Research Article

Is the Future the Right Time?

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Abstract. Spanish and English speakers tend to conceptualize time as running from left to right along a mental line. Previous research suggests that this representational strategy arises from the participants' exposure to a left-to-right writing system. However, direct evidence supporting this assertion suffers from several limitations and relies only on the visual modality. This study subjected to a direct test the reading hypothesis using an auditory task. Participants from two groups (Spanish and Hebrew) differing in the directionality of their orthographic system had to discriminate temporal reference (past or future) of verbs and adverbs (referring to either past or future) auditorily presented to either the left or right ear by pressing a left or a right key. Spanish participants were faster responding to past words with the left hand and to future words with the right hand, whereas Hebrew participants showed the opposite pattern. Our results demonstrate that the left-right mapping of time is not restricted to the visual modality and that the direction of reading accounts for the preferred directionality of the mental time line. These results are discussed in the context of a possible mechanism underlying the effects of reading direction on highly abstract conceptual representations.

Keywords: conceptual metaphor, Hebrew, Spanish, time, semantics, spatial cognition, linguistic relativity, writing systems

In order to facilitate our understanding of abstract concepts (e.g., justice, happiness, time), it has been suggested that we need to ground them onto more concrete domains, such as space. This grounding is often called Conceptual Metaphor, a term that refers to the use of a source domain (concrete) to help understanding a target domain (abstract concept). Conceptual metaphors were originally detected in the linguistic analysis of everyday expressions (i.e., "looking *forward* to see you"; Clark, 1973; Lakoff & Johnson, 1980) and the empirical evidence supporting their psychological reality is steadily growing (see, e.g., Meier & Robinson, 2004, for emotional concepts; or Schubert, 2005, for social power). Many abstract concepts use space as their structural donor (Gentner, Bowdle, Wolff, & Boronat, 2001). Here we will focus on one of those: time. Our goal is to evaluate whether directional reading-writing habits affect the preferred form of the conceptual mapping of time onto space: left-to-right or right-to-left.

Directional reading habits have been shown to influence performance in several perceptuo-motor tasks. Native users of a left-to-right orthographic system probably never noticed that they prefer paintings, portraits, and pictures with a rightward direction (Chokron & De Agostini, 2000; Gaffron, 1950; Nachson, Argaman, & Luria, 1999). In contrast, readers of right-to-left orthographies such as Arab and Hebrew show the opposite preference (Chokron & De Agostini, 2000; Nachson et al, 1999).

When bisecting lines, French participants are biased to the left whereas Israelis are biased to the right (Chokron & De Agostini, 1995). Korean participants having learned to read in a vertical top-to-bottom right-to-left direction, compared to their peers having learned to read from left to right, tended to place their drawings more to the left on the page (Barrett, Kim, Crucian, & Heilman, 2002). Moreover, the left-to-right bias in inhibition of return normally found with English speakers is reversed in native Arab speakers (Spalek & Hammad, 2005).

Nachson (1981) compared Hebrew and Arabic native speakers from Israel with English native speakers from Europe and America in a task involving the reproduction from memory of a horizontal series of objects presented visually. When they reproduced the series, English participants proceeded more often from left to right, whereas Arabic participants tended to proceed from right to left. Hebrew speakers were somewhere in between, a result which has been observed in several other studies (e.g., Tversky, Kugelmass, & Winter, 1991). The difference between Arabs and Hebrews is thought to be due to the fact that the Hebrew orthography is not a completely right-to-left system: Words are written and read from right to left, but single letters are frequently written from left to right (Lieblich, Ninio, & Kugelmass, 1975). Moreover, the numerical system as well as the musical notation runs from left to right (Braine, 1968). Importantly, the differences between left-to-right and right-to-left readers found in some of these studies are stronger in young children and start to weaken around the seventh grade, coinciding with the learning of a new language at school, English. Nachson (1983) investigated whether the introduction of this left-to-right language was the origin of the effect. He compared a group of young English-Hebrew bilinguals from Israel with young English and Hebrew monolinguals. As predicted by the reading-writing habits hypothesis, bilingual young children (from grade 1 to 6) showed a pattern more similar to seventh grade children (when English is introduced at school) than age-matched monolingual participants.

Overall, directional biases linked to reading direction in perceptuo-motor tasks have been interpreted as the result of the habitual direction of perceptual scanning (as when reading or interpreting charts) or performing actions (as in writing). The evidence about the effect of reading habits on higher-order cognitive processes is less clear, and its interpretation more complex. Chatterjee, Southwood, and Basilico (1997) showed that English participants tend to represent agent-patient actions with the agent to the left of the patient. Mass and Russo (2003), and Dobel, Diesendruck, and Bölte (2007) showed that Arabs (vs. Italians) and Hebrews (vs. Germans) tended to place agents on the right side of the patient. However, Altmann, Saleem, Kendall, Heilman, and Gonzalez Rothi (2006) did not find traces of such contrasting preferences when comparing a group of Arabic to a group of English native speakers, nor did Barrett et al. (2002) when comparing their left-to-right and right-to-left reading groups of Korean participants. Contrary to Chatterjee et al. (1997), both English and Arab participants in Altmann et al. (2006) study tended to place agents on the right. They interpreted this right spatial bias as the result of the left hemisphere advantage for language processing. Nevertheless, because their English participants were living in Saudi Arabia, we think that their interpretation should be reconsidered. It has been discussed earlier that the exposure of right-to-left readers to a left-to-right orthography can change and even invert their pattern of response (Nachson, 1983). The opposite could also be true: an inversion of the effect for English readers being exposed to Arab language. A similar problem was also present in the Barrett et al. (2002) study. Even if their Korean top-to-bottom right-to-left readers learned to read and write this way in first place at school (during the Japanese occupation), they had been exposed all the rest of their life to a left-to-right orthographic system.

A second conceptual domain in which spatialization has been shown to be affected by reading habits is the number mental line. Dehaene, Bossini, and Giraux (1993) reported an association between small numbers with left space and large numbers with right space, what they called the "Spatial-Numerical Association of Response Codes" (the SNARC effect). In their final experiment, they found that the SNARC is reduced and even disappears when Persian-French bilingual participants are tested (Persian is written from right to left). Using monolingual Arabic speakers, Zebian (2005) was able to find a complete reversal of the SNARC effect. Moreover, she also found a reduction of the effect in English-Arabic bilinguals, and no effect in illiterate Arabic monolinguals.

Currently, that the mental representation of the abstract concept of time also resources to a left-to-right spatial axis is a well-established notion. Centrally presented words referring to the past and to the future (verbs and adverbs) are able to orient visual attention (Ouellet, Santiago, Funes, & Lupiáñez, 2009) and prime motor responses (Ouellet, Santiago, Funes et al., 2009; Santiago, Lupiáñez, Pérez, & Funes, 2007; Torralbo, Santiago, & Lupiáñez, 2006; Weger & Pratt, 2008) in correspondence with the habitual reading and writing direction of the participants: past words facilitate left space, and future words facilitate right space. Moreover, presenting these words on the left or right side of a fixation point also interacts with their temporal meanings (Santiago et al., 2007; Torralbo et al., 2006). Finally, Santiago, Román, Ouellet, Rodríguez, and Pérez-Azor (2008) extended those results to naturalistic event sequences shown by means of silent movie clips and photograph series. These findings suggest that the concept of time is mapped onto a horizontal axis running from left to right, as expected from the reading habits hypothesis, but do not rule out the possibility that these results are due to universal perceptual, motoric, or cerebral factors.

Some evidence already points to the fact that at least some aspects of the spatialization of time are not universal and do indeed vary across cultures. Looking at other spatial mappings in which time partakes, Núñez and Sweetser (2006) reported that, contrary to Spanish native speakers, Aymara speakers both speak and gesture about time as if the future is located behind them and the past in front of them. Casasanto et al. (2004) studied how distance and quantity information could modulate the estimation of time across four different cultural groups. Their study showed that English and Indonesian participants (who mainly use the "Time as Distance" metaphor in their native language) were only influenced by physical distance in a time estimation task, whereas Greek and Spanish participants (who use more often the metaphor "Time as Quantity" in their native language) were only influenced by physical quantity in the same task. Boroditsky (2001) found that, contrary to English speakers, Mandarin speakers responded faster to temporal questions when primed by vertical displays compared to horizontal displays, a pattern congruent with the more frequent use of vertical metaphors in Mandarin than in English (however, this study has proven difficult to replicate, see Chen, 2007; January & Kako, 2007, what suggests that its conclusions should be taken with great care). Finally, Boroditsky (2008) showed that Mandarin and English speakers tend to spatially organize temporal sequences in ways that depend on the proportion of space-time linguistic expressions in use in their corresponding language.

Given these signs of cultural flexibility in temporal conceptual mappings, and the evidence linking the spatialization of agent-patient structure and number sequences with the directionality of reading habits, the domain of time seems to be a prime candidate to be similarly affected by those habits. If the influence of reading habits generalizes to the temporal domain, it may be a sign of the workings of a common underlying mechanism. The question of what may have in common agent-patient structure, number sequence, and time that makes them all similarly amenable to be affected by the directionality of reading habits arises as an intriguing and theoretically fruitful question (in the Discussion section we will briefly explore a possible answer).

However, those few studies that so far have directly addressed this question used temporal order judgment tasks only and never used other modality than vision. Tversky et al. (1991) asked English, Hebrew, and Arab participants to represent graphically a day sequence (breakfast, lunch, and dinner) by placing three stickers on a board. English participants majoritarily used a left-to-right arrangement, Arab participants used a right-to-left arrangement, and Hebrew participants lay somewhere in between. Chan and Bergen (2005, Exp. 3), using a similar procedure, reported that English and Chinese participants consistently preferred left-to-right arrangements of events, whereas Taiwanese participants, who habitually read Chinese from top-to-bottom and right-to-left, showed a wide variation, including a high proportion of right-to-left arrangements.

The prior studies suffer from a methodological problem: Their task is likely to activate a highly conscious problem-solving mode of thought, and therefore, a wide variety of strategies. So far, the only relevant report using a more automatic and implicit task is Fuhrman and Boroditsky (2007). They used triplets of pictures, each representing different stages of an event ("early", "middle", and "late"). In each trial, their participants were presented with the "middle" picture as reference point followed by either the "early" or "late" picture, and were asked to make a temporal judgment ("earlier" or "later"). The results showed that earlier and later in a temporal sequence facilitated left and right manual responses, respectively, for English speakers and right and left responses, respectively, for Hebrew participants.

The main goal of the present investigation is to widen the empirical base of a putative effect of reading habits on the conceptualization of time. Moreover, we do so improving on several aspects of prior studies. Firstly, the present task is highly implicit and automatic and, therefore, more likely to be free of strategic biases. Secondly, prior cross-cultural studies investigated the representation of time by means of tasks that resource to a sequence of events. In other words, participants were asked to judge relative order of events. We aim to extend these results to stimuli directly referring to the past or to the future. To do so, we used words with an intrinsic temporal reference (conjugated verbs and temporal adverbs) as in Santiago et al. (2007) and Torralbo et al. (2006) studies, with two different groups of participants, Spanish and Hebrew native speakers.

Note also that all prior studies that investigated the left-right horizontal axis mapping of time used visual tasks. This is the same modality which is thought to be involved in the construal of the left-right spatial representation of time, vision (when reading, writing, looking at graphs, comics, gestures, etc.). It is perhaps possible that the use of the visual modality in these tasks activates the left-right mapping of time. In the case of those studies using printed words (e.g., Santiago et al., 2007; Torralbo et al., 2006) the directional action of reading might itself constitute an additional source of spatial biases. In order to provide a clearer test of preferred thought strategies, we decided to present stimuli in another modality, audition. Participants were asked to judge the temporal reference of auditorily presented words, to either the left or right ear (via headphones), by pressing a left or right key.

Firstly, we expected to replicate previous findings in the Spanish group (Santiago et al., 2007): They should be faster processing past words presented on the left ear and responded to with the left hand, as well as future words presented and responded on the right. Secondly, Hebrew participants should show the opposite pattern at both levels (perceiving and responding): They should show facilitation for the association of past with right and future with left.

Experiment

Participants

Participants were divided into two groups: 20 native Spanish speakers living in Spain (16 women, one left-handed, mean age 22.3 years) and 28 native Hebrew speakers living in Israel (18 women, one left-handed, mean age 26.9 years). 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 (see Appendix): 24 words referring to the past (e.g., "dijo" – "he said") and 24 referring to the future (e.g., "dirá" – "he will say"). It is important to note that the formation of the future tense in Hebrew and Spanish is considerably different. In Spanish, an inflexional ending (agreeing with the elliptical subject in person and number) is added to the verb stem, whereas in Hebrew, it is via a prefix (agreeing with the subject in person, number, and gender) added to the verb stem ("א" – "I will"; "י" – "he, they will"; "נ" – "we will"; "ת" – "she, you will").

The word set 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. 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 1.70 GHz.

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).

Participants sat in a quiet room in front of a computer at approximately 60 cm from the screen. 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" key in Spanish or "ז" or "צ" key in Hebrew. Spanish and Hebrew response keys occupy similar locations in their keyboards. The fixation cross remained on screen during word presentation and for a further 4,000 ms or until a response was detected. Before the beginning of the next trial, a blank screen was presented for 1,000 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.

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

			Group	
Temporal reference	Response location	Target location	Spanish	Hebrew
Past	Left	Left	1328 (6.05)	1538 (3.89)
		Right	1376 (4.85)	1543 (4.04)
	Right	Left	1435 (7.1)	1550 (3.29)
		Right	1393 (7.35)	1510 (2.79)
Future	Left	Left	1433 (6.15)	1489 (6.68)
		Right	1472 (6.45)	1510 (7.25)
	Right	Left	1430 (5.05)	1553 (6.46)
		Right	1399 (5.05)	1502 (4.86)

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. Each block consisted of 16 practice and 96 experimental trials. The experiment lasted about 15–20 min.

Results

Errors occurred on 507 trials (5.5% of the trials). Correct trials with latencies below 850 ms and above 3,000 ms (334 trials and 3.84%) were considered outliers and also discarded from the latency analysis.[1] Results are summarized in Table 1. Two 2 (Group: Spanish or Hebrew) × 2 (Temporal Reference: past or future) × 2 (Target Location: left or right) × 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, $F1(1, 46) = 3.412$, $p = .071$; $F2 < 1$. Contrary to the Spanish group, Hebrew participants tended to respond more accurately on future than past words, $F1(1, 46) = 8.914$, $p < .005$; $F2(1, 92) = 2.275$, $p > .1$. There were no significant interactions (Group × Response Location: $F1(1, 46) = 2.063$, $p > .1$; $F2(1, 92) = 1.932$, $p > .1$; Temporal Reference × Response Location: $F1(1, 46) = 1.666$, $p > .1$; $F2(1, 92) = 2.863$, $p = .094$; Group × Temporal Reference × Response Location: $F1(1, 46) = 1.012$, $p > .1$; $F2(1, 92) = 1.51$, $p > .1$; Group × Response Location × Target Location: $F1(1, 46) = 1.192$, $p > .1$; $F2(1, 92) = 1.219$, $p > .1$; Temporal Reference × Response Location × Target Location: $F1(1, 46) = 1.507$, $p > .1$; $F2 < 1$; all other Fs < 1).

The ANOVAs on latencies showed that Spanish participants tended to respond faster than Hebrew participants, $F1(1, 46) = 3.562$, $p = .065$; $F2(1, 92) = 12.346$, $p < .001$. Main effects of Response location, $F1(1, 46) = 1.056$, $p > .1$; $F2(1, 92) = 2.7$, $p > .01$, Temporal Reference, $F1(1, 46) = 2.441$, $p > .1$; $F2 < 1$, and Target Location (both Fs < 1) were not significant. Responses were faster when the stimulus was presented on the same side of the response, $F1(1, 46) = 18.247$, $p < .001$; $F2(1, 92) = 18.828$, $p < .001$. All other interactions involving Target Location were far from significance (Target Location × Group, $F1(1, 46) = 2.085$, $p > .1$; $F2(1, 92) = 1.566$, $p > .1$, all other Fs smaller than or near to 1 and ps > .1). The Group factor did not interact significantly with Response Location ($F1$ and $F2 < 1$) but it showed a trend to interact with Temporal Reference, $F1(1, 46) = 14.86$, $p < .001$; $F2 < 1$. 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, $F1 < 1$; $F2(1, 92) = 7.425$, $p < .01$.

Of central interest for the purpose of this study, there was a clear interaction between Group, Temporal Reference, and Response Location, $F1(1, 46) = 5.156$, $p < .05$; $F2(1, 92) = 27.181$, $p < .001$. 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, $F1(1, 46) = 4.571$, $p < .05$; $F2(1, 92) = 31.509$, $p < .001$, whereas it did not reach significance for Hebrew participants, $F1 < 1$; $F2(1, 92) = 3.097$, $p = .082$.

[1] Although 850 ms may seem a too high minimum cut-off value, it should be noted that reaction times are measured from the beginning of auditory presentation of stimuli. Materials were majoritarily bi- or trisyllabic, and grand average reaction time in correct trials was 1494 ms.

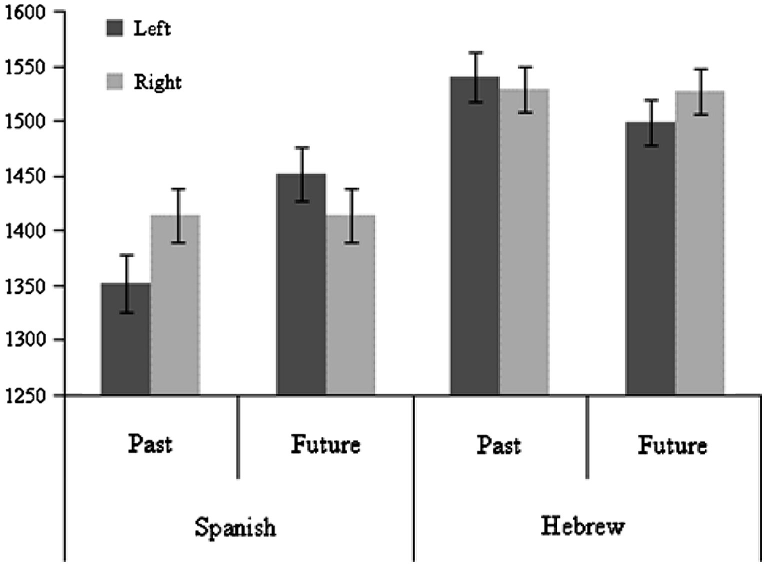

Figure 1. Mean RTs (in ms) for Spanish and Hebrew groups and their left-right responses to past and future concepts.

Discussion

Our results were clear-cut. Spanish participants showed facilitation when responding to past words with their left hand and future words with their right hand. This pattern replicates in the auditory modality prior results by Santiago et al. (2007) and Torralbo et al. (2006) using visual presentation of words.

Of greater interest, Hebrew participants showed the opposite pattern. Their responses were faster when responding to past with their right hand and future with their left hand, supporting the hypothesis that the spatial grounding of time along the horizontal left-right axis is linked to the habitual direction of reading and writing. Note also that our participants did not have to read the target words and all instructions were auditorily presented, which rules out the possibility of spatial biases being induced on the spot by the directional action of reading, and suggests a deeper influence of reading habits on spatial construals of abstract meanings.

The fact that the congruency effect was weaker with Hebrew participants compared to their Spanish equivalent is congruent with previous findings comparing English to Hebrew participants (e.g., Tversky et al., 1991). This is probably due to the characteristics of the Hebrew writing system, which is not entirely right to left (see Introduction), and also to the fact that all our Hebrew participants have learned and frequently used an orthographic system (English) which proceeds in the opposite direction to that of their first language (Nachson, 1983). This was not the case for our Spanish participants (none of them read or wrote a right-to-left writing language).

It is still unclear why we did not obtain a facilitation effect at the perceptual level, as it was observed with visual stimuli in prior studies (Santiago et al., 2007; Torralbo et al., 2006). One explanation relates to the more complex computation needed by sound localization, often resulting in a null effect on spatial tasks (Spence & Driver, 1994). However, if this were the case, it would be difficult to explain how we obtained a congruency effect between Target Location and Response Location (Simon & Rudell, 1967). Another possibility is that the perceptual facilitation effect with temporal words is modality dependent.

However, our guess is that the auditory spatial frame of reference created by the left or right presentation of auditory stimuli was not salient enough to counteract the visual frame of reference. Studies on the selection of spatial frames of reference show competition between simultaneously active frames (e.g., Carlson, 1999). Consistent with this possibility, recent research from our laboratory demonstrates that incrementing the saliency of the auditory frame of reference by instructing participants to perform the task blindfolded results in a facilitation effect at the perceptual level as well (Ouellet, Santiago, & Román, 2009).

To conclude, present data using a paradigm which makes simultaneously salient both spatial and temporal dimensions show that the direction of habitual reading and writing is able to bias how time is mapped onto a left-right mental line: the preferred mapping runs in the same direction as the orthographic system. Why should this be the case? Santiago, Román, and Ouellet (2009) suggest a possible mechanism. Under their mental model theory of abstract reasoning, people build mental models in order to support comprehension and thought. Such models include all the elements (both structure and content) needed to solve the problem at hand, and they are constrained to be maximally internally coherent. When mental models are built from text in a left-to-right orthography, entities are mentioned literally from left to right. A strategy that helps building a maximally coherent mental model for such a situation is, therefore, to place their referents from left to right in mental space. Due to pragmatic constraints, events that occur earlier are usually mentioned earlier (Levinson, 1983), which in writing means more to the left. The proposed strategy then results in the habit of placing earlier events on left mental space followed by later events being located more to the right.

The same mechanism can readily be extended to explain the left-to-right arrangement of numbers (Dehaene et al., 1993), and even to explain the trend to draw agents on the left of patients, as reported by Chatterjee et al. (1997; see the Introduction). As the languages assessed so far use an SVO word order, and agents typically surface at subject position (Bock, 1982), maximally coherent mental models will arise when agents are placed on the left and patients on the right. Of course, both for time and agent-patient structure, reversals are expected when the written input runs from right to left.

To sum up, the spatialization of event order, number sequences, and agent-patient structure may be the emerging result of a common, underlying strategy of thought, one that intends to fulfill a very global constraint on all mental models: To have a maximal internal coherence.

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References

Altmann, L. J. P., Saleem, A., Kendall, D., Heilman, K. M., & Gonzalez Rothi, L. J. (2006). Orthographic directionality and thematic role illustration in English and Arabic. *Brain and Language, 97*, 306–316.

Barrett, A., Kim, M., Crucian, G.P., & Heilman, K. M. (2002). Spatial bias: Effects of early reading direction on Korean subjects. *Neuropsychologia, 40*, 1003–1012.

Bock, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89*, 1–47.

Boroditsky, L. (2001). Does language shape thought? English and Mandarin speakers' conceptions of time. *Cognitive Psychology, 43*, 1–22.

Boroditsky. L. (2008). Do English and Mandarin speakers think differently about time? In B.C. Love, K. McRae, & V. M. Sloutsky (Eds.), *Proceedings of the 30th annual conference of the cognitive science society* (pp. 427–431). Austin, TX: Cognitive Science Society.

Braine, L. G. (1968). Asymmetries of pattern perception observed in Israelis. *Neuropsychologia, 6*, 73–88.

Carlson, L. A. (1999). Selecting a reference frame. *Spatial Cognition and Computation, 1*, 365–379.

Casasanto, D., Boroditsky, L., Phillips, W., Greene, J., Goswami, S., Bocanegra-Thiel, S., et al. (2004). How deep are effects of language on thought? Time estimation in speakers of English, Indonesian, Greek, and Spanish. In K. D. Forbus, D. Gentner, & T. Regier (Eds.), *Proceedings of the 26th annual conference of the cognitive science society* (pp. 186–191). Mahwah, NJ: Erlbaum.

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: Lawrence Erlbaum.

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

Chen, J.Y. (2007). Do Chinese and English speakers think about time differently? Failure of replicating Boroditsky (2001). *Cognition, 104*, 427–436.

Chokron, S., & De Agostini, M. (1995). Reading habits and line bisection: A developmental approach. *Cognitive Brain Research, 3*, 51–58.

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research, 10*, 45–49.

Clark, H. H. (1973). Space, time, semantics and the child. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 27–63). New York, NY: Academic Press.

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.

Fuhrman, O., & Boroditsky, L. (2007). Mental time-lines follow writing direction: Comparing English and Hebrew speakers. In D. S. McNamara & J. G. Trafton (Eds.), *Proceedings of the 29th annual conference of the cognitive science society* (pp. 1001–1007). Austin, TX: Cognitive Science Society.

Gaffron, M. (1950). Right and left in pictures. *Art Quarterly, 13*, 312–331.

Gentner, D., Bowdle, B., Wolff, P., & Boronat, C. (2001). Metaphor is like analogy. In D. Gentner, K. Holyoak, & B.N. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 199–253). Cambridge, MA: MIT Press.

January, D., & Kako, E. (2007). Re-evaluating evidence for the linguistic relativity hypothesis: Response to Boroditsky (2001). *Cognition, 104*, 417–426.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago, IL: The University of Chicago Press.

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

Lieblich, A., Ninio, A., & Kugelmass, S. (1975). Developmental trends in directionality in drawing in Jewish and Arab Israeli children. *Journal of Cross Cultural Psychology, 6*, 504–511.

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

Meier, B.P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science, 15*, 243–247.

Nachson, I. (1981). Cross-cultural differences in directionality. *International Journal of Psychology, 16*, 199–211.

Nachson, I. (1983). Directional preferences in bilingual children. *Perceptual and Motor Skills, 56*, 747–750.

Nachson, I., Argaman, E., & Luria, A. (1999). Effects of directional habits and handedness on aesthetic preference for left and right profiles. *Journal of Cross-Cultural Psychology, 30*, 106–114.

Núñez, R., & Sweetser, E. (2006). With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science, 30*, 1–49.

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2009). *Thinking about the future moves attention to the right.* doi: 10.1037/a0017176.

Ouellet, M., Santiago, J., & Román, A. (2009). *A multisensory interaction effect in the conceptual realm of time*. Manuscript in preparation.

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., Rodríguez, N., & Pérez-Azor, P. (2008). In hindsight, life flows from left to right. *Psychological Research.* doi:10.1007/s00426-008-0220-0.

Santiago, J., Román, A., & Ouellet, M. (2009). Flexible foundations of abstract thought: A review and a theory. In A. Maas & T. Schubert (Eds.), *Spatial dimensions of social thought*. Mouton de Gruyter. Manuscript in press.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime User's Guide*. Pittsburg: Psychology Software Tools Inc.

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*, 1–21.

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.

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science, 16*, 15–18.

Spence, C. J., & Driver, J. (1994). Covert spatial orienting in audition: Exogenous and endogenous mechanisms. *Journal of Experimental Psychology: Human, Perception and Performance, 20*, 555–574.

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.

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

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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