The Quarterly Journal of Experimental Psychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pqje20

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Accepted author version posted online: 18 Nov 2011. Version of record first published: 16 Feb 2012

To cite this article: Jessica L. Sullivan & Hilary C. Barth (2012): Active (not passive) spatial imagery primes temporal judgements, The Quarterly Journal of Experimental Psychology, 65:6, 1101-1109

To link to this article: http://dx.doi.org/10.1080/17470218.2011.641025

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2012, 65 (6), 1101–1109

Psychology Press
Taylor & Francis Group

Active (not passive) spatial imagery primes temporal judgements

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Previous research has shown that primes that induce particular spatial perspectives can influence temporal judgements. However, most studies have used priming stimuli that involve both spatial and motor language and imagery. Here we ask whether the motor content of these stimuli plays an important role in their ability to serve as effective primes. A total of 198 adult participants made temporal judgements after exposure to spatial primes involving varying levels of imagined effort. Spatial primes involving imagined motor actions, but not those involving equivalent passive motions through space, successfully primed decisions about time. This suggests that motor content, rather than spatial content alone, contributes to the priming effects that arise when people make temporal judgements after exposure to particular spatial perspectives.

Keywords: Spatial cognition; Temporal judgements; Metaphors; Priming.

English speakers use a shared vocabulary to talk about the domains of space and time: "We *moved* the meeting/truck *forward*", "That was a *long* wait/hotdog", and "We're rapidly *approaching* the deadline/guardrail" all invoke language appropriate for discussing either spatial or temporal topics (e.g., Clark, 1973). Compelling experimental evidence indicates that these apparent connections between the domains of space and time are not limited to patterns of speech; they also influence cognitive processes. For example, temporal judgements are often shaped by spatial input, as demonstrated by many studies in which both linguistically and nonlinguistically presented spatial information altered participants' decisions about time (e.g., Boroditsky, 2000; Casasanto & Boroditsky, 2008; McGlone & Harding, 1998).

These studies have pointed to two ways in which spatial input can influence decisions about time. First, the spatial extent of a visual stimulus can bias adults' and children's judgements of temporal duration (e.g., Casasanto & Boroditsky, 2008; Srinivasan & Carey, 2010); for example, participants primed with a long line judged the duration of a tone to be longer than did participants primed with a short line. These studies have

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We thank the members of the Cognitive Development Lab at Wesleyan University. The Wesleyan University Psychology Department, a Jacobs Graduate Fellowship, and a National Science Foundation (NSF) Graduate Fellowship to J.S. supported this work.

http://www.psypress.com/qjep
http://dx.doi.org/10.1080/17470218.2011.641025

revealed that magnitude judgements made in the spatial domain can influence the domain of time.

In a separate (and somewhat conceptually distinct) set of studies, researchers have shown that participants can also adopt a particular spatial perspective and then transfer this perspective onto the domain of time when making judgements about the relative ordering of events. These studies make use of the fact that spatial locations and temporal events can be viewed from one of at least two perspectives. In an "object-moving"/"time-moving" perspective, an event or object is seen as approaching a person (e.g., "The holidays/horses are rapidly approaching us"). Alternatively, in an ego-moving perspective, the person is seen as approaching the event or object (e.g., "We're rapidly approaching the holidays/horses"). Although the content of these two types of utterance is quite similar, priming participants with a description of a particular spatial perspective can apparently cause them to adopt that perspective when making a subsequent temporal judgement. For example, participants tend to think about time as approaching them (e.g., "the deadline is rapidly approaching") after being primed with an imagined "object-moving" spatial scenario in which they are pulling a wagon towards themselves (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Gentner, Imai, & Boroditsky, 2002; Matlock, Ramscar, & Boroditsky, 2005; McGlone & Harding, 1998).

We focus here on the commonly reported finding that when linguistic primes induce certain spatial perspectives, they tend to influence temporal judgements accordingly. Although the influence of these primes is typically attributed to their spatial qualities, the primes usually include both motor and spatial components. It is possible, therefore, that these primes effectively influence judgements about time because of both their spatial and their motor content. For example, previous studies have used primes that involve a stick figure walking toward a plant or pulling on a wagon (Boroditsky, 2000; Boroditsky & Ramscar, 2002), a snail running (Casasanto, Fotakopoulou & Boroditsky, 2010), scenes described using motor words like "run" (Matlock et al., 2005; Ramscar, Matlock, & Dye, 2010), and engagement in self-powered motion (Boroditsky & Ramscar, 2002). As a result, it is unclear whether these spatial primes can bias temporal judgements specifically because they depict spatial motion, or because they depict a motor activity (but see Boroditsky, 2000, for one possible example of priming without imagined motor activity). There is a large body of research demonstrating the importance of self-motion, whether real or imagined, in other spatial contexts. For example, across many spatial tasks, levels of success differ between participants who performed real or imagined self-motion and those who experienced real or imagined object or display motion (e.g., Huttenlocher & Presson, 1973, 1979; Presson, 1982; Simons & Wang, 1998). Will any imagined spatial motion prime decisions about time, or is there something special about imagined motor activity?

Motor language leads to neural processing signatures similar to those associated with engagement in motor action. It is therefore plausible that linguistic spatial primes that involve motor action might operate differently from spatial primes that do not. For example, hearing motor language activates motor cortex, and simply imagining motion is sufficient to induce motor and premotor cortex activation (Filimon, Nelson, Hagler, & Sereno, 2007). The motor system is automatically activated when processing action verbs, and regions of the brain associated with hand, foot, and mouth motor actions are selectively involved in processing sentences about kicking, grasping, and eating (Tettamanti et al., 2005). Further, action words related to hand movements activate regions associated with stroking/grasping, even when they are presented in a purely metaphorical context (Rohrer, 2005). Taken together, this body of research suggests that adults' processing of motor language recruits regions of the brain typically associated with engaging in a particular motor action.

Given the effects of action words on neural processing, it may be the case that the motor components of linguistic spatial primes used in studies of spatiotemporal relationships play an important role in the priming effects described earlier. Suggestive evidence in support of this view comes from research demonstrating that imagining self-

powered motion may be cognitively similar to actually engaging in motor action. For example, engaging in imagined motor activities can increase the accuracy, speed, and precision of executing those activities in real life (e.g., Yágüez et al., 1998; Yue & Cole, 1992). Even watching another person's effortful motion is sufficient to alter a participant's rate of respiration (Paccalin & Jeannerod, 2000), and imagining engaging in exercise increases respiration and perceived exertion to a greater extent than imagining watching another person exercise (Wang & Morgan, 1992). Recent research has also demonstrated that imagining rotating a difficult-to-move object is more difficult than imagining moving an easy-to-move object, and that this effect is present only when participants engage in motor (and not purely visual) imagery (Flusberg & Boroditsky, 2011).

Taken together, this body of research suggests that humans both imagine and process descriptions of motion much as they process actual motor action. Therefore, stimuli that describe or depict motor action may be remarkably effective primes for influencing temporal judgements specifically as a result of their motor content. This distinction is important because most of the relevant literature suggests that the priming effects of spatial content on temporal perspective-taking arise from a fundamental conceptual relationship between space and time, but it is possible that some or all of the influence of these spatial primes comes from their motor content rather than from their spatial properties alone. Previous studies of the transfer of spatial perspectives onto temporal judgements have not generally distinguished the effects of primes that require participants to engage in motor imagery (by imagining pulling a chair, approaching the end-point of a line, or engaging in travel, e.g., Matlock et al., 2005; McGlone & Harding 1998) from those that do not.[1]

Here we explore the possibility that the motor content of spatial primes, rather than their spatial content alone, contributes to priming effects on decisions about time. We build upon prior findings that a simple spatial prime that induces an *ego-moving* perspective (such as imagining moving yourself toward a chair) versus an *object-moving* perspective (such as imagining moving a chair toward yourself) influences people's responses to ambiguous temporal questions ("Next Wednesday's meeting has been moved forward two days. What day is the meeting on now that it has been rescheduled?"). Those primed with an ego-moving perspective more frequently answer "Friday", because they tend to interpret *forward* as referring to their own motion through time, while those primed with an object-moving perspective interpret *forward* as referring to the day of the appointment's movement towards them and are more likely to answer "Monday" (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Gentner et al., 2002; Matlock et al., 2005; McGlone & Harding, 1998).

We hypothesized that if purely spatial scenarios can prime particular temporal perspectives, then participants primed with scenarios involving passive (nonmotor) movement should perform similarly to participants primed with closely matched scenarios involving active movement. However, if motor content contributes to priming effects on decisions about time, spatial primes that require imagining effortful motion should be more effective than primes that require imagining passive movement. In the present study, we manipulated the level of imagined effort in a spatial prime. We then examined the effects of the manipulation of imagined effort on responses to a subsequent ambiguous temporal question, while holding spatial language, trajectory of movement, and vividness of imagery constant across conditions.

Spatial primes varied in the amount of effort exerted by an actor in an imagined spatial scenario. In two active conditions with differing degrees of effort, participants imagined a self-powered motor activity (e.g., pulling either a light or a heavy wagon towards themselves). In the passive

[1] Sentences involving fictive motion, such as "The road runs along the coast", can prime temporal judgements. Although these primes do not explicitly require participants to imagine effortful motion, it is thought that they lead participants to "subjectively scan a path" (e.g., Ramscar, Matlock, & Boroditsky, 2009); they also frequently use motor language ("run" in the above example).

condition, participants imagined passive spatial movement (watching a wagon roll towards their body). One possible outcome is that the motor content of a spatial prime does not influence the likelihood that it will influence subsequent temporal judgements. If this is the case, then all three conditions—the two active and one passive spatial primes—should influence the perspective that participants adopt when making decisions about the order of events in time. If, on the other hand, a spatial prime's motor content does contribute to commonly observed priming effects on temporal judgements, these conditions should produce different priming effects. This could occur in one of two ways. One possibility is that the spatial prime's effectiveness when influencing temporal perspective taking varies as a function of the amount of effort associated with the prime. This view predicts stronger priming effects for primes depicting relatively large amounts of effort, with decreasing effectiveness of the prime as effort decreases. A second possibility is that the spatial prime's effectiveness depends on the simple presence or absence of motor content. If this is the case, then both active spatial scenarios should prime temporal judgements, but the passive spatial prime should not.

Method

Participants

One hundred and ninety-eight members of the Wesleyan University community participated in exchange for a small prize. Participants were randomly assigned to one of the six test conditions or to the baseline condition ($n = 28$ per condition), and provided written responses. Four participants were excluded from analysis for failure to follow directions, and four were excluded for answering the test question (the "meeting" question described earlier; Boroditsky, 2000; Boroditsky & Ramscar, 2002; Gentner et al., 2002; Matlock et al., 2005; McGlone & Harding, 1998) with a day other than Friday or Monday. Thirty additional participants provided data to norm our stimuli (described below).

Materials

Stimuli were paper packets containing a brief story about a person or object's movement accompanied by written instructions and a schematic stick-figure image of the person and object (similar to the images used in Boroditsky & Ramscar, 2002). All stories began with "Imagine you are the person in this story". The stories then described a motion-related event. In half the stories, a wagon moved towards a person and an X (inducing an object-moving perspective), and in half the person moved towards an X (inducing an ego-moving perspective). Each story was accompanied by an image of the depicted scene. This image varied minimally between conditions. Within each condition, the direction of movement was balanced equally between left and right. The stories varied by the amount of effort the actor in the story expended to create movement: high effort, low effort, and passive. Thus, there were six possible conditions: Mover (2) × Effort (3).

In the ego-moving scenarios, a figure was described as being on a conveyor belt and moving towards an X. For the passive condition, the conveyor belt was on and moving towards the X. In the low- and high-effort conditions, the conveyor belt was off, and the figure walked to the X. To manipulate the imagined amount of effort, the figure was described as wearing either a very light or a very heavy backpack.

In the object-moving scenarios, a figure stood next to an X and across from a wagon. For the passive condition, the wagon was described as rolling towards the figure and the X. In the low- and high-effort conditions, the figure pulled on a rope to move the wagon towards the X. To manipulate the amount of effort expended in moving the wagon, the wagon was described as being full of either very light balloons or very heavy sand bags.

Stories and the pictures that accompanied them were normed by independent raters ($n = 30$) for perceived level of effort expended by the actor and for vividness of the story, to ensure that the effortful scenarios did not simply produce more vivid (and perhaps more effective) imagery. Raters' responses were subjected to repeated measures analyses of variance (ANOVAs),

confirming that mean ratings of effort varied significantly across the passive, high-effort, and low-effort conditions for both the ego-moving, $F(2, 58) = 86.301$, $MSE = 0.795$, $p < .0001$, and object-moving, $F(2, 58) = 53.031$, $MSE = 1.268$, $p < .0001$, scenarios. Average ratings of vividness of imagery varied by no more than 0.88 on a 7-point scale across effort conditions, and repeated measures ANOVA demonstrated that there was no significant difference in reported vividness due to the manipulation of effort, $F(2, 58) = 1.532$, $MSE = 0.486$, $p = .23$.

The test question was an ambiguous question about time: "Next Wednesday's meeting has been moved forward two days. What day is the meeting on now that it has been moved?" (e.g., Boroditsky, 2000; Matlock et al., 2005; McGlone & Harding 1998).

Procedure

Participants assigned to one of the six test conditions were instructed to read the story, look at the accompanying image, and draw an arrow on the image indicating the path of motion described in the story. They then answered the test question on the following page. In the baseline condition, participants responded to the test question before seeing the story. To prevent participants from suspecting the purpose of the experiment, the prime and test question were the first two pages of an eight-page packet containing unrelated materials.

Results

Consistent with past research, there was a strong prior tendency to choose "Friday" over "Monday" (see Figure 1): In the baseline condition, 77% of respondents selected "Friday", reflecting an apparent preexisting tendency to take an ego-moving perspective as found in previous studies (Núñez, Motz, & Teuscher, 2006; Ramscar et al., 2010; see Clark, 1973, for a possible explanation of this behaviour). Accordingly, we analysed each test condition against baseline. Participants in the ego-moving conditions did not produce "Friday" responses more often than did baseline participants (Fisher's exact test, passive ego-moving $p = .55$, low-effort ego-moving $p = .76$, high-effort ego-moving $p = .37$), probably because of the strong preexisting tendency to choose "Friday".

In both the high- and the low-effort object-moving conditions, participants produced "Monday" responses significantly more frequently than baseline: The active-motion spatial primes successfully influenced their temporal judgements (Fisher's exact test, low effort $p = .009$, high effort $p = .007$). These data are consistent with previous studies showing that primes that evoke imagined active spatial motion can influence decisions about time (e.g., Boroditsky, 2000; Boroditsky & Ramscar, 2002; Gentner et al., 2002; Matlock et al., 2005; McGlone & Harding, 1998; Ramscar et al., 2010).

Our key findings were as follows. Although both active object-moving primes influenced participants' judgements about time, responses in the passive object-moving condition did not differ from baseline responses (Fisher's exact test, $p = 1.000$) or from the passive ego-moving condition (Fisher's exact test, $p = .547$). Responses in the passive object-moving condition were significantly different from those in the high-effort or low-effort object-moving conditions (Fisher's exact test, low effort $p = .045$, high effort $p = .006$). This result suggests that active, but not passive, spatial primes influence our thoughts about time (see Figure 1).

These findings cannot be explained by the relative vividness of stories presented: Norming data revealed no significant difference in ratings of vividness across effort conditions for the object-moving condition, $F(2, 58) = 2.224$, $MSE = 0.779$, $p = .12$. Further, it does not appear that the effectiveness of a spatial prime decreases as a function of the amount of effort expended: The low- and high-effort object-moving conditions did not differ significantly from each other (Fisher's exact test, $p = .573$), and the likelihood of a "Monday" response actually decreased slightly as effort increased: A total of 70% responded "Monday" in the low-effort object-moving condition, compared to 61% in the high-effort object-moving condition. Rather, in the object-moving conditions, active motion primes (but not passive motion primes)

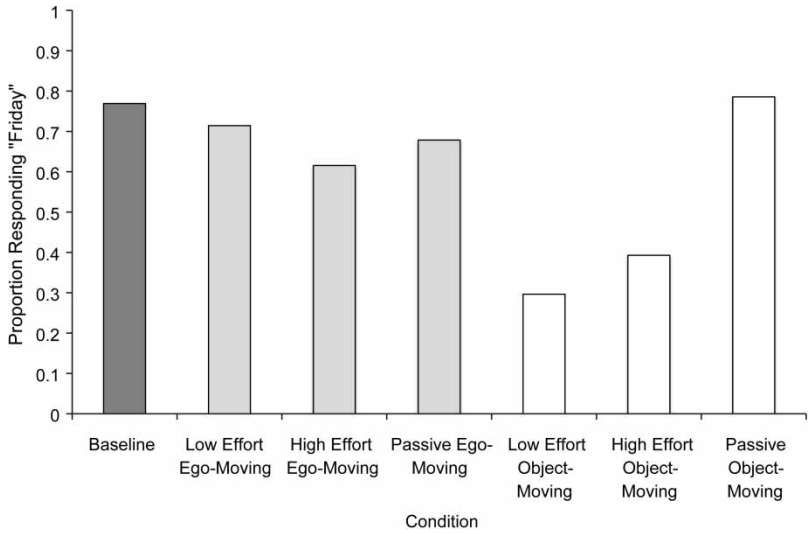

Figure 1. *Proportion of "Friday" (ego-moving) responses by condition.*

influenced temporal decisions. A 2 (mover: ego-moving, object-moving) × 3 (effort: low effort, high effort, passive) ANOVA revealed main effects of mover, $F(1, 159) = 5.86$, $MSE = 1.29$, $p = .017$, and effort, $F(2, 159) = 4.36$, $MSE = 0.96$, $p = .014$, and an interaction of mover and effort, $F(2, 159) = 4.41$, $MSE = 0.97$, $p = .013$.[2] This confirms that the spatial prime influenced participants' response to the question about time differently based on the perspective presented in the prime (ego-moving or object-moving). It also demonstrates that the level of effort in the prime influenced participants' temporal judgements (driven specifically by the passive vs. active effort distinction; see above). We interpret these findings to indicate that spatial primes depicting active motion influence participants' thoughts about time differently than do primes depicting passive spatial motion.

Discussion

In this study, primes involving imagined active spatial motion scenarios, but not those involving closely matched passive spatial motion scenarios, influenced participants' temporal judgements. These results are consistent with past research showing that spatial primes involving effortful motor activity influence judgements about time (e.g., Boroditsky & Ramscar, 2002; Gentner et al., 2002; Matlock et al., 2005; McGlone & Harding, 1998; Ramscar et al., 2010), adding to the existing body of literature on space–time relationships by showing that passive spatial motion primes, at least under the conditions tested here, did not prime participants to adopt a particular temporal perspective.

Because primes used in the present study were normed for vividness, it is unlikely that these results stem solely from how interesting or compelling the primes were. Instead, it appears to be the case that imagined engagement in motion evokes a different experience from imagined observation of motion, leading to corresponding differences in the resulting priming effects (at least in the context of spatial-perspective primes). Active motion scenarios are more likely to induce a particular spatial priming effect than are very similar

[2] Because these data are binomial, we also conducted a binomial logit regression predicting response (Monday or Friday) from mover, effort, and their interaction. This analysis demonstrated the same effects as those reported above (all $ps < .025$).

passive scenarios. This suggests that imagined self-motion, rather than imagined motion through space in itself, may be an important component of the priming effects observed in earlier studies: The motor content of a spatial prime influences whether this prime will induce a shift in temporal perspective taking.

At the outset of this study, we hypothesized two possible ways in which the motor content of a prime might influence its effectiveness in causing a shift in temporal perspective taking. One possibility was that as the perceived effortfulness of motor content increased, the likelihood of a participant adopting a particular spatial perspective (and then transferring this perspective onto the domain of time) would also increase. Another possibility was that the simple presence of motor content in a spatial prime would facilitate perspective taking relative to nonmotor spatial primes. Our data support the latter conclusion: This study found no difference between the influence of low-effort and high-effort primes on temporal judgements, suggesting that increased imagined levels of effort in spatial priming scenarios do not lead to increased priming effects on temporal judgements.

Could demand characteristics have produced these findings? Some recent studies have criticized common methods used to manipulate the amount of effort expended in real-life situations (such as the wearing of backpacks; Durgin et al., 2009). These studies suggest that demand characteristics introduced by real-world backpack wearing (and presumably other related manipulations) are sufficient to explain some effects on perceptual judgements that were previously attributed to effort. We think it is unlikely that such concerns apply to the present study. Although it is not impossible that participants in our study guessed the purpose of the backpacks (or wagons) in our imagined-effort scenarios, it is highly implausible that our naive participants could have used this information to shape their responses to the "meeting" question.

Both our low- and high-effort primes successfully induced shifts in temporal perspective taking, while our passive prime did not. This demonstrates that the effectiveness of our spatial primes was substantially reduced when the motor component was removed. Based on the present data, there appears to be a strong role for motor imagery in increasing the effectiveness of spatial primes, and this effect appears to be binary, not continuous: Primes that invoke motor imagery are more effective than those that do not. Additional studies will be required, however, to definitively rule out the possibility that the degree of effort in an imagined motor action influences its effectiveness in priming temporal judgements.

The lack of an effect of active versus passive spatial motion in the ego-moving condition remains to be explained. We suspect that this result may be attributed to the high baseline rate at which people adopt an ego-moving perspective, consistent with previous research (Núñez et al., 2006; Ramscar et al., 2010): In our study, participants in the baseline condition (who received no prime) were much more likely to adopt an ego-moving perspective when making temporal judgements. This bias towards a Friday (ego-moving) response is consistent with two predictions about the space–time metaphor—one linguistic and one conceptual. First, recent work has demonstrated that the use of the preposition *on* (which was used in our critical test question) may bias temporal judgements by increasing the likelihood of a Friday (ego-moving) response. This is due to semantic properties of prepositions like *in* and *on*. One recent study showed that 70% of participants said "Friday" when the preposition *on* was used in the ambiguous meeting-day test question, and our baseline data match these values closely. However, it is important to note that, while our choice of preposition may have inflated the likelihood of a "Friday" response slightly, more than 60% of people in a no-prime/no-preposition condition also spontaneously adopted an ego-moving perspective: Linguistic patterns alone cannot account for the baseline tendency for adults to adopt an ego-moving perspective (Kranjec, Cardillo, Schmidt, & Chatterjee, 2010). This makes sense in light of early accounts of the space–time metaphor, which proposed that in the absence of additional linguistic or contextual cues, adults will tend to interpret ambiguous spatial and temporal terms from an ego-moving perspective (Clark,

1973). This is because humans experience the world from this perspective under everyday conditions. Future studies will continue to explore the ways in which this default perspective may be modulated by passive versus active spatial primes.

If it is indeed the case that passive spatial imagery is not sufficient to induce the transfer of perspective from the spatial to the temporal domain, this may suggest an alternative interpretation of experiments such as Boroditsky and Ramscar's (2002) train study. In that study, strong effects of spatial priming on temporal judgements were found at both the beginning and the end of a train journey, when participants were perhaps most likely to be thinking about engaging in motion (boarding or departing the train). Yet, when participants were at the midpoint of their journey (and were therefore experiencing passive motion), these effects diminished. This finding was thought to result from participants' differing levels of awareness of spatial motion (Matlock et al., 2005), but it is possible in light of the present study that people who are more likely to be engaging in motor imagery (such as those near the beginning or end of a journey) are also more likely to form a strong spatial perspective than those who are not.

The cognitive link between the domains of space and time has been the subject of much debate in recent years. Numerous studies have shown that spatial primes depicting extent (e.g., long/short lines) influence temporal judgements about duration (e.g., Casasanto & Boroditsky, 2008; Srinivasan & Carey, 2010), even in the absence of linguistic cues or motor activation. This suggests a deep conceptual connection between the domains of space and time. However, the present findings suggest that the relationship between spatial and temporal perspective taking may be more nuanced. This study demonstrates that not just any spatial prime will induce the changes in a participant's perspective that are necessary to prime temporal judgements. Rather, the effectiveness of a spatial prime appears to be mediated by the engagement of motor imagery. Distinguishing between purely spatial primes and those that include both spatial and motor content may be useful for understanding the source and scope of the conceptual links between space and time.

Original manuscript received 13 April 2011
Accepted revision received 22 October 2011
First published online 20 February 2012

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