

Do potential past and future events activate the Left-Right Mental Timeline?

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Current evidence provides support for the idea that time is mentally represented by spatial means, i.e., a left-right mental timeline. However, available studies have tested only factual events, i.e., those which have occurred in the past or can be predicted to occur in the future. In the present study we tested whether past and future potential events are also represented along the left-right mental timeline. In Experiment 1 participants categorized the temporal reference (past or future) of either real or potential events and responded by means of a lateralized (left or right) keypress. Factual events showed a space-time congruency effect that replicated prior findings: Participants were faster to categorize past events with the left hand and future events with the right hand than when using the opposite mapping. Crucially, this also occurred for potential events. Experiment 2 replicated this finding using blocks of trials comprising only potential events. In order to assess the degree of automaticity of the activation of the mental timeline in these two kinds of events, Experiment 3 asked participants to judge whether the expressions referred to factual or potential events. In this case, there was no space-time congruency effect, showing that the lateralized timeline is active only when relevant to the task. Moreover, participants were faster to categorize potential events with the left hand and real events with the right hand than when using the opposite mapping, suggesting for the first time a link between the mental representations of lateral space and potentiality.

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A large number of studies support the suggestion by Lakoff and Johnson (1980) that space is used to conceptualize time. Among other possibilities, time can be represented as flowing from left to right in space, at least in languages with a left-to-right orthography (see Santiago, Lupiáñez, Pérez, & Funes, 2007, for Spanish; Tversky, Kugelmass, & Winter, 1991, for English; Ulrich & Maienborn, 2010, for German). Santiago et al. (2007) presented verbs referring either to the future or to the past, and participants categorized their temporal reference by pressing either a left or right response key. Responses were faster when past words were responded to with the left hand and future words with the right hand in comparison to a reversed mapping condition. Space-time congruency effects such as this one have been interpreted as evidence of the use of an underlying left-to-right mental timeline.

Yet, all available studies of the lateralized mental timeline have used past and future factual events. Some studies have used single words (temporal adverbials and tensed verbs: Flumini & Santiago, 2013; Ouellet, Santiago, Israeli, & Gabay, 2010; Santiago et al., 2007; Torralbo, Santiago, & Lupiáñez, 2006; Weger & Pratt, 2008). Others have used short adverbial phrases (Casasanto & Bottini, 2014) or whole sentences (Ulrich & Maienborn, 2010). Still others have used sequences of events which can be objectively placed in temporal succession (Fuhrman & Boroditsky, 2010; Santiago, Román, Ouellet, Rodríguez, & Pérez-Azor, 2010). The aim of the present research is to test whether potential events are also able to activate the left-right mental timeline. To our knowledge, this is the first study to tap directly onto this question.

The ability to represent potential events, both past and future, is central to human cognition. Developmental studies suggest that this ability is reached only after the child enters the formal operational stage (Piaget & Inhelder, 1985). Moreover, children with learning problems often have difficulties in imagining potential events (Schlemenson, 2004). Representing potential events supports the manipulation of alternative scenarios and the evaluation of their consequences in order to make decisions about courses of action (Baumeister & Masicampo, 2010; Hegarty, 2004; Johnson-Laird, 1980). Past potential events are a necessary component of counterfactuals (e.g., “If I had been your father, I hadn't allowed you to do it”; see Gilead, Liberman, & Maril, 2012). They are also related to studies of the processing of negation (as any potential past event is something that did not happen). The mental representation of uncertain and negated events has recently arised strong interest from embodied approaches to language comprehension (Ferguson, Tresh, & Leblond, 2013; Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Orenes, Beltrán, &

Santamaría, 2014; De Vega et al., 2014). If comprehension is mediated by detailed, modal mental simulations of linguistic content, as these approaches propose, uncertain and negated events pose an important theoretical challenge. Kaup et al. (2007) showed that, when the context implies a choice between two alternative events, speakers create a simulation of the negated actions separated from the simulation of the real events. In the same line, De Vega and Urrutia (2012) suggested that negations could momentarily activate a counterfactual representation of the negated events as if they had actually happened, followed by the representation of the real events, and De Vega et al (2014) observed commonalities in the brain activations induced by negations and counterfactuals. These findings suggest that, at least in some contexts, counterfactual and negated events may be internally simulated in the same way as real events are.

Spanish verb forms provide a great opportunity to assess the strength of space as a ground domain of temporal metaphorical mappings when the events are potential. Potentiality is encoded in syntax and morphology in many ways, but a central strategy is by means of verb aspect, in particular, mood. Spanish has a set of verb forms that stereotypically encode potentiality (e.g., for present-future: “Él dormiría” - “He would sleep”, and “(Si) él durmiera...” - “(If) he would sleep...”; for past: “Él habría dormido (si)...” - “He would have slept (if)...” y “(Si) él hubiera dormido...” - “(If) he had slept”) (Ruiz Campillo, 2014). Note that English translations are only approximate, as Spanish verb forms provide clearer information regarding mood than many other languages. For example, the closest English verb form to the Spanish Pretérito Pluscuamperfecto de Subjuntivo (Subjunctive Pluperfect Past, a stereotypical verb form for events that might have happened, but did not; “si yo hubiera sonreído, ella me habría mirado”) is the Third Conditional (“If I had smiled, she would have looked at me”). The English Third Conditional is a complex construction that requires a Past Perfect verb in the conditional clause and a conditional construction in the main clause. Thus, the Past Perfect is used in English for past events occurring before a past reference point both when the event was real as well as when it was potential, and both uses are common. In contrast, the Spanish Pretérito Pluscuamperfecto de Subjuntivo is used preferentially for potential events, thereby providing a clearer potentiality marker. Additionally, Spanish verb endings and auxiliaries provide simultaneously information about potentiality (mood) and time (tense). For example, in “comió” (“he ate”), “-ió” indicates a past factual event. Although verb use in context may sometimes differ from preferred interpretations, Spanish speakers can recognize the stereotypical mood and tense of verb forms in

simple sentences without much context. The present studies used this kind of sentences.

Prior research has shown that the mental simulations of concrete factual events activate a left-right mental timeline. The present study aims to shed light on whether potential events are also mentally arranged along a left-right axis. In order to answer this question, the present study used a standard space-time conceptual congruency task following Santiago et al. (2007). In Experiment 1, factual past and future events were mixed with potential past and future events. Events were presented by means of short Spanish sentences containing a pronoun and a conjugated verb. The conjugation of the verb indicated whether the event was factual or potential as well as whether it was past or future. Participants were asked to categorize all sentences as referring to past or future by means of lateralized left and right keypresses. In one block they used a congruent mapping (left-past right-future) and in another block the mapping was reversed.

EXPERIMENT 1

We expected that potential events would activate the lateralized mental timeline as well as factual events do. Therefore, we predicted an interaction between temporal reference and response side both for factual and potential events. It is important to point out that only the interaction with response side is informative for this prediction. Because the conditions defined by the factors potentiality and time were not matched in stimulus length in characters, word frequency, verb form complexity, verb form frequency, and so on, we cannot make predictions regarding main effects nor interactions between factors other than response side. Time and potentiality are between-item factors, and therefore, their main effects or two-way interaction might arise because of uncontrolled item variables. In contrast, response side is a within-item factor, and therefore, its interaction with either time and/or potentiality cannot be accounted for by differences among items.

METHODS

Ethics Statement. In all the experiments reported in this paper, written informed consent was obtained from all participants. The studies were approved by the Committee for Ethics in Human Research of the University of Granada and the University of La República (Montevideo).

Participants. Twenty eight Psychology undergraduate students (32.5 mean age, one left-handed, 13 women) of the Autonomous University of Barcelona volunteered to participate without any compensation. All of them were native Spanish speakers. We conducted an a priori power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with power ($1 - \beta$) set at 0.90 and $\alpha=.10$, two-tailed, for an effect size of .30. This showed $N=23$ is a sample size big enough to detect a small-sized effect with a 90% probability.

Materials. Verb forms were generated from 20 intransitive regular Spanish verbs conjugated in four paradigms (80 Spanish expressions in total, see Table 1 in the Appendix). No constraints were set on the kind of meanings expressed by these verbs, as they were not relevant to current concerns. We used intransitive verbs to avoid strong feelings of semantic anomaly when those verbs appear in sentences without an object. Sentence length was between 13 and 20 characters. The factual past condition used verbs in Indicative Perfect Past form (“ella despertó” - “she woke up”) and the factual future condition used verbs in Indicative Simple Future (“nosotros dormiremos” - “we will sleep”). The potential past condition used verbs in Subjunctive Pluperfect Past (“él hubiera trabajado” - roughly corresponding to “[if] he had worked”) and the potential future condition used Indicative Conditional (“ella se dormiría” - “she would fall asleep”). Note that the selected verb forms stereotypically mark factuality and potentiality in Spanish. Indicative Perfect Past and Indicative Simple Future stereotypically refer to events which have occurred in the past or will occur in the future, respectively. Spanish Subjunctive Pluperfect Past stereotypically refers to past events that could have happened but have not (thereby past potential events). The Spanish Conditional stereotypically refers to events that will happen in the future if some condition is met, with the condition remaining uncertain (thereby future potential events). Verb forms do not exhaust all the resources available in Spanish to mark the potentiality of an event. For example, potentiality can also be marked by the use of conditional conjunctions (e.g., “if”) or modal phrases (e.g., “it is possible that”, “it’s a fact that”). However, we decided to rely only on verb forms to mark potentiality in order to introduce as few differences as possible with already published studies about the timeline in Spanish using single verbs as stimuli (see Introduction) as well as to expose participants to time and potentiality information simultaneously. Lexical frequency, imaginability (concrete vs abstract words) and phrase length were not strictly controlled because the key contrast of interest in the present design compares the experimental sentences with themselves in two response

conditions (left vs. right hand). In other words, we were not interested in main effects of temporal reference nor potentiality, but in their interaction with responding hand.

Procedure. The experiment was programmed in E-Prime (Schneider, Eschman, & Zuccolotto, 2002) and run in a sound attenuated room. Stimuli were presented at the centre of a computer screen (spanning 6.23° of visual angle, in white letters over a black background). The distance between screen and participant was 0.60 m. One session lasted approximately 20 minutes. Participants pressed a left (“a”) or right (“6”) response keys on a keyboard. The keys were covered by stickers of the same colour. At the beginning of each trial a fixation cross was presented for 500 ms before a randomly chosen sentence appeared on the centre of the screen. It remained on screen until the participant’s response or a maximum time of 4,000 ms. Then there was an interval of 3,000 ms. Wrong responses were followed by a 440 Hz beep that lasted 500 ms. The next trial started 3,000 ms after a correct response or the offset of the auditory feedback.

There were two experimental blocks, one for the congruent time-response mapping and the other for the incongruent mapping. In the congruent condition, participants pressed the left key in response to past verb forms (both real and potential), and the right key in response to future verb forms (both real and potential). In the incongruent condition, this mapping was reversed. The order of blocks was counterbalanced over participants. The whole set of 80 verbal stimuli was used in each block. Before each block there was a practice block of eight trials per condition. Written instructions were presented on screen at the beginning of each block.

Design. Latency and accuracy were analyzed by means of repeated measures ANOVAs including the factors Potentiality (real vs. potential) X Time (past vs. future) X Response side (left vs. right) X Order of conditions (congruent-incongruent vs. incongruent-congruent). The Order of conditions factor was introduced to decrease error variance. However, because of its irrelevance to present hypotheses, its effects and interactions will not be reported further. The design was a factorial design with all factors manipulated within participants.

Open Materials and Data. E-prime programs and full data sets for all the experiments in this study can be downloaded from <https://osf.io/cxjhr/>.

RESULTS

Due to experimenter error, three verbal stimuli in the factual condition (“Nosotros silbamos”, “Nosotros dormimos” and “Nosotros soñamos”) were ambiguous as to their conjugation (they take identical forms in Indicative Past and Present), and were removed. These represented 3.0% (168) of total trials. Response errors occurred on 6.0% (258) of the remaining trials and were excluded from the latency analysis. After discarding wrong item and error response trials, in order to avoid the influence of outliers we excluded latencies below 400 ms and above 3,500 ms, which amounted to discarding an additional 1.5% (62) of correct trials. The cut-offs were set by visual inspection of the reaction time (RT) distribution, at points where it was leveling off, with the preestablished requirement of not leaving out more than 2% of correct trials. The rejection rate was kept constant across experiments. Fixed cut-offs are a standard way to deal with outliers and they have both advantages and disadvantages when compared with other methods (Ratcliff, 1993). They are the method used in many of the prior studies on the timeline for real events (e.g., Santiago et al., 2007; Torralbo et al., 2006). By establishing cut-offs that leave out the same percentage of data points in all experiments, we made sure that the trimming of latencies was consistent across experiments that may have different grand means.

Reaction Time Analysis. Table 2 in the Appendix shows cell mean latencies and number of errors. Centrally for our hypotheses, Time interacted with Response side ($F(1,27)=8.71$, $p=.006$, $\eta^2=.24$). Post-hoc comparisons showed that both the contrast between Past-Left vs. Past-Right ($p<.031$) and between Future-Left vs. Future-Right ($p<.001$) reached significance. Moreover, there was no three-way interaction between Potentiality, Time, and Response side ($F<1$), indicating that the size of the interaction between Time and Response side was the same for both real and potential events. This was supported by independent repeated measures ANOVA analyses of the interaction between Time and Response side for real events ($F(1,27)=8.33$, $p=.008$, $\eta^2=.24$) and potential events ($F(1,27)=7.56$, $p=.01$, $\eta^2=.22$). Figure 1 illustrates these results.

Additionally, there was an interaction between Potentiality and Time ($F(1,27)=7.86$, $p=.009$, $\eta^2=.23$), and no interaction between Potentiality and Response side ($F(1,27)=1.34$, $p=.26$, $\eta^2=.05$). There were significant main effects of both Potentiality ($F(1,27)=6.94$, $p=.01$, $\eta^2=.21$) and Response side ($F(1,27)=5.05$, $p=.03$, $\eta^2=.16$). There was no main effect of Time ($F<1$).

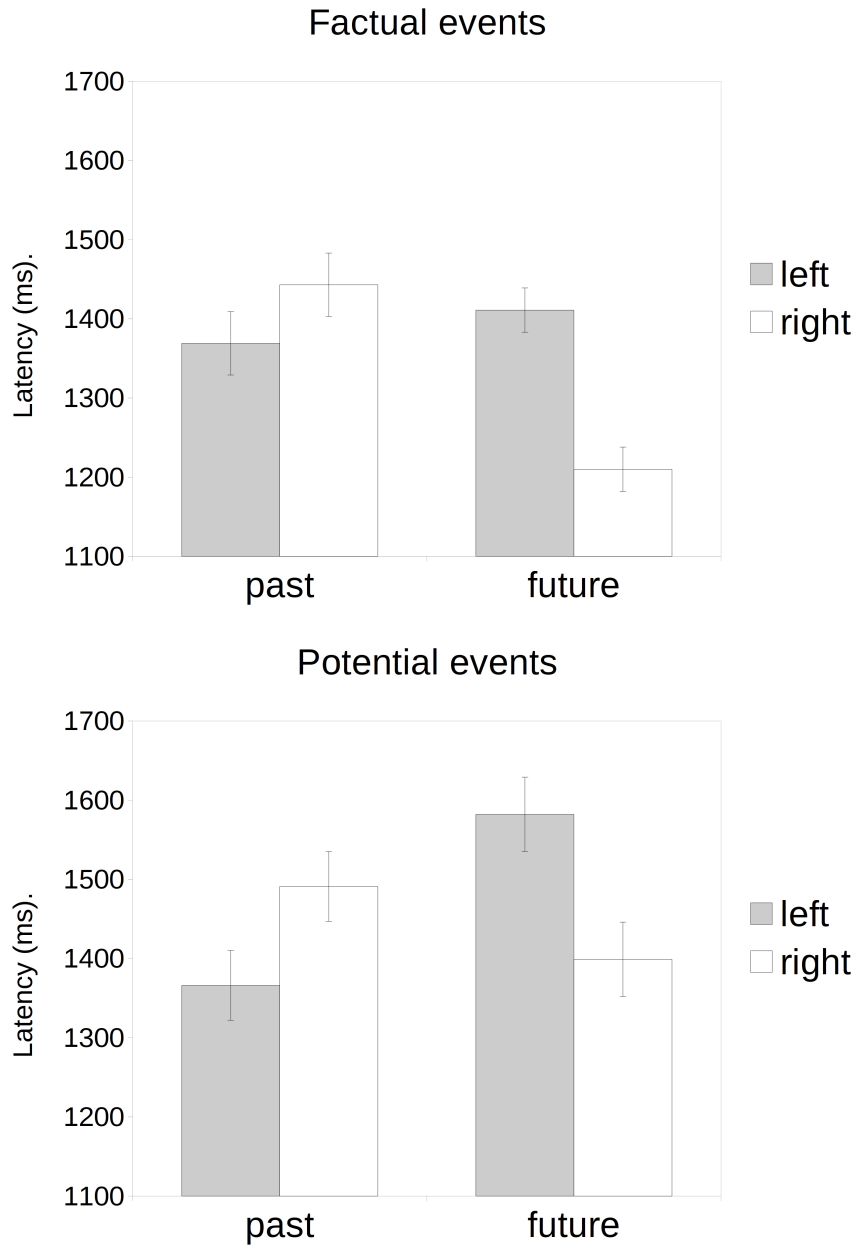


Figure 1. Mean latencies (ms) for factual and potential events in Experiment 1 (error bars show Standard Error of the Mean corrected for within-subject designs following Cousineau, 2005). Participants' task was to judge past versus future reference.

Accuracy Analysis. The interaction between Time and Response side and the three-way interaction between Potentiality, Time, and Response side were non-significant (all $F < 1$). There was also an unexpected interaction between Potentiality and Response side ($F(1,27)=8.18$, $p=.008$, $\eta^2=.23$): accuracy was greater when potential events were responded to with the left hand and factual events with the right hand than when using the opposite mappings. This interaction was not predicted by present hypotheses and constitutes a novel finding. The interaction between Potentiality and Time ($F(1,27)=13.21$, $p=.001$, $\eta^2=.33$) was significant. There were no main effects (Potentiality: $F(1,27)=3.69$, $p=.07$, $\eta^2=.12$; Time: $F < 1$; Response side: $F(1,27)=2.20$, $p=.15$, $\eta^2=.08$).

DISCUSSION

Experiment 1 revealed a space-time congruency effect both for factual and potential events. Participants responded faster to both kinds of events when past was mapped to the left hand and future to the right hand than with the opposite mapping. The size of the effect was the same for both event kinds. This pattern of results suggests that past and future potential events are represented along the left-right mental timeline as well as factual events are.

However, there is an alternative explanation of the interaction between Time and Response side in the processing of potential events. On this account, by intermixing factual and potential trials and assigning response keys to past and future reference throughout the block we may have induced a carry-over of the space-time congruency effect from factual to potential trials. In other words, it is possible that potential trials only showed the left-right past-future congruency effect because they were intermixed with factual trials, which do show the effect.

One way to sort out the carry-over account is to remove the factual trials altogether, keeping only the potential trials. The carry-over account is based on the possibility that factuality would play a role on activating the left-right past-future mental timeline.

Additionally, accuracy data suggested the interesting possibility that potentiality by itself may be able to interact with left-right space, a previously unreported finding. We will delay a detailed discussion of this effect until we explore it further in Experiment 3, where participants were asked to discriminate factual from potential events.

EXPERIMENT 2

The aim of this experiment was to examine whether potential past and future verb forms are able to activate left and right space when presented in a context that does not include factual events. As in Experiment 1, the interaction between Time and Response side was the crucial prediction: we expected that performance would be better in the congruent conditions.

METHODS

Participants. Thirty four Psychology undergraduate students of the Universidad de la República at Montevideo (26.8 mean age, 3 left-handed, 23 women) volunteered without compensation. They were all native Spanish speakers. Because Experiments 2 and 3 worked with the same parameters of Experiment 1, the previously conducted power analysis can also be used to estimate the minimum sample size in them. In both experiments, sample size was greater than this minimum.

Materials and Procedure. Verbal stimuli were the 40 potential expressions of Experiment 1. Conditions regarding sound attenuation, screen size and resolution, and visual angle, were similar to Experiment 1. The procedure was identical to Experiment 1 in all other details.

Design. Latency and accuracy were analyzed by means of a repeated measures ANOVA including the factors Time (past vs. future) X Response side (left vs. right), both manipulated within participants.

RESULTS

Errors occurred on 5.23% (142) of the trials, and were excluded from the latency analysis. After inspection of the RT distribution we excluded correct trials with latencies below 335 ms and above 4,000 ms, what amounted to discarding an additional 1.7% (43 trials).

Reaction Time Analysis. Centrally for the hypothesis, a significant interaction between Time and Response side emerged ($F(1,33)=6.53, p=.02, \eta^2=.17$; see Table 2 in the Appendix). Figure 2 illustrates these results. Post-hoc comparisons showed that both the Past-Left vs. Past-Right ($p=.045$) and Future-Left vs. Future-Right ($p<.003$) contrasts reached significance. We also analyzed together the data from potential trials in the two studies

including Experiment as a factor. In the overall analysis, the interaction between Time and Response side was also significant ($F(1,60)=13.45$, $p=.001$, $\eta^2=.18$). Moreover, the three-way interaction between Time, Response side and Experiment was not significant ($F<1$). Thus, the space-time congruency effect had the same size in Experiments 1 and 2. There was a main effect of Response side ($F(1,33)=5.06$, $p=.03$, $\eta^2=.13$), but not of Time ($F<1$).

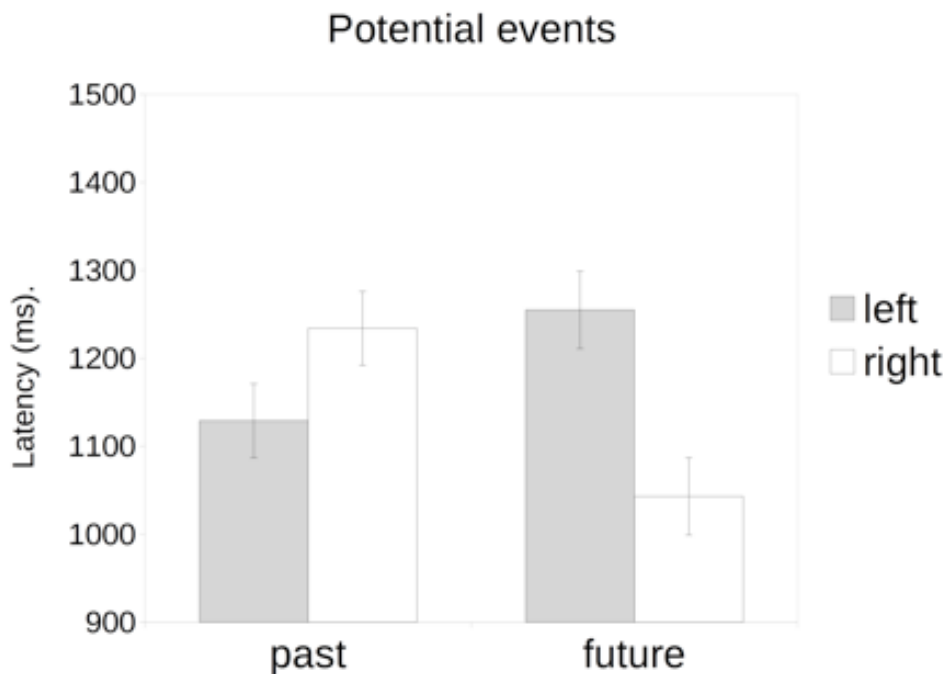


Figure 2. Mean latencies (ms) for potential events in Experiment 2 (error bars show Standard Error of the Mean corrected for within-subject designs, Cousineau, 2005). Participants' task was to judge past versus future reference.

Accuracy Analysis. The interaction between Time and Response side was not significant ($F(1,33)=3.15$, $p=.09$, $\eta^2=.09$). Neither Time ($F<1$) nor Response side ($F(1,33)=1.31$, $p=.26$, $\eta^2=.04$) produced significant main effects.

DISCUSSION

A clear space-time congruency effect was observed when potential past and future events were presented without factual events in the experimental context: participants responded faster when past was mapped to the left hand and future to the right hand, than with the opposite mapping. The size of the effect was not different from that observed in Experiment 1. Therefore, present data rule out the possibility that the congruency effect observed for potential events in Experiment 1 was induced by the presence of factual events in the experimental materials.

The results of Experiments 1 and 2 provide evidence of a genuine space-time congruency effect for potential events. Our final experiment explored the boundary conditions of this effect. Available studies suggest that the activation of the space-time association is not automatic (Ulrich & Maienborn, 2010; Flumini & Santiago, 2013): it is activated only when temporal discrimination is required by the task. In order to assess whether the activation of the left-right timeline is also automatic for potential events, in Experiment 3 we asked participants to judge the potentiality of the events, instead of their reference to past or future. An additional advantage of this manipulation is that it turns potentiality into a task-relevant dimension, thereby increasing its saliency. Under these conditions we will test whether potentiality is able to generate congruency effects with the dimension of space. If the activation of the link between potentiality and space is also non-automatic, it should now generate a significant congruency effect.

EXPERIMENT 3

This experiment had two goals: firstly, to test whether the space-time congruency effect in both factual and potential events can be found when time is a task-irrelevant dimension; and secondly, to test whether there is a space-potentiality congruency effect when potentiality is a task-relevant dimension. We presented the same expressions as in Experiment 1 and asked participants to judge whether each expression referred to a real or potential event.

METHODS

Participants. Thirty new Psychology undergraduate students of the Universidad de la República participated as volunteers (26 mean age, no

left-handers, 25 women). They were all native Spanish speakers and volunteered without compensation.

Materials. Verbal stimuli were the same as in Experiment 1, with four exceptions: Firstly, the ambiguous items in Experiment 1 (“Nosotros silbamos”, “Nosotros dormimos” and “Nosotros soñamos”) were fixed by changing their conjugation from first person plural to third person singular, which is not ambiguous. Additionally, the verb “permanecer” (“to remain”) was replaced by the verb “sonreír” (“to smile”) because by itself “permanecer” does not express a specific event.

Procedure. The procedure followed closely Experiment 1, with the following exceptions. At the beginning of the session, we ensured that participants clearly understood what we meant by factual and potential events by means of an example. Additionally, the practice block was extended to 16 trials per condition. This was because, on pilot testing, the potentiality task was shown to be more difficult than the temporality task. In one mapping condition, participants pressed the left key in response to a factual event and the right key in response to a potential event. In the other mapping condition the assignment was reversed.

Design. Latency and accuracy were analyzed by means of a repeated measures ANOVA including the same factors as in Experiment 1: Potentiality (factual vs. potential) X Time (past vs. future) X Response side (left vs. right).

RESULTS

Errors occurred on 5.4% (257) of the trials, and were excluded from the latency analysis. After inspection of the RT distribution we excluded correct trials with latencies below 450 ms and above 3,200 ms, what amounted to discarding an additional 1.6% (74 trials).

Reaction Time Analysis. Centrally for our concerns, the interaction between Time and Response side disappeared ($F < 1$) and we found an interaction between Potentiality and Response side ($F(1,29) = 6.99$, $p = .01$, $\eta^2 = .19$): responses were faster when potential events were mapped onto the left hand and factual events onto the right hand than when using the opposite mapping. Post-hoc comparisons showed that both contrasts,

Factual-Left vs. Past-Right ($p=.01$) and Potential-Left vs. Potential-Right ($p<.01$), reached significance. Moreover, the three-way interaction between Potentiality, Time, and Response side was also non-significant ($F<1$; see Table 2 in the Appendix). Figure 3 illustrates these results. Additionally, the interaction between Potentiality and Time was replicated ($F(1,29)=11.98$, $p=.002$, $\eta^2=.30$). Potentiality ($F(1,29)=4.51$, $p=.04$, $\eta^2=.14$) produced a main effect, as in Experiment 1. In contrast to that experiment, the main effect of Time was significant ($F(1,29)=18.87$, $p<.001$, $\eta^2=.39$) whereas Response side was not ($F<1$).

We analyzed together the data from Experiments 1 and 3 with the aim of comparing the effects of the type of task (time vs. potentiality judgment) on the interactions between Time and Response side, as well as on the newly found interaction between Potentiality and Response side. The overall two-way interaction between Time and Response side was significant ($F(1,56)=8.55$, $p=.005$, $\eta^2=.13$), and it was modulated by Experiment ($F(1,56)=8.21$, $p=.006$, $\eta^2=.13$), supporting a change in the space-time congruency effect, from being present in Experiment 1 to being absent in Experiment 3. Additionally, the overall two-way interaction between Potentiality and Response side reached significance ($F(1,56)=7.94$, $p=.007$, $\eta^2=.12$), and its interaction with Experiment fell short of it ($F(1,56)=3.52$, $p=.07$, $\eta^2=.06$). The independent analyses of Experiment 1 and 3 reported above support as the most likely conclusion that it was absent in Experiment 1 and present in Experiment 3. Therefore, the task-relevant conceptual dimension in each experiment (time vs. potentiality) interacted with side of response.

This analysis also uncovered some additional effects, which are not central to the concern of this research, as they do not involve interactions with the Response side factor. The overall main effect of Time ($F(1,56)=7.86$, $p=.007$, $\eta^2=.12$) was also affected by the change in task ($F(1,56)=14.75$, $p<.001$, $\eta^2=.21$), in a way that does not lend itself to a straightforward interpretation: it changed from a 25 ms advantage of future over past events in Experiment 1 to a 107 ms advantage of past over future events in Experiment 3. Furthermore, the overall interaction between Potentiality and Time was not significant ($F<1$), because it took opposite shapes in the two experiments ($F(1,56)=18.28$, $p<.001$, $\eta^2=.25$): when participants judged time, future factual events were faster than potential events, but past factual and potential events did not differ; when participants judged potentiality, future factual and potential events did not differ, and past real events were faster than past potential events.

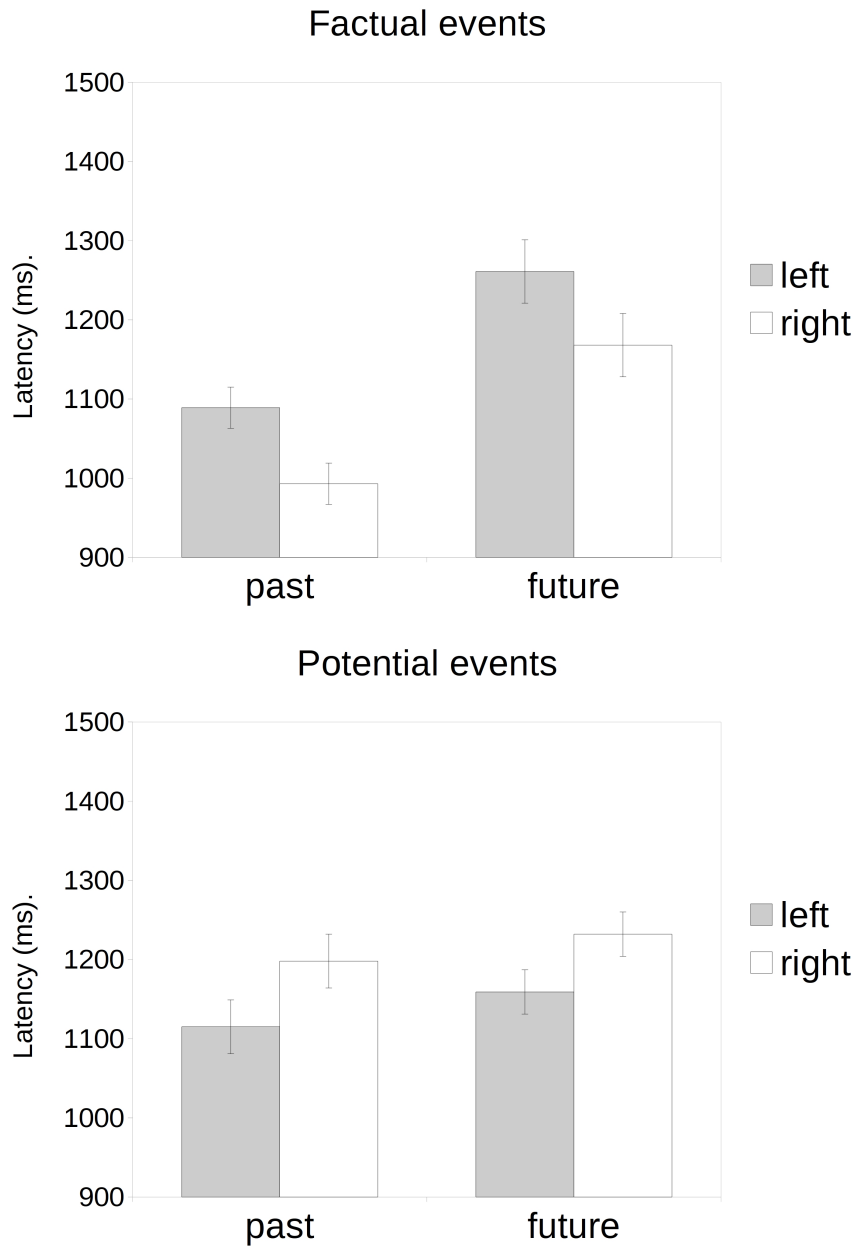


Figure 3. Mean latencies (ms) for factual and potential events in Experiment 3 (error bars show Standard Error of the Mean corrected for within-subject designs, Cousineau, 2005). Participants' task was to judge factual versus potential reference.

Finally, some effects were not affected by Experiment. The overall main effects of Potentiality ($F(1,56)=11.59, p=.001, \eta^2=.17$) and Response side ($F(1,56)=4.19, p=.05, \eta^2=.07$) were significant and remained constant across experiments (Potentiality X Experiment: $F(1,56)=1.44, p=.24, \eta^2=.03$; Response side X Experiment: $F(1,56)=1.98, p=.17, \eta^2=.03$). The overall three-way interaction between Time, Potentiality, and Response direction was not significant, nor did it interact with Experiment (both $F_s < 1$).

Accuracy Analysis. The interactions between Time and Response ($F < 1$), Time, Potentiality, and Response ($F(1,29)=2.52, p=.12, \eta^2=.08$), and Potentiality and Response side were not significant ($F(1,29)=2.65, p=.11, \eta^2=.08$). There was an interaction between Time and Potentiality ($F(1,29)=4.91, p=.04, \eta^2=.15$) and a main effect of Time ($F(1,29)=40.09, p < .001, \eta^2=.58$). The main effect of Response side also failed to be significant ($F(1,29)=3.06, p=.09, \eta^2=.10$).

DISCUSSION

In a task using a potentiality judgment, the latency measure did not detect any space-time congruency effect, neither for factual nor potential events. This result supports the non-automaticity of the activation of the lateralized mental timeline, as suggested by Ulrich and Maienborn (2010). Instead, there was a space-potentiality interaction: participants responded faster when potential events were mapped to the left hand, and factual events to the right hand, than when using the opposite mapping. This interaction was suggested by the accuracy analysis of Experiment 1 and it was confirmed by the overall ANOVA of latency data from Experiments 1 and 3. We discuss this finding in the following section.

Experiment 3 also revealed some intriguing additional findings of the task demands: the change from a time judgment task to a potentiality judgment task reversed the main effect of temporal reference, and affected the shape of the interaction between temporal reference and potentiality. As these effects do not involve interaction with response side they are irrelevant to test the spatial representation of abstract concepts. They could be due to conceptual connections between time and potentiality which are independent from their spatial aspects and somehow dependent on the task-relevance of the conceptual dimensions. Unfortunately, what could be these connections and how they give rise to the observed effects is at present unclear and will need to be explored in more detail in future research.

GENERAL DISCUSSION

Do potential events activate the mental timeline? The present study provided an initial answer to this question: Yes, speakers can map time onto space when processing potential events. Experiment 1 showed that the space-time congruency effect for potential events was indistinguishable from the effect observed for real events. Experiment 2 showed that the effect is genuine and arises even when the experimental materials include only potential events. Finally, Experiment 3 showed that when time becomes task-irrelevant and potentiality becomes task-relevant, the space-time congruency effect vanishes away and is replaced by a space-potentiality effect, such that processing is facilitated when potential events are mapped onto the left hand and factual events onto the right hand (as compared to the opposite mapping). Therefore, both space-time and space-potentiality mappings seem non-automatic and can be modulated by task demands.

This finding is relevant to the debate about the automaticity of congruency effects. The best studied congruency effect related to an abstract concept is the Space Number Association of Response Codes (SNARC), first reported by Dehaene, Bossini, and Giraux (1993). In the SNARC effect small numbers are responded to faster with the left hand and larger numbers with the right hand. It arises in tasks where accessing magnitude information is not relevant (such as deciding whether a number is odd or even). Moreover, the mere perception of a number induces shifts of visual attention toward the left or right depending on its magnitude (Fischer, Castel, Dodd, & Pratt, 2003). However, this finding has been difficult to replicate (Fattorini, Pinto, Rotondaro, & Doricchi, 2015) and the implicitness of the odd-even task is questionable. In this context, present data suggest that other abstract dimensions such as time and potentiality are activated in ways that are clearly non-automatic and depend on their relevance to the task.

Present data thus suggest that a mental timeline is activated both when people represent sequences of factual and potential events, whenever the task does require a consideration of the order of those events. If this interpretation is correct, current findings add to the literature that shows that language comprehension implies the creation of mental simulations of linguistic content (Barsalou, 2003) even when the described events are negated or counterfactual (De Vega et al., 2014). Present findings suggest that these mental simulations not only contain analogical dimensions linked to the internal characteristics of the simulated events, but also represent in

analogical fashion aspects which are external to the events, such as their order or potentiality.

However, while the space-time congruency effect can be interpreted straightforwardly in the current research context, the newly attested space-potentiality effect poses interesting challenges. What could be the causes of the space-potentiality effect? One possibility relies on the inherently predictive character of future events. For instance, speakers of Aymara refer to the future using the word for “back”, and to the past using the word for “front” (Núñez & Sweetser, 2006). These authors suggested that the motivation for this conceptual mapping is the fact that the past can be “seen” clearly, as it has already happened, but the future cannot. Under this account, the potentiality of the future would support mapping both future and potential onto right space in Spanish speakers. However, present data actually show the opposite mapping (potential-left, factual-right), and therefore rule out this account.

An alternative account is based on the polarity correspondence hypothesis proposed by Proctor and Cho (2006). If both potentiality and lateral space can be processed as polar dimensions, with a marked and an unmarked (default) pole, the polarity correspondence hypothesis would predict that processing should be facilitated when the poles of the same sign are mapped onto each other. It seems intuitively correct to assume that the unmarked pole of the dimension of potentiality is the factual pole, and that the unmarked pole of the dimension of lateral space is the right side (at least for right-handers). Therefore, mapping factual on the right and potential on the left would facilitate processing as compared to the reversed mapping.

This view can account for the observed space-potentiality congruency effect and at present we believe it is the best available explanation of it. However, it opens other challenging questions. Recently, Santiago and Lakens (2015) have shown that polarity correspondence cannot explain the mapping of time (nor numbers) onto lateral space. What are, then, the factors that make some conceptual dimensions, such as the potentiality dimension, able to generate a polarity correspondence effect and that distinguish it from the dimension of time, which is not? At present we believe that the answer may be related to processing characteristics linked to the horizontal left-right axis versus the vertical axis. Lakens (2012) showed that the congruency effect between social power and vertical space is affected by factors predicted by polarity correspondence. Social power is conceptualized as a vertical dimension (“power is up”, see Lakoff & Johnson, 1980), as shown by expressions such as “the commands came from above”. In a recent study using the same rationale as Santiago and

Lakens (2015), Chang and Cho (2015) showed that, in contrast to time and number, loudness does behave as predicted by the polarity correspondence hypothesis. Loudness is also conceptualized as a vertical dimension through the “more is up” metaphor (Lakoff & Johnson, 1980), linguistically manifested in expressions such as “turn the volume up” or “turn it down”. Linguistic expressions suggest that potentiality is also a vertical dimension, as something factual and certain is “tied down” whereas something potential is “still in the air”. Time and numbers, instead, map onto the left-right axis (Bonato, Zorzi, & Umiltà, 2012). This pattern suggests that the relevant spatial axis is the main factor that distinguishes conceptual dimensions that generate polarity correspondence effects from those that do not. Some studies aimed to test this possibility are currently under course in our lab. If space-time and space-potentiality congruency effects finally deserve a single theoretical interpretation or they require different mechanisms is something that remains to be seen.

To conclude, the present study has shown that potential past and future events can activate the lateralized mental timeline to the same extent as factual events do. In doing so, it has also revealed an interesting new phenomenon: the mental representation of potentiality can also establish links to the lateral spatial dimension, at least under conditions in which potentiality is task relevant. Future research will address the exact nature of this relation.

RESUMEN

¿Hay activación de la línea mental del tiempo de izquierda a derecha para eventos potenciales? La evidencia experimental disponible actualmente sustenta la afirmación de que el tiempo se representa mediante una línea mental del tiempo que va de izquierda a derecha. Sin embargo, todos los estudios hasta el momento examinan eventos factuales, es decir, aquéllos que efectivamente han ocurrido en el pasado o que con certeza sucederán en el futuro. En el presente estudio examinamos si los eventos potenciales pasados y futuros también se representan a lo largo de una línea mental lateral. En el Experimento 1 los participantes categorizaron la referencia temporal (pasado o futuro) tanto de eventos factuales como potenciales presionando una tecla de respuesta lateralizada (izquierda o derecha). Los eventos factuales mostraron un efecto de congruencia espacio-tiempo que replica los hallazgos previos: los participantes fueron más rápidos para categorizar eventos pasados con la mano izquierda y eventos futuros con la mano derecha, en comparación con la asignación motora opuesta. Crucialmente, lo mismo ocurrió para los eventos potenciales. El Experimento 2 replicó estos hallazgos usando bloques compuestos sólo por ensayos con eventos potenciales. Con el objetivo de evaluar la automaticidad de la línea mental del tiempo, el Experimento 3 solicitó a los

participantes juzgar si las mismas expresiones se referían a eventos factuales o potenciales. En este caso, no se encontró el efecto de congruencia espacio-tiempo, mostrando que la línea mental del tiempo se activa sólo cuando es relevante a la resolución de la tarea. Además, los participantes fueron más rápidos para categorizar los eventos potenciales con la mano izquierda y los eventos fácticos con la mano derecha, en comparación con la asignación motora opuesta. Este resultado sugiere, por primera vez, una relación entre las representaciones mentales del espacio lateralizado y la potencialidad.

REFERENCES

- Barsalou, L.W. (2003). Situated simulation in the human conceptual system. *Language and Cognitive Processes, 18*, 513-562
- Baumeister, R.F., & Masicampo, E.J. (2010). Conscious thought is for facilitating social and cultural interactions: How mental simulations serve the animal-culture interface. *Psychological Review, 117*, 945-971. doi:10.1037/a0019393
- Bonato, M., Zorzi, M., & Umiltà, C. (2012). When time is space: Evidence for a mental time line. *Neuroscience and Biobehavioral Reviews, 36*, 2257-2273. doi:10.1016/j.neubiorev.2012.08.007
- Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*, 473-479. doi: 10.1037/a0033297
- Chang, S., & Cho, Y.S. (2015). Polarity correspondence effect between loudness and lateralized re- sponse set. *Frontiers in Psychology, 6*. doi:10.3389/fpsyg.2015.00683
- Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorial in Quantitative Methods for Psychology, 1*, 42-45. doi.10.20982/tqmp.01.1.p042
- Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122*(3), 371. doi.org/10.1037/0096-3445.122.3.371
- De Vega, M., & Urrutia, M. (2012). Discourse updating after reading a counterfactual event. *Psicológica, 33*(2), 157-173
- De Vega, M., De León, I., Hernández, J. A., Valdés, M., Padrón, I., & Ferstl, E. C. (2014). Action sentences activate sensory motor regions in the brain independently of their status of reality. *Journal of Cognitive Neuroscience, 26*, 1363-1376. doi:10.1162/jocn
- Fattorini, E., Pinto, M., Rotondaro, F., & Doricchi, F. (2015). Perceiving numbers does not cause automatic shifts of spatial attention. *Cortex, 73*, 298-316. doi.org.proxy.timbo.org.uy:443/10.1016/j.cortex.2015.09.007
- Faul, F., Erdfelder, E., Lang, A.G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191. doi:10.3758/BF03193146
- Ferguson, H. J., Fresh, M., & Leblond, J. (2013). Examining mental simulations of uncertain events. *Psychonomic Bulletin & Review, 20*, 391-399. doi:10.3758/s13423-012-0348-1
- Fischer, M. H., Castel, A. D., Dodd, M. D., & Pratt, J. (2003). Perceiving numbers causes spatial shifts of attention. *Nature Neuroscience, 6*, 555-556. doi.10.1038/nn1066
- Flumini, A., & Santiago, J. (2013). Time (also) flies from left to right... if it is needed! In M. Knauff, M. Pauen, N. Sebanz, & I. Wachmuz (Eds.), *Proceedings of the 36th*

- Annual Conference of the Cognitive Science Society* (pp. 2315-2320). Austin, TX: Cognitive Science Society.
- Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*, 1430-1451. doi:10.1111/j.1551-6709.2010.01105.x
- Gilead, M., Liberman, N., & Maril, A. (2012). Construing counterreal worlds: The role of abstraction. *European Journal of Social Psychology*, *42*, 391-397. doi:10.1002/ejsp.1862
- Hegarty, M. (2004). Mechanical reasoning by mental simulation. *Trends in Cognitive Sciences*, *8*, 280-285. doi:10.1016/j.tics.2004.04.001
- Johnson-Laird, P.N. (1980). Mental models in cognitive science. *Cognitive Science*, *4*, 71-115.
- Kaup, B., Yaxley, R.H., Madden, C.J., Zwaan, R.A., & Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly Journal of Experimental Psychology*, *60*, 976-990. doi:10.1080/17470210600823512
- Lakens, D. (2012). Polarity correspondence in metaphor congruency effects: Structural overlap predicts categorization times for bipolar concepts presented in vertical space. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 726-736. doi:10.1037/a0024955
- Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.
- Núñez, R.E., & 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*, 401-450. doi:10.1207/s15516709cog0000_62
- Orenes, I., Beltrán, D., & Santamaría, C. (2014). How negation is understood: Evidence from the visual world paradigm. *Journal of Memory and Language*, *74*, 36-45. doi:10.1016/j.jml.2014.04.001
- Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*, 308-314. doi:10.1027/1618-3169/a000036
- Piaget, J., & Inhelder, B. (1985). *De la lógica del niño a la lógica del adolescente*. Barcelona: Paidós Ibérica.
- Proctor, R.W., & Cho, Y.S. (2006). Polarity correspondence: A general principle for performance of speeded binary classification tasks. *Psychological Bulletin*, *132*, 416-442. doi:10.1037/0033-2909.132.3.416
- Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin*, *114*, 510-532. doi: 0.1037/0033-2909.114.3.510
- Ruiz Campillo, J.P. (2014). La lógica del espacio. Un mapa operativo del sistema verbal del español. *Journal of Spanish Language Teaching*, *1:1*, 62-85. doi:10.1080/23247797.2014.898518
- Santiago, J., & Lakens, D. (2015). Can conceptual congruency effects between number, time, and space be accounted for by polarity correspondence? *Acta Psychologica*, *156*, 179-191. doi:10.1016/j.actpsy.2014.09.016
- Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M.J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review*, *14*, 512-516. doi: 10.3758/bf03194099
- Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2010). In hindsight, life flows from left to right. *Psychological Research*, *74*, 59-70. doi:10.1007/s00426-008-0220-0

- Schlemenson, S. (2004). *Subjetividad y lenguaje en la clínica psicopedagógica. Voces presentes y pasadas*. Buenos Aires. Paidós.
- Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime Reference Guide*. Pittsburgh: Psychology Software Tools Inc.
- Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*, 745-757. doi:10.1207/s15516709cog0000_67
- Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515-557. doi: 0010-0285/9
- Ulrich, R., & Maienborn, C. (2010). Left-right coding of past and future in language: The mental timeline during sentence processing. *Cognition*, *117*, 126-138. doi:10.1016/j.cognition.2010.08.001
- 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. doi: 10.3758/pbr.15.2.426

APPENDIX

Table 1. Verbal Stimuli used in Experiment 1. English translations are shown within brackets. Note that the English translations often provide less rich information about subject gender and number, and about verb tense and mood than the Spanish original (see discussion in the main text). Note also that the items “Ellos iniciaron” (“they started”), “Nosotros silbamos” (“We whistled”), “Nosotros soñamos” (“We dreamt”) and all items with “permanecer” (to remain) were used in Experiment 1, but substituted in Experiment 3 by the third person singular (“Él inició”, “Él silbó”, “Él soñó”), and by the verb “sonreír” (to smile: FP: He smiled; FF: He will smile; PP: He had smiled; PF: He would smile).

Verbs	Factual Past (FP)	Factual Future (FF)	Potential Past (PP)	Potential Future (PF)
Actuar	Ellas actuaron	Ellas actuarán	Él hubiera actuado	Ellas actuarían
Apartarse	Tú te apartaste	Tú te apartarás	Te hubieras apartado	Tú te apartarías
Callarse	Usted se calló	Él se callará	Se hubiera callado	Él se callaría
Cambiar	Ellos cambiaron	Tú cambiarás	Tú hubieras cambiado	Tú cambiarías
Despertar	Ella despertó	Ella despertará	Hubiera despertado	Ella despertaría
Dormir	Nosotros dormimos	Nosotros dormiremos	Se hubiera dormido	Ella se dormiría
Escaparse	Usted se escapó	Usted escapará	Se hubiera escapado	Usted escaparía

Iniciar	Ellos iniciaron	Ellos iniciarán	Él hubiera iniciado	Ellos iniciarían
Llegar	Ellos llegaron	Usted llegará	Tú hubieras llegado	Usted llegaría
Marchar	Ellos marcharon	Ellos marcharán	Yo hubiera marchado	Ellos marcharían
Morir	Ellos murieron	Ellos morirán	Ella hubiera muerto	Ellos morirían
Nadar	Ellos nadaron	Ellos nadarán	Ella hubiera nadado	Ellos nadarían
Ocultarse	Usted se ocultó	Yo me ocultaré	Me hubiera ocultado	Yo me ocultaría
Permanecer	Él permaneció	Yo permaneceré	Hubiera permanecido	Yo permanecería
Retirarse	Tú te retiraste	Tú te retirarás	Me hubiera retirado	Tú te retirarías
Silbar	Nosotros silbamos	Ellos silbarán	Yo hubiera silbado	Ellos silbarían
Soñar	Nosotros soñamos	Nosotros soñaremos	Él hubiera soñado	Él soñaría
Sudar	Ellos sudaron	Ellos sudarán	Él hubiera sudado	Ellos sudarían
Trabajar	Usted trabajó	Usted trabajará	Él hubiera trabajado	Usted trabajaría
Volar	Ellos volaron	Ellos volarán	Yo hubiera volado	Ellos volarían

Table 2. Mean latencies in milliseconds and proportion of errors per condition (within brackets). All Time-Response side pair-wise contrasts of latencies reached significance in post-hoc analyses of Experiments 1 and 2. All Potentiality-Response side pair-wise contrasts reached significance in post-hoc analyses of Experiment 3.

Potentiality- Time conditions	Experiment 1: Temporal task		Experiment 2: Temporal task		Experiment 3: Potentiality task	
	Left	Right	Left	Right	Left	Right
Factual Past	1,369	1,443			1,089	993
	(.06)	(.07)			(.02)	(.01)
Factual Future	1,411	1,210			1,261	1,168
	(.04)	(.02)			(.11)	(.06)
Potential Past	1,366	1,491	1,129	1,234	1,115	1,198
	(.04)	(.07)	(.02)	(.08)	(.05)	(.05)
Potential Future	1,582	1,399	1,255	1,043	1,159	1,232
	(.07)	(.11)	(.07)	(.04)	(.06)	(.04)

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