The Role of Grammatical Aspect in the Dynamics of Spatial Descriptions

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Abstract. What role does grammatical aspect play in the time course of understanding spatial language, in particular motion events? Although processing differences between past progressive (was walking) and simple past (walked) aspect suggest differences in prominence of certain semantic properties, details about the temporal dynamics of aspect processing have been largely ignored. The current work uses mouse-tracking [1] to explore spatial differences in motor output response to contextual descriptions and aspectual forms. Participants heard descriptions of terrain (difficult or easy) and motion events described with either the past progressive or simple past aspectual form while placing a character into a scene to match this description. Overall, terrain descriptions modulated responses to past progressive more than to simple past in the region of the screen corresponding to the path. These results, which suggest that perceptual simulation plays a role in the interpretation of grammatical form, provide new insights into the understanding of spatial descriptions that include motion.

Keywords: Spatial language, Motion verbs, Event understanding, Mouse-tracking, embodied cognition.

1 Introduction

Language and space are intimately connected. All languages have a system for specifying basic spatial relations, including where things are relative to other things and where they are relative to time. Some of this happens by concatenating lexical items to indicate where an object is at any given moment. For instance, the expression "at the end" in "John is at the end of his driveway", tells us that John is standing, sitting or otherwise positioned in the end region of his driveway at the time of speaking. All languages have a way to express movement, including movement to and away from landmarks, for instance, "John went to the end of this driveway" or "John is coming from the end of his driveway". In these cases, an agent (John) moves from one position to another in space and time. Spatial expressions like these are so ubiquitous in language that we rarely give them a second thought when we are describing or listening to descriptions of physical space. And despite a huge and well-informed literature

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on how spatial descriptions are used in linguistics and psychology, surprisingly little is known about how grammar influences the way they are processed in real-time. In particular, what role does grammatical aspect play in the interpretation of past events, especially motion events? When is it important to highlight the ongoing nature of an event versus its completion, and what consequences does this often implicit distinction have for understanding where agents and objects are at any given movement? This research explores these questions using mouse-tracking, a robust dense-sampling method designed to track the fine-grained details of spatial processing in a number of cognitive domains [1]. This method allows us to pinpoint where things are at any given moment relative to linguistic input and physical space.

Grammatical aspect provides temporal information about the unfolding of events. In this way it provides the speaker and listener implicit, detailed temporal information about a reported event, for instance, whether it was completed and whether it was a short or long [2, 3]. Such temporal information can certainly influence the way a sentence is understood. Take, for example, the following sentences: "David walked to the university," and "David was walking to the university." Both sentences describe an event that occurred in the past, but they use different aspectual forms. The first uses the simple past form of the verb "ran," and emphasizes the completion of the action. The second uses the past progressive form, and emphasizes the ongoing nature of the action. The forms verb+ed and was verb+ing are often used to describe the same situation in English. (In some languages, this perfective versus imperfective distinction is pronounced and highly differentiated. In English, the distinction is much more diffuse. See Croft [4] and Frawley, [3].) However, just how they differ in terms of processing is understudied and many questions remain about how they influence spatial reasoning.

In recent work, we began to explore how aspect influences spatial reasoning in a series of simple offline studies [5]. In each study, people were shown a picture of a path that extended from the foreground of the scene into the background of the scene where it terminated at a destination landmark (e.g., a university, mountain range). Below the picture was a sentence that related to the scene shown in the picture. The sentence included a moving agent and a motion verb described with either the simple past or past progressive aspectual form, for instance, "This morning David walked to the university" (simple past) or "This morning David was walking to the university" (past progressive). On the path were 10 unevenly spaced identical silhouette characters who appeared to be heading to the destination landmark (e.g., figure with leg extended forward and arms bent as if in motion and facing the university). Participants were instructed to "circle the man that the sentence is most naturally referring to." The results showed that participants were more likely to circle a character in the middle region of the path with past progressive sentences (for instance, was walking), and more likely to circle a character in the latter region of the path in response to simple past sentences (for instance, walked). These results indicated that when participants read simple past sentences, they focused on the end of the path, or the location of the completed action in the scene. In contrast, when they read past progressive sentences, they focused on the middle section of the path, where the ongoing action would be taking place. In these and related offline studies, we showed that different aspectual forms have clear consequences for spatial reasoning, in particular, the conceptualization of motion events.

The findings of our offline studies resonated with reaction time studies conducted by Madden and Zwaan [6]. In analyzing the on-line processing of simple past and past progressive event descriptions in a sentence-picture verification task, they found that people were generally quicker to respond to pictures showing a completed action after they reading a simple past sentence (e.g., "The car sped through the intersection") versus a past progressive sentence (e.g., "The car was speeding through the intersection"). However, no such latency differences were found when participants read past progressive sentences and saw pictures of intermediate action. In brief, their studies showed that the simple past draws attention to the end state of the action and the past progressive draws attention to a wide and varied range of intermediate stages of an action. Although their work provided insights into the processing of aspect and its impact on spatial reasoning, many questions remained about the details of processing. (For related work on aspect and spatial representation, see 7, 8, and 9).

Such reaction time data have revealed valuable insights into the processing of aspect. However, as suggested by the work of Madden and Zwaan [6], they are somewhat limited when investigating details of representation (especially with the past progressive, on-going form). In addition to considering the findings of the offline and reaction time experiments mentioned above, it is necessary to consider relevant research on real-time cognitive processing in the dynamics of the response. To gain new insights into the role of aspect in event understanding, we consider relevant work on real-time cognitive processing in response dynamics. Factors that can affect response latencies have been shown to also have the capacity to influence later facets of response dynamics. For instance, Abrams and Balota [10] demonstrated that word frequency is capable of influencing not only response latencies but also response kinematics after a response has been initiated, suggesting ongoing language processes may co-exist with ongoing motor processes (see also 11, 12 and 13). Their work makes a strong case for examining the dynamic variables of motor movements initiated in response to a stimulus.

To better understand the potential differences in the on-line processing of different aspectual forms, here we use the methodology of computer-mouse tracking. Monitoring the streaming x- and y-coordinates of goal-directed mouse movements in response to spoken language is a useful indicator of underlying cognitive processes. In contrast to ballistic saccades, arm movements allow for a continuous, smooth motor output within a single trial to complement eye-tracking research. Spivey, Grosjean, and Knoblich [1] demonstrated that these mouse movements can be used to index the continuous activation of lexical alternatives. By recording the x,y coordinates of the mouse as it moved with the goal-directed hand motion to click on the appropriate object, competition between the partially activate lexical representations was revealed in the shape and curvature of the hand-movement trajectories.

Further, Dale, Kehoe, and Spivey [14] employed this mouse-tracking methodology to explore the underlying processing of categorization. In a series of four experiments, participants used the mouse to click on one of two categories (e.g., "mammal" or "fish") to categorize either a typical exemplar ("cat") or an atypical exemplar ("whale"), while the computer-mouse movements were recorded. The results showed spatial differences in the average trajectories of the two conditions, with the atypical exemplars' average trajectory diverging away from the typical exemplars' average trajectory towards the competing category response button. Additionally, the movement durations for each condition were significantly different for the two conditions, with the atypical trajectories having longer overall movement durations than the typical trajectories. These results reveal nonlinear time course effects in the process of categorization, and significant attraction towards the competing category name in the atypical exemplar trajectories. Moreover, they provide evidence to complement reaction time data by examining the overall movement durations of the two types of trajectories.

Some of our own work indicates that mouse-tracking is useful and informative for exploring research questions on the on-line processing of grammatical aspect [15]. In one experiment, participants listened to sentences like, "Tom jogged to the woods and then stretched when he got there," or "Tom was jogging to the woods and then stretched when he got there." While participants heard these sentences, they saw scenes consisting of a path curving upwards from left to right, and terminating at the destination described in the sentence. A character was located to the right of the beginning of the path and under the destination, separated from the scene by a black box framing the destination and path. Similar to our earlier offline results, participants dropped the character closer to the center of the path with past progressive sentences and closer to the destination with simple past sentences. Further, the two aspectual forms elicited significantly different movement durations: Participants moved the character into the scene for a longer duration of time with past progressive sentences than when they heard simple past sentences. These drop location and movement duration results converge with and further inform earlier research, supporting that past progressive aspect focuses attention on the on-going nature of the action while simple past aspect focuses attention on the end state of that action, even during real time processing.

In the current experiment, we set out to extend these findings by investigating the way aspect may interact with terrain descriptions. Research has shown that context descriptions interact with fictive motion sentences to produce both differences in patterns of eye movements and in reaction times [16, 17]. Eye movement data have also elucidated the real-time comprehension of fictive motion sentences. Fictive motion sentences contain motion but no actual movement takes place. For example, "The road ran through the valley" contains ran, but the road does not actually run. Richardson and Matlock [17] had participants listen to a context sentence describing the terrain, and then a target sentence containing fictive motion. When participants first heard context sentences describing the terrain as difficult, inspection times and eye-movement scanning along the path were increased as opposed to when participants heard the terrain described as easy. These results support earlier reaction time results, in which participants read narratives describing a terrain, and then made decisions about whether a fictive motion sentence was related to the preceding context [16]. Participants were slower to respond to fictive motion sentences when they had read context sentences describing slow travel, long distances, or difficult terrain, than when the they had read contexts describing fast travel, short distances, or easy terrain. However, no such differences in context descriptions was found when the target sentence did not contain fictive motion (e.g, "The road is in the valley"). Taken together, the results provide evidence that fictive motion descriptions affect both reaction times and eye-movements by evoking mental representations of motion, and that this is then influenced by contextual constraints on that motion. The eye-movement data allow for a closer look at the way the constructed mental model and the linguistic description are coordinated.

However, the impact and coordination of such descriptions and grammatical aspect has not been explored. Here we use the mouse-tracking methodology to investigate how different aspectual forms interact with similar context descriptions. Participants heard two sentences. The first provided a contextual description of the path and the second manipulated grammatical aspect. For example, on target trials participants heard a context sentence describing the path as either difficult (i.e., "The road to the university was rocky and bumpy") or easy (i.e., "The road to the university was level and clear"), before a simple past target sentence (i.e., "David walked to the university where he sat in class") or a past progressive verb target sentence (i.e., "David was walking to the university where he sat in class"). At the same time participants heard these sentences, participants saw scenes like Figure 1 below.

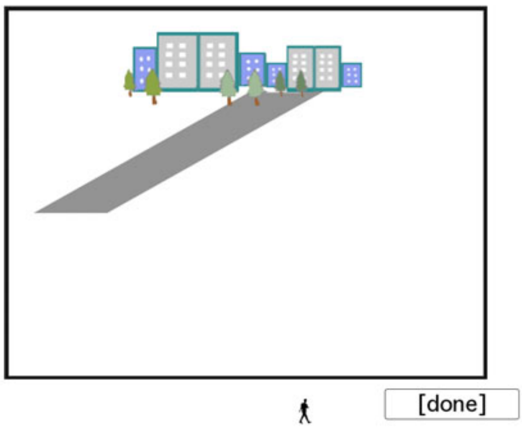

Fig. 1. In our experiment, the auditory stimuli (Table 1) were accompanied by a visual scene, like this example

This scene contained a diagonal path that originated halfway up the screen and extended from the extreme left to the top and center of the screen (corresponding to the destination in the sentence). The orientation of the path was changed to this short, diagonal path from the long, curvy path of earlier research [5, 15] to allow for more thorough and precise investigations of potential spatial and movement duration differences. A character was located to the right of the beginning of the path and under the destination. It was outside of the scene (i.e., separated by a black box that framed the destination and path).

We explored several hypotheses around the role of grammar in the processing of spatial descriptions and motion conceptualization. If past progressive sentences elicit more attention to the path, then the effect of context description was expected to be greater with past progressive sentences than when they contained simple past sentences. We predicted that context would modulate movement durations and spatial attraction to the path more in the past progressive sentences than in the simple past sentences. We also wanted to explore the influence of the visual scene's path on movement durations. The visual scene---with a path starting halfway up the screen---would enable us to examine if the trajectories produced in response to each aspectual form would reliably differ for the entire trajectory of the hand or only in the region of the screen corresponding to the path. If differences emerged across the entire trajectory, then the effect of grammatical aspect would appear to be more global, and to exert influence across the entire event description. However, if differences emerged only in the region of the screen corresponding to the path, then the effect of grammatical aspect would appear to be specific to the parts of the event it describes.

2 Method

2.1 Participants

A total of 64 undergraduates at Cornell University participated in the experiment for extra credit in psychology courses. All participants were right handed and native speakers of American English.

2.2 Materials

Twelve sentences were created from adapting the stimuli used in the offline studies of Matlock and colleagues [15]. They contained a range of motion verbs, including walk, job, run, and hike. A final clause that described an event at the destination was added to encouraging movement all the way to the destination. Similarly, two contexts for each stimulus were created. Hence, four versions of each of the 12 experimental items were created, as shown below: (1a) rough context description, simple past sentence, (1b) rough context description, past progressive sentence, (1c) smooth path description, simple past sentence, (1d), smooth path description, past progressive sentence.

1a) *The road to the university was rocky and bumpy.* David walked to the university where he sat in class.
1b) *The road to the university was rocky and bumpy.* David was walking to the university where he sat in class.
1c) *The road to the university was level and clear.* David walked to the university where he sat in class.
1d) *The road to the university was level and clear.* David was walking to the university where he sat in class.

Sentences were recorded using a Mac-based speech synthesizer program. Each of the 12 experimental items was spliced in order to produce both a past progressive and a simple past version, ensuring that the prosody of both of the targets was otherwise identical. Similarly, the context description was spliced onto the beginning of each of these target sentences. A pause of one second separated the offset of each context sentence from the onset of the target sentence. The experimental items were counterbalanced across four presentation lists. Each list contained three instances of each condition, so that all participants heard all twelve target sentences, but only heard one version of each.

Corresponding visual scenes were created for each target sentence pair. Each target visual scene consisted of a diagonal path starting halfway up and on the extreme left side of the screen. The path slanted to the right, terminating in the middle at the top of the screen. A character was located to the right of the beginning of the path and under the destination, separated from the scene by a black box framing the destination and path. See Figure 1 above. The only moveable item in the scene was the character, which subtended an average of 1.53 degrees of visual angle in width by 2.05 degrees in height. The destinations were an average of 11.22 degrees of visual angle in width by 4.09 degrees in height, and the path itself occupied a square of 8.42 degrees of visual angle in width by 6.11 degrees of visual angle in height. The character was located 14.25 degrees of visual angle from the destination. The stimuli were presented using Macromedia Director MX, and mouse movements were recorded at an average sampling rate of 40 Hz. The display resolution was set to 1024 x 768.

Additionally, to keep participants from developing strategies specific to the experimental sentences, 12 filler items were created. The fillers were of the same form as the target sentences: each contained a context description and either a past progressive or simple past sentence. These filler trials varied from the target trials such that the context description provided no information about the path (i.e., "The weather in the valley was warm and humid") and such that they described no movement along the path (i.e., "Janet swam in the pool and then dried in the sun,"). These filler items were accompanied by 12 filler scenes, created using a short path beginning on the right side of the screen and slanting to the top, center of the screen. Besides the direction of the path, each filler scene was quite similar to the target scenes, for instance, character outside of a scene that contained the path and destination mentioned in the filler sentence.

2.3 Procedure

Participants were asked to make themselves comfortable in front of the computer, and allowed to adjust the mouse and mouse-pad to a location that suited them. First, participants read instructions to place the character in the scene to make the scene match the sentences they heard. Upon signaling to the experimenter that they understood the task, they were next presented with two practice trials (similar in form to the filler trials), followed by the experimental task. At the onset of each trail, participants were presented with the entire visual scene. After a 500 ms preview, the sound file began. After the participant had moved the character (though not to any particular location), a "Done" button appeared in the bottom left corner of the screen. Participants clicked this button to move to the next trial. A blank screen with a button in the center labeled "Click here to go on" separated trials from each other. The entire experiment lasted approximately 20 minutes.

3 Results

Mouse movements were recorded during the grab-click, transferal, and drop-click of the character in the experimental trials. Prior to the analyses, the data were screened to remove extremely long trials. Movement durations 20 seconds or more were removed because they constituted an unusually long time for a mouse-movement. Using this criteria, only three trials (less than 0.4%) of trajectories, were excluded.

3.1 Drop Locations

Previous offline results revealed that participants chose a location closer to the middle of the path as the best representative of a past progressive sentence, while selecting a location closer to the destination as the best representative of a simple past sentence [5, 15]. By plotting the drop point (location along the path where each participant let go of the mouse to "drop" the character) in each of the four conditions, the current results demonstrate a similar trend. See Figure 2. There was not a significant interaction of terrain description and aspect (p's > .5). However, there was a main effect of aspect when comparing the average drop x-coordinate, $F(1,62) = 8.462$, $p < 0.005$, with the average drop x-coordinate being further left (closer to the path) when participants heard past progressive sentences ($M = 476.71$, $SD = 68.81$) than when they heard simple past sentences ($M = 494.82$, $SD = 61.74$). Similarly, there was a main effect of aspect when comparing the average drop y-coordinates, $F(1,62) = 6.048$, $p < 0.017$, with the average drop y-coordinate being lower (further from the destination) when participants heard past progressive sentences ($M = 219.04$, $SD = 37.02$) than when they heard simple past sentences ($M = 210.65$, $SD = 41.01$). This tendency to drop a character closer to the path in the past progressive condition, and closer to the destination in the simple past condition, replicates previous evidence that the ongoing nature implied by a past progressive sentence draws attention to the middle portion of the path, whereas there is a tendency to focus attention on the destination in response to simple past sentences.

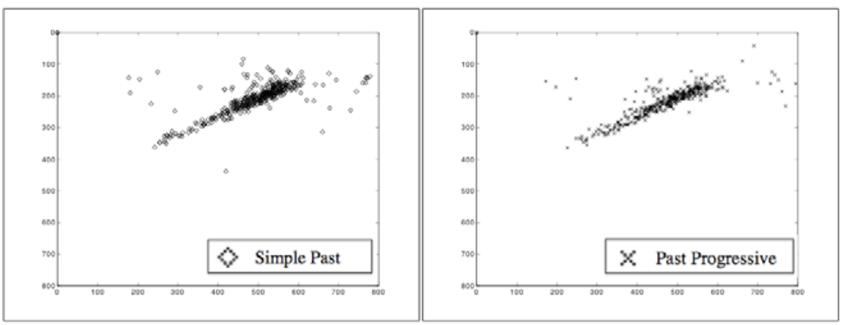

Fig. 2. Drop locations in response to simple past sentences (left panel) and past progressive sentences (right panel)

3.2 Movement Durations

We began our investigation of online processing by looking at the temporal dynamics of the movement of the character. There was no significant interaction of context and aspect when comparing overall movement durations (i.e., the length of time from the initial grab of the character to the final drop of the character into the scene), p's> .2. However, there was a significant interaction of context and aspect on movement durations within in the region of the screen corresponding to the depicted path, $F(1, 63) = 4.6$, $p < .036$. See Figure 3. In the region of the path, the average movement duration for simple past sentences was not substantially different when the context was first described as rough (*M*= 2448.33, *SD*=1848.88) or smooth (*M*=2478.72, *SD*= 1527.17). On the other hand, the average movement duration in the region of the path for the past progressive sentences was slower when the context was first described as rough (*M* = 2667.70, *SD*=1679.86) than when it was described as smooth (*M*=2121.88, *SD*=1240.13). Because simple past sentences focus attention on completed action, context descriptions do not significantly impact the movement dynamics. On the other hand, because past progressive sentences encourage attention to the ongoing-ness of the action, context descriptions of the location of that ongoing action do influence processing. These data extend previous research, suggesting that aspect influences the real-time movement dynamics of the event being described, not merely the endstate of that event. Also, as predicted, the context descriptions modulate this on-line measure when aspect focuses attention to the ongoing action of the motion event.

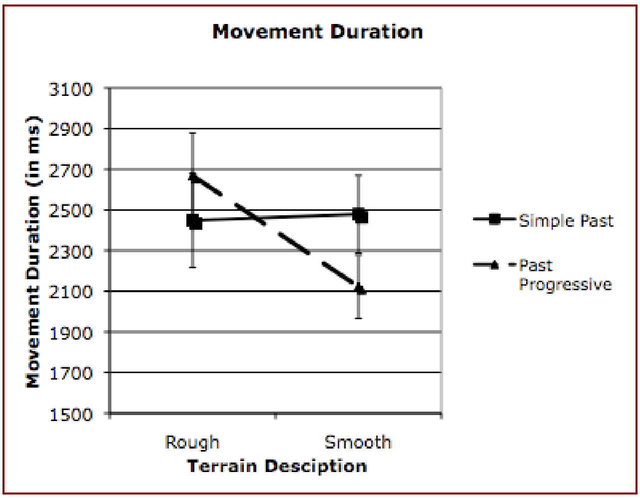

Fig. 3. Movement duration differences in the region of the visual scene corresponding to the path. When participants heard rough terrain descriptions preceding the past progressive sentences, they moved the character more slowly in the region of the screen corresponding to the path than when they heard the terrain described as easy. Terrain description did not change such movement durations when participants heard simple past sentences.

3.3 Raw Time

To begin to compare spatial attraction to the visual scene's path across conditions, we first looked at average x- and y-coordinates within eight 500ms time-bins of the movement duration. There was no significant interaction between aspect and terrain, *p*'s>.1, or main effect of either variable, *p*'s>2. However, breaking the movement into time bins serves only as an approximation of actual attraction over raw time. These 500ms time-bins were not time locked to the sound files, and hence did not have a fixed starting time. Because the offset of the verb occurred late within the sound files and because many participants did not begin to move the character until after the end of the sound file (with an average 1400 ms lag between offset of verb and end of sentence), these data are not synchronized to a fixed point. Future work will address potential raw time spatial differences more fully.

3.4 Spatial Attraction

The movement duration differences only in the region of the path suggest that there is an interaction between the linguistic and visual information. In other words, these movement duration differences are only observed in the relevant region of the visual scene. In order to further explore this apparent interaction of grammatical aspect and visual scene information, we examined the spatial differences in trajectories. Figure 4 shows the average time-normalized trajectories in each of the four conditions. The mean simple past and past progressive trajectories at each of the 101 time-steps in the top panel of Figure 4 illustrate that in the rough terrain context, the average past progressive trajectory curved more toward the path than the average trajectory elicited by the simple past sentences, but only near the end of the trajectory. However, in the smooth terrain description, (Figure 2, bottom), there appears to be greater attraction toward the path across a greater portion of the trajectory for the past progressive sentences.

To determine whether the divergences observed across the simple past and past progressive sentence trajectories in the rough and smooth terrain descriptions were statistically reliable, we conducted a series of t-tests. These analyses were conducted separately on the x- and the y-coordinates at each of the 101 time-steps. In order to avoid the increased probability of a Type-1 error associated with multiple t-tests, and in keeping with Bootstrap simulations of such multiple t-tests on mouse trajectories [14], an observed divergence was not considered significant unless the coordinates between the simple past- and past progressive-sentence trajectories elicited p-values < .05 for at least eight consecutive time-steps.

In the rough context description condition, there was significant divergence of the past progressive x-coordinates away from the simple past x-coordinates and toward the path between time-steps 89 and 101, p's <.04, and no significant divergence in the y-coordinates. This difference is commensurate with the observed differences in drop locations for past progressive and simple past sentences described earlier. Even though there was no significant interaction between aspect and context description on drop location, this significant divergence so late in the time-normalized trajectories may simply be an artifact of drop locations.

On the other hand, in the smooth context description, there were significant divergences of the past progressive x-coordinates away from the simple past x-coordinates towards the path between time steps 48 and 60, p's <.4, and again between time steps 65 and 89, p's < .03. There was also significant divergence of the average past progressive y-coordinates away from the average simple past y-coordinates and towards the path between time steps 89 and 101. Again, this y-coordinate divergence late in the trajectory may be an artifact of the drop locations in each condition.

These results are encouraging, but they are not as convincing as the path-movement duration results (Figure 3). It is curious that the spatial attraction differences were detected in the smooth context description but not as robustly in the rough context description. Perhaps the visual stimuli used to depict the path simply did not appear to afford difficult or uneven travel, and the incongruence in the linguistic description and the visual appearance of the path hindered the emergence of full spatial differences in this context description. Future work will investigate this possibility.

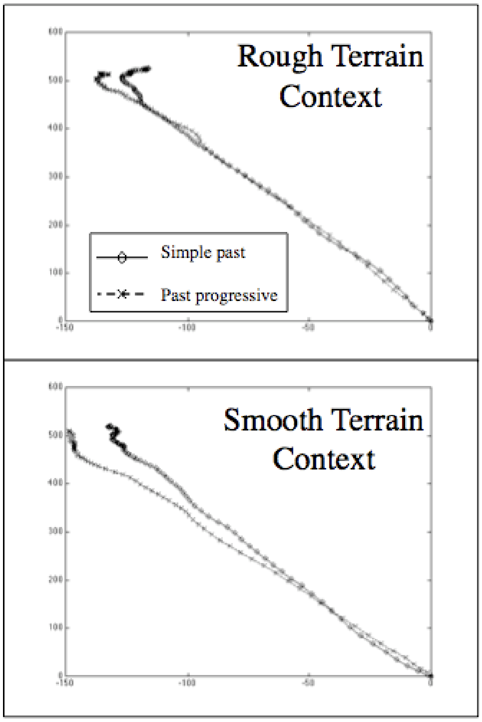

Fig. 4. Average time-normalized simple past and past progressive trajectories in rough and smooth terrain contexts. To some extent in both terrain descriptions (but to a greater extent in the smooth terrain description), participants moved the character into the scene with greater spatial attraction to the path when they had heard a past progressive sentence than when they had heard a simple past sentence.

4 Discussion

Our work provides new insights into how grammar influences the understanding of everyday spatial descriptions, specifically, events that include a path and moving agent. We provide new insights into how different aspectual forms can robustly influence the processing of event descriptions. The results reveal that the processing of spatial descriptions by examining continuous motor output in response to aspectual and contextual differences. Because past progressive aspect focuses attention to the location of the ongoing nature of the verb, contextual descriptions describing the location of the ongoing action significantly interact with grammatical aspect. On the other hand, simple past aspect focuses attention to the location of a completed action, and so contextual description do not influence processing of these sentences in the same way. This is consistent with previous research with mouse-tracking tasks [15], sentence-picture verification tasks [6], and offline spatial reasoning tasks [5].

Although these results are extremely promising, future work is needed. For example, while mouse-tracking is provides a continuous motor output, mouse-tracking is not meant to serve as a general replacement for eye-tracking, specifically because mouse-tracking is not as immediate as the eye-tracking, lagging 200-300ms behind initiating an eye-movement. Therefore, eye-tracking provides more immediate information about intermediate stages of processing. Therefore, future work should look at the immediate time course of processing aspect through the use of more immediate dependent measures. Similarly, our continuing program of research will also look at processing differences with specific verbs, namely verbs that have an inherent perspective to parts of the path, e.g. ‘enter’ and ‘leave’ or ‘come’ and ‘go’.

The current research has implications for several areas of research on spatial language. Although grammatical aspect is known to provide information about the temporal aspects of processing (e.g., completed or not completed, repeated or not repeated), our results indicate that aspect can significantly influence spatial reasoning in the time course of processing. Our work also introduces a novel method for investigating descriptions and depictions of spatial scenes. The beauty of the approach is that it affords careful examination of the temporal dynamics of processing spatial language. In addition, our results provide evidence to support cognitive linguists’ claims regarding meaning as a conceptualization of spatial descriptions, and the idea that aspect, like many domains of language, involves dynamic conceptualization [18, 19].

More broadly, this work resonates with embodied cognition work on perceptual simulation and language understanding [11]. It also dovetails with the methodological advances of Balota and Abrams [20] by providing new evidence from the temporal dynamics of a response after the response has been initiated, and demonstrating that the motor system is not a robot-like automaton triggered by completed cognitive processes. Rather, motor processes are co-extensive with cognitive processes during perceptual/cognitive tasks [e.g., 20, 21]. This work also comports with our understanding of how spatial mental models and visual information are coordinated in motor output. Similarly to the way understanding of spatial events is created and observed through tracking eye movements [17, 22], this work demonstrates that event understanding takes place differently as a function of changes in context descriptions and grammatical aspect. Finally, the work explores a new way that language about space and thought about space are related.

References

1. Spivey, M.J., Grosjean, M., Knoblich, G.: Continuous Attraction Toward Phonological Competitors. PNAS 102, 10393–10398 (2005)
2. Comrie, B.: Aspect. Cambridge University Press, Cambridge (1976)
3. Frawley, W.: Linguistic Semantics. Lawrence Erlbaum Associates, Hillsdale (1992)
4. Croft, W.: Aspectual and Causal Structure in Event Representations. In: Gathercole, V. (ed.) Routes to Language Development: In Honor of Melissa Bowerman, pp. 139–166. Lawrence Erlbaum Associates, Mahwah (2009)
5. Matlock, T., Fausey, C., Cargill, S., Spivey, M.: On the Path Toward Understanding the Dynamics of Aspect Descriptions in Motion Events. Paper presented at 48th Annual Meeting of the Psychonomic Society, Long Beach, California (November 2007)
6. Madden, C.J., Zwann, R.A.: How Does Verb Aspect Constrain Event Representations? Memory & Cognition 31, 663–672 (2003)

7. Ferretti, T.R., Kutas, M., McRae, K.: Verb Aspect and the Activation of Event Knowledge in Semantic Memory. Journal of Experimental Psychology: Learning, Memory, & Cognition 33, 182–196 (2007)
8. Magliano, J.P., Schleich, M.C.: Verb Aspect and Situation Models. Discourse Processes 29, 83–112 (2000)
9. Morrow, D.G.: Prominent Characters and Events Organize Narrative Understanding. Journal of Memory and Language 24, 304–319 (1985)
10. Abrams, R.A., Balota, D.A.: Mental Chronometry: Beyond Reaction Time. Psychological Science 2, 153–157 (1991)
11. Barsalou, L.: Language Comprehension: Archival memory or preparation for situated action? Discourse Processes 28, 61–80 (1999)
12. Barsalou, L.W.: Continuing Themes in the Study of Human Knowledge: Associations, Imagery, Propositions, and Situations. In: Gluck, M.A., Anderson, J.R., Kosslyn, S.M. (eds.) Memory and Mind: A Festschrift for Gordon H. Bower, pp. 209–227. Lawrence Erlbaum Associates, New Jersey (2007)
13. Pulvermuller, F.: Words in the Brain's Language. Behavioral and Brain Sciences 22, 253–279 (1999)
14. Dale, R., Kehoe, C., Spivey, M.: Graded Motor Responses in the Time Course of Categorizing Atypical Exemplars. Memory and Cognition 35, 15–28 (2007)
15. Anderson, S.E., Matlock, T., Fausey, C., Spivey, M.J.: On the Path to Understanding Online Processing of Grammatical Aspect. In: Proceedings of the 30th Annual Conference of the Cognitive Science Society, pp. 143–148. Lawrence Erlbaum Associates, Mahwah (2008)
16. Matlock, T.: Fictive Motion as Cognitive Simulation. Memory & Cognition 32, 1389–1400 (2004)
17. Richardson, D.C., Matlock, T.: The Integration of Figurative Language and Static Depictions: An Eye Movement Study of Fictive Motion. Cognition 102, 129–138 (2007)
18. Langacker, R.W.: Foundations of Cognitive Grammar: Theoretical Prerequisites. Stanford University Press, Stanford (1987)
19. Talmy, L.: Toward a Cognitive Semantics. MIT Press, Cambridge (2000)
20. Balota, A.D., Abrams, R.A.: Mental Chronometry: Beyond Onset Latencies in the Lexical Decision Task. Journal of Experimental Psychology: Learning, Memory, & Cognition 21, 1289–1302 (1995)
21. Gold, J.I., Shadlen, M.N.: Representation of Perceptual Decision in Oculomotor Commands. Nature 404, 390–394 (2000)
22. Spivey, M., Geng, J.: Oculomotor Mechanisms Activated by Imagery and Memory: Eye Movements to Absent Objects. Psychological Research 65, 235–241 (2001)