Journal of Experimental Psychology: General
2014, Vol. 143, No. 2, 473–479

0096-3445/14/$12.00 DOI: 10.1037/a0033297

BRIEF REPORT

Mirror Reading Can Reverse the Flow of Time

Daniel Casasanto
University of Chicago

Roberto Bottini
University of Milan–Bicocca, Milan, Italy

How does culture shape our concepts? Across many cultures, people conceptualize time as if it flows along a horizontal timeline, but the direction of this implicit timeline is culture specific: Later times are on the right in some cultures but on the left in others. Here we investigated whether experience reading can determine the direction and orientation of the mental timeline, independent of other cultural and linguistic factors. Dutch speakers performed space–time congruity tasks with the instructions and stimuli written in either standard, mirror-reversed, or rotated orthography. When participants judged temporal phrases written in standard orthography, their reaction times were consistent with a rightward-directed mental timeline, but after brief exposure to mirror-reversed orthography, their mental timelines were reversed. When standard orthography was rotated 90° clockwise (downward) or counterclockwise (upward), participants' mental timelines were rotated, accordingly. Reading can play a causal role in shaping people's implicit time representations. Exposure to a new orthography can change the direction and orientation of the mental timeline within minutes, even when the new space–time mapping directly contradicts the reader's usual mapping. To account for this representational flexibility, we propose the *hierarchical mental metaphors theory*, according to which culturally conditioned mappings between space and time are specific instances of a more general mapping, which is conditioned by the relationship between space and time in the physical world. Conceptualizations of time are culture specific at one level of analysis but may be universal at another.

Keywords: culture, metaphor, orthography, space, time

Supplemental materials: http://dx.doi.org/10.1037/a0033297.supp

Space and time are intertwined in the human mind, as they are in the physical world. The theory that people use spatial representations to think about time, inspired by patterns in metaphorical language (Clark, 1973; Lakoff & Johnson, 1980), is now supported by many behavioral and neuroscientific experiments (e.g., Basso, Nichelli, Frassinetti, & Pellegrino, 1996; Boroditsky, 2000; Casasanto & Boroditsky, 2008; Torralbo, Santiago, & Lupiáñez, 2006; Ulrich & Maienborn, 2010; Weger & Pratt, 2008).

Often, the way people talk about time using spatial metaphors corresponds to the way they spatialize time in their minds, implicitly. In English, spatial metaphors for temporal sequences suggest that events flow along the sagittal (front–back) axis: deadlines lie *ahead* of us or *behind* us; we can look *forward* to our golden years or look *back* on our greener days (Clark, 1973; Lakoff & Johnson, 1980). Accordingly, English speakers have been found to lean subtly forward when thinking about the future and lean backward when thinking about the past (Miles, Nind, & Macrae, 2010).

Yet, the way people use space to talk about time is not necessarily the way they use space to *think* about it. No known spoken language uses the lateral (left–right) axis for time: Monday comes *before* Tuesday, not *to the left* of Tuesday (Casasanto & Jasmin, 2012; Cienki, 1998). Despite the total absence of left–right metaphors in spoken language, there is strong evidence that people implicitly associate time with left–right space and that the direction in which events flow along people's imaginary timelines varies systematically across cultures. In a temporal diagram task, English speakers tended to place "breakfast" on the left of "lunch" and "dinner" on the right, whereas Arabic speakers preferred the opposite arrangement (Tversky, Kugelmass, & Winter, 1991). This cross-cultural reversal in the left–right mapping of time has been confirmed in reaction time (RT) tasks comparing Hebrew speakers with speakers of English (Fuhrman & Boroditsky, 2010) and Spanish (Ouellet, Santiago, Israeli, & Gabay, 2010). The left–right

This article was published Online First June 17, 2013.

Daniel Casasanto, Department of Psychology, University of Chicago; Roberto Bottini, Department of Psychology, University of Milan–Bicocca, Milan, Italy.

This research was supported in part by grants from the Consejería de Innovacion, Ciencia y Empresa, Junta de Andalucía, European Regional Development Fund (P09-SEJ-4772), the Spanish Ministry of Economy and Competitivity (PSI2012-32464), and by a James S. McDonnell Foundation Scholar Award to Daniel Casasanto. Preliminary versions of Experiment 1 were reported in the *Proceedings of the 32nd Annual Meeting of the Cognitive Science Society* (August 2010, Portland, Oregon) and the *Proceedings of Spatial Cognition VII* (August 2010, Mt. Hood, Oregon).

Correspondence concerning this article should be addressed to Daniel Casasanto, Department of Psychology, University of Chicago, 5848 South University Avenue, Chicago, IL 60637. E-mail: casasanto@alum.mit.edu

mapping of time surfaces in spontaneous hand gestures that accompany speech. English and Spanish speakers' gestures tend to place earlier times on the left and later times on the right of body-centered space, but Arabic speakers' gestures show the opposite pattern; the directions used in hand gestures correlate with the directions of reading and writing in these languages (Casasanto & Jasmin, 2012; de la Fuente, Santiago, Román, Dumitrache, & Casasanto, 2013; see also Cienki, 1998; Cooperrider & Nuñez, 2009).

Despite this clear correlation, it is not known to what extent the direction of reading and writing is a *cause* or an *effect* of cross-cultural variation in implicit space–time mappings. In principle, a writing system could emerge with one directionality or another as a consequence of culture-specific conceptions of time—not the other way around. Furthermore, cultural practices tend to covary. Groups who write from left to right also tend to spatialize time on calendars and graphs from left to right and to gesture according to a left-to-right mental timeline. This covariation leaves open a host of possible scenarios according to which orthography could either play a primary causal role, a mediating role, or no causal role at all in determining the direction of the mental timeline.

Here we investigated whether experience with orthography is sufficient to determine the direction and orientation of people's implicit timelines. Native Dutch speakers performed one of five versions of a space–time congruity task, with the instructions and stimuli presented in either standard, mirror-reversed, or rotated orthography. Reading each line of a text in Dutch requires moving one's eyes and one's attention gradually from the left to the right side of the page or the computer screen. Therefore, moving rightward in space is tightly correlated with "moving" later in time, reinforcing an association of earlier times with the left side of space and later times with the right. We reasoned that if the habit of reading from left to right plays a causal role in determining the direction of the mental timeline, then changing the direction (and orientation) of orthography should cause a corresponding change in readers' implicit mental representations of time.

Experiment 1: Can Mirror Reading Reverse the Flow of Time?

In the canonical version of the space–time congruity task, participants saw past-oriented phrases (e.g., *een jaar daarvoor* [English: "a year before"]) and future-oriented phrases (e.g., *een dag daarna* [English: "a day after"]) written in standard Dutch orthography (Figure 1a). As soon as each phrase appeared, participants pressed a colored button (located on the left or right of a keyboard) to indicate whether the phrase referred to an earlier or a later time. The left–right position of the keys was irrelevant to the earlier–later judgment. Still, we predicted that if Dutch speakers ordinarily conceptualize events according to a rightward-directed implicit mental timeline, they should be faster to judge the temporal reference of phrases when required to press the left button for earlier times and the right button for later times, compared with the opposite key mapping.

In the mirror-orthography version of the task, all of the instructions and stimuli were shown in mirror-reversed text (Figure 1b). If moving one's eyes (or one's attention) leftward during reading is sufficient to cause Dutch speakers to use a leftward-directed mental timeline (like Arabic and Hebrew speakers), they should be faster to make temporal reference judgments when pressing the left button for *later* times and the right button for *earlier* times, compared with the opposite key mapping.

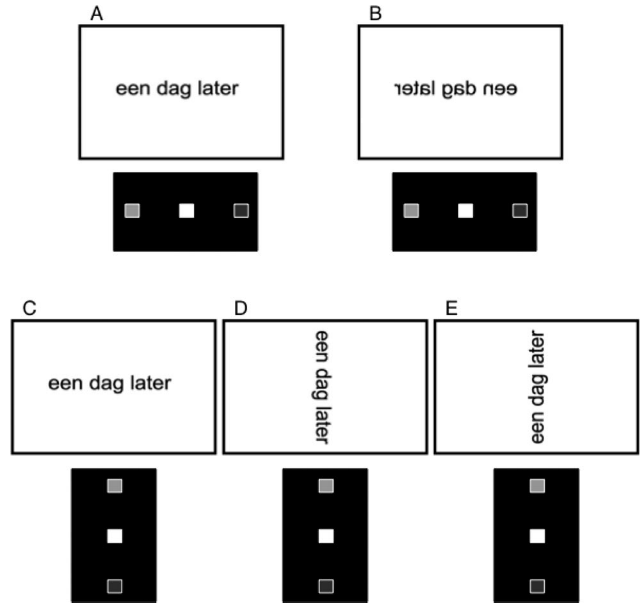

Figure 1. Apparatus for Experiments 1 and 2. For Experiment 1, the keyboard was mounted horizontally, perpendicular to the floor. Panel A (top left): In the standard-orthography version, instructions and stimuli appeared in standard Dutch orthography. Panel B (top right): In the mirror-reversed-orthography version, instructions and stimuli appeared in mirror-reversed orthography. For Experiment 2, the keyboard was mounted vertically. Panel C (bottom left): In the standard-orthography version of Experiment 2, instructions and stimuli appeared in standard Dutch orthography. Panel D (bottom center): In the downward-orthography version, instructions and stimuli appeared in standard Dutch orthography rotated 90° clockwise. Panel E (bottom right): In the upward-orthography version, instructions and stimuli appeared in standard Dutch orthography rotated 90° counterclockwise.

Method

Participants. Native Dutch speakers ($N = 104$) from the Radboud University (Nijmegen, the Netherlands) performed Experiment 1 for payment. Half were assigned to the standard-orthography version ($N = 52$), and the other half to the mirror-orthography version ($N = 52$).

Materials.

Stimuli. Three-word temporal phrases were constructed in Dutch. The first word was an indefinite article, the second word a temporal interval, and the third word an adverbial indicating a "direction" in time (i.e., toward the past or toward the future). Twelve temporal intervals were crossed with four adverbials to produce 48 temporal phrases, half referring to earlier times and half to later times (see Appendix). Phrases appeared in the center of a 13-in. Macintosh laptop screen (Apple Inc., Cupertino, CA) in 48-point Arial font. Instructions and stimuli were presented in standard Dutch orthography for half of the participants and mirror-reversed Dutch for the other half.

Apparatus. Participants were seated at a desk. A laptop computer was secured on top of a box in front of them, raising the screen to approximately eye level. A universal serial bus (USB) keyboard (U.S.–international) was mounted horizontally on the front face of box, with the keys facing the participant at shoulder level. All keys were masked except for the three response keys: the *A* key on the left, the apostrophe key on the right, and the *H* in the middle. The middle key was aligned with the center of the screen, and the left and right keys were equidistant from it. The left key was covered with a blue sticker and the right key a red sticker, or vice versa, with the key colors counterbalanced across subjects.

Procedure. Instructions were presented before each of two blocks in which each of the 48 temporal phrases was presented once, for a total of 96 trials. In one block, participants were instructed to press the blue button if the phrase referred to an interval of time in the past and the red button if it referred to an interval of time in the future. In the other block, the mapping between the red/blue keys and earlier/later phrases was reversed. To ensure that participants remembered the correct color–time mappings, we required that they repeat them aloud five times before each block.

At the beginning of each trial, the word "Ready" appeared in the center of the screen and remained there until the participant pressed the middle white button. "Ready" was then replaced by a fixation cross. Participants held down the white button for as long as the fixation was shown. Its duration was varied randomly from 300 to 450 ms in 50-ms increments to discourage participants from making anticipatory movements. The fixation was then replaced by one of the 48 temporal phrases. The phrase remained on the screen until the participant responded, at which time it was replaced by the "Ready" message to begin the next trial.

Participants pressed buttons with the index finger of the dominant hand and were required to sit on their nondominant hand. The spatial direction of responses was never mentioned, but one colored button was on the right and the other on the left of the middle white button. Therefore, pressing the correctly colored button required orthography-congruent movements for one block (e.g., rightward movements for "future" during standard orthography) and orthography-incongruent movements for the other block, with the order of congruent and incongruent blocks counterbalanced across participants. A space–time congruity effect was computed for each participant by comparing response times during orthography-congruent and orthography-incongruent responses (between blocks, within items). Testing lasted about 10 min.

Results and Discussion

RTs were analyzed for accurate responses only. This resulted in the removal of 3% of the data. RTs greater than 2.5 standard deviations from the average were also excluded, resulting in the removal of 3% of the accurate trials.

RTs were analyzed using linear mixed-effects regressions fit by maximum likelihood in R (R Core Team, 2012) with the lmer() function in the lme4 library (Baayen, Davidson, & Bates, 2008). Random intercepts were included for subjects and items. All categorical predictors (congruity, orthography, and block) were entered using deviation coding. *P* values and 95% highest posterior density intervals of the parameter estimates were estimated using Markov chain Monte Carlo (MCMC) sampling with 10,000 samples; the pvals.fnc() function in the R language library was used.

Results of the standard-orthography version showed the expected main effect of congruity with the rightward timeline (pMCMC = .0001; Figure 2a; Table 1). For the same temporal phrases, responses were 170 ms faster when the key mapping was consistent with the rightward timeline than when it was reversed. This effect was similar across Block 1 and Block 2, as indicated by the absence of any Congruity × Block interaction (pMCMC = .95).

Results of mirror-orthography version showed no main effect of congruity when both blocks were combined (pMCMC = .43). Since the leftward space–time mapping is in direct opposition to the Dutch speakers' usual rightward mapping, we expected that effects of training with mirror-reversed text might not be evident immediately. The experiment was designed to allow comparison of

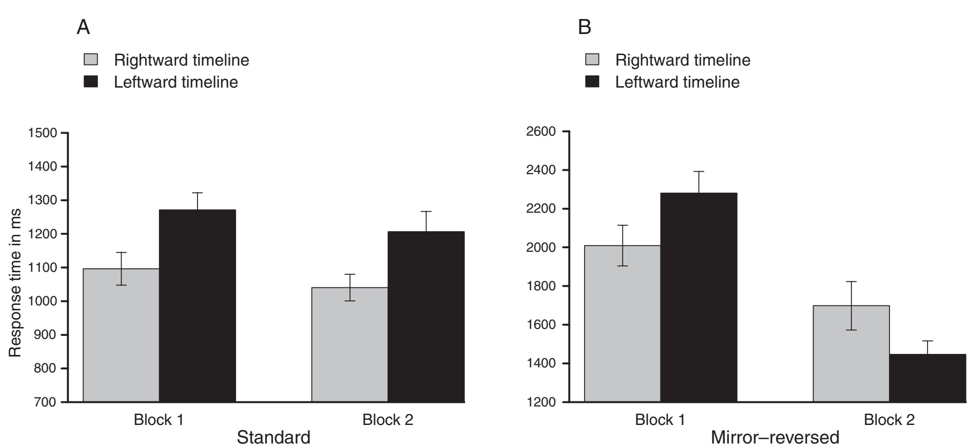

Figure 2. Results of Experiment 1. In the standard-orthography version (Panel A), the congruity effect did not differ between blocks: Participants were faster when the key mapping reflected the rightward flow of time. In the mirror-reversed-orthography version (Panel B), a standard congruity effect was found in the first block, but this effect was reversed in the second block, after a few minutes of exposure to mirror-reversed orthography. Error bars indicate standard errors of the mean.

Table 1
Results of Experiment 1

Orthography/fixed effect	Parameter estimate	HPD interval	pMCMC	β	Ss η_p^2	It η_p^2
Standard						
Congruity	169	[146, 194]	.0001***	.17	.39	.78
Block	−61	[−85, −37]	.0001***	−.06	.05	.33
Congruity × Block	−7	[−233, 225]	.95	−.004	.001	.002
Mirror-reversed						
Congruity	17	[−25, 56]	.43	.007	.001	.003
Block	−582	[−623, −541]	.0001***	−.32	.73	.92
Congruity × Block	−531	[−983, −62]	.02*	−.15	.06	.67

Note. The parameter estimate and standardized parameter estimate (β) provide measures of effect size appropriate for the linear mixed regression model. For comparison with previous studies, we also report measures of effect size from an analysis of variance (ANOVA) by subjects (Ss η_p^2) and an ANOVA by items (It η_p^2). HPD = highest posterior density; MCMC = Markov chain Monte Carlo.
$^{*}p < .05$. $^{***}p < .001$.

the congruity effect during the first presentation of the 48 stimuli (Block 1) and the second presentation of the same stimuli (Block 2). There was main effect of block that was irrelevant to our hypotheses, indicating that participants got faster with practice (pMCMC = .0001). Of interest for the predicted effect of orthography, there was a significant Congruity × Block interaction (pMCMC = .02). In Block 1, orthography-*incongruent* responses were fastest (pMCMC = .04; Figure 2b, left columns; Table 2), showing the persistence of the Dutch speakers' usual mental timeline at the beginning of the experiment. By Block 2, however, orthography-*congruent* responses were fastest, indicating a reversal in participants' implicit mental timelines (pMCMC = .03; Figure 2b, right columns).

In further analyses, we compared the results of the standard- and mirror-orthography versions. There was a highly significant Congruity × Orthography interaction (pMCMC = .0001; Table 3), showing that the space–time congruity effect was modulated by orthography. A three-way interaction of Congruity × Block × Orthography (pMCMC = .04) indicated that the predicted Congruity × Orthography interaction was driven by the reversal of the Dutch speakers' usual rightward mental timeline during the second block of mirror orthography.

A subset of participants from the standard-orthography (n = 22) and mirror-orthography (n = 22) versions performed a second space–time congruity task a few minutes after completing Experiment 1 to allow us to determine whether reading experience has consequences for subsequent mental representations of time. Participants heard the names of celebrities (e.g., Elvis Presley, Lady Gaga) and pressed the right or left button to indicate whether the celebrity became famous before or after they (the participants) were born. RTs showed a significant effect of mirror-reading training on participants' subsequent left–right mappings of time (see supplemental online materials), suggesting that beyond the online effects of reading experience, exposure to mirror-reversed orthography influenced associations between space and time in memory.

Experiment 2: How Flexible Are Spatial Representations of Time?

If moving one's eyes (or one's attention) through space and time in a particular direction during reading causes the corresponding space–time mapping to become activated, then it should be possible to change both the direction and orientation of the mental timeline arbitrarily by changing the orthography. In Experiment 2, we exposed new groups of participants to stimuli and instructions presented in either standard orthography or in orthography that was rotated 90° downward or upward to determine whether experience reading downward- or upward-directed text could cause them to implicitly conceptualize events as flowing along a downward- or upward-directed mental timeline.

Method

Participants. A new sample of native Dutch speakers (N = 60) from the Radboud University community performed Experiment 2 for payment. Each participant performed either the

Table 2
Main Effects of Congruity Within Each Block of Experiment 1

Orthography/block	Parameter estimate	HPD interval	pMCMC	β	Ss η_p^2	It η_p^2
Standard						
Block 1	175	[56, 293]	.004**	.18	.11	.68
Block 2	166	[48, 294]	.0008***	.17	.09	.64
Mirror						
Block 1	276	[19, 533]	.04*	.14	.06	.44
Block 2	−251	[−465, −32]	.03*	.16	.06	.63

Note. Ss η_p^2 = effect size for an ANOVA by subjects; It η_p^2 = effect size for an ANOVA by items; HPD = highest posterior density; MCMC = Markov chain Monte Carlo; β = standardized parameter estimate; ANOVA = analysis of variance.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 3
Results of Experiment 1 (Standard and Mirror-Reversed Orthography Combined)

Fixed effect	Parameter estimate	HPD interval	pMCMC	β	Ss η_p^2	It η_p^2
Congruity	92	[68, 116]	.0001***	.06	.03	.49
Orthography	−703	[−832, −579]	.0001***	−.44	.44	.95
Block	−320	[−344, −297]	.0001***	−.21	.13	.92
Congruity × Orthography	153	[107, 202]	.0001***	.05	.02	.41
Congruity × Block × Orthography	520	[11, 1017]	.04*	.08	.02	.65

Note. Ss η_p^2 = effect size for an ANOVA by subjects; It η_p^2 = effect size for an ANOVA by items; HPD = highest posterior density; MCMC = Markov chain Monte Carlo; β = standardized parameter estimate; ANOVA = analysis of variance.
* $p < .05$. *** $p < .001$.

standard-orthography version (n = 18), the downward-orthography version (n = 20), or the upward-orthography version (n = 22).

Materials and procedure. All materials and procedures were identical to Experiment 1 with the following exceptions. The keyboard was oriented vertically rather than horizontally, necessitating upward or downward button presses. Stimuli and instructions were either presented in standard orthography (Figure 1c) or were rotated 90° clockwise (Figure 1d) or 90° counterclockwise (Figure 1e).

Results and Discussion

RTs were analyzed for accurate responses only, resulting in the removal of 4% of the data. RTs greater than 2.5 standard deviations from the average were also excluded, resulting in the removal of 3% of the accurate trials. RTs analyses were conducted using a mixed linear regression model with Subjects and Items as repeated random factors, as in Experiment 1.

Participants in the standard-orthography version showed no main effect of congruity with either a downward- or upward-directed mental timeline (pMCMC = .42; Figure 3, left columns; Table 4). When exposed to downward orthography, however, participants showed a main effect of congruity with the downward timeline (pMCMC = .0001; Figure 3, middle columns), and when exposed to upward orthography, participants showed a main effect of congruity with the upward timeline (pMCMC = .02; Figure 3, right columns). Comparing the results of the downward- and upward-orthography versions, we found a two-way Congruity × Orthography interaction (pMCMC = .0001) that confirmed the direction specificity of the orthography training effect.

General Discussion

Ordinarily, Dutch speakers represent events as flowing along a rightward-directed mental timeline, consistent with the direction they usually move their eyes through space and time as they read. Yet, after about 5 minutes of reading mirror-reversed text, the direction of participants' mental timelines completely reversed. Likewise, although ordinarily Dutch speakers show no implicit mapping between space and time on the vertical axis, a few minutes of exposure to downward- or upward-rotated orthography caused them to represent events as flowing downward or upward along a vertically oriented mental timeline. Exposure to a new orthography influenced participants' spatial representations of time during a subsequent task, indicating that reading experience modifies implicit associations between space and time in memory. Together, these results provide the first evidence that orthography can play a causal role in determining the direction that time flows in people's minds and illustrate both the automaticity and the flexibility with which people activate spatial schemas for temporal sequences.

How could a few minutes of exposure to a new orthography rotate or even reverse people's usual mental timeline, established over a lifetime of reading experience? We propose that the flexibility of the mental timeline (and of similar mental metaphors) arises from the existence of a hierarchy of implicit associations based on different kinds of experiences. People's implicit associations between space and time could be characterized as a set of nested *intuitive hypotheses* (Goodman, 1955; Kemp, Perfors, & Tenenbaum, 2007). At the top of the hierar-

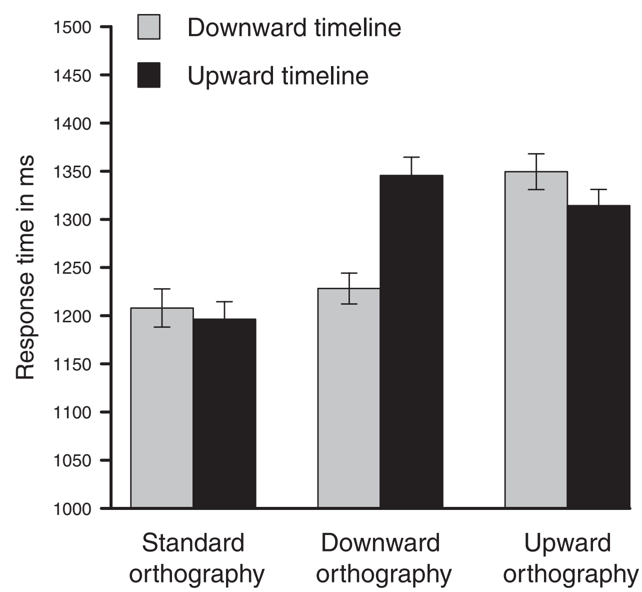

Figure 3. Results of Experiment 2. In the standard-orthography version (left columns), there was no congruity effect with the upward or downward timeline. In the downward-orthography version (center columns), reaction times (RTs) were fastest when key mapping was consistent with the downward timeline. In the upward-orthography version (right columns), RTs were fastest when key mapping was consistent with the upward timeline. Error bars indicate standard errors of the mean.

Table 4
Results of Experiment 2

Orthography/fixed effect	Parameter estimate	HPD interval	pMCMC	β	Ss η_p^2	It η_p^2
Standard						
Congruity	−15	[−52, 22]	.42	−.02	.01	.003
Block	−19	[−58, 16]	.29	−.02	.02	.01
Congruity × Block	169	[−235, 592]	.41	.09	.03	.26
Downward						
Congruity	120	[87, 154]	.0001***	.13	.22	.38
Block	−154	[−189, −121]	.0001***	−.17	.28	.62
Congruity × Block	−189	[−563, 237]	.34	−.10	.02	.30
Upward						
Congruity	41	[6, 73]	.02*	.04	.02	.06
Block	−200	[−234, −166]	.0001***	−.22	.58	.70
Congruity × Block	26	[−351, 385]	.89	.01	.001	.02
Downward versus upward						
Congruity × Orthography	157	[110, 207]	.0001***	.17	.10	.45

Note. Ss η_p^2 = effect size for an ANOVA by subjects; It η_p^2 = effect size for an ANOVA by items; HPD = highest posterior density; MCMC = Markov chain Monte Carlo; β = standardized parameter estimate; ANOVA = analysis of variance.
* $p < .05$. *** $p < .001$.

chy is the *overhypothesis*, which comprises a family of *specific hypotheses.* In this case, the overhypothesis could be "Progress through time corresponds to change in position along a linear spatial path." This correspondence could be learned as children observe the relationship between space and time in moving objects, or it could be part of infants' innate core knowledge (Casasanto, 2010; Lakoff & Johnson, 1980; Srinivasan & Carey, 2010). Either way, the overhypothesized association between space and time is presumably universal across cultures, and it should be direction nonspecific: More time passes as moving objects travel farther in any direction.

Once children are exposed to cultural practices with consistent directionality, they accumulate a preponderance of evidence for one specific hypothesis. For Dutch children, reading and writing experience provides evidence for the specific hypothesis "Progress through time corresponds to *rightward* change in position along a linear spatial path," strengthening this hypothesis at the expense of its competitors and causing Dutch speakers to use a rightward-directed mental timeline by default.

According to this proposal, which we call *hierarchical mental metaphors theory*, strengthening the culturally preferred specific hypothesis does not cause its competitors to be lost: only weakened. Retaining all of the overhypothesized space–time mappings in long-term memory is what affords the flexibility we observe in these experiments: Participants in our training experiments were not learning a *new* space–time mapping, nor were they abolishing their usual mapping. Rather, when Dutch speakers were exposed to a new orthography, this experience increased the weight of evidence for one of their overhypothesized (but culturally dispreferred) space–time mappings, strengthening it to the point that it influenced behavior and transiently weakening their culturally preferred mapping as a consequence. On this theory, people's mental metaphors for temporal succession can be fundamental to their conception of time but also remarkably flexible. These mappings are culture specific at one level of analysis but may be universal at another.

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59,* 390–412. doi:10.1016/j.jml.2007.12.005

Basso, G., Nichelli, P., Frassinetti, F., & Pellegrino, G. (1996). Time perception in a neglected space. *NeuroReport, 7,* 2111–2114. doi:10.1097/00001756-199609020-00009

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75,* 1–28. doi:10.1016/S0010-0277(99)00073-6

Casasanto, D. (2010). Space for thinking. In V. Evans & P. Chilton (Eds.), *Language, cognition, and space: State of the art and new directions* (pp. 453–478). London, England: Equinox.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106,* 579–593. doi:10.1016/j.cognition.2007.03.004

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in English speakers. *Cognitive Linguistics, 23,* 643–674. doi:10.1515/cog-2012-0020

Cienki, A. (1998). Metaphoric gestures and some of their relations to verbal metaphoric expressions. In J.-P. Koening (Ed.), *Discourse and cognition: Bridging the gap* (pp. 189–204). Stanford, CA: Center for the Study of Language and Information.

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.

Cooperrider, K., & Nuñez, R. (2009). Across time, across the body: Transversal temporal gestures. *Gesture, 9,* 181–206. doi:10.1075/gest.9.2.02coo

de la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2013). When you think about it, the past is in front of you: How culture shapes spatial conceptions of time. Manuscript submitted for publication.

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit non-linguistic task. *Cognitive Science, 34,* 1430–1451. doi:10.1111/j.1551-6709.2010.01105.x

Goodman, N. (1955). *Fact, fiction, and forecast*. Cambridge, MA: Harvard University Press.

Kemp, C., Perfors, A., & Tenenbaum, J. B. (2007). Learning overhypotheses with hierarchical Bayesian models. *Developmental Science, 10,* 307–321. doi:10.1111/j.1467-7687.2007.00585.x

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

Miles, L. K., Nind, L. K., & Macrae, C. N. (2010). Moving through time. *Psychological Science, 21,* 222–223. doi:10.1177/0956797609359333

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

R Core Team. (2012). *R: A language and environment for statistical computing* [Computer software manual]. Available from http://www.R-project.org/

Srinivasan, M., & Carey, S. (2010). The long and the short of it: On the nature and origin of functional overlap between representations of space and time. *Cognition, 116,* 217–241. doi:10.1016/j.cognition.2010.05.005

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:10.1016/0010-0285(91)90005-9

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 time-line. *Psychonomic Bulletin & Review, 15,* 426–430. doi:10.3758/PBR.15.2.426

Appendix

Dutch Temporal Phrases Used for Experiments 1 and 2 With English Translations

Time	Dutch	English
Past	een seconde daarvoor/eerder	a second before/earlier
	een moment daarvoor/eerder	a moment before/earlier
	een minuut daarvoor/eerder	a minute before/earlier
	een uur daarvoor/eerder	a hour before/earlier
	een dag daarvoor/eerder	a day before/earlier
	een week daarvoor/eerder	a week before/earlier
	een maand daarvoor/eerder	a month before/earlier
	een seizoen daarvoor/eerder	a season before/earlier
	een jaar daarvoor/eerder	a year before/earlier
	een decennium daarvoor/eerder	a decade before/earlier
	een eeuw daarvoor/eerder	a century before/earlier
	een millennium daarvoor/eerder	a millennium before/earlier
Future	een seconde daarna/later	a second after/later
	een moment daarna/later	a moment after/later
	een minuut daarna/later	a minute after/later
	een uur daarna/later	a hour after/later
	een dag daarna/later	a day after/later
	een week daarna/later	a week after/later
	een maand daarna/later	a month after/later
	een seizoen daarna/later	a season after/later
	een jaar daarna/later	a year after/later
	een decennium daarna/later	a decade after/later
	een eeuw daarna/later	a century after/later
	een millennium daarna/later	a millennium after/later

Received August 27, 2012
Revision received June 6, 2013
Accepted June 7, 2013 ■