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Multimodal Influences of Orthographic Directionality on the "Time is Space" Conceptual Metaphor

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Abstract

The present study aimed to test whether the "Time is Space" conceptual metaphor is grounded on the sensori-motor experience of reading and writing. Two groups of participants differing in their directional reading/writing system (Spanish and Hebrew) carried out a time judgment task on auditorily presented words referring either to the past or the future. As expected, our results showed opposite congruency effects in the two groups: Spanish participants were faster responding to past words with their left hand and to future words with their right hand, whereas Hebrew participants showed the opposite pattern. However, contrary to Santiago et al. (2007) with visual stimuli, we did not observe a facilitation effect at the perceptual level: stimulus location (left/right) did not interact with temporal meaning. In two additional experiments, the saliency of the auditory spatial frame of reference was increased, relative to the visual spatial frame, by asking Spanish participants to perform the task blind-folded. Under these conditions, temporal meaning interacted with both stimulus location and response side.

Introduction

If you ask an English native speaker to situate the Big Bang on a horizontal timeline he will certainly point to the leftmost part of it. The opposite should be true if you ask him to point to the Big Crunch.

Santiago, Lupiáñez, Pérez, & Funes (2007) and Torralbo, Santiago & Lupiáñez (2006) demonstrated that this left-past right-future representation of time is psychologically real. They asked Spanish participants to discriminate past and future words (verbs and adverbs) presented to the left or right on the screen by pressing a left or right key. They observed facilitation effects both at perceptual and motoric levels: past words were responded faster when either response or presentation side was on the left and future words when on the right.

This finding can be understood in terms of Conceptual Metaphor theory (Lakoff & Johnson, 1980). Its basic tenet is that abstract concepts need to be grounded on more concrete conceptual domains. According to this theory, all concepts are based on sensori-motor experiences. The representation of a concrete concept such as space is based on our direct experience with space. However, the conceptualization of an abstract concept is more complex. Time, like justice, love, or happiness, cannot be touched, seen, tasted or smelled. To be conceptualized, it is thought that they need to use concrete concepts as structural donors.

It has been hypothesized that the sensory-motor experience responsible for the left-past right-future representation of time is related to the exposure of participants to a left-to-right orthographic system. However, Santiago et al (2007) and Torralbo et al (2006) did not test this hypothesis by comparing left-to-right to right-to-left readers.

Several perceptuo-motor tasks have demonstrated to be sensitive to the reading and writing habits of the participants. As an example, Nachson (1981) showed that English compared to Hebrew and Arab native speakers were more prone to reproduce series of objects from left to right. Chokron & De Agostini (2000) observed that French participants preferred pictures with a rightward direction whereas Israeli right-to-left readers showed the opposite pattern.

The influence of reading habits is also present on higher-order cognitive processes, such as those representing agent-patient relations. Maass & Russo (2003) and Dobel, Diesendruck & Bölte (2007) showed that right-to-left readers, compared to left-to-right readers, tended to represent agents on the right side of patients. This mapping is coherent with the normal agent-patient order of appearance and the direction of writing because all the languages used in these studies mainly use a SVO word order (German, Italian, Arab, and Hebrew).

More akin to the concept of time are those few studies that have investigated the relation of temporal sequences to reading/writing directionality. Tversky, Kugelmass, & Winter (1991) observed that whereas English participants represent graphically a day sequence from left to right (breakfast, lunch and dinner), Arab and Hebrew native speakers tend to do it the other way (dinner, lunch and breakfast). Chan & Bergen (2005, exp. 3) compared English and Chinese (left-to-right readers) to Taiwanese (right-to-left readers) participants in a similar task. The two first groups preferred to arrange sequentially the events from left to right, whereas Taiwanese participants showed a wide variation, including a high proportion of right-to-left arrangements. Fuhrman & Boroditsky (2007), with a less reflexive task, showed that earlier and later in a sequence facilitated left and right manual responses respectively for English speakers and right and left responses respectively for Hebrew participants.

All these cross-cultural studies suffer from some methodological problems. First, with the exception of Fuhrman & Boroditsky (2007), their task is likely to activate a highly conscious problem-solving mode of thought, and therefore, a wide variety of strategies. For this reason we decided to use a highly implicit and automatic task.

Second, in these studies participants were asked to judge relative order of events. We hereby aim to extend these results to stimuli directly referring to the past or to the future, by means of the use of conjugated verbs and temporal adverbs.

Third, they all used the modality of vision, which is involved in reading, mediating by hypothesis the construal of the left-right spatial representation of time. It is possible that the use of the visual modality in these tasks activates the left-right mapping of time. So, we decided to use another modality, audition. The fact that our participants did not have to read the target words also rules out the possibility of spatial biases being induced on the spot by the directional action of reading itself.

Fourth, prior cross-cultural studies only investigated the priming of motor responses, they did not look at how space perception could modulate the semantic access of temporal references, as in Santiago et al (2007). The present study includes this factor.

Experiment 1

Participants from two groups differing in the direction they first learned to read and write (Spanish vs. Hebrew) were asked to judge the temporal reference of words, which were auditorily presented either to the left or right ear (via headphones), by pressing a left or right key.

We predicted that the auditory presentation of words referring to the past or to the future would result in congruency effects between temporal meanings and both stimulus location and response side. At both levels, Spanish participants should show facilitation for the association of past with left and future with right, whereas Hebrew participants should show the opposite pattern.

Participants

Twenty native Spanish speakers living in Spain (16 females, one left-handed, mean age 22.3) and twenty-eight native Hebrew speakers living in Israel (18 females, one left-handed, mean age 26.9) took part in Experiment 1. They all reported to have normal hearing.

Materials

We used the same list of words as in Torralbo et al (2006) for the Spanish group, and their translation for the Hebrew group: 24 words referring to the past (e.g., "hizo" - "עשה" - "he made") and 24 referring to the future (e.g., "hará" - "יעשה" - "he will make").

The word set comprised 18 verbs inflected in either past or future tense, and 6 past and 6 future temporal adverbs (e.g., "antes" - "לפני" - "before"). Eight further words were used for the practice block. Spanish words and instructions were recorded from a female native Spanish speaker, and Hebrew words and instructions were recorded from a female native Hebrew speaker. They were auditorily presented via a Sony headphone set, model MDR-023. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002) and ran in an Intel Pentium IV PC 1.70GHz.

Procedure and design

The procedure for the Spanish and Hebrew groups was identical with the only exception of location (Spain vs. Israel) and language of the target words and instructions (Spanish vs. Hebrew).

The headphone set was fixed on their head before the experiment began. All instructions were given auditorily via the headphones, and participants could press a key ("p" in Spanish or "פ" in Hebrew) if they wanted the instructions to be repeated. When participants were ready, they pushed the space bar to start the experiment. First, a white fixation cross was presented over a black background for 250 ms, followed by a spoken word presented to the left or right ear. Word location was completely orthogonal to temporal reference. Participant's task was to discriminate if the word referred to the past or to the future by pressing "z" or "m" keys in Spanish or their equivalent in Hebrew ("ז" or "צ" keys). The fixation cross remained on screen during word presentation and for a further 4000 ms or until a response was detected. Before the beginning of the next trial, a blank screen was presented for 1000 ms. Reaction time was measured from the onset of stimulus presentation.

The experiment had two blocks, differing in the mapping of the left and right keys to "past" or "future" judgments. The order of blocks was counterbalanced over participants. Within each block, each experimental word was presented once on the left and once on the right location. Participants were allowed to take a break between blocks.

Results

Errors occurred on 507 trials (5.5% of the trials). Correct trials with latencies below 850 ms and above 3000 ms (334 trials, 3.84%) were considered outliers and also discarded from the latency analysis. Two 2 (Group: Spanish or Hebrew) X 2 (Temporal Reference: past or future) X 2

(Target Location: left or right) X 2 (Response Location: left or right) ANOVAs taking both participants (*F1*) and items (*F2*) as random factors were used for the latency and accuracy analyses. In the analyses by participants, Temporal Reference, Target Location and Response Location were all within-subject factors. In the analyses by items, Temporal Reference was a between-items factor while Target Location and Response Location were within-item factors. In both *F1* and *F2* analyses, Group was a between-subjects and items factor.

There were somewhat more errors on future than past words ($F1(1, 46) = 3.41$, $p = 0.071$; $F2 < 1$). Contrary to the Spanish group, Hebrew participants tended to respond more accurately on future than past words ($F1(1, 46) = 8.91$, $p < 0.005$; $F2(1, 92) = 2.28$, $p > 0.1$). No other main effects or interactions were significant (Temporal Reference X Response Location: $F1(1, 46) = 1.67$, $p > 0.1$; $F2(1, 92) = 2.86$, $p = 0.094$; all other *p*s > 0.1).

The ANOVA on latencies showed that Spanish participants tended to respond faster than Hebrew participants ($F1(1, 46) = 3.56$, $p = 0.065$; $F2(1, 92) = 12.35$, $p < 0.001$). Main effects of Temporal Reference, Target Location and Response Location were not significant (all *p*s > 0.1). Responses were faster when the stimulus was presented on the same side of the response ($F1(1, 46) = 18.25$, $p < 0.001$; $F2(1, 92) = 18.83$, $p < 0.001$). All other interactions involving Target Location were far from significance (with all *F*s smaller than or near to 1). The Group factor did not interact significantly with Response Location (both *F*s < 1) but it showed a trend to interact with Temporal Reference ($F1(1, 46) = 14.86$, $p < 0.001$; $F2 < 1$). Whereas Spanish participants responded faster to past tense words, Hebrew participants gave faster responses for future words. This was probably due to the fact that future in Hebrew is marked by a prefix, allowing a faster recognition of the temporal reference for these words. Past words tended to be responded faster with the left hand and future words with the right hand ($F1 < 1$; $F2(1, 92) = 7.42$, $p < 0.01$).

Of central interest for the purpose of this study, there was a clear interaction between Group, Temporal Reference and Response Location ($F1(1, 46) = 5.16$, $p < 0.05$; $F2(1, 92) = 27.18$, $p < 0.001$). Hebrew and Spanish participants showed opposite patterns of congruency between response side and temporal reference: Spanish participants showed the left-past right-future congruency pattern, whereas Hebrew participants responded faster with their left hand to future words and with their right hand to past words (see Figure 1). Planned comparisons demonstrated that this congruency effect was significant for Spanish participants ($F1(1, 46) = 4.571$, $p < 0.05$; $F2(1, 92) = 31.509$, $p < 0.001$) whereas it did not reach significance for Hebrew participants ($F1 < 1$; $F2(1, 92) = 3.097$, $p = 0.082$).

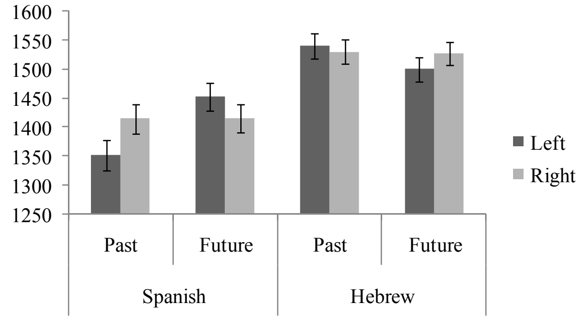

Figure 1. Mean RTs (in ms) for Spanish and Hebrew groups and their left-right responses to past and future concepts in Experiment 1.

Discussion

As predicted by the reading/writing hypothesis, when compared to Spanish participants, Hebrew participants showed a diametrically opposed pattern: they were faster when responding past with their right hand and future with their left hand, whereas the Spaniards replicated prior observations by Santiago et al. (2007) and Torralbo et al. (2006).

This facilitation effect shows for the first time that the temporal meaning of auditorily presented words can activate the left-right mapping of time. It also shows and that the left-right mapping for words intrinsically referring to the past and future is also linked to the participant's directional reading/writing system.

The fact that the congruency effect was weaker with Hebrew native speakers is not a new phenomenon (Tversky et al, 1991) and it may have two possible causes, at least.

First, the Hebrew writing system is not entirely right-to-left: single letters are normally written from left-to-right (Lieblich, 1975), and so are numbers and music notation (Braine, 1968).

Second, all our Hebrew participants were highly proficient in English, which is a left-to-right language. Nachson (1983), using other tasks sensitive to orthographic direction, demonstrated that the introduction of English at school (around the 7th grade) for Hebrew participants could weaken the right-to-left bias and even reverse it.

A question remains: Why we did not obtain a facilitation effect at the perceptual level, as observed with visual stimuli in prior studies? (Santiago et al, 2007; Torralbo et al, 2006). The observed congruency effect between Target Location and Response Location (Simon & Rudell, 1967) rules out the possibility that participants were unable to localize sound sources. A possibility is that the perceptual facilitation effect with temporal words is modality dependent, but this would make difficult to explain our facilitation effect for manual responses.

Working only within the visual modality, Carlson (1999) demonstrated that various spatial frames are activated at the same time and that they compete to serve as the spatial frame of reference, often resulting in an inhibition of the non-dominant spatial frame of reference. Lewald (2007) observed that participants were more accurate to localize sounds when blindfolded, which was due to the fact that the auditory spatial frame was not inhibited by the visual frame of reference in that condition.

Therefore, it is possible that there is a competition between the visual vs. auditory frames of reference for the mental timeline mapping and that the dominant visual spatial frame (Middlebrooks & Green, 1999) inhibits the non-dominant auditory spatial frame of reference.

If this is true, increasing the saliency of the auditory frame and decreasing the saliency of the visual frame should result in a significant interaction between Temporal Meaning and Target Location. Otherwise, this interaction should remain non-significant.

Experiment 2

We tried to increase the saliency of the auditory spatial frame of reference in a first group of participants by presenting the words via two external speakers situated on their left and right sides, instead of using headphones. Moreover, in a second group, this manipulation was supplemented by asking the participants to perform the task blind-folded.

We wanted to investigate whether increasing the saliency of the auditory spatial frame alone was enough to convert it in the dominant frame or if it was necessary to decrease the saliency of the visual spatial frame.

Participants

Participants were all native Spanish speakers divided into two groups: thirty-six (31 females, three left-handed, mean age 21.9) for the sighted group and thirty-eight (30 females, four left-handed, mean age 22.5) for the blindfolded group. They all reported to have normal hearing.

Procedure and design

Everything was the same as in Experiment 1, with the following exceptions: headphones were replaced by two external NGS (Sphere 2.0) speakers placed to the left and right of the participants (1 m. away from the screen each) and oriented in their direction. Participants in the second group were blindfolded during all the experiment and the experimenter helped them to get seated and finding the response keys on the keyboard.

Results

Trials on which an error was made (903 trials, 6.36 %) and correct trials with latencies below 850 ms and above 3000 ms (270 trials, 2.03%) were excluded from the latency analysis. The design of the analysis of Experiment 2 was as in Experiment 1, except that the Group factor now referred to sighted and blindfolded participants and that it was a within-item factor in the items analysis.

The analysis of accuracy showed a trend to make less errors on future than past words ($F1(1, 72) = 3.23$, $p = 0.076$; $F2 < 1$). Congruent with the reading/writing hypothesis, there were somewhat more errors on left responses to future words and right responses to past words compared to the opposite ($F1(1, 72) = 2.49$, $p > 0.1$; $F2(1, 46) = 13.05$, $p < 0.001$) and this effect tended to be stronger in the blindfolded group ($F1(1, 72) = 1.06$, $p > 0.1$; $F2(1, 46) = 6.23$, $p < 0.05$). The interaction between Group, Target Location, and Temporal Reference approached significance ($F1(1, 72) = 3.36$, $p = 0.071$; $F2(1, 46) = 3.37$, $p = 0.073$), but planned comparisons for each group showed no significant influences (all *p*s > 0.1). There was an interaction between Target Location and Response Location ($F1(1, 72) = 4.38$, $p < 0.05$; $F2(1, 46) = 7.29$, $p < 0.01$), indicating that the sounds were localized. None of the other interactions or main effects was significant (all *p*s over 0.1).

Latency analyses showed that sighted participants were faster that blindfolded ($F1(1, 72) = 3.79$, $p = 0.055$; $F2(1, 46) = 151.78$, $p < 0.001$) and that past words were responded to faster than future words ($F1(1, 72) = 29.77$, $p < 0.001$; $F2 < 1$). The Response Location by Target Location congruency effect was replicated ($F1(1, 72) = 4.98$, $p < 0.05$; $F2(1, 46) = 7.36$, $p < 0.01$), and it tended to be greater in the sighted group ($F1(1, 72) = 2.86$, $p = 0.095$; $F2(1, 46) = 3.75$, $p = 0.059$). As for the Spanish participants in Experiment 1, participants in Experiment 2 were faster to respond with their left hand to past words and with their right hand to future words ($F1(1, 72) = 4.38$, $p < 0.05$; $F2(1, 46) = 7.29$, $p < 0.01$). This pattern was enhanced in the sighted group ($F1(1, 72) = 1.18$, $p > 0.1$; $F2(1, 46) = 4.34$, $p < 0.05$).

The most important result of this second experiment was the interaction between Temporal Reference, Target Location and Group ($F1(1, 72) = 4.18$, $p < 0.05$; $F2(1, 46) = 2.85$, $p = 0.098$). Planned comparisons showed that the interaction between Temporal Reference and Target Location was significant only within the blindfolded group (blindfolded: $F1(1, 72) = 6.01$, $p < 0.05$; $F2(1, 46) = 4.57$, $p < 0.05$; sighted: both *F*s < 1; see Figure 2).

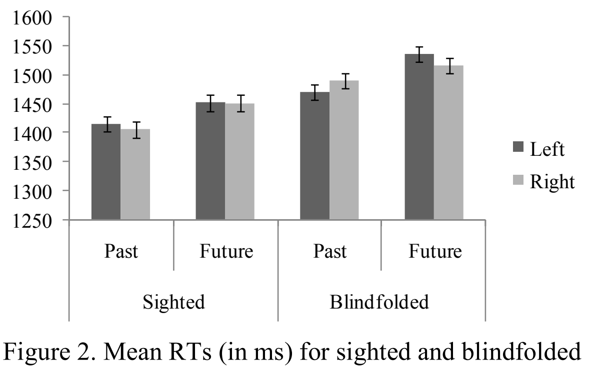

Figure 2. Mean RTs (in ms) for sighted and blindfolded groups and their responses to past and future meanings presented to the left or to the right external speaker in Experiment 2.

Discussion

Results of Experiment 2 were clear-cut. First, we replicated the results observed in Experiment 1 with native Spanish speakers. Our participants showed a left-past right-future facilitation of response codes.

Second, incrementing the saliency of the auditory spatial frame combined with decreasing the saliency of the visual frame of reference succeeded in revealing an auditory spatial modulation of the semantic access for past and future meanings. This result rules out the possibility that the horizontal mental timeline is modality specific. It is important to note that the use of external speakers instead of headphones alone was not sufficient. It was necessary to blindfold participants in order to make them rely on the auditory spatial frame of reference.

General Discussion

Experiment 1 extended previous findings with temporal sequences to words intrinsically referring to the past or future. Such way of referring to time confirmed that the directionality of the orthography a person first learned to read can account for the directionality of the spatial representation of time over the left-right horizontal axis: it flows from left to right for Spanish and in the opposite direction for Hebrew native speakers.

However, Experiment 1 also showed a weaker congruency effect with Hebrew participants compared to their Spanish equivalent. This could be accounted for the fact that the Hebrew writing system is not entirely right-to-left and also for the fact that all our Hebrew participants had learned and frequently used an orthographic system (English) which proceeds in the opposite direction to that of their first language (see the discussion of Experiment 1).

The fact that the left-right mapping of time is accessed in the present studies through a sensory modality (audition) not involved in its development suggests that this mapping is linked to the abstract, amodal concept of time.

A theory proposed by Santiago, Román & Ouellet (submitted) explains how routinary events, such as reading, can affect the way mental models are constructed in order to facilitate our understanding of abstract concepts like time. When reading, events that occur earlier are also generally mentioned earlier in the text (Levinson, 1983), which means more to the left in a left-to-right orthography, and more to the right in a right-to-left orthography. This spatial positioning of events in the text would be transposed to a coherent mental model representation.

This strategy can generalize to other left-to-right mappings, like the arrangement of numbers (the so-called SNARC effect, Dehaene, Bossini & Giraux, 1993), and the arrangement of agents on the left of patients in drawings (Chatterjee, Southwood & Basilico, 1997). In SVO word order languages, agents normally occupy subject position, whereas patients surface in object position (Bock, 1982). In a left-to-right language, the result is that agents are normally written more to the left and patients more to the right. Maximally coherent mental models will arise when agents and patients are placed in the same position they are normally situated in the text. Reversals in these arrangements are expected when the orthography runs in the opposite direction (see Zebian, 2005, for numbers; Maass & Russo, 2003, and Dobel, Diesendruck & Bölte, 2007, for agent-patient organization).

Contrary to Santiago et al. (2007) with visual stimuli, stimulus location in Experiment 1 failed to interact with temporal meaning. Experiment 2 permitted to show that this was due to a competition between visual and auditory spatial frames of reference in which the auditory spatial frame of reference was not salient enough to win.

Experiment 2 also showed that the visual frame of reference is much stronger than the auditory spatial frame. Even if the visual frame was not relevant to the task at hand and the auditory frame was made more salient, the visual frame still remained dominant. Only when the use of the visual frame was completely prevented by asking our participants to perform the task blindfolded, was the location of the auditory stimulus able to interact with temporal meaning.

To conclude, present results support the idea that time is conceptualized as a horizontal left-right mental line, which flows in a direction consistent with the direction of reading/writing. They also support that this mental line is of a central nature: it is not linked exclusively to either perceptual or motoric codes, and it can be accessed through both the visual and auditory modalities.

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