Cognitive Processing
https://doi.org/10.1007/s10339-017-0851-4

RESEARCH REPORT

Mouse-tracking evidence for parallel anticipatory option evaluation

Edward A. Cranford[1] · Jarrod Moss[1]

Received: 19 May 2017 / Accepted: 13 December 2017
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Abstract

In fast-paced, dynamic tasks, the ability to anticipate the future outcome of a sequence of events is crucial to quickly selecting an appropriate course of action among multiple alternative options. There are two classes of theories that describe how anticipation occurs. Serial theories assume options are generated and evaluated one at a time, in order of quality, whereas parallel theories assume simultaneous generation and evaluation. The present research examined the option evaluation process during a task designed to be analogous to prior anticipation tasks, but within the domain of narrative text comprehension. Prior research has relied on indirect, off-line measurement of the option evaluation process during anticipation tasks. Because the movement of the hand can provide a window into underlying cognitive processes, online metrics such as continuous mouse tracking provide more fine-grained measurements of cognitive processing as it occurs in real time. In this study, participants listened to three-sentence stories and predicted the protagonists' final action by moving a mouse toward one of three possible options. Each story was presented with either one (control condition) or two (distractor condition) plausible ending options. Results seem most consistent with a parallel option evaluation process because initial mouse trajectories deviated further from the best option in the distractor condition compared to the control condition. It is difficult to completely rule out all possible serial processing accounts, although the results do place constraints on the time frame in which a serial processing explanation must operate.

Keywords Anticipation · Prediction · Mouse tracking · Option evaluation · Decision making · Long-term working memory

Introduction

In fast-paced, dynamic tasks, experts are often required to make quick decisions in response to a changing environment. In these tasks, experts are better than novices at anticipating the outcome of an event, and this fact has been demonstrated in domains such as elite-level sports (North et al. 2011; McRobert et al. 2011), aviation (Sohn and Doane 2003), and combat (Ward et al. 2011). This research suggests that experts' superior anticipatory skills allow them to respond in a goal-directed and timely manner.

Anticipatory skill relies on the formation of a detailed mental representation of the current situation, called a situation model, formed through integration of information from perception and long-term memory (Ericsson and Kintsch 1995; Kintsch 1988; Zwaan and Radvansky 1998). Relevant information encoded into the situation model early in an event sequence along with associated potential responses allows the performer to select a plausible response option for execution at the appropriate time. Support for this view of anticipatory skill comes from a number of studies summarized in a meta-analytic review that found that experts encode and use relevant information occurring early in an event sequence to aid in anticipatory decision-making processes (Mann et al. 2007). The option selection process operates in two stages. The first stage involves the generation of potential options, and the second stage involves the evaluation of the options in order to select the most appropriate option for execution. However, there is some disagreement

Some of the results were presented at the 2013 North American Society for Psychology of Sport and Physical Activity conference and the 2014 Annual Meeting of the Psychonomic Society. The data for this study can be found at https://osf.io/7cznf/.

Handling editor: Martin V. Butz (University of Tübingen). Reviewers: Robert Wirth (University of Würzburg), Thomas Faulkenberry (Tarleton State University), Joost Rommers (Radboud University).

✉ Jarrod Moss
jarrod.moss@msstate.edu

[1] Department of Psychology, Mississippi State University, P.O. Box 6161, Mississippi State, MS 39762, USA

among theories on whether the option selection process operates in a serial or parallel manner (Klein et al. 1995; North et al. 2011; Johnson and Raab 2003; Ward et al. 2011). The aim of the present study is to investigate how people evaluate plausible response options when more than one is available.

Theories of anticipatory option generation and evaluation

Serial theories

Klein (1993, 1997) developed the recognition-primed decision theory to describe how experts, in highly familiar tasks, make use of their extensive domain-specific knowledge to generate a course of action without having to evaluate if the action will work or explicitly compare alternative options. According to this theory, option selection is a serial process in which plausible responses are generated and evaluated one at a time. The theory also suggests that experts generate options in order of quality, so that higher-quality options are generated earlier. Thus, in time-pressured situations experts rely on pattern matching of typical situations to identify successful actions in a single-step process to produce an appropriate response (Klein 1997). Support for the theory has come from examinations of how chess experts evaluate options with and without time pressure (Calderwood et al. 1988; Klein et al. 1995). Experts evaluated move options in a serial order, and the options evaluated early in the sequence were of better quality than those later in the sequence.

The principle of recognition-primed decision making has been applied in the take-the-first heuristic developed by Johnson and Raab (2003). This heuristic states that, due to the associative nature of memory, options with the greatest connection strength to the current situation or that have been used in previous similar situations are activated first. The initially activated option is the option selected by the take-the-first heuristic. In studies supporting this heuristic, expert handball players were shown to generate predictions in a serial order from best to worst (Johnson and Raab 2003) and compared to less-skilled players, generated fewer options of higher quality (Raab and Johnson 2007). Although the results of these studies appear to support a serial action selection process, the nature of the tasks in the experiments inherently constrains responses to be reported serially. Verbal statements must occur in sequence.

Parallel theories

As an alternative to a serial selection process, it has been argued that experts evaluate viable options simultaneously through passive construction/integration processes operating on skilled memory representations known as retrieval structures (Ericsson and Kintsch 1995; Kintsch 1988). This long-term working memory theory allows for rapid decisions to be made with simultaneous evaluation of multiple potential options, rather than a single, sufficing option. The theory proposes that, through extensive practice in a particular activity, experts have developed extensive associative knowledge bases that include declarative facts, procedural knowledge, and previously encountered patterns of such knowledge called retrieval structures. The retrieval structure is composed of a set of stable retrieval cues and associations so that, in familiar situations, relevant environmental information can be rapidly and reliably encoded and stored in long-term memory. For example, when an expert chess player encounters a familiar situation, the configuration of pieces activated in working memory serves as a set of retrieval cues to access pertinent information in long-term memory regarding what possible moves may prove successful. Long-term working memory allows experts to rapidly form a detailed situation model that includes prior knowledge and current contextual information that is continuously updated as the situation evolves (Kintsch 1988, 1998). Retrieval structures do not prescribe a single response to a given situation, but potentially include many possible responses that prior experience has shown to be useful (Ericsson et al. 2000; Zwaan and Radvansky 1998).

This theory has been supported by a number of studies examining option selection of experts in the domains of soccer (North et al. 2011; Roca et al. 2011), cricket (McRobert et al. 2009, 2011), and law enforcement (Ward et al. 2011). In general, these studies involved asking participants to provide retrospective verbal reports of everything they were thinking during a filmed event sequence. The verbal reports were coded for occurrences of evaluation statements (positive, neutral, or negative assessments of previous statements), predictions (statements about what action would or could occur next), and deep planning (statements considering possible alternatives beyond the next move). Serial theories predict that greater experience reduces the amount of evaluation needed, the number of predictions made, and also the amount of deep planning. However, experts were found to produce more evaluation, prediction, and deep planning statements than less-skilled participants. In contrast to serial theories, with greater skill, the number of alternative options evaluated increased rather than decreased.

One limitation of these experiments supporting a parallel account is the use of retrospective verbal reports. Retrospective reports are reconstructed representations and provide data that are potentially incomplete or inaccurate (Ericsson and Simon 1980). Verbal reports can only provide data for consciously accessible information that is output in serial order. For example, although prior research supporting a parallel theory showed that experts reported a greater number of predictions and evaluations than novices, arguing against hypotheses posited by serial theories, the generation and evaluation of options was still reported one option at a time. Because verbal reports provide only indirect evidence of cognitive processes, and expert anticipation processes involve rapid and non-conscious processing, there is a need for a methodology that can provide insight into the anticipation process during the event instead of after the fact. The current experiment fulfills this need by using a method of continuous mouse tracking developed by Spivey et al. (2005).

Continuous mouse tracking

Continuous mouse tracking of mental trajectories has proved to be a useful tool in analyzing cognitive processes (Freeman et al. 2011; Spivey et al. 2009). There are two premises behind the use of tracking mouse movements to measure cognition. The first premise is that cognition is not a discrete process in which information is fully processed by one system before being passed to the next system in a series of operations. Instead, cognition is better represented as a continuous and dynamic process in which moment-to-moment partial information is continually updated over time guiding a system closer to a stable goal state (Spivey and Dale 2006; Spivey et al. 2010). Second, the perceptual, cognitive, and action systems are coupled such that one system continuously feeds information to other systems, guiding behavior through their interaction (Freeman et al. 2011; Spivey et al. 2005).

Experiments have shown that continuous arm movements can be tracked and that these trajectories provide a window into the cognitive processes involved in perceptual recognition (Spivey et al. 2005), decision making (McKinstry et al. 2008), statistical learning and anticipation (Dale et al. 2012; Duran and Dale 2009), and categorization (Dale et al. 2007). For example, Spivey et al. (2005) recorded the continuous and curved trajectories of mouse movements as participants chose which of two competing phonologically similar objects (e.g., candy–candle) or phonologically dissimilar objects (e.g., jacket–candle) matched a spoken word. A similar distractor “pulled” the mouse trajectory away from a straight line toward the target object. The explanation for these results is that as the cognitive system evolves over time, the activation of the incorrect, but similar representation decreases as activation of the correct representation increases, leading to a more curved trajectory than the more direct path taken toward the target in the dissimilar condition with only one valid target. Therefore, the competition between the options at a phonological level is revealed through the actions of the motor system as it controls the mouse. The present study examines whether similar evidence of competition among potential outcomes can be seen through tracking the position of the mouse as participants evaluate multiple options available to them.

In another study, Dale and colleagues (2012) investigated anticipatory movements of a mouse cursor during statistical learning of event sequences. Participants clicked on a sequence of cues when they appeared in one of the four possible positions. Participants showed increased anticipatory movements with increasing regularity in the pattern of position sequences. Two strategies were observed: (1) a strategy to react, involving centering the mouse cursor between the next potential positions in wait for the next circle appearance, and (2) a strategy to predict, involving moving the mouse cursor past the center and toward the next position sequence. The prediction strategy was used more often as regularity of the sequences increased and with practice. The authors concluded that a reaction strategy may be used when multiple alternatives may be possible and that the prediction strategy will be used when one notices a regularity or pattern in the stimuli. In the present study, it is likely that both strategies will be used as participants evaluate the plausibility of multiple available options.

Prediction and evaluation when reading narrative stories

Due to the established role of comprehension processes in action-oriented domains (e.g., North et al. 2011; Sohn and Doane 2003) and because prior mouse-tracking studies have successfully been used to study language processes (for review, see Spivey et al. 2009), the present study addresses anticipation within the domain of narrative story comprehension. Text comprehension shares many of the same task characteristics as the tasks previously used to study anticipation processes (e.g., Raab and Johnson 2007; Ward et al. 2011). For example, comprehension of text has been shown to involve long-term working memory skills (Ericsson and Kintsch 1995; Kintsch 1998; Zwaan and Radvansky 1998). Narrative text comprehension, in particular, may provide an analogous task to prior research because narratives are often read from the perspective of the protagonist (Horton and Rapp 2003; Zwaan 1999) and provide a dynamic situation that unfolds over time. In a familiar narrative setting, as readers attend to the text they can accurately understand the goals of the protagonist and form expectations, or predictive inferences, of typical courses of action (Graesser et al. 1994; Zwaan and Radvansky 1998). In fact, the parallel theory discussed earlier has at its core the theory of long-term working memory that has been shown to apply in both comprehension and action-oriented domains (Ericsson and Kintsch 1995; North et al. 2011; Sohn and Doane 2003).

Research within the domain of narrative reading comprehension has consistently shown that predictive inferences are generated only when the story sufficiently constrains the number of possible outcomes and when the story is based on familiar situations so that the reader has relevant and accessible prior knowledge about what may happen next (Graesser et al. 1994; McKoon and Ratcliff 1992). The narratives used in the present study are based on familiar situations in which the reader should have relevant prior knowledge about what may happen next. However, the current stories were designed to lead to multiple possible consequences. While some research has shown that predictive inferences are not generated when multiple alternative inferences are possible (Klin et al. 1999), others revealed that the targeted predictive inference was only weakly activated (Weingartner et al. 2003) and that multiple plausible inferences can be generated (Cranford 2016).

Prior research on predictive inferences in text comprehension concerns the automatic activation of inferences when the goal of the reader is to read for comprehension. However, in the present study, participants are given an explicit goal to predict what action the main character will perform by the end of the story. Research has shown that generating predictive inferences is enhanced under strategic prediction goals (Allbritton 2004; Calvo et al. 2006; Magliano et al. 1999), thereby enhancing representation of information at the situation model level (Calvo et al. 2006; McDaniel et al. 2001). Therefore, in the present study, participants should be able to generate multiple predictive inferences while reading very short stories that are based on typical, everyday events with the explicit goal to make predictions. These inferences will provide information about the plausibility of different outcomes, and that information can be used to evaluate which of these outcomes is most likely. Narrative text comprehension of typical everyday event sequences provides a domain where it is relatively easy to recruit "experts" to assess whether mouse tracking can provide insight into the theoretical question of whether anticipatory option selection processes are serial or parallel.

Present study

In the current study, participants are presented with a short narrative story describing a common situation via audio recording and asked to predict what the outcome might be by moving a mouse cursor toward one of three possible options displayed on a screen. The options are provided to participants prior to hearing the story; therefore, the task requires participants to evaluate the options as the story progresses without generating options. As participants listen to a story, with the goal to predict what the protagonist will do, the contents of the story will activate relevant information about what may happen next. If new information arrives that is inconsistent with one option and/or consistent with another, then the evaluation process will lower the plausibility of that option being a likely ending and raise the plausibility of an alternative option. Thus, if multiple options are available to participants, then the question is whether participants evaluate multiple options serially or in parallel.

The task interface and a sample story are shown in Fig. 1. The options for possible story endings are arranged equidistant around a central starting point. The options can be unrelated options or plausible options. For the plausible options, one of the two is a better option than the other and considered the correct option (the "best" option). The other plausible option serves as a distractor because it is a plausible outcome given the situation described in the story, although less likely to occur than the best option. In the distractor condition, the best option and the plausible distractor are presented along with one unrelated option that does not share any context with the story. In the control condition, the best option is displayed with two unrelated options. Three options were used so that on any given trial there was not a default expectation about which direction to begin mouse movements.

All narratives consisted of three sentences. By the end of the first sentence, in the control condition, only the best option is contextually similar to the story. In the distractor condition at this point, only the best option and the plausible distractor option are contextually similar to the first sentence. As the story progresses more and more evidence supports the best option such that at the end of the third sentence, the best option should clearly be the appropriate ending. When comparing control and distractor trials, serial and parallel theories make different predictions about how the mouse should move as described in Fig. 2. Similar to Dale et al. (2012), in the present experiment, we expect to observe two anticipatory strategies that are both shown in Fig. 2: (1) reactive, involving moving the mouse toward the center between two plausible options, or (2) predictive, involving moving the mouse toward one option, either as a correct or incorrect prediction. However, a parallel theory would suggest that even the predictive movements would show a deviation toward the plausible distractor option.

Trajectories were primarily assessed for the angle of deviation from the best option, direction and acceleration changes, the proportion of time spent in regions of interest (ROIs), and mouse position scores. If evaluation is a parallel process, in the distractor condition compared to the control condition, initial movements should deviate further from the best option and toward the competitor, there should be more movement changes, and more time spent in areas between options and less time near the best option, resulting in lower scores. However, if evaluation is a serial process, then mouse movements in the distractor condition should be similar to those in the control condition; initial movements should not have greater deviation toward the competitor, there should not be more movement changes, and the proportion of time

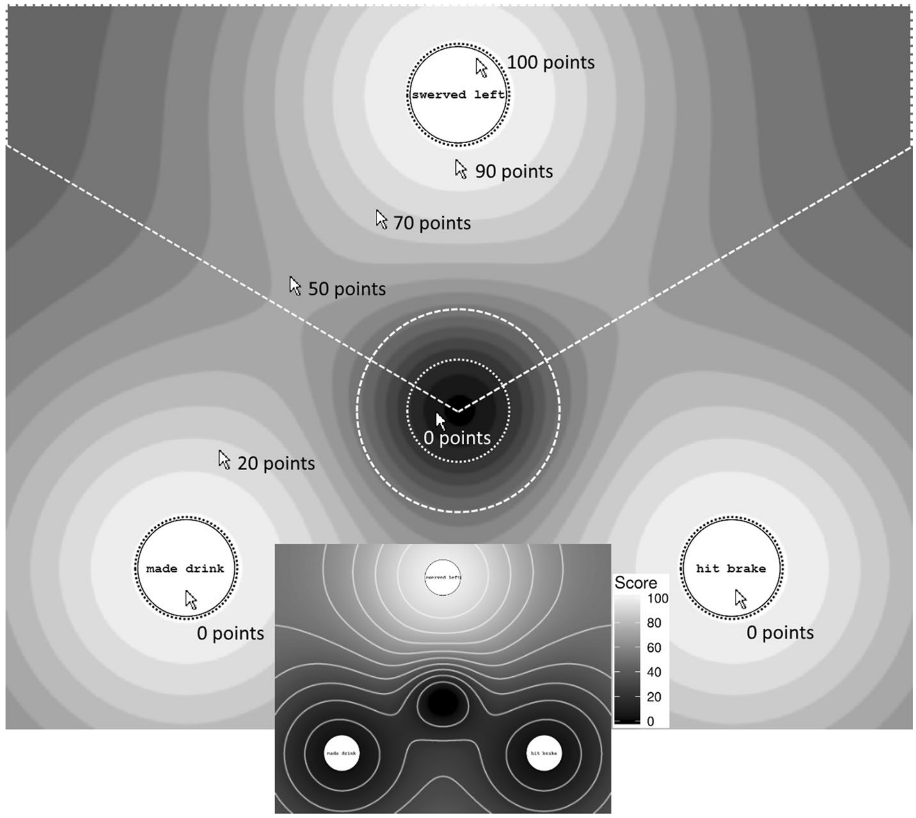

Fig. 1 Description of the task interface, scoring system, and regions of interest. The story for this example is: "Katie was driving down the highway one evening when she noticed a truck in front of her with many loose items in the back. She was paying close attention, when suddenly she saw a large box fall out of the truck. With enough time to react, Katie grabbed the wheel hard and…" Three options are displayed equidistant around the dark area in the center. In this example, the top option, "swerved left" is the best option, the bottom-right option, *hit brake*, is a plausible distractor, and the bottom-left option, *made drink*, is an unrelated option. Participants were encouraged to continuously move the mouse during the second and third sentences by awarding points based on the proximity of the mouse to the best option at the end of each sentence. Participants actually saw a rainbow-colored gradient (purple–blue–green–yellow–red) instead of the dark–light gradient depicted here which served as a guide to how many points would be awarded. The option circles are surrounded in red (white here) and represent a maximum score; the center start area is purple (black here) and represents a score of zero. If the mouse is located at the other incorrect options, or at the start area, then zero points are awarded for each scoring opportunity. Participants receive more points, up to 100, the closer the mouse is to the best ending option and would receive 50 points if they were in the middle green area (gray here) between the best option and another option. Although the background was displayed as a rough representation of scoring, actual scores were calculated by Eq. 1 and are more accurately represented by the panel insert at the bottom. In the panel insert, each contour line represents a change in ten points. Regions of interest were defined to examine time spent in different areas of the display. The black dotted circles surrounding the ending options define the Red regions. The smaller white dotted circle in the center defines the Start region. The larger white dashed circle in the center defines the area of initial trajectories. All other areas not inside the dotted circles define the Other region. The entire area inside the white dashed lines defines the Best region. The dotted/dashed circles/lines, mouse cursors, and point descriptions were not visible to participants

spent in each of the ROIs should be similar, resulting in similar high scores.

Participants were also presented with a set of non-cohesive stories. These stories focused on a single protagonist, but the three sentences did not represent a cohesive series of events. According to long-term working memory theory, these stories should not elicit any predictions, should be harder to encode into a meaningful representation because readers cannot make use of retrieval structures, and thus result in poorer recall at a later test of memory (e.g., see Sohn and Doane 2003). These stories were presented to ensure that participants were reading the narrative stories for comprehension and making use of retrieval structures when reading the cohesive stories. If so, then recall of the non-cohesive stories should be worse than recall of the cohesive stories.

In summary, the present experiment explores anticipation processes by continuously tracking mouse movements to measure the cognitive processing during option evaluation. Tracking the mouse trajectories during a narrative anticipation task should help clarify whether people, in

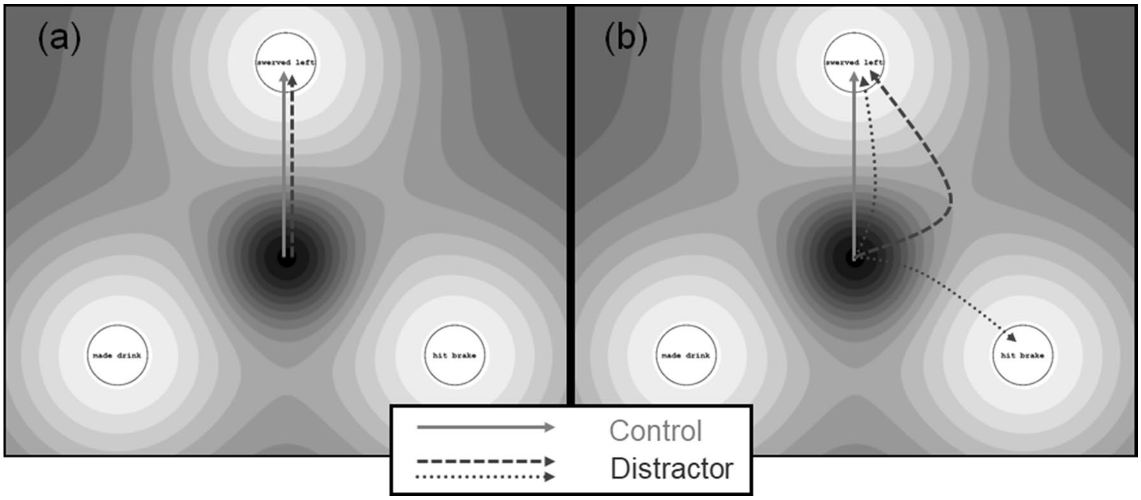

Fig. 2 Predictions for **a** serial theories and **b** parallel theories under each condition. The top option, "swerved left," is considered the best option in this example. The bottom-right option, "hit brake," is the plausible distractor option in the distractor condition. In the control condition, the bottom-right option would be an unrelated option, "went hunting." For serial theories (**a**), initial mouse movements should be directed toward the best option in both control and distractor conditions. For parallel theories (**b**), initial movements should be directed toward the best option in the control condition. In the distractor condition, movements could be reactive (solid line) toward the middle area between the two plausible options, predictive (dotted lines) and correct toward the best option, or predictive, but incorrect toward the plausible distractor option

dynamic and familiar tasks, evaluate a single sufficient option or multiple potential options in parallel.

Method

Participants

Sixty-five native English-speaking undergraduates with normal or corrected-to-normal color vision from Mississippi State University participated for course credit. Informed consent was obtained from all individual participants included in the study.

Materials

Sixty-three-sentence stories were created for this experiment: 30 cohesive and 30 non-cohesive stories (stimuli are presented in Appendix 1). The stories each had at least three possible endings. Each cohesive story was written using a few general rules: (1) The first sentence would set the context of the situation and reveal the protagonist, (2) the second sentence would elaborate on the situation and guide the story toward an action, and (3) the third sentence would reveal the action the protagonist is going to perform. The non-cohesive stories consisted of three unrelated sentences featuring the same protagonist. The possible endings for each story, used as options in the task interface, consisted of one- or two-word phrases that included a verb and, if necessary, a noun (e.g., "swerved left"). The stories and their possible endings were selected based on a norming study that included 72 additional participants (see Appendix 2 for details). The norming study was used to ensure that each cohesive story did have a best ending and to select one plausible distractor and two unrelated endings for the main experiment. Five additional stories were selected from the norming study to serve as practice trials.

The non-cohesive stories were created because long-term working memory theory predicts that readers access and use retrieval structures to aid comprehension and encoding when reading about familiar situations. At the end of the study, a cued recall task was performed comparing recall for non-cohesive stories to cohesive stories to ensure participants were reading for comprehension and making use of retrieval structures when reading the cohesive stories. Access to retrieval structures for cohesive stories should result in greater recall for cohesive stories than for non-cohesive sentences. An example of a non-cohesive story is: "John forgot his briefcase when he went into work one morning. During his midday break, he went to the roof for a cigarette. John was in a hurry so he ran quickly to the curbside and…" ("hailed taxi" or "called wife").

The task was run using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) and was presented on a 17-inch monitor (1280 × 1024; 60 Hz). The stories were audio-recorded and presented via headphones. Figure 1 shows a grayscale screenshot of the task interface with scoring and ROI information overlays. For each story, the three options for endings were displayed equidistant from each other around a center start area. A box with the word "Start" was displayed in the center of the screen at the start of each trial and remained on the screen until the end of the first sentence. The start box was 138 by 138 pixels and ending option circles were 138 pixels in diameter. The distance from the center of the start box to the center of any of the ending option circles was approximately 448 pixels. A standard mouse was used to interact with the display. Mouse acceleration was turned off, and the speed was set to the middle of the range (6th step from the left out of 11 total steps) in the Windows' settings. The actual background of the task interface was rainbow-colored, as described in Fig. 1, and served as a visual representation of how many points would be awarded if the cursor was in that contour band. The background was designed in Mathcad 15.0 (Parametric Technology Corporation, Needham, MA) as was the scoring function. Scores were determined by Gaussian function based on the proximity of the mouse cursor to the best option, as defined by Eq. 1:

$$\text{Score} = 0.5 * \left[1 - \left(\frac{1}{e^{0.00005*D_C^2}}\right) + \left(\frac{1}{e^{0.000008*D_1^2}}\right) + \left(\frac{-1}{e^{0.00001*D_2^2}}\right) + \left(\frac{-1}{e^{0.00001*D_3^2}}\right)\right] \quad (1)$$

where D_C is the distance from the mouse cursor to the center of the start box, D_1 is the distance from the mouse cursor to the nearest edge of the best ending option circle, and D_2 and D_3 are distances from the mouse cursor to the nearest edges of the other two options' circles. The numerators for the last two terms are set to −1 to represent valleys at the center and the two non-best options, and a hill is present only at the best option. The insert at the bottom of Fig. 1 accurately represents the scoring function.

Design and procedure

The design was a two (story type: cohesive and non-cohesive) by two (plausibility condition: control and distractor) within-subjects design. After providing informed consent, participants were told that they would be listening to stories and be provided with three possible endings on the computer screen for which they were to predict which option best ends the story. They were asked to respond as quickly and accurately as they could and to continuously move the mouse cursor toward the position on the screen where they felt would maximize their score. Participants were informed that they would receive more points, up to 100, the closer they were to the best option at the end of the second sentence and again at the end of the third sentence and fewer points, down to zero, the closer they were to the start area or the other two options. A visual "dartboard" was provided as a background so participants could see how many points each region was worth. The dartboard point system, shown in Fig. 1 where the different contours correspond to different scores, was described to participants in detail during the instruction phase. These efforts were to ensure participants would begin moving the cursor as quickly as possible and to continue moving the cursor throughout the story so that mouse movements would reflect active anticipation processes.

For each trial in the narrative anticipation task, participants heard a story and were presented with a set of three options for endings. The endings were displayed randomly in one of the three option locations on the screen. In the distractor condition, the best option, the plausible distractor option, and one unrelated option were displayed. In the control condition, the best option and two unrelated options were displayed. After participants read the options and were ready to hear the story, they clicked a start button that was centered between the three options. This click caused the story to begin playing through the headphones. During the first sentence, the mouse cursor was trapped inside the start box. This procedure was to ensure that all participants, for every trial, encoded the general context of the narrative before moving the mouse toward an option. After the first sentence was complete, the mouse cursor was moved to the center of the start box and the start box disappeared. Participants were then allowed to move the mouse out of the box and toward a position on the screen that would maximize points. At the end of the third sentence, participants heard a tone indicating the end of the story and prompting them to click on the ending option of their choice as quickly as possible. After selecting an option, participants were given feedback on the second- and third-sentence scores they received for that trial as well as their cumulative score for the entire experiment.

The movement of the mouse was continuously tracked while performing the narrative anticipation task. The mouse movements of interest are during the second and third sentences. All 60 stories were completed in semi-random order such that, for every four stories, two were cohesive and two were non-cohesive. For every trial, the coordinates of the mouse were recorded once every 5–6 ms.

Prior to performing the narrative anticipation task, participants completed five practice trials to familiarize them with the task. During practice, the experimenter instructed the participant to begin movements as early as possible and to continue moving the mouse throughout the story if they paused while listening to the stories. After completion of the narrative anticipation task, participants performed a cued recall task. During the recall task, participants were given the first sentence of one of the stories previously seen in the main experiment and asked to type out the next sentence as accurately as they could. All participants completed the same 20 stories selected randomly from the full set of 60 stories (ten cohesive and ten non-cohesive). Participants were instructed that simply providing the gist of the next sentence was acceptable. The entire session took less than 1 h to complete.

Mouse-tracking measures

Mouse-tracking measures include the trajectory of the initial mouse movements, movement changes in direction and acceleration, the proportion of time the mouse was in ROIs, and the scores obtained at the end of the second and third sentences. Trajectories were acquired by rotating and/or mirroring the position data for each trial as needed such that the best option was located in the top position and, for distractor trials, the plausible distractor was located in the bottom-right position. The initial mouse-movement trajectory was defined as a straight line from the mouse cursor position at the beginning of the second sentence (i.e., at the center of the start box) to the first mouse cursor position that exceeded a distance of 138 pixels from the center of the start box. This area is designated by the dashed circle in the center of the display in Fig. 1 and encompassed the blue-hued area (center dark area in Fig. 1). The radius was twice the distance from the center of the start box to the middle of one of its edges (or twice the radius of the Start ROI circle in Fig. 1) and was approximately 31% of the total distance of a straight line from the center of the start box to the center of one of the options, ending just before entering the green area (gray area between the options and the center dark area in Fig. 1). Therefore, exiting this region meant the participant was making a decision that would reward points and not hovering around the center of the display waiting for disambiguating information. This trajectory was then used to determine the angle of deviation between the initial mouse-movement trajectory and a straight path from the center of the start box to the best ending option.

Direction changes were measured as changes in direction from one particular option toward another option. For each trial, angles were calculated between the vector defined by the current position and the previous position as well as the vectors defined by the previous position and the centroid of each of the options, providing an angle of deviation for each of the three options. The smallest of the three angles indicates the mouse is moving toward that option. The result was an index of which option the mouse is moving toward at each point in the trajectory. When a trajectory changes from going toward one option to going toward another option, then this was flagged as a change in direction. The mouse had to move a minimum distance of at least 10 pixels in order for the direction change to be counted. This was done to eliminate small deviations in the mouse trajectories and focus only on the larger, more important changes.

Acceleration changes were measured as the number of times the trajectory changes from positive acceleration to negative acceleration, and vice versa. A velocity profile was first calculated, smoothed across a moving window of 30 coordinates, which is similar to that of Dale and Duran (2011). The 30-coordinate smoothing is equivalent to the 6-coordinate smoothing performed by McKinstry et al. (2008) because mouse coordinates were collected at a higher frequency in the present study (~ 40 Hz as compared to ~ 200 Hz in the present study). Acceleration values were then computed between each of the velocity measures. A change in acceleration was marked when the acceleration changes from positive to negative, or vice versa (essentially looking for 0-crossings in the acceleration profile). In order to eliminate small jitters in acceleration (particularly when the mouse is moving slow), an acceleration value had to maintain a change of sign for at least three consecutive time points. For example, a single negative acceleration in the middle of a string of positive accelerations would not be counted as an acceleration change. The total number of changes was subtracted by one to account for the fact that even a straight movement increases velocity toward an option and then decreases velocity to stop on the option.

Four ROIs were defined to examine the proportion of time the mouse was in particular regions of the display as shown in Fig. 1. The Start ROI was centered at the start box with a radius of 69 pixels and included the center area where participants received zero points. The Red ROIs included the three areas encompassed by the ending option circles. The Other ROI included all other areas in the display not included in the Red or Start ROIs. The Start, Red, and Other ROI's make up 100% of the display. The Best ROI was an additional ROI that included the third of the screen sliced 120° from the center of the start box and centered on the best ending option.

Scores were obtained to examine how far away the mouse cursor was from the best ending option at the end of the second and third sentences. Scores were computed using Eq. 1 above. When looking at Fig. 1, a score peaks at 1 if the cursor is within the best ending option circle. A score reaches a minimum of 0 if the cursor is in either of the other ending option circles or within the Start ROI. This score was rounded up to the nearest 10th of a point and multiplied by 100 to give a score range of 0–100 in 10-point increments.

Results

Preliminary analyses

The recall task data were examined to test the prediction that cohesive stories would show higher recall than non-cohesive stories. To eliminate subjectivity in evaluating whether a response in the recall task was correct, responses from the comprehension test were checked for accuracy using the

"One-to-Many Comparison" method on the Latent Semantic Analysis (LSA) Web site (http://lsa.colorado.edu; Landauer and Dumais 1997). Using LSA, each response was compared to the second and third sentences of the story. LSA scores are a cosine value with higher scores indicating greater similarity between the response and the sentences of the story. Memory was better for cohesive stories ($M = 0.46$, SD = 0.10) than non-cohesive stories ($M = 0.40$, SD = 0.13), indicating that participants were making use of retrieval structures in long-term memory when performing the narrative anticipation task, $t(62) = 4.38$, $p < 0.001$, $d = 0.57$. For effect size, Cohen's d was calculated using the pooled standard deviation. Recall was also scored by a human with similar results; responses were more accurate for cohesive than non-cohesive stories. This result indicates that the cohesiveness manipulation was successful and impacted memory as anticipated.

For the narrative anticipation task, accuracy for predicting the story endings was high ($M = 97.28\%$, SD = 2.25%), indicating that participants had a clear understanding of the best ending by the end of the story. In all mouse trajectory analyses, only correct prediction trials were included. Trials were excluded from analysis if both the overall time spent in the Start region and the time to initially move the mouse out of the Start region were greater than three standard deviations from the respective means (i.e., more than 70.80% of the total time was spent in the Start region and more than 5.95 s elapsed before movement began). Two participants were excluded from all analyses because more than 49% of their trials would have been eliminated. For the remaining participants, the exclusion criteria affected 0.86% of the data, or 34 total trials.

Mouse-tracking results

All analyses were conducted using repeated measures ANOVA, comparing the effects of plausibility condition (control or distractor) and sentence (second or third sentence), except for analyses of initial trajectories because these only occurred during the second sentence. For clarity, presentation of analyses is restricted to the cohesive stories; non-cohesive stories were excluded from further analysis because the difference between serial and parallel models of option evaluation was thought to be best addressed by examining stories in which sufficient knowledge could be used to make an anticipatory prediction. While there were differences in how participants moved the mouse during non-cohesive stories compared to cohesive stories, the results generally indicated that movements were more sporadic, involving greater deviation in initial trajectories, more movement changes, more time spent between options, and lower scores. Without being able to construct a reliable situation model or make predictions about how the story would end, mouse movements were largely random and uninformed. As mentioned, the non-cohesive stories were included to verify that the cohesive stories led to better memory, as predicted if participants had sufficient background knowledge to construct a coherent situation model.

The mean mouse trajectories are shown in Fig. 3 and match the predictions made for a parallel theory, as shown in Fig. 2b. To produce the mouse trajectories displayed in Fig. 3, each trial was split into 200 equal bins of time. Each bin represents 1/200th of the entire story which controls for differences in story length. For each trial, mean mouse positions were computed for each time bin. Each time bin was averaged across all trials within each condition and then across participants. On average, the mean trajectories in the control condition were directed toward the best option and those in the distractor condition were directed toward the middle area between the two plausible options. The binning and mean trajectory were done for this figure only, and all analyses were based on the raw coordinates of the individual mouse trajectories. Table 1 presents the means for each mouse-tracking measure discussed below: (1) the angle of deviation from the best ending option for the initial mouse-movement trajectory (i.e., deviation from best), (2) the number of changes in direction and acceleration (i.e., movement changes), (3) the proportion of time the mouse was in various ROIs, and (4) the scores obtained at the end of each sentence.

Analysis of initial trajectories

To evaluate the Angle of Deviation hypothesis, the angle between the initial trajectory line and a line from the center of the start box to the center of the best ending option circle defined the angle of deviation from the best ending option (deviation from best). As described earlier, all data were rotated and/or mirrored such that the best option was at the top at 0° and the plausible distractor option for the distractor condition was at the bottom right at 120°.[1] Trajectories to the right of the best option were coded as positive values from 0° to 180°. Trajectories to the left of the best option were coded as negative values from 0° to −180°. Therefore, if the plausible distractor biased the angle of deviation, then the mean trajectory for the distractor condition should be a

[1] The deviation of initial trajectories was analyzed with location of the best option (top of the screen, bottom left, or bottom right) included as a factor, and the results revealed no main effect of option location, $F(2,61) = 0.78$, $p = 0.459$, $\eta_p^2 = 0.01$, nor an interaction with plausibility condition, $F(2,61) = 1.34$, $p = 0.266$, $\eta_p^2 = 0.02$. Within distractor trials, the direction of the competitor relative to the perceived best option (clockwise or counterclockwise) did not affect the deviation from perceived best option, $t(62) = 0.72$, $p = 0.475$, $d = 0.03$.

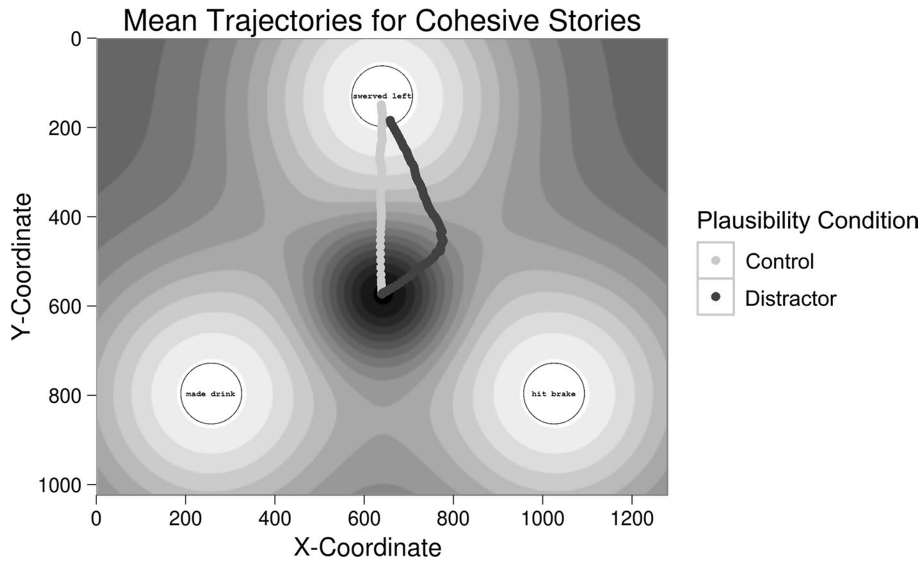

Fig. 3 Mean trajectories for cohesive stories. The data match the parallel long-term working memory theory predictions displayed in Fig. 2b

Table 1 Means for all dependent measures within cohesive stories for each plausibility condition and sentence ($N = 63$)

Dependent measure	Means for cohesive stories			
	Distractor		Control	
	Second	Third	Second	Third
Deviation from best (degrees)	44.77 (18.66)	NA	− 0.44 (13.36)	NA
Movement changes				
Number of direction changes	1.57 (1.21)	0.79 (0.46)	1.23 (0.86)	0.40 (0.44)
Number of acceleration changes	7.35 (3.30)	4.08 (2.63)	6.62 (2.75)	2.24 (1.87)
Proportion time in ROIs				
Best ROI	0.54 (0.09)	0.81 (0.10)	0.77 (0.09)	0.96 (0.03)
Red ROI	0.35 (0.21)	0.74 (0.19)	0.43 (0.20)	0.85 (0.18)
Other ROI	0.49 (0.22)	0.26 (0.19)	0.40 (0.20)	0.15 (0.18)
Start ROI	0.16 (0.09)	0.004 (0.01)	0.17 (0.09)	0.003 (0.01)
Entries in red	0.93 (0.55)	0.72 (0.24)	0.90 (0.36)	0.39 (0.27)
Scores	65.31 (9.97)	93.45 (7.31)	86.32 (8.98)	99.04 (2.17)

Standard deviations are in parentheses. Entries in red refers to the number of times the mouse cursor entered an option circle

positive value and deviate further from 0 degrees than the mean trajectory for the control condition.

As shown in Table 1, the mean trajectory for control trials did not deviate from zero, $t(62) = -0.26$, $p = 0.793$, $d = -0.03$, but the mean trajectory for distractor trials deviated from zero toward the plausible distractor option, $t(62) = 19.04$, $p < 0.001$, $d = 2.40$. In addition to examining deviation from zero, the deviation of the distractor trajectories was compared to the deviation of the control trajectories. The distractor trajectories deviated further from the best option than did control trajectories, $t(62) = 18.76$, $p < 0.001$, $d = 2.43$.

In the distractor condition, the initial trajectory was directed near the midpoint between the best option and the plausible distractor option. However, this result could indicate either that the typical trajectory was to the midpoint or that some trajectories in the distractor condition were directed toward the best option at 0° and some were directed toward the plausible distractor at 120° resulting in a mean trajectory between these options. This distinction is important because the latter result would more directly support a serial theory. Figure 4 shows the distribution of initial trajectories for all distractor and control trials. In the control condition, most of the initial trajectories are toward the best option. However, in the distractor condition, peaks in the distribution occur at the best option, at the plausible distractor option, and between these two options. In order to examine whether the distributions in the two conditions were unimodal or multimodal, Hartigan's dip statistic (Hartigan and Hartigan 1985) was used as recommended by (Freeman

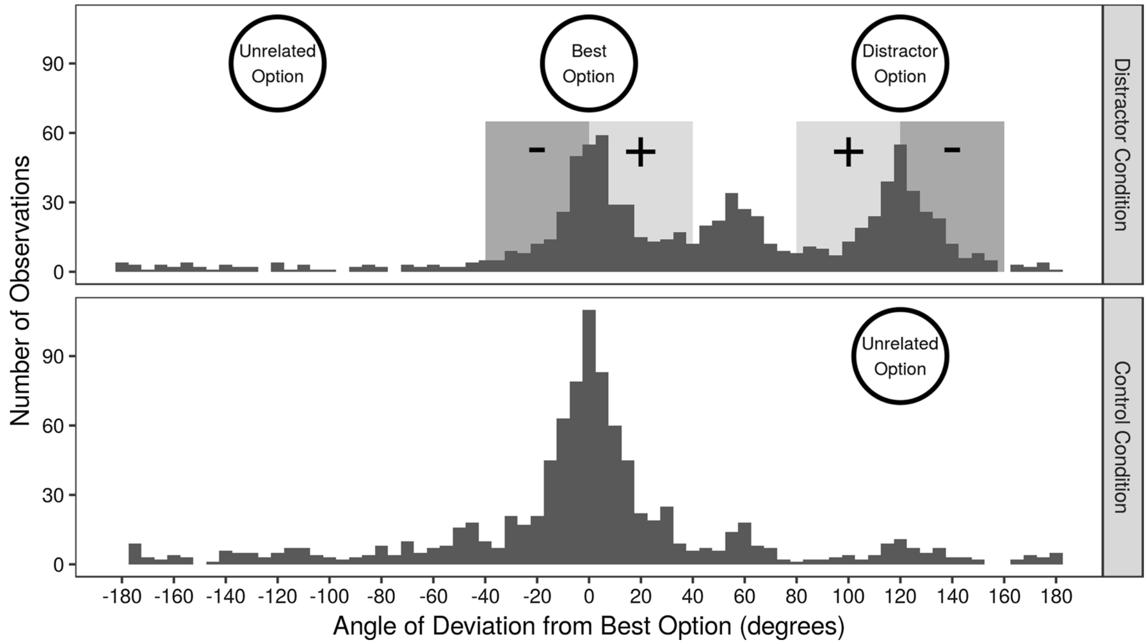

Fig. 4 Distribution of initial trajectory angles. The best option is at 0°, the unrelated option is at − 120°, and, for the distractor condition, the plausible distractor option is at + 120° (for the control condition, the second unrelated option is at + 120°). For analysis of trajectories within 40° of the perceived best option, the shaded areas behind the histogram define the angles being analyzed and the ± signs within the bands indicate whether angles were coded as positive or negative

and Dale 2013). There was no evidence that the control condition distribution was multimodal, $D = 0.010$, $p = 0.85$, but there was evidence that the distractor condition distribution was multimodal, $D = 0.048$, $p < 0.001$. Hartigan's dip statistic only tests whether there is evidence to reject the null hypothesis of a unimodal distribution. In order to determine the number of modes, Silverman's test was used (Silverman 1981) and showed that there was evidence for more than two modes, $p < 0.001$. An alternative method to determine the number of modes is to fit Gaussian mixture models to the data and determine the number of modes that has the best fit using a measure like BIC to determine the most parsimonious fit. This was done using the R package mclust (Fraley et al. 2012), which also found that a mixture of Gaussian distributions with three modes was the best fit to the distractor condition.

It appears that participants generally moved the mouse toward one of three regions in accordance with the two strategies observed in Dale et al. (2012), a reaction strategy and a prediction strategy. When multiple plausible options were available, participants either moved the mouse toward the middle area between plausible options until there was enough information to make a choice (reaction) or began movements toward one of the plausible options (prediction), sometimes resulting in a correct prediction and sometimes resulting in an incorrect prediction. For the reactive movements toward the middle area between the best ending option and one other option (i.e., angles between 30° and 90° from the best option), initial trajectories were directed toward the middle area more often in the distractor condition ($M = 26.86\%$, SD = 21.67%) than in the control condition ($M = 20.78\%$, SD = 20.01%), $t(62) = 3.80$, $p < 0.001$, $d = 0.48$.[2]

For correct predictive movements, the distractor trajectories were directed within 40° of the best option only 40.86% (SD = 15.39%) of the time and significantly less than control trajectories ($M = 68.01\%$, SD = 19.24%), $t(62) = 11.57$, $p < 0.001$, $d = 1.56$. The range of data used in these results is indicated in Fig. 4. For incorrect predictive movements, 33.25% (SD = 16.09%) of distractor trajectories were directed toward the plausible distractor, and when combined with trajectories toward the best option ($M = 74.11\%$, SD = 21.24%), the trajectories were directed toward a plausible option more often in the distractor condition than in the control condition, $t(62) = 3.12$, $p = 0.003$, $d = 0.30$. It

[2] Interestingly, there appeared to be some individual differences in the use of this reaction strategy with 11 participants making a move toward the middle on more than one-third of the trials in the distractor condition, 17 participants never moving toward the middle, and the remaining 35 participants using this strategy at least once but on less than on third of the trials. Furthermore, there was a significant correlation between proportion of use of this strategy on the distractor cohesive stories and the distractor non-cohesive stories, $r = 0.76$, $p < 0.001$.

seems that participants do not always begin moving toward the highest quality option in the distractor condition.

While some of the trajectories toward the plausible distractor were incorrect predictions, sometimes participants may have initially perceived this option to be the best. For both incorrect and correct predictive movements, it could still be possible that the competing option caused a deviation in the trajectory. In order to assess this possibility, we examined whether there were differences between those trajectories that were within 40° to the left or right of the best option in the control condition and within 40° to the left or right of the best option or the plausible distractor option in the distractor condition, as defined in Fig. 4. The rationale for this analysis is that trajectories within this 40° window were trials in which participants perceived a best option and moved toward it, making a prediction that a particular option would likely end the story rather than moving toward the middle area between plausible options until more information became available. This perceived best option may have been either the best option or the plausible distractor option in the distractor condition.

For the control condition, trajectories toward the left of the best ending option were coded as negative values and trajectories toward the right of the best ending option were coded as positive values. Therefore, a mean of 0° would indicate no deviation to the left or right of the best option while a mean greater than 0° would indicate a pull toward the plausible distractor option.[3] The mean trajectory for control trials ($M = 0.10°$, SD = 6.31°) did not deviate significantly from zero, $t(62) = 0.12$, $p = 0.902$, $d = 0.02$, indicating no significant pull from alternative options. For the distractor trials, there were two possible perceived best options. Trajectories toward either plausible options were calculated between − 40° and 40°. Therefore, positive values for any condition mean there was a pull toward a plausible option and negative values mean there was a push away from a plausible option (i.e., a pull toward the distractor from the best option or a pull toward the best option from the distractor would both be positive). The results show that the presence of a competitor option in the distractor condition caused a significant deviation away from the perceived best option ($M = 2.91°$, SD = 5.75°), $t(62) = 4.02$, $p < 0.001$, $d = 0.51$. This deviation was also greater in the distractor condition than in the control condition where a plausible competitor was not present, $t(62) = 2.66$, $p = 0.010$, $d = 0.47$. If the analysis is restricted to only the trajectories that initially move toward the best option, excluding those toward the plausible, there is also a significant deviation difference between the control and distractor conditions, $t(62) = 3.24$, $p = 0.002$, $d = 0.52$.

It may be possible that the deviation observed is because the trajectory started toward the best option, but then changed to move toward the plausible option prior to the trajectory angle being measured. Examining only those trajectories that started toward the best option and had no acceleration or direction changes prior to the measurement of the initial angle, there is still more deviation in the distractor condition than in the control condition, $t(60) = 2.89$, $p = 0.005$, $d = 0.49$. These trajectories are also significantly different from zero ($M = 3.81$, SD = 7.99), $t(60) = 3.72$, $p < 0.001$, $d = 0.48$. These results indicate that the cause of the deviation is not consistent with a change in trajectory prior to measuring the angle of deviation.

Movement change analyses

The data were analyzed for the number of direction changes and acceleration changes to examine whether there were abrupt shifts in processing during the second and third sentences. A greater number of direction or acceleration changes mean there is greater complexity in the movement of the mouse. Mean movement changes are displayed in Table 1 for both the second and third sentences. If the presence of multiple plausible options produces abrupt shifts in processing, then there should be greater complexity in distractor trials compared to control trials. These analyses were conducted using a 2 × 2 ANOVA with within-subject factors of plausibility condition (control or distractor) and sentence (second or third sentence).

During mouse movements, participants changed directions more in the distractor condition than in the control condition, $F(1,62) = 25.47$, $p < 0.001$, $\eta_p^2 = 0.29$. Also, participants changed direction more during the second sentence than the third sentence, $F(1,62) = 65.42$, $p < 0.001$, $\eta_p^2 = 0.51$. The interaction was not significant, $F(1,62) = 0.25$, $p = 0.621$, $\eta_p^2 < 0.01$. Participants became more certain in the correct ending as the story progressed, but the availability of the plausible distractor resulted in greater movement complexity. When examining only those trajectories within 40° of the best option, more direction changes occurred in the distractor condition ($M = 1.84$, SD = 1.80) compared to the control condition ($M = 1.15$, SD = 1.09), $F(1,62) = 16.05$, $p < 0.001$, $\eta_p^2 = 0.21$, and more during the second sentence ($M = 0.99$, SD = 0.11) than the third sentence ($M = 0.39$, SD = 0.47), $F(1,62) = 38.90$, $p < 0.001$, $\eta_p^2 = 0.39$. The interaction was not significant, $F(1,62) = 2.73$, $p = 0.104$, $\eta_p^2 = 0.04$. However, a paired t test showed that during the initial trajectory there was no difference in the number of direction changes between distractor trials ($M = 0.20$, SD = 0.22) and control trials ($M = 0.25$, SD = 0.21), $t(62) = 1.42$, $p = 0.160$, $d = 0.23$.

[3] If all deviations of trajectories were coded as positive values, then any effect seen would be due to a push away from the best option, but would not necessarily show the effect of the plausible distractor on the best option.

There were more acceleration changes during in the distractor condition than in the control condition, $F(1,62) = 27.93$, $p < 0.001$, $\eta_p^2 = 0.31$. Also, participants made more acceleration changes during the second sentence than the third sentence, $F(1,62) = 270.70$, $p < 0.001$, $\eta_p^2 = 0.81$. The effect of plausibility conditions was greater during the third sentence, $F(1,62) = 7.93$, $p = 0.007$, $\eta_p^2 = 0.11$. The correct answer became clearer as the story progressed, but the availability of the plausible distractor option caused greater complexity further into the story. Again, when examining only trials with initial trajectories within 40° of the best option, more acceleration changes occurred in the distractor condition ($M = 10.43$, SD = 5.98) compared to the control condition ($M = 7.53$, SD = 3.91), $F(1,62) = 25.74$, $p < 0.001$, $\eta_p^2 = 0.29$, and more during the second sentence ($M = 6.02$, SD = 2.72) than the third sentence ($M = 2.15$, SD = 1.78), $F(1,62) = 204.50$, $p < 0.001$, $\eta_p^2 = 0.77$. The interaction was not significant, $F(1,62) = 0.09$, $p = 0.768$, $\eta_p^2 = 0.001$. However, a paired t-test showed that during the initial trajectory there was no difference in the number of acceleration changes between distractor trials ($M = 0.44$, SD = 0.76) and control trials ($M = 0.45$, SD = 0.74), $t(62) = 0.29$, $p = 0.770$, $d = 0.01$.

ROI analyses

The data were analyzed for the proportion of time, during the second and third sentences, that the cursor was in one of the four ROIs defined in Fig. 1. Mean proportion of time spent within each ROI is displayed in Table 1. These analyses were conducted using a 2 × 2 ANOVA with within-subject factors of plausibility condition (control or distractor) and sentence (second or third sentence). Participants moved the mouse cursor out of the Start ROI in about the same amount of time in the distractor condition as the control condition, $F(1,62) = 0.56$, $p = 0.459$, $\eta_p^2 < 0.01$, indicating that participants were not strategically waiting to move the mouse in the distractor condition. More time was spent at the Start ROI in the second sentence than the third sentence, $F(1,62) = 292.40$, $p < 0.001$, $\eta_p^2 = 0.083$, as participants made most initial movements early during the second sentence. The interaction was not significant, $F(1,62) = 1.48$, $p = 0.229$, $\eta_p^2 = 0.02$.

The majority of time was spent in the Best ROI, and more time was spent in the Best ROI in the control condition than in the distractor condition, $F(1,62) = 310.00$, $p < 0.001$, $\eta_p^2 = 0.83$. More time was spent in the Best ROI during the third sentence than the second sentence, $F(1,62) = 1407.00$, $p < 0.001$, $\eta_p^2 = 0.96$. The effect of sentence was greater during distractor trials than control trials, $F(1,62) = 20.63$, $p < 0.001$, $\eta_p^2 = 0.25$. As participants progressed through the story, it was easier to decide on the best option early during the control trials, but it took more time in the distractor condition as participants spent more time considering alternatives.

More time was spent in the Red ROI in the control condition than in the distractor condition, $F(1,62) = 61.72$, $p < 0.001$, $\eta_p^2 = 0.50$. More time was spent in the Red ROI during the third sentence than the second sentence, $F(1,62) = 689.20$, $p < 0.001$, $\eta_p^2 = 0.92$. The effect of sentence was also greater during control trials than distractor trials, $F(1,62) = 6.90$, $p = 0.011$, $\eta_p^2 = 0.10$. This result is consistent with participants spending more time considering alternative options in the distractor condition than in the control condition while deciding on the best option earlier in control trials. Accordingly, more time was spent in the Other ROI in the distractor condition than the control condition, $F(1,62) = 74.42$, $p < 0.001$, $\eta_p^2 = 0.55$. More time was spent in the Other ROI during the second sentence than the third sentence, $F(1,62) = 273.80$, $p < 0.001$, $\eta_p^2 = 0.82$. The interaction was not significant, $F(1,62) = 2.73$, $p = 0.103$, $\eta_p^2 = 0.04$. In the distractor condition, more time was spent in between options compared to the control condition in which more time was spent in the region encompassing the best option.

To ensure the participants were not moving back and forth between options during distractor trials as predicted by a serial theory, an analysis was performed on the mean number of times the cursor entered the Red ROIs per trial (see Table 1, Entries in Red). Participants moved into the Red ROIs fewer times per trial in the control condition than in the distractor condition, $F(1,62) = 40.88$, $p < 0.001$, $\eta_p^2 = 0.40$. Also, more entries into Red ROIs occurred during second sentence than the third sentence, $F(1,62) = 31.89$, $p < 0.001$, $\eta_p^2 = 0.34$. This effect of sentence was larger during control trials than distractor trials, $F(1,62) = 24.65$, $p < 0.001$, $\eta_p^2 = 0.28$. While trajectories typically entered a Red ROI 1.29 (SD = 0.37) times per trial in the control condition, trajectories typically entered a Red ROI 1.65 (SD = 0.60) times per trial in the distractor condition. Because both means were below two entries, participants were not frequently switching back and forth between options in either condition.

End-of-sentence scores

The scores obtained at the end of the second and third sentences provide a measurement of the distance the mouse cursor was from the best ending option, and means are shown in Table 1. These analyses were conducted using a 2 × 2 ANOVA with within-subject factors of plausibility condition (control or distractor) and sentence (second or third sentence). Higher scores indicate that the mouse was closer to the best ending option and that participants were resolving ambiguities as the story progressed. Scores were higher in the control condition compared to the distractor condition, $F(1,62) = 285.89$, $p < 0.001$, $\eta_p^2 = 0.82$, suggesting greater evaluation of alternative options in the distractor condition. As the story progressed, scores improved, $F(1,62) = 468.55$,

$p < 0.001$, $\eta_p^2 = 0.88$. There was a greater difference between control and distractor condition scores after the second sentence than after the third sentence, $F(1,62) = 95.33$, $p < 0.001$, $\eta_p^2 = 0.61$. The correct ending became clearer as the story progressed, but in the distractor condition, the alternative option was still considered through the end of the story.

Discussion

The present study examined anticipatory option selection processes by exploring whether people evaluate possible predictions about the outcome of a situation serially or in parallel. The recognition-primed decision theory claims predictions are generated serially with evaluation following each generated option such that higher-quality predictions are generated first (Klein 1993, 1997). Therefore, experts in familiar settings can generate a single sufficing prediction about how to respond without the need to generate and evaluate alternatives (Johnson and Raab 2003; Raab and Johnson 2007). Long-term working memory theory claims predictions are generated and evaluated simultaneously through activation of retrieval structures that provide access to multiple potential options, thereby enhancing decision quality (Ericsson and Kintsch 1995; North et al. 2011). By examining the mouse trajectories captured while performing a narrative anticipation task, the present study provides evidence that option evaluation is more consistent with parallel theories, including long-term working memory theory.

The Angle of Deviation hypothesis tested whether the presence of a plausible distractor option would cause initial mouse movements to deviate slightly away from the best option and toward the plausible distractor. As predicted by a parallel theory, initial trajectories deviated further from the best option toward the plausible distractor in the distractor condition while trajectories did not deviate from the best option in the control condition. This deviation in the distractor condition suggests that participants were considering multiple plausible options in parallel. Although the frequency distribution of initial trajectories showed three peaks—one at the best option, one at the plausible distractor option, and one in between the two options—a follow-up analysis examining only those trajectories directed toward a perceived best option showed that even these trajectories deviated consistently toward the alternative plausible option in the distractor condition. While fewer trajectories are directed toward the best option in the distractor condition compared to the control condition, a majority of trajectories were directed toward one of the two plausible options rather than between the options, suggesting that participants make initial movements toward the perceived best option, a claim consistent with both serial and parallel theories. However, the deviation toward the other plausible option is not consistent with serial theories. Serial theories only predict a pull toward the distractor if a change in the perceived best option occurs. However, even trials with no movement changes showed a pull toward the distractor. The evidence seems most consistent with more than one choice being evaluated at a time.

It has been shown that a serial processing module feeding into a motor system that blends together two discrete motor commands separated in time can account for differences in mouse trajectory data that seem to support a parallel processing account (Van Der Wel et al. 2009). However, there have been arguments against the plausibility of this account (Spivey et al. 2010). In particular, one of the arguments by Spivey et al. concerns early deviations that are difficult to account for under a model that incorporates a serial processing module. The crux of the argument put forth by Van Der Wel et al. is that a motor command to move to one area of the screen followed after a serial processing delay by a second motor command to another location will result in a curved path. In the current study, the data most difficult for such a model to account for would be the deviation analysis that only examined trajectories which started toward the best option and had no direction or acceleration changes prior to the initial angle being measured. It is difficult to see how this kind of serial model that blends motor command would have resulted in no detectable change in direction or acceleration, but still show a consistent deviation toward the plausible option. The mean time for a trajectory to cross the circle in Fig. 1 where initial trajectory was measured was 887 ms. So at the very least, if some model with a serial option evaluation component can account for this pattern of results, it must switch between multiple options within this amount of time. This initial deviation data seem the most difficult for a serial theory to account for.

Analysis of movement dynamics revealed that participants make more direction and acceleration changes when multiple plausible options are available compared to when only one plausible option is available. There were far fewer direction changes than acceleration changes, indicating that movements toward a particular option involved multiple accelerations and decelerations before a movement was made toward an alternative option. The results indicate that participants adjust their predictions as more information is provided to favor one option over another option. In line with parallel theories, participants consider multiple options rather than a single sufficing option. It is possible that a serial process could lead to such shifts in processing if the new information leads to a positive evaluation of the alternative option. However, when initial movements are directed toward the best option, serial theories predict that no shifts in processing should occur because the best option was selected first and further evidence accumulation would be consistent with the selected option. Even if there is enough time for evaluation to continue on the alternative option, the output of such evaluation would lead to a negative evaluation of the alternative option in comparison with the best option. Therefore, the participant should not move the mouse away from the best option. Serial theories have difficulty in explaining the results, because, when examining only trials where initial trajectories were directed toward the best option, there were more direction and acceleration changes in the distractor trajectories compared to control trajectories.

An analysis of time spent in ROIs and scores obtained in the task is also consistent with participants considering multiple potential options in parallel. Analysis of the scores revealed that the mouse cursor was positioned further from the best option at the end of both the second and third sentences in the distractor condition. This result indicated that participants were not as certain in what the final prediction would be in the distractor condition and considered alternative potential actions that could occur. However, in all trials that were analyzed, participants did end up selecting the correct option. Therefore, it was not simply that participants were more likely to select the incorrect ending in the distractor condition. An examination of the ROIs revealed that, in the distractor condition, the mouse cursor was positioned between options in the Other ROI a significantly greater proportion of the time than in the control condition, and within the ending option circles (the Red ROI) for significantly less time. Although a serial theory predicts that similar results could be obtained if participants are moving back and forth between options, the mean number of entries into the Red ROIs was below two in both conditions. While the number of entries into the Red ROIs was greater in the distractor condition, when considered alongside the deviation results, it seems more likely that participants were occasionally moving toward the plausible distractor option while deviating toward the best option, entering the plausible distractor option, and then moving toward the best option, rather than moving directly toward the plausible distractor option and then switching to another option. Therefore, these results are not inconsistent with a parallel theory. Contrary to a serial model, while considering multiple endings, participants did not move straight toward a best ending option and remain inside the option circle until another ending option became more viable.

The results of the comprehension test provide additional support to the long-term working memory theory. Participants had better memory for cohesive stories than non-cohesive stories. This memory advantage is likely due to participants making use of long-term memory retrieval structures for the familiar situations presented in the cohesive stories. Through access to a retrieval structure, the participants were able to rapidly encode the current situation in memory. During the comprehension test, a cue, such as the first sentence of a story, was able to activate the retrieval structure and provide access to the information that was previously encoded.

The combined results therefore support the claims made by parallel theories that experts evaluate more options, rather than fewer, in order to improve the quality of their decisions (McRobert et al. 2009, 2011; North et al. 2011; Ward et al. 2011). According to long-term working memory theory, early in the event sequence, multiple potential options may be activated in memory and these options are evaluated in parallel. As events progress, the activation strength of the alternative options decreases and the activation strength of the best option increases. This change in activation strength was evident in the mouse trajectories; as more information was accumulated, the trajectories moved closer to the best option. Mouse trajectories were pulled toward the plausible distractor because this option is being considered in the cognitive system, which in turn influences the motion of the hand (Freeman et al. 2011; Spivey et al. 2009). One explanation for this pull is that the cognitive system sends information about what the best option is to the motor system in order to move the mouse toward that option. However, when there is a plausible distractor present, the signal processed by the motor system contains information to move the hand toward the best option as well as a weaker signal to move toward the plausible distractor. Therefore, the mouse trajectory is pulled away from the best option.

The advantage of using continuous mouse tracking is that it can measure cognitive activity as the mouse position data are captured while the hand is in motion. Prior research has relied on verbal protocol data to evaluate the generation and evaluation of predictions. When a situation is presented to participants, they verbalize what the person in the scene would do next, or what action they themselves would do next. Possible predictions must be verbalized in serial order. Therefore, it was difficult to discern whether the generation and evaluation of predictions is made in parallel and verbalized sequentially or if the predictions are made serially and verbalized sequentially. This study provides a proof of concept that continuous mouse tracking can examine the evaluation process on-line during the course of processing in narrative text comprehension, and this domain was used because it is one in which many adults are experts. Mouse tracking is just one instance of monitoring motor output, and these results could potentially be generalized to monitoring differences in body position that may be more easily studied in non-computer tasks.

A further step in this line of research, using continuous metrics, will be to apply these methods to domains such as sports, military combat, and aviation and to compare expert and novice groups. Prior research performed by North et al. (2011), and others (e.g., McRobert et al. 2009, 2011; Roca et al. 2011), present participants with a video segment of a series of actions, such as a soccer player dribbling the ball down the field, and participants must decide what the player will do when the video is stopped, such as who the soccer player will pass the ball to. It should be possible to measure movement competition in such tasks by tracking kinematics of the body in natural settings and/or a computer mouse in a computer-based task. The Nintendo Wii remote has already been used in many studies examining cognitive dynamics (Dale et al. 2008; Duran and Dale 2009; Duran et al. 2010; O'Hora et al. 2013), and similar technologies could be applied to traditional anticipation tasks. It should also be possible to examine the degree to which these types of anticipatory processes are seen in aspects of text comprehension.

Limitations

The present study had participants listen to one sentence of the situation before making movements. These movements were not initiated until ~ 700 ms after the participants were allowed to begin moving. Due to this delay, it is possible that participants could have had time to generate multiple options serially and then explicitly adopt a strategy to move toward the midpoint between two plausible endings. However, even in cases where there was a clear movement toward one ending option, there was still a slight deviation toward the other plausible option. This slight deviation does not seem consistent with an explicit strategy of moving between two options. Future work might be able to more conclusively rule out this explanation by using eye tracking to see where attention is focused as the mouse is moving. Tracking of eye movements has been used extensively in studies of prediction during discourse comprehension (Altmann and Kamide 1999; Bonhage et al. 2015; Calvo et al. 2001; Chambers and San Juan 2008; Coco et al. 2016; Kamide et al. 2003; Kukona et al. 2011) and perceptual anticipation in sports (Gegenfurtner et al. 2011; McRobert et al. 2009, 2011; North et al. 2009; Raab and Johnson 2007; Roca et al. 2011; Savelsbergh et al. 2002; Ward and Williams 2003) and can easily compliment computer-based mouse-tracking studies.

Another limitation is that ending options were presented to participants before the story was presented. Therefore, participants did not necessarily have to generate possible options and the results only support the notion that options are evaluated in parallel. The recognition-primed decision theory asserts that options are generated serially and evaluated serially, while long-term working memory theory asserts that options are generated in parallel and evaluated in parallel. There is potential for a theory in which options are generated serially and evaluated in parallel. The present data are consistent with long-term working memory theory and such a hybrid theory, but not a serial theory. Future research would be needed to more directly assess the option generation stage of the anticipation process, and continuous mouse tracking may prove a useful measure.

A final limitation is that the colored background might have caused participants to strategically move the mouse to certain positions on the screen. While this possibility cannot be completely ruled out, there was still a deviation in the initial trajectories toward a plausible distractor. In these instances, participants are more likely using the option as an indicator of where to move and not the colored background. In the present experiment, the colored background was useful in getting participants to move the mouse continuously throughout the story. Classic mouse-tracking paradigms with two options at the top and the start position at the bottom are ideal, but stimuli must be sufficiently quick so that participants do not reach the top middle of the screen before decisions are made. Future studies may benefit from shorter stimuli in order to make use of the classic mouse-tracking designs.

Conclusion

The mouse-tracking data support a theory in which multiple predictions are evaluated in parallel. The data show that mouse trajectories deviated further toward alternative predictions in the distractor than the control condition. Ultimately, there likely are hypothetical models with some serial option evaluation component that could be designed to explain the current data. It is not possible to conclusively rule out a whole class of theories with one study. The current data provide a number of results including timing and deviation data that along with the current literature seem to us to be most consistent with parallel theories of option evaluation. Continuous metrics such as mouse tracking should be used in conjunction with currently employed methods to help shed light on the cognitive mechanisms underlying anticipation. The current study lays the groundwork for future research that examines anticipation in more complex domains.

Acknowledgements Special thanks to Maranda Duncan and Adrian Lewis for helping to create stimuli, Chris Austin for helping program the experiment to capture mouse movements, and Evan Cranford for helping design the task background and scoring algorithm.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights This research involved human participants, and informed consent was obtained. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Mississippi State University Institutional Review Board for the Protection of Human Subjects in Research and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Appendix 1: Stimulus materials

Table 2 lists the stories used in the experiment, the possible options presented to the participants, and the duration (in seconds) of the recordings.

Table 2 List of stories used in the experiment

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
*C_Rose	Rose was very excited about her upcoming prom, but could not find that perfect dress. On the morning of the prom, Rose's mother surprised her with the dress she had worn to her own prom. Rose did not like her mother's dress, but wanted to please her, so she…	cooked	folded flag	called friends	wore dress	14.63
*C_Ken	At the local grocery, Ken's job was to separate the oranges from the tangerines. His job was much more boring and unsatisfying than his old job as a party clown. One day, after five hours of mindless work, Ken grabbed three oranges out of the bin and began to…	kneel down	dig hole	peel them	juggle	15.83
*C_Tabitha	Tabitha was working her first day at her new job at the hair salon. After removing the towel from the head of her first client, the client screamed at the sight of the purple hair. In order to avoid a confrontation and rectify the mistake, Tabitha apologized and…	blew whistle	threw ball	quit job	refunded money	16.90
*C_Reese	Reese was sitting in class one day when all of the sudden the fire alarm started to ring. Following protocol, the teacher began to gather the students and line them up to exit the building. Having been taught what to do in this situation, Reese stood up and …	snorkeled	played poker	jumped up	lined up	14.35
*C_Cynthia	Cynthia was alone in her house, lying on the sofa, reading a rather boring book. With each page she turned, her eyes grew more and more tired. Right before her final blink, Cynthia's arms fell to her side and she…	punted ball	flew plane	found remote	fell asleep	12.95
C_Steven	Steven's parents grounded him for the weekend, but his friends were having a party that he really wanted to go to. The night of the party, Steven laid in his bed waiting for his parents to fall asleep. After he was sure they had gone to bed, Steven got up and…	swam laps	raised hand	pouted	sneaked out	14.63
C_Alex	Alex was sitting at the table facing a gigantic clown-shaped cake. All of his friends and family were standing around him singing the famous song. The crowd stopped singing and Alex closed his eyes, made a wish, puckered his lips and…	shrugged shoulder	hiked hill	cut cake	blew candles	15.33
C_Mary	Mary was grocery shopping one evening when she noticed her child slipping a bag of candy into his pocket. After witnessing this event, Mary was furious. She ran over to the guilty child, bent him over, and…	fell asleep	showered	yelled	spanked child	12.95
C_Olivia	Olivia was lying in the hospital bed, sick with a bad cough. Her friends were visiting her, leaning over her bed, and offering support. Olivia did not want to get her friends sick so every time she was about to cough, she used her hand to…	kick machine	tap beat	drink water	cover mouth	14.25
C_Rhianna	Rhianna is always seen checking her phone for text messages during class. One day she was in class checking messages and her professor caught her. Rhianna quickly put down her phone, looked at the professor, and respectfully…	rowed boat	rocked cradle	turned off	apologized	12.88

Table 2 (continued)

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
C_David	David was doing yard work on a beautiful Saturday morning. The weeds had grown very tall and the yard looked quite pitiful. David pulled out the old lawnmower and began to…	drop pen	bang drum	trim hedges	cut grass	10.85
C_Lenny	Lenny was on his way home, but first had to make a stop at the meat market. He walked into the tiny shop and up to the counter, but could not find the butcher anywhere. In a hurry, Lenny reached across the counter and…	spun top	burnt log	waited patiently	rang bell	11.97
C_Amy	Amy was supposed to be doing homework, but decided to watch television instead. Suddenly, she saw her mom pull into the driveway. Knowing her mom would be upset, she quickly grabbed the remote and…	dried clothes	danced	made snack	pressed power	11.13
C_Katie	Katie was driving down the highway one evening when she noticed a truck in front of her with many loose items in the back. She was paying close attention, when suddenly she saw a large box fall out of the truck. With enough time to react, Katie grabbed the wheel hard and…	went hunting	made drink	honked horn	swerved left	14.42
C_Jamie	Jamie was outside playing basketball with two of his friends one afternoon. A bystander walked up to the group and asked if he could join in the game. The teams were uneven so Jamie looked at the man and happily…	washed dog	read magazine	changed game	invited man	12.00
C_Samantha	Samantha was playing soccer with a few friends. She had the ball when she noticed an opponent running toward her. She quickly checked to her left and, spotting an open teammate, Samantha…	combed hair	disarmed bomb	took shot	passed ball	10.64
C_Susan	Susan had been at the bar talking to the mysterious man all night long. He was quite interesting, and though she was leaving soon, she hoped to see him again. To ensure another meeting, Susan leaned toward the man and…	fastened belt	ran light	cheers glasses	whispered number	12.95
C_Gracie	Gracie always loved playing with Will during recess. As soon as the bell rang, Gracie ran to the play cabinet and claimed the kickball. After finding Will, Gracie put the ball at her feet and immediately…	built castles	slept	threw ball	kicked it	11.55
C_Sophia	Sophia had not eaten all day so she walked into her favorite restaurant. She was very hungry and devoured her main course. When the waiter returned with the check, she immediately declined the check and…	splashed water	took bath	opened menu	ordered desert	11.90
C_Christopher	Christopher started working on the report for his history class which was due in the morning. Needing more information, he decided to do some research on the internet, but was surprised to find a full report created by someone else. Although he had never cheated before, Christopher knew the only way to get his report done on time would be if he…	jumped up	skated ice	started writing	downloaded report	19.16
C_Mark	Mark was finally on his way home after working a long day outside in the cold and rain. After opening the front door, he noticed that his wife had recently cleaned the carpet. Knowing that if he took another step it would be his last, Mark…	shot deer	woke baby	stayed outside	removed shoes	14.56

Table 2 (continued)

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
C_Daniel	Daniel was driving home during the afternoon rush-hour traffic. He was constantly having to brake and then accelerate when, finally, he saw freedom as the road cleared ahead. Daniel quickly accelerated to cruising speed and took his foot off the pedal as he…	walked dog	watered lawn	hit brake	set cruise	14.77
C_Andrew	Andrew was jogging down the street one early afternoon, on his way to karate class. As he turned the corner, he witnessed two young men attempting to steal a purse from an elderly woman. Noticing the men were unarmed, Andrew realized he had no other option but to …	roll marble	whip horse	attack men	defend woman	14.98
C_Michelle	Michelle was walking to her statistics class in college and noticed a recently painted wall with an attached sign that read "Do Not Touch." Michelle has always been impulsive and somewhat rebellious. Almost instinctively and without regret, Michelle reached out her hand and…	sailed boat	pulled rope	smeared paint	touched wall	17.02
C_Paul	Paul worked at the local packaging plant that was suffering from a recession. Paul, with many of his friends, were laid off from work. Without a job, Paul had to…	jump rope	sky dive	protest closing	file unemployment	9.45
C_Anthony	Anthony was at the gas station filling his truck with gas. He finished filling up his tank, but the gas continued to flow out. Not knowing what to do, Anthony quickly ran inside the station to…	pause film	wink eye	grab bucket	tell manager	11.69
C_Kevin	Kevin was driving on a country road one cold and icy morning. Up ahead, he saw a deer running toward the road, but it was still fairly far away. Kevin knew the only way to miss the deer would be to…	dance	fish	turn wheel	brake	13.00
C_Carol	Carol was the last person left around the bonfire. The weary fire was quickly dying out. Carol tiredly reached down for a bucket of water and…	baked cake	swiped card	added wood	doused flames	9.24
C_Donald	Donald was working on his car one morning. He was looking under the hood when he heard a loud bang. Startled, Donald quickly jumped up and…	bowled strike	fed fish	closed hood	banged head	8.80
C_Allen	Allen was quietly sitting in his seat, watching a film at the local movie theater. He was nervous because it was the first time he ever sneaked in without paying for a ticket. When Allen saw a security guard walking up the rows toward him, he quickly grabbed his things and…	stirred soup	changed tire	changed seat	ran out	15.83
C_Thomas	Thomas was in class, listening to his teacher give a lecture, but he did not understand some of the material. Normally he would not ask a question, but he knew the material would be on tomorrow's test. Reluctantly, Thomas looked up at the teacher and…	fried bacon	tamed lion	took notes	raised hand	14.49
C_Brian	Brian was standing at the edge of the smooth, glassy lake. He bent down and picked up a rock that was laying at his feet. Reaching his arm back as far as he could, Brian…	danced	cooked	dove in	skipped rock	10.36
C_Christina	Christina went to eat lunch at the new diner in her neighborhood. She started to eat and realized there was a fingernail in her sandwich. Christina was disgusted so she…	applied perfume	sang	ordered smoothie	informed manager	9.60

Table 2 (continued)

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
C_Emma	Emma was cooking a stew in the kitchen, about to add the pepper. As Emma poured in the pepper, leaning over the pot, she felt a sneeze coming up. To avoid a ruined stew she brought her hand to her face and…	strummed guitar	laid down	sneezed	covered nose	12.39
C_Timmy	Timmy's mother just finished baking cookies. She left the cookies on top of the stove as she went to check on Timmy's baby sister. Timmy, unable to resist the sweet smell, reached for a cookie on top of the stove and…	washed dishes	popped balloon	spilled pan	stole cookie	12.53
NC_Erin	Erin decided she wanted to go on a special hike one morning. After working out, she decided to go to the movies with a friend. After a long visit with her mother, Erin quickly packed her things into the car and…	fluffed pillow	wrote check	packed snack	said goodbye	11.13
NC_Dianna	After arguing with her boyfriend, Dianna decided to go to a friend's house to visit. Jumping into the pool, she laughed and played. Exhausted from the day, Dianna turned on the water and…	finger painted	mowed lawn	splashed water	took shower	10.01
NC_Linda	Linda recently got a promotion at her day job. Having eaten a tremendous amount of food, she went home. On her afternoon bike ride, Linda hit a bump and immediately…	ignored noise	emptied trash	got sick	crashed bike	9.24
NC_Margaret	Margaret was a successful bartender working at a local night club. As she cleaned her station and collected her tips, the boss played some music. But worried about her mother being sick, Margaret decided to pick up the phone and…	cook rice	throw disk	count tips	call mother	12.02
NC_Betty	Betty has always had a sweet tooth and chocolate was her absolute favorite. She took the DVD and placed it in the tray. After fighting to stay awake, Betty decided to lay down and…	dry clothes	exercise	press play	fall asleep	9.59
NC_Ruth	Ruth decided to start painting a picture one early morning. She went swimming at the lake with her best friends. After raking the leaves into a pile, Ruth then began to…	polish silver	cheat test	tag friends	bag leaves	9.10
NC_Sarah	Sarah was always the perfect child, never getting into a bit of trouble. While walking downtown she saw her old childhood friend and wanted to say hello. After finishing cooking and making the table, Sarah sat down and started to…	kick teacher	send resume	shake hands	eat dinner	13.44
NC_Angela	Angela finished her long day at the office and started to head back home. After she finished the next chapter in the book, she quit reading. Having a headache all day, Angela decided to grab some pain medication from the cabinet and…	pull hair	dance	remove glasses	take pills	11.55
NC_Dorothy	Dorothy sprained her ankle in the middle of the softball game. The hospital food reminded her of the slop she ate at the orphanage as a child. Wanting to get back to her family, Dorothy got into her car, turned the ignition key, and finally started to…	blow kiss	run around	ice ankle	drive home	12.88
NC_Janet	Janet woke up and knew that today was her mother's birthday. While washing her car she got a call from her friend inviting her to dinner. Because she was in a nostalgic mood, Janet went to her bookcase, removed an old yearbook, opened it, and began to…	Tie bow	Steal food	Call mom	Read comments	13.56

Table 2 (continued)

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
NC_Ruby	Ruby wanted to go to her high school dance, but didn't have a date. She went to the stylist and had her hair done. Her sister had just finished practice and was running to the car, so Ruby reached across the passenger seat and…	threw rock	studied hard	went alone	unlocked door	12.42
NC_Mia	Mia was at her birthday party having a lot of fun. She jumped onto her new pony and rode the rest of the day. Mia ran up the stairs, climbed into bed, and…	told lie	walked dog	ate cake	fell asleep	8.82
NC_Laurie	The summer had ended and Laurie was on her way to college. She wanted to go to the concert, but did not know where it was. After the concert was over, Laurie met the drummer and…	made budget	weaved hair	emailed friend	got autograph	10.64
NC_Nancy	Nancy was looking for babysitter so she could have a date with her husband. After putting the dishes away she sat down on the couch to watch her shows. Nancy realized her dress had a stain on it, so she quickly decided to…	Rock cradle	Make bracelet	Call friend	Change dresses	12.11
NC_Chloe	Chloe was going shopping with her friends on the day after Thanksgiving. She planned to meet the group at her favorite cafe for breakfast. Chloe wanted to put in her favorite pair of earrings, so she went to her jewelry box and…	disarmed bomb	passed ball	had fun	found them	11.62
NC_Scott	Scott was getting ready for the fireman's ball. He was thinking about dinner ever since he returned home from work. Because the stain wouldn't come out, Scott ran to his room and …	hummed song	petted cat	shaved beard	changed shirt	9.34
NC_Frank	Frank was going to help out at his children's school during the holidays. He left work early, forgetting to inform his boss. As he thought about his wife, Frank passed by a flower stand and…	cupped hand	made bed	ran back	bought roses	10.06
NC_Larry	Larry always wanted to know what it was like to live in a foreign country. He went to read at his favorite store on main street. The steam rose from the cup as Larry brought it to his lips and slowly…	rolled marble	tugged rope	bought muffin	sipped coffee	10.78
NC_Jeffrey	Jeffrey was walking to the grocery store one afternoon. Sometimes he likes to run, but this day it was too hot. Seeing the child fall off her bike, Jeffery rushed over to the girl and…	cocked gun	filled bottle	dropped bag	helped her	9.94
NC_Eric	Eric walked his dog one cold winter morning. He was nervous about flying a plane for the first time. After flushing the toilet, Eric walked over to the sink and…	threw punch	warned friend	splashed face	washed hands	8.89
NC_Greg	Greg was pacing back and forth across the newly finished hardwood floor. He was upset with his son for getting in trouble at school. After hearing the joke from his wife, Greg couldn't help but to…	play drums	watch birds	punish son	laugh	10.34
NC_Joshua	Joshua decided he wanted to cook a wonderful meal for his soon-to-be wife. He finished the book, feeling satisfied with the ending. Upon hearing the news about the death of his friend's father, Joshua immediately picked up the phone and…	caught firefly	cuddled bear	poured wine	called friend	13.54

Table 2 (continued)

Story ID	Story text	Options				Duration (s)
		Neutral 1	Neutral 2	Plausible	Best	
NC_Walter	Walter was stressed with the recent surge of work that was given to him at his job. He looked at the weather forecast and saw that it was going to rain later in the week. Having just received his income tax refund in the mail, Walter decided to go to the local clothing store and…	sell house	climb tree	call-in sick	buy suit	15.90
NC_Peter	Peter was upset that his beloved cat had become ill. For now, there was nothing else he could do so he left the house. After buying his ticket and popcorn, and sitting down in the seat of the movie theater, Peter leaned back and…	slapped sister	ate grapes	started crying	watched movie	12.18
NC_Ryan	Ryan was anxiously waiting in line to use the restroom. The meeting with the financiers was going very well. After partying for quite a long time, Ryan realized he was too intoxicated to drive home so he…	jumped rope	played soccer	hurried back	called cab	11.62
NC_Carl	Carl rushed to the hospital to see his sickly grandmother. He knew he wasn't going to have much time to work on the homework so he decided to finish it early. Seeing the poor man on street next to the bus stop really upset Carl so he reached into his pocket and…	swept floor	rowed boat	prayed	gave money	13.93
NC_Jack	Jack was watching the news before he had to go. He ate a large meal in preparation for the first day of training. Upon leaving the house Jack noticed his shoes were not tied, so he immediately bent down and…	flew kite	dyed t-shirt	ripped pants	tied shoe	10.93
NC_Justin	Justin was sitting on the couch watching the football game. He saw his neighbor riding a new lawnmower. After hearing the news that he was going to have a second child, Justin went to his wife and…	Started fire	Popped trunk	Muted sound	Hugged her	10.99
NC_Terry	Terry had many friends and threw the best parties around town. He became very embarrassed after his card was denied at the crowded store. Terry plugged in his jukebox and began to…	ride horse	bike trail	leave store	sing	10.02
NC_John	John forgot his briefcase when he went into work one morning. During his midday break, he went to the roof for a cigarette. John was in a hurry so he ran quickly to the curbside and…	splashed water	typed letter	called wife	hailed taxi	9.94

C cohesive stories, *NC* non-cohesive stories

[a]Indicates stories used as practice trials

Appendix 2: Norming study

Participants in the norming study were 72 undergraduates from Mississippi State University who completed the experiment for course credit. The experiment was presented as an online survey. Participants read 59 cohesive stories and 30 non-cohesive stories that were created for the experiment. For each story, participants read the three sentences and were then presented with 11 possible endings (three good endings, four possible endings, and four unrelated endings). Participants were asked to (1) select one of the endings that would best complete the story and (2) select three more endings from the same list that could possibly complete the story. The two endings that were selected least often as possible endings, and never chosen as a best ending, were used as unrelated options in the present experiment. The ending that was selected most often as the best ending was used as the best option. Finally, the ending that was selected the most as a possible, but non-best ending was used as the plausible distractor.

Of the 59 cohesive stories, 35 were selected for the experiment. Stories were included if they met the following criteria: (1) If one option was selected as the best option by the majority of the participants (mean proportion who chose best option as the best = 69.8%), (2) if one option was selected as a possible alternative option a majority of the time (mean proportion who chose plausible option as a possible alternative option = 64.0%) and rarely selected as the best option (mean proportion who chose plausible option as a best option = 4.6%), and (3) if the best and possible endings both shared context with each sentence of the story. Therefore, if participants naturally generated options when reading the stories, then the two plausible options provided would likely be included in the set. Five stories from this final set of 35 were randomly selected for practice trials. All of the non-cohesive stories were used. Each of the non-cohesive stories had a unique best ending, a plausible distractor, and two unrelated endings.

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