Research Article

A Multisensory Interaction Effect in the Conceptual Realm of Time

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Abstract. Recent studies on the conceptualization of abstract concepts suggest that the concept of time is represented along a left-right horizontal axis, such that left-to-right readers represent past on the left and future on the right. Although it has been demonstrated with strong consistency that the localization (left or right) of visual stimuli could modulate temporal judgments, results obtained with auditory stimuli are more puzzling, with both failures and successes at finding the effect in the literature. The present study supports an account based on the relative relevance of visual versus auditory-spatial information in the creation of a frame of reference to map time: The auditory location of words interacted with their temporal meaning only when auditory information was made more relevant than visual spatial information by blindfolding participants.

Keywords: conceptual metaphor, time, semantics, spatial cognition, multisensory integration, auditory perception

Time Flows in Writing Direction

In left-to-right writing cultures, a common way to graphically map time is over a horizontal axis in which past is mapped more to the left and future more to the right (e.g., years on the *x*-axis in charts increase from left to right, comic strips run in the same direction, and advertisements presenting two photographs of the same person before and after a treatment will normally locate them on left and right space, respectively).

Research on the conceptualization of time demonstrated that this mapping of time is psychologically real. Torralbo, Santiago, and Lupiáñez (2006, Exp. 2) and Santiago, Lupiáñez, Pérez, and Funes (2007) used a congruency task in which Spanish participants performed a temporal judgment with their left or right hand on temporal words (past or future conjugated verbs and temporal adverbs), presented visually either on the left or right side of the screen. Congruency effects were found both for response side and stimulus location: On both dimensions, past words were faster on the left and future words on the right (see also Weger & Pratt, 2008).[1] Santiago, Román, Ouellet, Rodríguez, and Pérez-Azor (2008) extended these results to everyday action sequences such as preparing a car trip, and Ulrich and Maienborn (2010) did the same to whole sentences. Ouellet, Santiago, Funes, and Lupiáñez (2010a) further demonstrated that past and future concepts could orient visuo-spatial attention accordingly to this left-to-right mental mapping.

Cross-cultural studies suggest that such a representation may be the result of habitual exposure to a directional orthographic system. When asked to represent graphically a temporal sequence, like "breakfast/lunch/dinner" (Fuhrman & Boroditsky, 2010, Exp. 1; Tversky, Kugelmass, & Winter, 1991), left-to-right readers tend to organize events as running from left to right, whereas right-to-left readers tend to do the opposite (see also Chan & Bergen, 2005, Exp. 3). What is more, when asked to make a fast temporal judgment on an event compared to another in a temporal sequence, English and Hebrew native speakers showed opposite patterns. In accord with the direction of the writing system they first learned, Hebrew native speakers, contrary to English participants, showed faster left- and right-hand responses to "later" and "earlier" events, compared to the opposite (Fuhrman & Boroditsky, 2010, Exps. 2 and 3).

Ouellet, Santiago, Israeli, and Gabay (2010b), following Santiago, Román, and Ouellet (2011), suggested that this left-right mapping of time may be the result of the close correlation between the spatial characteristics of the activity of reading and the time of described events in the text. For pragmatic communicative reasons, events are normally referred to in chronological order (Levinson, 1983). Therefore, when reading a left-to-right written text, past events will be located to the left and future events to the right. This spatial positioning of events in the text would then permeate the mental model representation of text meaning.

[1] The congruency effect between temporal meaning and screen location only approached significance in Santiago et al. (2007), but it was clearly significant in Torralbo et al. (2006).

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Is the Horizontal Representation of Time of Central Nature?

On a different note, findings on embodiment research (e.g., Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005) show how parts of the sensory-motor activity involved in the development of a concept are integrated into a simulation when the same concept is called upon. For the left-right spatial representation of time, it would mean a reactivation of the sensory-motor experience of reading, which is mostly visual in nature. If so, a question arises concerning the modality independence of the left-right mapping of time. If this representation of time depends on a reactivation of visual experiences, is this representation of a central nature or sensory-motor dependent?

Practically all the studies investigating the psychological reality of the left-right mapping of time used visual paradigms and very little is known about this mapping within other modalities. What is more, cross-modal studies like that of Alais, Morrone, and Burr (2006) demonstrated that the processing of certain auditory- or visual-modality-specific stimuli could resort to modality-dependent attentional mechanisms. Therefore, testing the left-right mapping of time in a modality not involved in the activities of reading and writing becomes central.

Ouellet et al. (2010b) considered the modality of audition as the best test bed because reading-writing directional habits cannot possibly correlate with left-to-right or right-to-left auditory stimulation. In their study, participants had to judge the temporal meaning of words (past or future conjugated verbs or adverbs of time) auditorily presented via headphones. This paradigm also permitted to avoid an induction of the left-right spatial representation of time by the action of reading itself.

Ouellet et al. (2010b) demonstrated that, as with written words (Santiago et al., 2007; Torralbo et al., 2006, Exp. 2), auditory temporal words could activate congruent manual responses (see also Ishihara, Keller, Rossetti, & Prinz, 2008). In their study, they also tested whether the spatial localization of sound origin would interact with temporal word meaning. To do so, they presented the words dichotically (to the left or right ear). Contrary to Torralbo et al. (2006, Exp. 2) and Santiago et al. (2007) with visual stimuli, there was no trace of an interaction between the left or right stimulus location and past or future reference. Interestingly, this occurred in the context of a congruency effect between word location and response side (Simon & Rudell, 1967), which rules out that participants were unable to localize sound origin, and opened the possibility that temporal concepts could not be mapped onto auditory locations.

An interpretation of these results (Ouellet et al., 2010b) would be that the left-right mapping of time is not of a central nature. In other words, it would mean that this spatial representation is associated to modality-specific attentional mechanisms (e.g., Alais et al., 2006). The reason why a significant congruency effect was found for manual responses would be due to the fact that, when writing, hand movements are, by definition, following the direction of the orthographic system. The correlation between the direction of the writing action and the chronological appearance of described events (Levinson, 1983) in the text would then merge into a motor-dependent left-right representation of time.

Nevertheless, a recent study by Lakens, Semin, and Garrido (2011) demonstrated that auditory, and not only visual locations, could interfere with temporal judgments. They asked their participants to judge on which side (left or right) the binaural presentation of a temporal word was louder. On critical trials, the temporal word was presented equally loud on both channels. On these trials, participants showed a significant tendency to judge future words louder on the right, even if the meaning of the words was irrelevant to the task.

The biggest differences between Ouellet et al.'s (2010b) and Lakens et al.'s (2011) studies are in the mapping of the response keys and in the nature of the task they used. In Ouellet et al. (2010b), participants had to respond on two keys aligned on a horizontal axis ("z" and "m"), whereas the alignment was vertical ("t" and "v") in Lakens et al. (2011). We strongly believe that this difference between both procedures did not influence the mapping of time onto auditory locations since Torralbo et al.'s (2006) demonstrated that the use of horizontally aligned keys favored the mapping of past and future concepts onto left and right perceptual locations, respectively. In any case, we decided to use the same mapping of response keys as in Ouellet et al. (2010b). Should the alignment of response keys be the cause, no interference of sound origin on temporal meaning should be observed.

We consider the differences in the nature of the task used as a better candidate. Whereas participants in the Ouellet et al.'s (2010b) study were asked to judge the temporal meaning of words while ignoring their auditory-spatial location, participants in Lakens et al. (2011) were asked to judge the auditory properties (localizing the louder side) of the signal while ignoring the temporal meaning of the words. In other words, participants in Ouellet et al. (2010b) were asked to focus their attention on the temporal meaning of words while ignoring auditory-spatial information, whereas it was the opposite in Lakens et al.'s (2011) study.

Does it mean that the mapping of time on auditory versus visual locations is working differently? In an auditory task, is it necessary to focus attention on the spatial locations, instead of on the temporal meaning?

The Hypothesis of the Relative Relevance of Auditory and Visuo-Spatial Information

An alternative explanation would be that the key factor is the relative relevance of auditory versus visual spatial information for the creation of the spatial frame of reference used to map time. Torralbo et al. (2006) investigated the projection of time onto two different spatial frames of reference, back-to-front and left-to-right horizontal axes. They observed that, when the two frames were available, only the more relevant frame for the task at hand was used for the mapping of time, never both at the same time. A similar phenomenon might happen between modalities, mapping time onto a frame in the more relevant modality, and thereby excluding the frame in the less relevant modality.

Studies on cross-modal integration describe how attention, when firstly attracted by an auditory signal, is normally transposed onto a visual location because vision is more reliable than audition in localization tasks (see Witten & Knudsen, 2005, for a review). The result is a topography of the visual space on which sound sources are mapped. Nevertheless, in some circumstances, audition is more precise and therefore more relevant than vision in localizing, as when looking for a sound origin in the dark (Knudsen & Brainard, 1995). In such circumstances, sound origin is mapped onto an auditory topographic map (e.g., Lewald, 2007).

According to our hypothesis, the same would happen with the left-right representation of time. Because vision is better than audition in spatial processing (Middlebrooks & Green, 1991), a frame based on visual real-world coordinates instead of auditory ones would be used to map time. A consequence of this visual mapping would be a null interference effect between sound origin and temporal meaning. The reason why this process did not occur in Lakens et al. (2011) would reside in the fact that they made the auditory-spatial domain more relevant than the visual one by asking their participants to discriminate between auditory locations. Their task favored the creation of an auditory-spatial frame on which time was mapped.

We aimed at investigating this hypothesis by asking our participants to perform the same task as in Ouellet et al. (2010b), but blindfolded. As argued earlier, circumstances in which auditory compared to visual spatial information is made more relevant, as when depriving participants from vision (Knudsen & Brainard, 1995; Lewald, 2007), should foster the mapping of time onto an auditory frame. The result, in that case, should be a modulation of temporal judgments by sound origin, as in Lakens et al. (2011).

Experiment

Participants

Thirty-eight native Spanish speakers (30 females, four left-handed, mean ages 22.5) from the University of Granada received course credit as incentive. None of them ever learned a right-to-left written language. They were all reported to have normal hearing and normal vision.

Materials

We used the same Spanish materials from Ouellet et al. (2010). The word set (see Appendix) comprised 18 verbs inflected in either past or future tense, and six past and six future temporal adverbs (e.g., "antes" – "before"). Eight further words were used for the practice block. Words and instructions were recorded from a female native Spanish speaker. Two external NGS (Sphere 2.0) speakers were placed to the left and right of the participants, 1 m away from the screen and oriented toward the participant. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002) and ran in an Intel Pentium IV PC 1.70 GHz.

Procedure and Design

Every detail of the procedure was kept identical to the Spanish group in Ouellet et al. (2010b), with the following exception: headphones were replaced by the two external loudspeakers and participants were blindfolded before entering the room.[2] They stayed blindfolded during all the experiment and the experimenter helped them to get seated and to find the response keys on the keyboard.

All instructions were given auditorily via the external loudspeakers, and participants could press a key ("p") if they wanted the instructions to be repeated. When participants were ready, they pushed the space bar to start the experiment. First, 250 ms of silence preceded a spoken word, which could be presented through the left or right loudspeaker. Word location was completely orthogonal to temporal reference. The participant's task was to discriminate whether the word referred to the past or to the future by pressing the "z" or "m" keys. After a response was detected or a maximum of 4,000 ms elapsed, 1,000 ms of silence followed before the beginning of the next trial. 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. All in all, the experiment consisted of 192 experimental trials and lasted about 25 min.

Results

Error trials (490 trials, 6.38%) and correct trials with latencies below 850 ms and above 3,000 ms (137 trials, 1.91%) were excluded from the latency analysis (see Table 1). These cutoff points were the same as in Ouellet et al.'s (2010) study and were established after inspection of the RT distribution. Latency and accuracy were analyzed by means of two ANOVAs (taking participants (F1) and items (F2) as random factors) crossing Temporal Reference (past or

[2] Two (unpublished) control experiments were run in our laboratory to test: (1) whether the presentation of words via external loudspeakers instead of headphones and (2) whether removing the visual fixation stimulus would be able to reintroduce the interaction between temporal meaning and left and right auditory locations that Ouellet et al. (2010) failed to observe. Neither factor changed the observed pattern of results. Thus, the key manipulation in the present experiment was to blindfold participants.

Table 1. Mean latency (ms) and percent errors (parentheses) per condition for the factors Response Location, Target Location, and Temporal Reference

		Temporal Reference	
Response Location	Target Location	Past	Future
Left	Left	1,460 (6.29)	1,554 (5.5)
	Right	1,477 (6.66)	1,545 (7.87)
Right	Left	1,481 (8.03)	1,517 (4.29)
	Right	1,502 (7.32)	1,490 (3.71)

future) × Target Location (left or right) × Response Location (left or right). 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 whereas Target Location and Response Location were within-item factors.

The analysis of accuracy showed fewer errors on future than past words, significant by participants only, $F1(1, 72) = 4.468$, $p < .05$; $F2 < 1$. There was also a trend to make fewer errors with the right than the left hand, $F1(1, 37) = 2.595$, $p > .1$; $F2(1, 46) = 3.1$, $p = .085$. Consistently with the left-right conceptual metaphor of time, there were somewhat more errors on left responses to future words and right responses to past words compared to the opposite, $F1(1, 37) = 2.4$, $p > .1$; $F2(1, 46) = 24.762$, $p < .001$. The congruency effect between Target Location and Response Location was significant by items only, $F1(1, 72) = 2.807$, $p > .1$; $F2(1, 46) = 6.831$, $p < .05$. None of the other interactions or main effects approached significance (all ps > .1).

Latency analyses showed that past words tended to be responded to faster than future words, $F1(1, 37) = 12.156$, $p < .01$; $F2 < 1$. As in Ouellet et al. (2010b), past and future words facilitated left and right responses, respectively (marginally by participants, $F1(1, 37) = 3.155$, $p = .084$; $F2(1, 46) = 14.123$, $p < .001$; see Figure 1.

The most important result was the now significant interaction between Temporal Reference and Target Location, $F1(1, 37) = 9.645$, $p < .01$; $F2(1, 46) = 4.566$, $p < .05$;

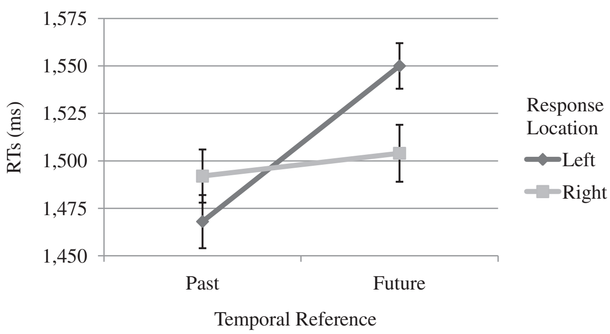

Figure 1. Mean RTs (ms) for left-right responses to past and future words.

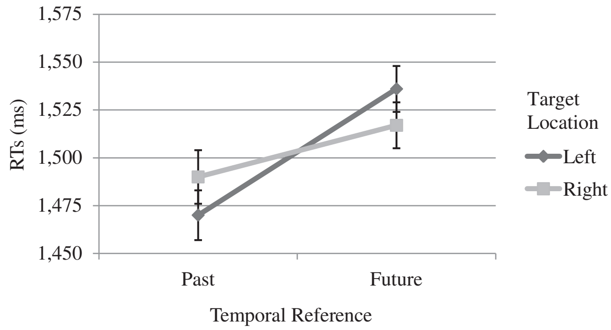

Figure 2. Mean RTs (ms) when perceiving past and future words to the left or right.

see Figure 2. None of the other interactions nor any other main effects were significant (all Fs smaller than or nearer to 1 and ps > .1).

Discussion

Apart from replicating the congruency effect between Temporal Reference and Response Location, as observed with the Spanish participants in Ouellet et al. (2010b), the deprivation of vision in our experiment allowed the emergence of a congruency effect with auditory-spatial locations. As it was previously observed with written words (Santiago et al., 2007; Torralbo et al., 2006, Exp. 2), participants were faster when the words presented on their left referred to the past and when the words presented on their right referred to the future, as compared to the opposite. This interaction occurred despite the fact that our participants had to make a judgment on temporal meanings instead of auditory-spatial locations (Lakens et al., 2011).

General Discussion

As discussed in the Introduction, the spatial representation of time is thought to originate from a correlation between time and the reading-writing activity (i.e., past events are usually mentioned earlier than future events, what causes a trend to locate the former to the left of the latter on the page in left-to-right scripts, whereas the opposite occurs in right-to-left scripts). An advantage of using audition to study the central nature of this mapping resides in the fact that audition cannot be involved in this correlation. On the one hand, research with visual paradigms reported both left and right motor responses and spatial perception congruency effects with past and future concepts (Santiago et al., 2007; Torralbo et al., 2006, Exp. 2). On the other hand, research with auditory paradigms demonstrated that auditory temporal stimuli could prime motor responses as visual temporal stimuli do (Ishihara, Keller, Rossetti, & Prinz, 2008; Ouellet et al., 2010b), but the results were mixed for the perceptual level. While Ouellet et al. (2010b) failed to obtain a perceptual congruency effect, Lakens et al. (2011), with a task making auditory-spatial information more relevant, could observe it. Here we investigated whether these contrasting results were due to the auditory dimension not being relevant enough in Ouellet et al.'s (2010b) task.

The results of the present study were clear-cut. First, we replicated the results observed in Ouellet et al. (2010b) with native Spanish speakers regarding left-right response congruency. Our participants showed a left-past/right-future facilitation of response codes. This representation of time linked to the result of an exposure to a directional orthographic system (Ouellet et al., 2010b; Santiago et al., 2011) can generalize to other left-to-right mappings, like the arrangement of numbers (the so-called SNARC effect, Dehaene, Bossini, & Giraux, 1993; Zebian, 2005), or the positioning of agents versus patients in transitive actions (Chatterjee, Southwood, & Basilico, 1997; Dobel, Diesendruck, & Bölte, 2007; Maass & Russo, 2003). Fischer, Mills, and Shaki (2010) have recently provided experimental evidence supporting the causal link between positions of numbers in text and the direction of the SNARC effect.

Second, the present study permitted us to show that the congruency effect between spatial perception and temporal meanings observed with auditory stimuli in Lakens et al. (2011) does not work differently than with visual stimuli (Santiago et al., 2007; Torralbo et al., 2006, Exp. 2). Contrary to Lakens et al. (2011) with auditory stimuli, and like Torralbo et al. (2006) and Santiago et al. (2007) with visual stimuli, our task made participants to focus their attention on the temporal meaning of words instead of on the spatial locations. Auditory relevance was increased by blindfolding participants. The mere fact of being unable to see caused the emergence of the perceptual congruency effect with auditory temporal words. Why should this be so? Our guess is that participants with their eyes open in Ouellet et al. (2010b) mapped time onto a visuo-spatial frame of reference instead of an audio-spatial one, whereas they used an auditory-spatial frame in the present study and in Lakens et al. (2011). This explanation will need more research, but it can be spelled out as follows.

Lewald (2007) provided evidence that, even when vision is *irrelevant* for the task at hand, a sighted person will localize sound origin by computing interaural differences, but also by executing a final calibration at the visual level. A vision deprived group, compared to a sighted group, was more accurate in a sound localization task, which he attributed to this calibration process. When vision is impaired, the mechanism being used for the visual calibration process becomes used for an auditory calibration process. The result is then an auditory topographic map when vision is prevented, but a visual topographic map on which sound origins are transposed when vision is available (Knudsen & Brainard, 1995).

It is also important to note that the mapping of time onto a left-right horizontal axis originates from visual experiences during reading (Chan & Bergen, 2005, Exp. 3; Fuhrman & Boroditsky, 2010; Ouellet et al., 2010b; Tversky et al., 1991). It is possible that such close relationships would also play a role when setting the spatial frame of reference. Vision might, in that case, be a better attractor than audition for the mapping of time.

Both potential causes would result in a preferred spatial mapping of time at a visual level. This would be the case most of the time, even if the spatial task is auditory (Ouellet et al., 2010b). Still, the mapping of time onto auditory spaces would be possible when auditory information is made more relevant than visual spatial information, as when asking participants to perform the task blindfolded (Knudsen & Brainard, 1995). The relevance of the auditory-spatial information could also be increased by means of task requirements, as in Lakens et al. (2011).

A similar explanation could also account for other effects occurring across the modalities of vision and smell or vision and touch, where vision is the dominant modality (Welch & Warren, 1980). Morrot, Brochet, and Dubourdieu (2001) asked expert wine tasters to describe the smell of white and red wine. First, they observed that experts used different terminologies to speak about red or white wine. Second, when white wine was artificially colored red, the experts described their smell using red wine terminology. Another effect is that of judging a bigger object as being heavier, even if the smaller and bigger objects weigh the same (Charpentier, 1891). In these two cases, the hybrid modality mapping of the concept of "wine category" or "weight" would be represented over the dominant mapping only, the visual.

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 code, and it can be accessed through both the visual and auditory modalities. Finally, they show how visual information predominates over auditory information in guiding this conceptual mapping, and how this predominance can be modulated by the relative relevance of vision versus audition.

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References

Alais, D., Morrone, C., & Burr, D. (2006). Separate attentional resources for vision and audition. *Proceedings of the Royal Society B, 273*, 1339–1345.

Chan, T.-T., & Bergen, B. (2005). Writing direction influences spatial cognition. In B. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society* (pp. 412–417). Mahwah, NJ: Erlbaum.

Charpentier, A. (1891). Analyse expérimentale: De quelques éléments de la sensation de poids [Experimental analysis: On some of the elements of sensations of weight]. *Archives de Physiologie Normale et Pathologique, 3*, 122–135.

Chatterjee, A., Southwood, M. H., & Basilico, D. (1997). Verbs, events and spatial representations. *Neuropsychologia, 26*, 284–391.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122*, 371–396.

Dobel, C., Diesendruck, G., & Bölte, J. (2007). How writing system and age influence spatial representations of actions. *Psychological Science, 18*, 487–491.

Fischer, M., Mills, R. A., & Shaki, S. (2010). How to cook a SNARC: Number placement in text rapidly changes spatial-numerical associations. *Brain and Cognition, 72*, 333–336.

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science, 34*, 1430–1451.

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: Evidence for the STEARC effect. *Cortex, 44*, 454–461.

Knudsen, E. I., & Brainard, M. S. (1995). Creating a unified representation of visual and auditory space in the brain. *Annual Review of Neuroscience, 18*, 19–43.

Lakens, D., Semin, G., & Garrido, M. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition, 20*, 437–443.

Levinson, S. (1983). *Pragmatics*. Cambridge, UK: Cambridge University Press.

Lewald, J. (2007). More accurate sound localization induced by short-term light deprivation. *Neuropsychologia, 45*, 1215–1222.

Mass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science, 14*, 296–301.

Middlebrooks, J. C., & Green, D. M. (1991). Sound localization by human listeners. *Annual Review of Psychology, 42*, 135–159.

Morrot, G., Brochet, F., & Dubourdieu, D. (2001). The color of odors. *Brain and Language, 79*, 309–320.

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010a). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance, 36*, 17–24.

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010b). Is the future the right time? *Experimental Psychology, 57*, 308–314.

Pulvermüller, F., Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience, 21*, 793–797.

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*, 512–516.

Santiago, J., Román, A., & Ouellet, M. (2011). Flexible foundations of abstract thought: A review and a theory. In A. Maas & T. Schubert (Eds.), *Spatial dimensions of social thought* (pp. 39–108). Leipzig, Germany: de Gruyter Mouton.

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2008). In hindsight, life flows from left to right. *Psychological Research, 74*, 59–70.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburg, KS: Psychology Software Tools.

Simon, J. R., & Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51*, 300–304.

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30*, 745–757.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology, 23*, 515–557.

Ulrich, R., & Maienborn, C. (2010). Left-right coding of past and future in language: The mental timeline during sentence processing. *Cognition, 117*, 126–138.

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin & Review, 15*, 426–430.

Welch, R. B., & Warren, D. H. (1980). Immediate perceptual response to intersensory discrepancy. *Psychological Bulletin, 3*, 638–667.

Witten, I. B., & Knudsen, E. I. (2005). Why seeing is believing: Merging auditory and visual worlds. *Neuron, 48*, 489–496.

Zebian, S. (2005). Linkages between number concepts, spatial thinking, and directionality of writing: The SNARC effect and the REVERSE SNARC effect in English and Arabic monoliterates, biliterates, and illiterate Arabic speakers. *Journal of Cognition and Culture, 5*, 165–190.

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Appendix

Experimental Materials

Past	Future
ayer (yesterday)	mañana (tomorrow)
anteriormente (previously)	posteriormente (subsequently)
antes (before)	después (after)
antiguamente (formerly)	inmediatamente (immediately)
recientemente (recently)	próximamente (soon)
anteayer (before yesterday)	enseguida (next)
apareció (he showed up)	apareceremos (we will show up)
buscasteis (you-plural looked for)	buscaremos (we will look for)
condujeron (they drove)	conduciremos (we will drive)
creyó (he believed)	creerá (he will believe)
decidisteis (you-plural decided)	decidiréis (you-plural will decide)
dijo (he said)	dirá (he will say)
fue (he went)	irá (he will go)
habló (he spoke)	hablarán (they will speak)
hizo (he made)	hará (he will make)
miró (he looked at)	miraremos (we will look at)
pensaron (they thought)	pensarán (they will think)
preguntó (he asked)	preguntará (he will ask)
probasteis (you-plural tried)	probaréis (you-plural will try)
pudimos (we were able to)	podremos (we will be able to)
quisimos (we wanted)	querremos (we will want)
trabajó (he worked)	trabajará (he will work)
tuvimos (we had)	tendremos (we will have)
vio (he saw)	verá (he will see)

