Time (also) flies from left to right... if it is needed!

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Abstract

The TIME IS SPACE metaphor consists in the use of a spatial mental time line (either left-right or front-back) to represent time. One of the issues still to be resolved is whether these space-time mappings can be automatically activated independently from the goals of the task. Prior attempts to settle this issue have failed to match adequately the temporally relevant and irrelevant tasks. In the present study we presented Spanish verbs and nonverbs conjugated in past and future forms in both a time judgment and a lexical decision task. Results showed that the left-right space-time mapping is only active when the task requires temporal discrimination, speaking against an automatic activation of the mental time line.

Keywords: time; space; mental time line; automaticity; flexibility; embodied cognition; conceptual metaphor.

Introduction

As a response to the symbol grounding problem (Harnad, 1990), the Embodied and Grounded Cognition view (e.g., Barsalou, 1999; Gibbs, 2006; Lakoff & Johnson, 1987) suggests that abstract concepts need to be grounded on concrete domains (i.e., those more directly based on sensory-motor experiences) in order to gain meaning. Under this view, language processing elicits an embodied simulation which is carried on by the very same neural systems used by perception, emotion and action (Barsalou, 2008; Gallese, 2008; Glenberg & Gallese, 2011; Glenberg et al, 2008). When abstract concepts are referred to, such simulation follows the guide of stored mappings between abstract and concrete concepts. One line of support for this idea comes from empirical studies on the abstract domain of TIME, which seems to be grounded on the concrete domain of SPACE. Response time studies have reported interactions between the processing of the temporal reference of words and sentences and a variety of response mappings: lateralized key presses, forward-backward manual movements, vocal responses (e.g., Boroditsky, 2001; Ouellet et al, 2010b; Santiago et al, 2007; Sell & Kaschack, 2011; Torralbo et al, 2006; Ulrich & Maienborn, 2010; Ulrich et al, 2012).

Space-time congruency effects are part of a wide family of studies that manipulate concrete and abstract dimensions in tasks that require elaborating and responding to aspects of the abstract dimension. In this context, modulations due to task-irrelevant concrete dimensions are often found on the processing of the abstract, task-relevant dimension. The resulting metaphoric congruency effect has been interpreted as the index of the use of underlying concrete representations to organize the abstract dimension, as i.e. in the SNARC effect (Dehaene et al, 1993).

Conceptual Metaphor Theory, which has a longstanding support from linguistics and psychological studies (e.g., Boroditsky, 2000; Clark, 1973; Lakoff & Johnson, 1980, 1999; Núñez & Sweetser, 2006; Talmy, 2000), pointed out that our vocabulary about abstract concepts has concrete roots. But one of the most interesting consequences of the empirical findings on conceptual metaphors has been the discovery of the existence of metaphoric mappings not explicitly attested in language (for a review, see Santiago et al 2011). In the last years, the most studied example has been one TIME IS SPACE metaphor, which maps temporal reference onto the left-right horizontal spatial axis. In contrast to the mapping of time onto the front-back axis, which is explicitly attested in many languages (e.g., Sell & Kaschack, 2011; Torralbo et al, 2006; Ulrich et al, 2012), in his review of cross-linguistic space-time metaphors Radden (2004) observed a total lack of linguistic conventions directly referring in speech to a horizontal left-right time dimension. However, we are all used to conventional associations of time as flowing from left to right (or right to left) along a horizontal axis in written language, graphs, and in many types of graphic devices (e.g., comic strips, calendars, etc.).

The interpretation of conceptual congruency effects as indexes of stable semantic memory mappings has been clearly contradicted by recent experimental results. There is evidence in the literature of different degrees of flexibility/automaticity depending on the abstract dimension studied, the task and materials used, the kind of mappings which are evaluated (Santiago et al, 2011). Nowadays, there seems to be a well-motivated support to the idea that conceptual congruency effects could be of a very contextual nature (e.g., Torralbo et al, 2006; Santiago et al, 2008; Santiago et al, 2012; Lakens et al, 2012).

One of the strongest cases of automatic activation has been observed for the mapping of affective evaluation to front-back responses: participants are faster in responding to positive and negative items by pulling and pushing a lever, respectively (e.g., Chen & Bargh, 1999). This occurs not only when the decision is based on the valence of the stimuli, but also when performing a lexical decision task (Wentura et al, 2000) and even a stimulus detection task (Chen & Bargh, 1999), which minimize the task-relevance of the evaluative dimension. In contrast, space-time mappings do not seem to be activated so automatically. Recently, two studies extending prior findings with temporal words (e.g., Santiago et al, 2007) to full sentences have tried to address the question of whether it is possible to observe an automatic activation of the mental time-line in an implicit task, investigating both the left-right (Ulrich & Maienborn, 2010) and the front-back (Ulrich et al, 2012) axes. These studies asked participants to carry out both an explicit temporal judgment task and a sensicality judgment task, observing space-time congruency effects only on the former.

The findings of Ulrich & Maienborn (2010) on the left-right mental time line left open the possibility that participants did not need to process the temporal reference of sentences in the sensicality judgment task. The non-sensical sentences were constructed by matching an agent and an object that do not fulfill the meaning restrictions of the verb (i.e, as in the past sentence "The fir trees have put on their coat while bathing", or in the future sentence "On next Sunday, the town-hall will marry the pea"). In order to judge whether these sentences are sensible or not, participants might have only assessed whether the action mentioned by the verb can be done by the actor (with the object) on the patient. In other words, whether the arguments fulfill the meaning constraints imposed by the verb. In order to control for this possibility, in their study on the front-back mental time line, Ulrich et al (2012) asked participants in the sensicality task to also perform a time judgment for each sentence at the end of the trial. Again, they failed to observe any interaction between response direction and temporal reference.

Several possibilities are left open by these two studies. A first one is that participants split their judgments into two sequential phases: they first focused on assessing meaning consistency, started response, and then assessed whether the sentence referred to a past or future event (in which case, the effect of temporal reference would be missed by the latency measure). A second, and very interesting possibility is that meaning access at sentence level is less automatic than at the word level, because the meaning of the sequence of words needs to be composed into the overall sentence meaning. Finally, it might be the case that the activation of the front-back time line is not automatic, but we cannot still be certain whether this is also the case for the left-right mental time line (due to the methodological concerns discussed above). A more automatic left-right time line would be consistent with findings of automatic activation of left-right space in tasks that required the processing of ordinal sequences (either learned on the spot or previously known) when the order dimension was completely irrelevant for the task (e.g., Gevers et al, 2004; Previtali et al, 2010), as well as with the well-known SNARC effect in parity tasks (Dehaene et al, 1993). It is clear that the issue of automatic activation of the mental time line is still far from being solved.

In our study we wanted to address simultaneously several of these possibilities. We focused on the processing of time-related single words with left and right responding (thereby testing the activation of the left-right mental time line) in both time-relevant and time-irrelevant tasks.

To create our materials, we selected isolated Spanish verbs with an intransitive reading (e.g., "dormir" - to sleep). As Spanish is a pronoun drop language, when these verbs are conjugated in past or future tense, they represent a full sentence (e.g., "durmió" means "He slept"). However, their meaning is acquired in a single fixation and through the activation of a single lexical item. So, the chances of a slower, more compositional comprehension strategy are lower. In order to create the nonwords, we modified the set of verbs by changing only one letter in their morphological stem. Therefore, the nonverbs did not pop out as such (e.g., "dormir" was changed to "dorpir"). Moreover, the nonverbs were also inflected in past and future ("durpió"). In this way, we made sure that in order to distinguish the existing from the non-existing verbs, participants had to pay close attention and deeply elaborate the stimulus. We presented these stimuli in a temporal judgment task (decide whether the stimulus refers to the past or the future; Experiment 1) and in a lexical decision task (decide whether the stimulus is a word or a nonword; Experiment 2) with lateralized manual responses. If the left-right space-time mapping can be activated automatically, both experiments should render significant space-time congruency effects. Otherwise, they should arise only in Experiment 1.

Experiment 1

Experiment 1 used centrally presented Spanish tensed verbs (technically corresponding to full sentences) and nonverbs in an explicit temporal judgment task. Responses were given by means of bimanual lateralized key presses.

Method

Participants 24 Psychology students from the University of Granada (5 males; age range 19-26 y.; 2 left-handed by self-report) participated for course credit. All participants had normal or corrected-to-normal vision and were naive as to the purposes of the experiment.

Materials We selected 148 Spanish verbs which are intransitive verbs, or at least allow a (very common) intransitive use. Such a kind of verbs was chosen because Spanish is a pro-drop language, so the subject of a verb can be dropped from the sentence. Thus, single conjugated intransitive verbs as used here can stand as full, grammatically correct and sensible sentences. In order to create the nonword set, each verb was modified by changing one letter in its stem, with the constraint of resulting in pronounceable phoneme sequences in Spanish.

The 148 verbs and 148 nonverbs were then conjugated in both the simple past perfect indicative and the simple future indicative (all six possible grammatical persons were more or less equally represented over the set). This resulted in 592 experimental stimuli of four types: past and future verbs, and past and future nonverbs. This total set was randomly divided into four lists of 148 stimuli each, avoiding item repetition. For example, from the item "faltar/falbar" the following four third person singular tensed versions were created: "faltó" (past verb), "faltará" (future verb), "falbó" (past nonverb), "falbará" (future nonverb), and each of them was randomly assigned to one of the four different lists. Each list was then composed of 37 items of each of the four stimulus types.

Procedure Stimuli were presented centered on a computer screen (Courier New font, 38 points, lower case), black printed on white background. Participants sat at a distance of 60 cm from the computer screen, and placed their left index finger on the Q key and their right index finger on the 9 key of the numerical keyboard in a standard QWERTY keyboard. The distance between response keys was 32 cm. Each trial began with the presentation of a central fixation cross (500 ms) followed by the target verb, that remained on screen until a response was made. Incorrect trials were followed by a 500 ms red uppercase X at the same location of the stimulus. Each incorrect trial was then followed by a 1000 ms blank screen. Correct trials were followed by a 1500 ms blank screen. Participants were instructed to decide whether the presented verb or nonverb referred to either the past or the future.

The experiment was divided into two blocks of 148 trials (separated by a two minutes break) in which the same list of stimuli were responded to using two different mappings of responses (past/future) to keys (left/right). The order of presentation of the two mappings was counterbalanced over participants. We did not control for factors known to affect word recognition times, such as frequency, length, or age of acquisition, because the theoretically interesting effect is the interaction between temporal reference and response hand when participants process the very same list of stimuli using the two possible response-key mappings. Each block was preceded by a short 4 trials training block using different stimuli. The experiment was programmed and run using E-prime 2.0.

Design and Analysis Data were analyzed using a mixed factorial ANOVA with the within-subjects factors Lexical status (word vs. nonword) x Temporal reference (past vs. future) x Key (left vs. right). Counterbalance was included in the design as a between-subjects factor in order to reduce noise, but because it is of no theoretical relevance, its main effect or interactions are not reported here.

Results

Errors occurred in 6.43% of trials and were analyzed independently. Reaction times (RTs) exceeding 2 standard deviations from each participant's mean were excluded from the analysis, leading to the removal of an additional 12.01% of data.

The ANOVA on RTs revealed a significant main effect of the factor Lexical status ($F(1, 22) = 36.55$, $MSe = 18071.56$, $p < .001$), due to longer latencies for nonwords (1106 ms) than words (989 ms). This result is completely in line with the psycholinguistic literature about the lexicality effect (e.g., Kinoshita el al., 2004; Pagliuca et al, 2010) and shows that participants were unable to focus only on the verb inflection in order to give their responses. There was also a Lexical status x Temporal reference interaction ($F(1, 44) = 13.25$, $MSe = 3451.7$, $p < .01$), due to past words being faster than future words (982 ms vs. 996 ms, respectively), whereas future nonwords were faster than past nonwords (1130 ms vs. 1083 ms, respectively). Finally, and most relevant to current concerns, there was also a significant interaction between Temporal reference and Key ($F(1, 44) = 12.03$, $MSe = 16640.96$, $p < .01$), which showed faster responses to past verbs and nonverbs with the left than with the right hand (1027 ms vs. 1085 ms, respectively; Newman-Keuls $p < .05$) and to future verbs and nonverbs with the right than with the left hand (1004 ms vs. 1075 ms, respectively; Newman-Keuls $p < .05$). This interaction was not modulated by Lexical status ($F(1, 44) = 1.03$, $MSe = 7707.96$, $p = .32$; Word: Past verbs - left hand M = 943 ms, Past verbs - right hand M = 1022 ms, Future verbs - left hand M = 1035 ms, Future verbs - right hand M = 958 ms; Nonword: Past verbs - left hand M = 1111 ms, Past verbs - right hand M = 1150 ms, Future verbs - left hand M = 1116 ms, Future verbs - right hand M = 1050 ms).

The analyses of accuracy revealed only a main effect of Lexical status ($F(1, 22) = 6.03$, $MSe = 2.43$, $p < .05$), which confirmed a greater easiness for participants in processing and responding to words than nonwords (2.1 vs. 2.7 mean errors, respectively).

No other main effects or interactions were significant.

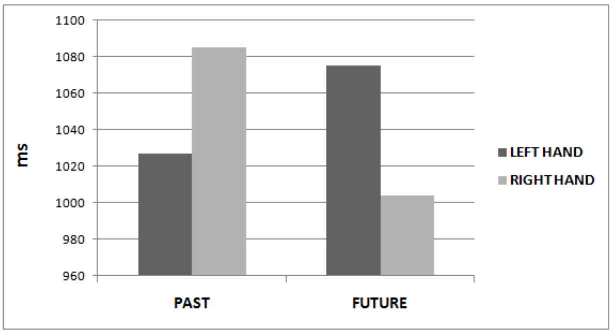

Figure 1. Mean latencies for the factors Temporal reference and Key in Experiment 1.

Discussion

Experiment 1 found a significant interaction between temporal reference of the stimulus and side of response, taking the form of a standard left-right space-time congruency effect: responses to past sentences were faster with the left hand and responses to future sentences were faster with the right hand, independently of their lexicality. These results replicate and extend prior findings in the literature (e.g., Torralbo el al., 2006; Santiago el al., 2007; Ulrich & Maienborn, 2010), suggesting, firstly, that a left-to-right mental time-line have been activated in this task, and secondly, that lexical status does not modulate its activation. In other words, the mental time line is used to process the temporal reference of both meaningful and meaningless words (which are also simple sentences in Spanish).

Experiment 2

Experiment 2 only differed from the prior experiment in the task instructions: participants were asked to decide whether the stimuli were real Spanish verbs or not. Thus, they carried out a lexical decision task for which temporal reference is irrelevant. The design of the experimental materials made sure that temporal reference information was equally present and salient in both the words and the nonwords.

Method

Participants 24 Psychology students from the University of Granada (1 male; age range 20-25 y.; 4 left-handed by self-report) participated for course credit. All participants had normal or corrected-to-normal vision and were naive as to the purposes of the experiment.

Materials and procedure Everything was identical to Experiment 1, with the only exception of the instructions: participants decided whether the stimuli were real Spanish verbs or not.

Design and Analysis

The data were analyzed using a mixed factorial ANOVA with the same factors as in Experiment 1: Lexical status (word vs. nonword) x Temporal reference (past vs. future) x Key (left vs. right) x Counterbalance (not reported further).

Results

Errors occurred in 5.19% of trials and were analyzed independently. Reaction times (RTs) exceeding 2 standard deviations from each participant's mean were excluded from the analysis, leading to the removal of an additional 9.56% of data.

The ANOVA on RTs reported two significant main effects. First, as expected, there was a main effect of Lexical status ($F(1, 22) = 64.84$, $MSe = 4141.01$, $p < .001$): latencies for nonwords (883 ms) were longer than for words (808 ms) as in Experiment 1. Second, the factor Temporal reference ($F(1, 22) = 26.22$, $MSe = 2464.2$, $p < .001$) was also significant, indicating shorter latencies for past (828 ms) than for future verbs (864 ms). No other main effects or interactions were significant in the RTs analyses. Thus, the lexical decision task failed to replicate the Temporal reference x Key interaction obtained in Experiment 1 ($F < 1$; Past verbs - left hand $M = 831$ ms, Past verbs - right hand $M = 824$ ms, Future verbs - left hand $M = 866$ ms, Future verbs - right hand $M = 862$ ms).

An omnibus ANOVA pooling together both experiments with the between-subjects factor Task (temporal vs. lexical) and the same within-subjects factors mentioned above revealed a significant three-way interaction between Task x Temporal reference x Key ($F(1, 46) = 12.59$, $MSe = 8342.15$, $p < .001$). This confirmed that the two tasks generated different patterns of results.

In the analyses of accuracy there was a main effect of Lexical status ($F(1, 22) = 10.28$, $MSe = 2.85$, $p < .01$), which indicated again that words were easier to process than non-words (1.5 vs. 2.3 mean errors, respectively).

No other main effect or interactions were significant.

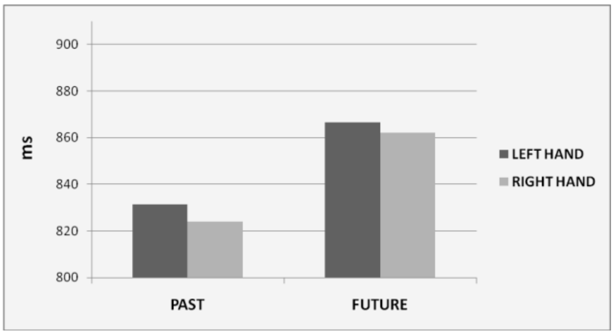

Figure 2. Mean latencies for the factors Temporal reference and Key in Experiment 2.

Discussion

The central observation of Experiment 2 was the absence of interaction between left-right responses and temporal reference. This null result occurred in the context of a very clear and sizeable interaction obtained in Experiment 1 using the same stimuli, procedures and participant population. Therefore, it seems that even when specially designed stimuli are used to make sure that temporal reference is processed, the emergence of a congruency effect between left-right space and time is strongly mediated by the context and the goal of the task: the effect can only be found when temporal processing is task-relevant.

General Discussion

The present study addressed the question of the automaticity of the activation of the left-right mental time-line. In line with prior findings (e.g., Torralbo et al, 2006; Ulrich & Maienborn 2010; Ulrich et al, 2012) there is flexibility, not automaticity, in the activation of the mental time-line(s). Short, single words and nonwords especially designed to secure a deep processing generated a strong space-time congruency effect when participants judged their temporal reference, but failed to do it in a lexical decision task. This result agrees well with the conclusions obtained by Ulrich et al (2012) regarding the front-back time line with longer sentences in German, and corroborates those by Ulrich and Maienborn (2010) regarding the left-right time line without some of their potential confoundings.

Present results are also consistent with the view that, all other factors being equal, only the conceptual mappings that are required to carry out the task are set up in working memory (Santiago et al, 2011). It also agrees well with the flexibility observed in the literature on the automaticity of affordance effects (e.g., Borghi et al, 2012; Natraj et al, 2013).

Obviously, present results leave open many future lines of inquiry, and the issue of the automaticity (or lack thereof) of the activation of the mental time line is still not closed. An important remaining question is whether it is possible to observe the activation of the mental time line in time-irrelevant tasks using different conditions. One interesting possibility has to do with the use of temporal stimuli which have a more direct link to temporal reference, such as dates, months or weekdays. Another possibility is that a more sensitive measure might be able to find the effects (e.g., mouse trajectories). Data are currently being collected about this latter possibility

If the activation of the mental time line remains task-dependent, then there raises the question of why. Other conceptual mappings on the spatial dimension have been shown to be activated automatically at least under certain conditions (e.g., evaluation with approach-avoidance responses, Chen & Barg, 1999; or number magnitude, Dehaene et al, 1993). Space and time seem to be intrinsically linked from the initial stages in development (Piaget, 1969) and the influence of space on temporal judgments in psychophysics tasks remains until the adult age (Casasanto & Boroditsky, 2008; Casasanto et al, 2010). Why then participants do not activate the spatial dimension automatically when processing linguistic stimuli with a temporal reference? Future research needs to address this question.

In conclusion, present results corroborate that the left-right space-time congruency effect is strongly mediated by the context and goal of the task, such that it only arises when the task explicitly requires judging temporal reference.

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