# On the Path to Understanding the On-line Processing of Grammatical Aspect

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## Abstract

What role does *grammatical aspect* play in understanding everyday motion events? Narrative understanding tasks have investigated differences between the past progressive (*was walking*) and the simple past (*walked*), showing differences in prominence of information, but details about the temporal dynamics of processing have been largely ignored. The current work uses a novel mouse-tracking method (adapted from Spivey, Grosjean, & Knoblich, 2005) to explore motor output in response to aspectual differences in language. Participants heard descriptions of motion events in the past progressive or simple past and used a mouse to place a character in a scene to match the description. Preliminary results indicate that different aspectual forms can lead to different character placements when people conceptualize motion along a path (e.g., slower mouse movements with past progressive). The results support the idea that perceptual simulation occurs in linguistic processing, in this case, at the level of grammar and with motor output.

**Keywords:** Language Processing; Event Understanding; Mouse-Tracking; Embodied Cognition; Motion Verbs

It is easy to imagine that language influences thought, but understanding the mechanics of this relationship is a more challenging endeavor. *How* does language influence the way people think about everyday events? Can grammar influence the way events are conceptualized, and if so, how? Could a simple contrast of hearing "-ed" versus "-ing" on a motion verb influence listeners' visual and motor output? To date, relatively little attention has been given to the role of grammatical aspect in the processing of every day events. The goal here is to explore whether and how aspect influences thought about motion in the context of motion verbs.

Language theorists agree that grammatical aspect provides temporal information about the internal structure of a verb, namely, that it provides information about the completion, duration, or repetition of the action (Comrie, 1976). Consider, for example, *He ran eight miles* and *He was running eight miles*. While both express information about an event in the past, the first sentence uses the simple past form of the verb *run* and emphasizes the completion of the action, while the second uses the past progressive form of the verb and emphasizes an ongoing-ness of the action.

Linguists have studied aspect extensively, but until recently, aspect has not received much attention in the psycholinguistic literature. One notable exception is a series of experiments by Madden and Zwann (2003), in which they demonstrated that differences in aspect produce decision and reaction time differences in narrative reading. In one experiment, participants were asked to choose a picture of an event after reading a sentence containing either a simple past verb or a past progressive verb. They found that participants were more likely to choose a picture showing a completed action, rather than a picture showing intermediate action, after reading a sentence containing a simple past verb. Similarly, in a second experiment, participants were quicker to respond to pictures showing completed actions after they had read a sentence containing a simple past verb than when they had read a sentence containing a past progressive verb. No decision or latency differences were found when participants read sentences containing past progressive verbs, most likely because in the past progressive condition, readers represented the ongoing action at different stages of completion. These results indicate that different aspectual forms lead to processing differences, because simple past verbs emphasize the completion of the action and past progressive verbs placing emphasize the ongoing action. (For other work on aspect and spatial representation, see Ferretti, Kutas, & McRae, 2007; Magliano & Schleich, 2000; Morrow, 1985).

Recently, the role of grammatical aspect in the understanding of events was explored further in a series of experiments that used pictures and sentences with motion verbs in the simple past and past progressive (Matlock, Fausey, Cargill, & Spivey, 2007). Each participant read either a simple past sentence, such as *This morning David walked to the university*, or a past progressive sentence, such as *This morning David was walking to the university,* and were instructed to chose one of ten identical characters on a path in a schematic drawing that the sentence most naturally referred to. In the first study, participants were more likely to circle a character in the middle of the path in response to sentences containing past progressive verbs (*walking*), and more likely to circle a character closer to the end of the path in response to sentences containing a simple past verb (*walked*). These and results from other experiments suggest that when participants were reading simple past verbs, they

focused on a landmark associated with the destination, where the completion of the action would take place in the scene. In contrast, when participants were reading past progressive verbs, they focused on the middle section of the path, where the ongoing action would be taking place in the scene.

The results of Madden and Zwaan (2003) and Matlock et al. (2007) suggest that people may simulate action in different ways when the action is described using different forms of grammatical aspect. However, little is known about real-time processing of grammatical aspect. Building on related real-time findings in the language comprehension literature, we have converged on a more direct way to test a simulation account of grammatical aspect understanding in the current paper.

Some evidence for perceptual simulation of an action-in-progress is seen in eye movements during the comprehension of action stories. Spivey & Geng (2001) recorded the eye movements of participants while they looked at a blank screen and heard short narratives describing events taking place in particular directions (up, down, leftward or rightward). Participants tended to spontaneously move their eyes more frequently in the direction of the described action (upward for the verb "climb", downward for the verb "fall") than any other direction. The findings were interpreted as evidence that there is a need for a spatial representation in interpreting linguistic descriptions, and they show the construction of the mental model as it is "acted-out" in the patterns of oculomotor output, providing strong evidence for the embodiment of language processing

Eye movement data have also elucidated the real-time comprehension of fictive motion sentences, which are sentences that contain an action verb but no actual movement or action. For example, *The road ran through the valley* contains the action verb *ran*, but the subject-noun phrase referent, a road, is stationery. In a series of narrative understanding tasks, Matlock (2004) had discovered that manipulating the description of a terrain (e.g., slow travel, long distances, or difficult terrain versus fast travel, short distances or easy terrain) influenced the understanding of fictive motion sentences but not of comparable sentences that contained no obvious fictive motion, such as *The road is in the valley*. Richardson and Matlock (2007) further explored the processing of fictive motion language by tracking participants' eye movements while they listened 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, both inspection times and eye-movement scanning along the path were increased as opposed to when participants heard the terrain described as easy. Taken together, these results provide evidence that fictive motion descriptions affect both reaction times and eye-movements by evoking mental representations of motion, and that this is 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 in real time.

Eye tracking is not the only method for looking beyond reaction times. More and more evidence has been put forth to suggest that factors influencing response latency may also affect later aspects of response dynamics. The temporal dynamics of the motor movement that executes a response contain volumes of virtually untapped data. As an example, Abrams and Balota (1991) had participants perform a lexical decision task by making rapid limb movements in opposite directions to indicate whether a string of letters was a word or not. As expected, they found that the frequency of the word influenced the reaction time, with high frequency words being responded to more quickly than low frequency words. They also found that word frequency influenced response kinematics after the response was initiated. Responses to high frequency words were executed with greater force than responses to low frequency words (Abrams & Balota, 1991). These findings suggest that word frequency not only influenced the time required to recognize a word, but also influenced the subsequent response dynamics, implying that the response system is not slavishly executing a complete command regarding the categorical status of the word. In a later experiment, they found that high-frequency words are responded to with greater acceleration than low frequency words (Balota & Abrams, 1995). They also found a consistent pattern of results in a memory scanning paradigm, where both onset latency and response dynamics after movement initiation were influenced by the memory set size and the presence of the probe word (Abrams & Balota, 1991). These results make a compelling case for looking not only at reaction time and ballistic eye movements, but also at the variables involved in the motor movement itself after it has been initiated.

## Purpose

To better understand the potential differences in the on-line processing of different aspectual forms of language, we employed a relatively new methodology called *computer-mouse tracking*. It has been demonstrated that monitoring 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 (2005) demonstrated that computer-mouse movements can be used to index the continuous activation of lexical alternatives. By recording the streaming x, y coordinates of the mouse cursor as it moved with the goal-directed hand motion to click on the appropriate object, competition between the partially activated lexical representations was revealed in the shape and curvature of the hand-movement trajectories. Mouse-tracking has since been used to investigate underlying processing in categorization (Dale, Kehoe, & Spivey 2007), sentence processing (Farmer, Anderson, & Spivey, 2007), and decision making (McKinstry, Dale, & Spivey, 2008).

Dale, Kehoe, and Spivey (2007) employed this mouse-tracking methodology to explore the underlying processing of categorization. In 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. In addition, the movement durations for each condition significantly differed 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.

In the current study, we recruited mouse-tracking to further investigate the influence of grammatical aspect on the understanding of motion events. We were especially interested in measuring the x,y coordinates of mouse movements as people conceptualized the motion of an agent along a path to a destination in the context of different aspectual forms, precisely, simple past (e.g., *walked*) versus the past progressive (e.g., *was walking*). Participants heard sentences that contained a motion verb in the past progressive or in the simple past and used a mouse to place a character into a scene that contained a path leading to a destination. Our hypothesis was that hearing a past progressive verb form would shift attention to the ongoing nature of the described action, and this shift in attention would lead participants to focus on parts of the motion before the final end-state.

Two empirical predictions follow from our hypothesis and were tested using the mouse-tracking paradigm. First, people might place the character in a different final location along the path depending on the form of the verb. Hearing a past progressive verb may result in placing the character in the middle of the path while hearing a simple past verb may result in placing the character at the end of the path. Second, people might move the character in a different manner depending on the form of the verb. Hearing a past progressive verb may result in simulating motion details associated with ongoing action and thus listeners have longer movement durations in response to past progressive compared to simple past verb forms.

## Method

**Participants.** Forty-seven undergraduates from Cornell University participated in the experiment for extra credit in psychology courses. All participants were right handed and native speakers of American English.

**Materials.** Linguistic and visual materials were created for target experimental stimuli as well as for filler stimuli.

*Linguistic target stimuli*. Twelve sentences were created by adapting sentences from the offline studies of Matlock et al. (2007). Sentences included two clauses to encourage participants to think about the full extent of the path. The first clause always described an event in the simple past or the past progressive, and the second always included a simple past event that occurred at the destination. Examples are shown in (1a) and (1b).

> (1a) Tom <u>was jogging</u> to the woods and then stretched when he got there.
> (1b) Tom <u>jogged</u> to the woods and then stretched when he got there.

Sentences were recorded using a Mac-based speech synthesizer program. Each of the 12 experimental items was spliced to produce a past progressive and a simple past version, ensuring that the prosody of both versions was identical, except for the verb. The experimental items were counterbalanced across two presentation lists. Each list contained six instances of each condition, so that all participants heard all 12 target sentences, but only heard one version of each.

*Visual target stimuli*. Corresponding visual scenes were created for each target sentence pair. Each target visual scene consisted of a box that contained a path curving from the left to the right up to the destination described in the sentence. A silhouette human character was located below the box and to the right of the beginning of the path (see Figure 1). The items in the scene were drawn one of the authors or taken from clipart and edited in Adobe Photoshop. The only moveable item in the scene was the character.
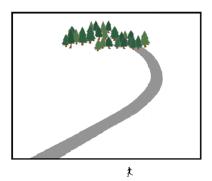


Figure 1. Example stimulus: Scene for (1a) or (1b).

*Filler stimuli*. To help ensure that participants did not develop strategies specific to the experimental sentences, thirty-six filler items were included. These items were of the same form as the target sentences. Half contained past progressive verbs, and half contained simple past verbs. These filler sentences differed from the target sentences in that they did not describe movement along the path. For example, the filler item *Janet swam in the pool and then dried in the sun*, accompanied a scene with a path leading to a pond (where the movement would have taken place).

We also created thirty-six filler scenes by using paths of different sizes and shapes. Twelve of these filler scenes depicted a long path curving from right to left, another 12

depicted a short path curving from left to right, and the remaining 12 depicted a short path curving from right to left. Besides the length and direction of the path, each filler item was similar in appearance to the target items. In particular, a silhouette character was displayed outside a boxed scene that contained a path and a destination.

In all visual stimuli, the character subtended an average of 1.53 degrees of visual angle in width by 2.05 degrees in height, and the destinations were an average of 11.22 degrees of visual angle in width by 4.09 degrees in height. The path itself occupied a square of 15.26 degrees of visual angle in width by 12.23 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, with a different random order for each participant. Mouse movements were recorded at an average sampling rate of 40 Hz. The display resolution was set to 1024 x 768.

**Procedure.** Participants were asked to make themselves comfortable in front of the computer screen, and informed that they could adjust the mouse and mouse-pad to a location that suited them on the right-hand side of the computer. First, participants read the instructions telling them to place the character into the screen to match the sentences they would hear. Next, they were presented with two practice trials (similar in form to the filler trials), and then the experimental task. At the onset of each trial, participants viewed one visual scene, and after a 500 ms preview period, 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. Trials were separated by a screen with a button in the center

labeled "Click here to go on." The entire experiment lasted about twenty minutes.

## Results

Our previous offline work, using a task with pictures and sentences in either the past progressive or simple past form, suggested that different verbal aspects lead to differences in attention. Precisely, greater attention was allotted to the to the end of the path with the simple past (Matlock et al., 2007). To investigate our first hypothesis that past progressive verbs shift attention to the aspects of the motion before the final end-state and therefore occasionally leading to drop-points (the location along the path where each participant let go of the mouse to "drop" the character before the end of the path) we plotted the drop point in each of the two conditions. As seen in Figure 2, the current results demonstrate a similar trend to that of Matlock, et al. (2007). When hearing a sentence containing a past progressive verb, many drops took place in the beginning and center of the path, whereas in the simple past condition most of the drop locations were closer to the end region of the path. Similarly, the drop location of the character in response to the past progressive verbs was more variable (Standard Deviation for x = 129.3 pixels, and for y=120.6 pixels) than in response to simple past verbs (Standard Deviation for x = 85.6 pixels, and for y= 89.5 pixels). This tendency to drop a character earlier along the path and in more variable locations along the path in response to the past progressive condition demonstrates that the ongoing nature implied by a past progressive verb draws attention to the middle portion of the path, whereas there is a tendency to focus attention further along the path in response to simple past verbs.
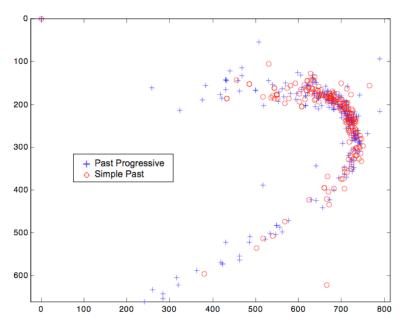


Figure 2: Final placement of characters in past progressive and simple past conditions

In investigating the second hypothesis, that past progressive verbs would shift attention to the ongoing nature of the movement and consequently lead participants to move the mouse more slowly along the path as they simulated the motion details associated with the ongoing action, we also explored the temporal dynamics of the movement of the character. Although velocity profiles did not differ substantially across the two conditions, average movement durations, or the amount of time between when the participant first clicked on the character to when the character was dropped along the path, did. That is, how long a participant spent moving the character from its initial position to its drop location varied across conditions. The average movement duration of the past progressive trajectories ($M = 3.63$ seconds, $SE = 0.17$) was reliably longer than the average movement duration of trajectories in the simple past condition( $M = 3.34$ seconds, $SE = 0.16$), $F(1, 46) = 6.15$, $p = 0.01$. (Outliers 2.5 standard deviations greater than the mean were excluded from this analysis, and this accounted for 7% of the data.) This concurs with other research, in that the ongoing-ness of the action implied by the past progressive form of the verb encourages perceptual simulation of the temporally extended process of the action more than the point of its completion.

## General Discussion

The results reported here are consistent with previous research using both narrative reading and offline judgment tasks, providing further evidence that different grammatical forms influence the processing of event descriptions, with the simple past (e.g., *walked*) focusing attention on the end of the path and the location of the completed action, and past progressive (e.g., *was walking*) focusing attention to the "middle" of the event and the region of that ongoing action. In addition to corroborating previous work on grammatical aspect, these data also reveal new insights about processing through the examination of continuous motor output. Overall, the past progressive elicited longer movement durations than did simple past, supporting the hypothesis that past progressive emphasizes the ongoing-ness of the action, resulting in a longer duration of movement along that path and a lingering in the middle of the path. This difference in movement duration was not due to differences in velocity profiles, and therefore seems to be due to distance traveled in each of the two conditions.

One possible prediction about the influence of grammatical aspect on motion event simulation might have been whether people trace movement along the path at all, or whether people place the character at the final destination without regard to the depicted path. One difficulty in analyzing such a prediction was participants' tendency to occasionally drop the character *on the path* (instead of at the destination) in response to past progressive verbs, despite the addition of the final clause that encouraged movement to the destination. While this tendency is a finding in itself, and concurs with Matlock et al.'s (2007) offline results, it makes

it challenging to answer questions about the how grammatical aspect influences adherence to a path during motion simulation. Note, however, that just because a past progressive verb focuses attention to the middle of the path while a simple past verb seems to focus attention to the end of the path (or completion of the action), this does not necessarily imply that past progressive verbs should be more richly perceptually simulated. Future research is needed to further clarify whether time differences observed here are in fact due to differences in the perceptual simulations created in response to these two forms of verbal aspect.

This current research has broader implications for several areas of research. Although grammatical aspect has been considered to provide only temporal flavoring to a verb, these data support that aspect does significantly influence on-line processing, which helps to inform and expand our understanding of implicit linguistic information. This work investigates grammatical aspect in a new way, allowing for the examination of more fine-grained temporal information, which complements the existing reaction time data. Also, it provides evidence to support cognitive linguists' claims regarding meaning as dynamic representation of linguistic descriptions (Langacker, 1987: Talmy, 2000).

Although the current research provides a valuable addition to the existing body of work on verbal aspect, future research will need to further clarify portions of these results. For example, it is possible that the longer movement durations in the past progressive condition were due to confusion caused by the second clause of our experimental sentences. In the target sentences, the verb of the second clause matched the first clause in the simple past condition (Tom <u>jogged</u> to the woods and then <u>stretched</u> when he got there), but not in the past progressive condition (Tom <u>was jogging</u> to the woods and then <u>stretched</u> when he got there). The longer movement durations in the past progressive condition could be due to confusion caused by this mismatch. However, because these data closely replicate previous research (Madden & Zwann, 2003; Matlock, et al., 2007), it is somewhat doubtful that this mismatch and any confusion caused by it drove the entire effect. However, our future research will remove this confusion in order to rule this out as possible interpretation. Future research will address the thorny problem of characterizing exactly what form the movement trajectories took in the two conditions by revising the visual scene, specifically the shape of the path.

More broadly, this work also resonates with embodied cognition work on perceptual simulation and language understanding (Barsalou, 1999). This works dovetails with the methodological advance of Balota and Abrams (1995) by providing new evidence from the temporal dynamics of a response after the response has been initiated, and demonstrating that action is not a robot-like automaton triggered by completed cognitive processes. Also this work agrees with our understanding of how 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 (Richardson &

Matlock, 2007; Spivey & Geng, 2001), this work demonstrates that event understanding takes place differently as a function of differences in grammatical aspect.

Our preliminary findings are consistent with the results of Matlock et al. (2007). They suggest that linguistic aspect engages systematic patterns of attention in the understanding of motion events. Closer analysis and additional tasks will no doubt provide additional evidence and sharper insights.

## Conclusion

Listeners' motor output varied as a function of the grammatical aspect of the verb in a motion description that they heard. More attention to the middle of a motion trajectory after listening to past progressive verbs than to simple past verbs provides converging evidence with recent offline studies about the influence of aspect on event representation. These results contribute to an increasing body of support for simulation accounts of language understanding.

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