main results of interest are shown in Figure 1.

The responses of 7 participants (4 from the English speaking group and 3 from the Hebrew speaking group) were discarded from analysis due to an exceptionally high error rate (over 40 percent). Error rate in the responses of the remaining 68 participants was 4.2%. The top and bottom 2% of all correct responses were then removed from analysis.

The remaining correct responses were submitted to a 2X2X2 mixed ANOVA, with Language (English/Hebrew) and Block order ('Left is earlier' first/'Right is earlier' first) as between subjects factors, and Key Mapping ('Left is earlier'/Right is earlier) as a within subjects factor. Both English and Hebrew speakers were faster in the key-mapping block congruent with the writing directionality of their native language, as was revealed by a significant Language by Key Mapping interaction: $F1(1, 64)=8.74$, $p<0.01$, two-tailed. Planned paired t-tests showed that English speakers were faster to respond when the 'earlier' response was mapped to the left side and the 'later' response to the right side, relative to the opposite key-mapping; $M_{left\ is\ 'earlier'}$=1183,45, $M_{right\ is\ 'earlier'}$ =1281.92, $t(33)=1.73$, $p<0.05$ (one-tailed).

The opposite pattern was observed in the Hebrew speaking group, with significantly shorter reaction times in the 'right is earlier, left is later' key mapping ($M_{left\ is\ 'earlier'}$=1202.2, MSE = 67.75, $M_{right\ is\ 'earlier'}$ =1109.15, MSE=67.75, $t(33)=2.14$, $p<0.02$ (one- tailed). None of the other main effects or interactions were found to be significant.

The Analysis of variance also revealed a key mapping by order of blocks interaction, $F1(1,64)=13.72$, $P<0.01$, two-tailed. Participants were always overall slower in the first key-mapping block they were presented with, regardless of congruency with writing directionality. Post-hoc paired t-tests revealed, that across language groups this training effect was significant both when the first block was the 'right is early' block ($M_{left\ is\ 'earlier'}$=1111.172, MSE=46.5, $M_{right\ is\ 'earlier'}$ =1240.61, MSE=58.79), $t(33)=2.82$, $p<0.05$, and when the first block was the 'left is early' block ($M_{left\ is\ 'earlier'}$=1274.48, MSE=74.78, $M_{right\ is\ 'earlier'}$=1156.475, MSE=63.8), $t(33)=2.12$, $p<0.05$. None of the other main effects or interactions were found to be significant.

Note that for the by-items ANOVA there were 18 stimuli triplets, that produced 36 comparisons (midpoint-earlier, midpoint-later). The by-items ANOVA confirmed the language by key mapping interaction effect found in the by-subjects analysis; ($F2(1, 34)=141.98$, $P<0.0001$). As in the by-subjects analysis, in the English group RT's were shorter in the 'left is earlier' block ($M_{left\ is\ 'earlier'}$=1178.364, MSE=13.85), $M_{right\ is\ 'earlier'}$ =1287.71, MSE=17.32), $t(35)=7.74$, $p<0.001$, one-tailed), whereas Hebrew speakers were faster in the 'right is earlier' block ($M_{left\ is\ 'earlier'}$=1190.73, MSE=15.24), $M_{right\ is\ 'earlier'}$ =1104.41, MSE=14.995, $t(35)=6.169$, $p<0.001$, one-tailed).

An order by Key Mapping interaction effect was also found to be significant ($F2(1, 34)=79.285$, $p<0.001$). Planned paired t-tests revealed that reaction-times were always shorter in the first block to be administered; when the 'left is earlier' block was administered first, items in this block were responded to slower than items in the 'right is earlier' block ($M_{\text{left is earlier}}=1264.021$, $MSE=15.33$, , $M_{\text{right is earlier}}=1153.378$, $MSE=14.01$, $t(35)=6.27$, $p<0.001$, one-tailed). When the 'right is earlier' block was administered first, the pattern was reversed, with shorter reaction times to the 'left is earlier' block ($M_{\text{left is earlier}}=1102.85$, $SD=92.01$, MSE , $M_{\text{right is earlier}}=1234.624$, $MSE=16.25$, $t(35)=8.191$, $p<0.001$). Again, none of the other main effects or interactions were found to be significant.

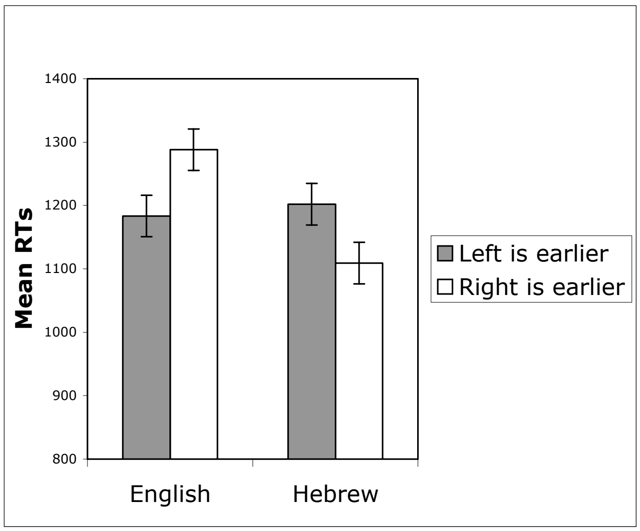

Figure 1: Language by Key Mapping Interaction (By Subjects)

Discussion

In this study we found evidence for a mental time-line that follows writing direction. We found that people automatically created spatial representations for temporal sequences that were shown to them in pictures. Further, the particular layout of the spatial representation for time varied across languages. It appears that the mental time-line extends from left to right for English speakers and from right to left for Hebrew speakers, in both cases following the direction of writing and reading in the two languages.

The present investigation extends findings from numerical reasoning studies to the domain of time. A stimulus-response compatibility effect, the Spatial-Temporal Association of Response Codes ('STARC') was observed, suggesting that participants consistently associated the location of a response-key with the 'location' of an event in time, relative to other events. In other words, people seem to represent time spatially, placing events along a 'mental time-line'.

In this case, the association was observed even when spatial schemas were not used explicitly to represent time, as in graphs, tables, or ordering tasks. This was true even though the spatial location of the response was irrelevant to the task. Further, it appears that spatial association between temporal order and response is not restricted to highly familiar ordinal sequences (like numbers, letters of the alphabet or months of the year). Because we found an STARC effect even with novel (to the subject) sets of pictures it appears that spatial representations for temporal order are created automatically on the fly,

This study also provides additional cross-linguistic evidence in support of the role of language related experience (i.e., reading and writing) in modulating other cognitive processes. Not only does literacy affect performance in space-related tasks, such as picture scanning and causality judgments, it also seem to modulate abstract, temporal reasoning. Repeated, daily, experience with the perceptual-motor schemes of a language seem to provide the speaker with automatic access to the spatial codes conveyed by its writing direction, directing their attention in a vector going from the location where the alphabet usually begins, and in the direction where it usually follows.

In the two language conditions, participants were consistently faster to respond to 'earlier' events when the response was mapped to the side of space where the alphabet sequence in their languages begins. This finding is consistent with Dehaene's suggestion, that the SNARC effect may be accounted for by writing habits (Dehaene, et al., 1993), and with previous findings revealing congruency between language directionality and the directionality of the mental number line found in stimulus-response congruency effects.

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