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Online Fictive Motion Understanding: An Eye-Movement Study With Hindi

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Two visual world eye-tracking studies explored the online simulation of illusory motion during comprehension of sentences containing fictive motion verbs in Hindi during perception (Experiment 1) and in imagery (Experiment 2). Experiment 1 was designed to see the effect of sentence structure on magnitude and time course of simulation motion as reflected in eye movements. Fixational eye movement data revealed significant gaze durations and number of fixations during comprehension of fictive motion sentences compared to a nonfictive motion sentence and an effect of sentence type. Experiment 2 used a blank-screen paradigm to measure motion simulation in the absence of a visual scene. However, there was no evidence of motion simulation for fictive motion sentences as reflected in eye-movement measures. The results indicate that figurative expressions, that is, fictive motion sentences, induce illusory motion simulation during active perception but not during imagery. Furthermore, the results indicate an effect of sentence structure on observed simulation.

Language use involves both literal and figurative expressions. However, theoretical accounts differ as far as processing of these two forms of language is concerned (Gibbs, 2001). Classical models consider figurative language distinct from literal language and demand greater processing load (Frisson & Pickering, 2001; Giora & Fein, 1999). In contrast to this, models that assume the role of simulation as the key to sentence understanding propose similar processing mechanisms for both literal and figurative language (Bergen, 2005). Notwithstanding this debate, there is now increasing evidence that motor simulation and enactment play important roles in processing both figurative and literal language (Anderson & Spivey, 2009; Fischer & Zwann, 2008; Taylor & Zwann, 2009). In this article we focus on mental simulation during comprehension of fictive motion sentences during perception and imagery.

For literal sentences, verbs often induce perception of motion (Meteyard, Bahrami, & Vigliocco, 2007). However, recent behavioral experiments suggest that subjects simulate illusory motion during processing of fictive motion sentences (Langacker, 1987; Matlock, 2004; Richardson & Matlock, 2007; Talmy 2000). For example, subjects simulate motion while comprehending sentences such as "*the tattoo runs between knee and ankle.*" In such sentences an entity that is itself not capable of self-motion assumes a sort of temporary ability to create the illusion of movement when a motion verb like *run* or *go* follows it. Studies using eye movements have shown higher deployment of visual attention to a scene while listening to a

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fictive motion sentence (Richardson & Matlock, 2007). Other behavioral (Bergen, Lindsay, Matlock, & Narayanan, 2007; Matlock, Ramscar, & Boroditsky, 2005) and neuroimaging studies (Wallentin, Østergaard, Lund, Østergaard, & Roepstorff, 2005) too indicate the presence of implicit motion simulation for such sentences. However, it is still not clear what precisely leads to such simulation of motion for fictive motion sentences. However, embodiment seems to be a dominant factor (Gibbs, 2006a). In this study we particularly focus on the information structure of sentences and examine its effect on mental simulation during both direct perception and imagery.

Information structure associated with a sentence could be expressed through different phenomena such as scrambling and intonational patterns (Chafe, 1976; Fanselow, 2008; Jackendoff, 1972). Few elements in the sentences are foregrounded, that is, subjects and others are remain in the background (Talmy, 2000). This study examines the prediction that this syntactic variation affects attentional mechanisms and possibly motion simulation as observed for fictive motion sentences. Hindi being a language with flexible word order allows testing of this hypothesis. In spite of several studies that have investigated how scrambling affects comprehension of literal sentences (Sekerina, 2003), very few have examined its effect on processing of figurative language. This study explores how fictive motion sentences in both scrambled and nonscrambled forms affect visual attention during scene perception. No previous study on figurative language processing or language–scene interaction has looked at this interaction. We demonstrate the issue in the following .

Let's consider a fictive motion sentence such as "The road runs across the valley." It is quite possible that higher allocation of visual attention while listening to such a sentence may be influenced by the sentence structure itself. In an eye-tracking paradigm, subjects may allocate higher visual attention to the display depicting "the road" as compared to "the valley" because it appeared as the subject of the sentence. Therefore, sentence structure can have important influence on comprehension and perception of fictive motion.

To investigate this issue further, we used topicalized versions of the sentences, where the subject is backgrounded and does not happen to be in a discourse-prominent position from an information structure perspective. This was possible to do in Hindi because Hindi is a free-word-order language and both topicalized and canonical forms of the expressions are similar in their meaning and are equally acceptable in everyday discourse. We reasoned that, if the subject prominence factor plays any role in eye movements during comprehension of fictive motion sentences, then we will observe limited motion simulation for the topicalized sentences compared to fictive motion canonical sentences. However, overall eye movements would be bigger for both versions of fictive motion sentences compared to the nonfictive motion sentences as predicted by simulation-based theories. Alternatively, if the subject's topic or position is not a factor in eye movement behavior, both the topicalized and canonical forms would induce similar simulation of motion, increasing gaze durations compared to the literal sentence, but their time course may be different, that is, the point at which we observe a peak in the proportion of fixations.

The other important issue that this research examined was mental simulation during imagery. Sentence comprehension could involve mental imagery (Just, Newman, Keller, McEleney, & Carpenter, 2004). It is still not known if mental simulation could be observed during imagery or if it is restricted to direct perception for fictive sentences. We used a novel paradigm to explore this possibility in which eye movements were recorded after the visual scene had disappeared (Altmann, 2004). Studying eye movements during both perception and imagery (Brandt &

Stark, 1997; Laeng & Teodorescu 2002) can provide valuable clues about the nature of simulation in these two conditions. Moreover, this would throw important light on the very nature of "simulation" in fictive motion sentences. The effect of language on eye movements (Altmann, 2004; Altmann & Kamide, 2009; Spivey, Richardson, & Fitneva, 2004) and spatial indexing of eye movements to blank space (O'Regan, 1992) led us to expect simulation during imagery. We reasoned that, if comprehension of fictive motion sentences could influence strategies of perception, then we may see the effect of such mental simulation during imagery.

Interestingly, eye movements during actual viewing of a scene and during imagery have been found to be largely similar during both linguistic and nonlinguistic tasks (Johansson, Holsanova, & Holmqvist, 2006). We predicted that if listeners process fictive motion sentences differently than nonfictive motion sentences during the visual display, then they would do so as well when the scene is removed. Alternatively, if such simulation only takes place during the concurrent processing of the scene and the sentence, then there would be no difference between fictive motion sentences and nonfictive motion control sentences during imagery. In particular, we predicted a significantly higher number of fixations and longer gaze durations for fictive motion conditions if the subjects simulate illusory motion during imagery.

In Experiment 1 we presented fictive motion sentences, both in their canonical as well as topicalized forms, along with their literal counterparts and measured participants' eye movements as they watched a static display. In Experiment 2, using a blank-screen paradigm (Altmann, 2004), we measured eye movements after the scene had disappeared to explore motion simulation during imagery. These experiments thus aimed to provide further cross-linguistic evidence of perceptual motion simulation during comprehension of figurative language under different task constraints.

EXPERIMENT 1

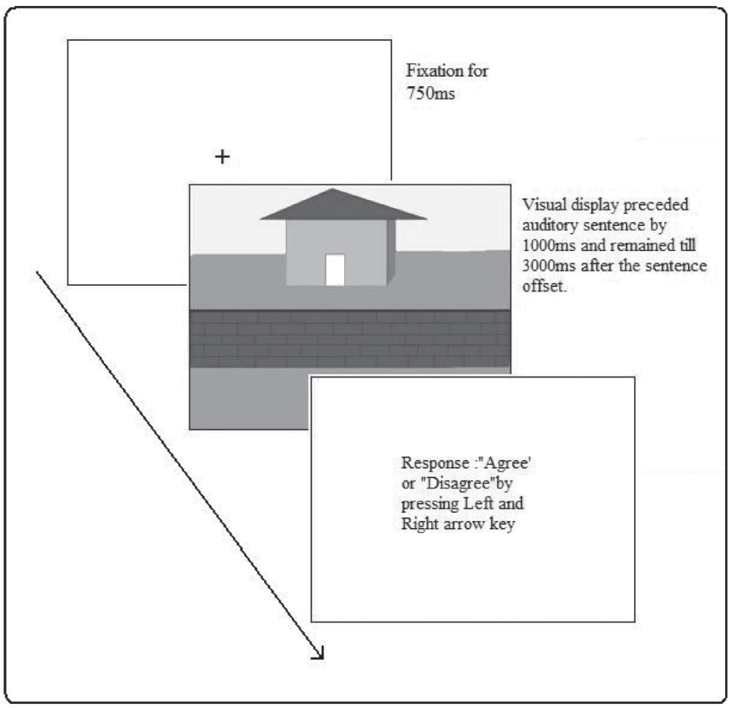
We explored the effects of topic and focus shifts through manipulation of the word order on time course and magnitude of such motion simulation as evident in eye movements. It was predicted that for both the topicalized and the canonical fictive motion sentences there would be substantially more fixations and longer gaze durations as well a continuous deployment of visual attention on the concerned part of the scene as compared to the literal sentences. This study would thus replicate findings of Richardson and Matlock (2007) for English and would test whether motion simulation is independent of certain structural constraints.

Method

Participants. Sixty native Hindi speakers (mean age 23 years) from the University of Allahabad participated in this eye-tracking experiment. Out of sixty participants 31 were women and 29 were men. Participants were randomly assigned to three experimental conditions. All had normal or corrected-to-normal vision. Informed consent was obtained from each participant prior to the experiment.

Stimuli. There were 15 experimental visual displays (Appendix B). These were semirealistic scenes created with Adobe Photoshop. These scenes depicted different spatial objects having paths that were either travelable (e.g., bridge, road) or nontravelable (e.g., fence, line of trees). We used equal numbers of horizontal and vertical objects to avoid any visual bias. The displays closely matched real depictions and were rated for their suitability. Figure 1 shows a typical experimental stimulus with the fictive and nonfictive versions of sentences. Displays were of 1024×768 resolution and filled the entire screen area of a 17-inch color monitor. A further 16 filler scenes were added along with the experimental items.

Auditory stimuli consisted of spoken sentences that described visual stimuli. For each visual display three sentences were recorded (Appendix A). Each fictive motion sentence had a topicalized and a canonical version. The literal or nonfictive motion sentence was always presented in its canonical form. Efforts were made to keep the length of the sentences similar. Sentences were recorded on Goldwave by a female native Hindi speaker. These recordings were saved as



FMC condition: *Yeh dewaar ghar ke saamne se ho kar guzarti hai*
[The wall goes from the front side of the house.]
NFM condition: *Yeh dewaar ghar ke saamne hai*.
[The wall is in the front of the house.]
FMT condition: *Ghar ke saamne se yeh dewaar guzarti hai*.
[From the front of the house goes the wall.]

FIGURE 1 Top: presentation sequence of an experimental trial. Bottom: the three types of sentences used for this display for three independent groups of subjects.

wave files and sampled at a rate of 4.41 kHz mono channels. An additional 16 filler sentences were recorded for filler pictures. An example of a filler sentence is "*yeh ladki gend se khel rahi ha*" [This girl is playing with a ball]. Therefore filler scenes depicted animate agents with actions. Examples of experimental sentences used with one scene can be seen in Figure 1.

FMC condition: *Yeh dewaar ghar ke saamne se ho kar guzarti hai*
(The wall goes from the front side of the house.)
NFM condition: *Yeh dewaar ghar ke saamne hai.*
(The wall is in the front of the house.)
FMT condition: *Ghar ke saamne se yeh dewaar guzarti hai*.
(From the front of the house goes the wall.)

Please note that the English translation of the Hindi topicalized sentence is not accurate as it is not possible to have that word order in English. The canonical and topicalized versions of fictive motion sentences differ only in their word order; their meaning remains the same. In all three conditions the same pictures were used. Furthermore, the same fillers were used in all the conditions. The mean duration was 4.4 ms (*SD* = 0.75) for Fictive Motion Cannonical (FMC) sentences, 4.2 ms (*SD* = 0.53) for Fictive Motion Topicalised (FMT) sentences, and 3.2ms (*SD*=0.62) for nonfictive motion sentences. The difference in length was not significant so as to affect durations of eye movements.

Picture and sentence pairs (FMC, FMT and Non Fictive Motion [NFM]) were rated for compatibility. Fifteen native Hindi speakers rated the compatibility of the sentences with the scenes on a 5-point Likert-type scale ranging from 1 (*highly incompatible/mismatch*) to 5 (*highly compatible/match*). The focus of the rating was to make sure that all three versions of the sentences were equally good descriptions of the respective scenes. The selected stimuli had mean ratings of 4.1 (*SD* = 0.41), 4.3 (*SD* = 0.37), and 4.2 (*SD* = 0.30) for FMC, FMT, and NFM sentences respectively. Participants who took part in the ratings of pictures and sentences were not included in the main eye-tracking study.

Apparatus. Participants were seated at a distance of 75 cm from a 17-inch color monitor running at a 75 Hz screen refresh rate. Participants' eye movements were recorded by SMI High speed eye tracking (Sensomotoric Instruments, Berlin, Germany) with a sampling rate of 1250 Hz. It is a video-based eye tracker that uses an image-processing algorithm to calculate pupil position with respect to the corneal reflex. Viewing was binocular, but data from the right eye were used for analysis. The visual stimuli subtended approximately 15-degree visual angle. Participants were instructed to keep head movements and eye blinks as minimal as possible. The participant rested his or her chin on a bar during viewing to minimize head movements.

Procedure. The experiment began with a calibration process that was automatic as participants looked at a fixation cross presented at 13 different locations on the monitor. The eye tracker accepted calibrated points automatically only when each point received one successful fixation for at least 400ms. After successful calibration the experimental trial began with a fixation cross at the center of the screen for 750 ms followed by presentation of the scene. At 1000 ms after onset of the scene a spoken sentence was presented (Figure 1). Auditory sentences were presented via speakers located on both sides of the monitor and equidistant from the subject. The scene remained on the screen until 3000 ms after offset of the spoken sentence. Eye movements were recorded from the onset of the visual display until its offset, that is, for 9 ms on average. Participants were given instruction (both oral and written visual instruction) to look at the pictures carefully while listening to the spoken sentences. Participants were told to pay attention to both the visual scene and the spoken sentence. To ensure that participants were looking and listening attentively, at the end of each trial they were required to give judgment in response to the question of whether the picture shown and the spoken sentences were compatible or not. However, this was not used for any further analysis. They were asked to press the left arrow key if they "agreed" and the right arrow key if they "disagreed." The next trial began only after participants had given the response. Each trial lasted for 9 to 10 sec on average depending on the duration of the spoken sentence. In all there were 32 trials in each condition, which included 16 filler items as well. Each experimental session took about 12 to 15 min to complete.

Data analysis. The dependent eye movement variables employed were total number of fixations, average duration of fixations, total number of saccades, and total gaze durations. These variables were measured only within a prespecified area of interest (AOI) in the scene. Each picture had one AOI that included a representation of the noun phrase with which the fictive motion event was associated, also known as the *trajector* in the literature (Talmy, 2000). AOIs were drawn manually enclosing the contours of the entity (noun phrase). The AOIs were dependent on the shape of the different entities (like road, rail track, etc.) although care was taken to make sure that the AOIs for all pictures were approximately equal in size without compromising their natural spatial layouts with respect to other objects, that is, a road with respect to a house, as in the example stimulus. We conducted two sets of analyses. The first included analyses of different eye movement variables from onset of the sentence until its offset. The second was a time–course analysis focusing on the proportion of fixations in the AOIs to the duration of the spoken sentences.

Results and Discussion

An analysis of variance with sentence type (FMC, FMT, and NFM) as a factor was conducted on the total number of fixations, total number of saccades, average gaze duration, and total gaze duration by subject (F_1) and by item (F_2).

Fictive motion sentences attracted higher fixations compared to literal sentences, indicating deployment of higher visual attention, $F_1(2, 57) = 12.44$, $p < 0.001$, and by item, $F_2(2, 45) = 5.17$, $p < .05$. There was a significant linear trend, $F(1, 57) = 24.45$, $p < .001$, indicating that subjects fixated more on the AOIs as they moved from NFM to FMT and then to FMC sentence types (Table 1). Planned comparisons revealed significantly more fixations for both types of fictive motion sentences compared to the nonfictive motion sentences, $t(57) = 3.96$, SEM = 1.96, $p < .001$, and both the canonical and topicalized forms of the fictive motion sentences differed significantly, $t(57) = 3.04$, SEM = 1.13, $p < 0.01$, indicating an effect of information structure on visual attention (Table 1).

However, the effect of sentence type on the number of saccades was not significant, $F_1(2, 57) = 0.1$, $p > .05$ and $F_2(2, 45) = 0.13$, $p > .05$. None of the planned comparisons showed any significant difference. This suggests subjects launched a similar number of saccades to the AOIs for all the different conditions but fixated selectively.

Average gaze duration showed a similar patterns of results as number of fixations. There was a main effect of sentence type on average gaze duration, $F_1(2, 57) = 7.65$, $p < .001$, and $F_2(2, 45) = 4.00$, $p < .05$. There was a significant linear trend, $F(1, 57) = 15.11$, $p < .001$,

TABLE 1
Means and Standard Deviations for Number of Fixations, Number of Saccades, Average Fixation Duration, and Total Gaze Duration on the Area of Interest for Different Sentence Types

	Number of Fixations Sentence Type		*Number of Entries*		*Average Duration of Fixation (ms)*		*Total Gaze Duration (ms)*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
NFM	10.06	2.04	5.05	0.97	532.35	167.64	2591.07	677.10
FMT	12.21	3.49	5.00	1.12	644.61	263.36	3029.15	995.98
FMC	15.66	4.70	4.99	1.14	806.14	226.45	3619.15	845.30

indicating an increase in average gaze durations on the AOI from NFM to FMC sentence type (Table 1). This indicates that on average eyes stayed more on the AOIs during comprehension of figurative language. Planned comparisons revealed significant difference between the nonfictive motion condition and both of the fictive motion conditions, $t(57) = 3.16$, SEM = 121.96, $p < .001$, and between the canonical and topicalized conditions, $t(57) = 2.29$, SEM = 70.41, $p < .05$, again indicating the effect of information structure on visual attention.

Overall subjects looked longer during comprehension of fictive motion sentences as indicated by total gaze duration, $F_1(2, 57) = 7.38$, $p < .001$, but not by item $F(2, 45) = .34$, $p > .05$. There was a significant linear trend, $F(1, 57) = 14.64$, $p < .001$, indicating linear increase of visual attention from NFM to FMC sentences. Planned comparisons revealed a significant difference between both fictive motion conditions and the nonfictive motion condition $t(57) = 3.15$, SEM = 465.29, $p < .01$, and between both forms of fictive motion sentences $t(57) = 2.19$, SEM = 268.63, $p < .05$.

Time course of motion simulation. For this analysis we counted fixations to the AOIs on the visual display from onset of the sentence until 5000 ms. We divided the total gaze record of 5000 ms into 100 slots, so each slot was of 50 ms. Figure 2 shows the change in proportion of fixations since sentence onset.

The aim of this experiment was to explore the magnitude of motion simulation during comprehension of fictive motion sentences in Hindi while manipulating information structures. The results indicate higher deployment of visual attention during comprehension of fictive motion sentences (Matlock & Richardson, 2004; Richardson & Matlock, 2007). However, we found an effect of word order on motion simulation, indicating a role of focused particles on such simulation. The time course plot (Figure 2) shows subjects deployed higher visual attention to the AOI during the comprehension of the noun. This suggests that linguistic structures could influence patterns of simulation during figurative language comprehension. Both the canonical and topicalized versions were semantically similar but had different word-order patterns. Therefore the difference in the variables could be due only to differences in the word order.

EXPERIMENT 2

Experiment 2 aimed to explore whether there is simulation of motion during processing of fictive motion sentences when the scene is absent, that is, during imagery. Keeping the stimuli and

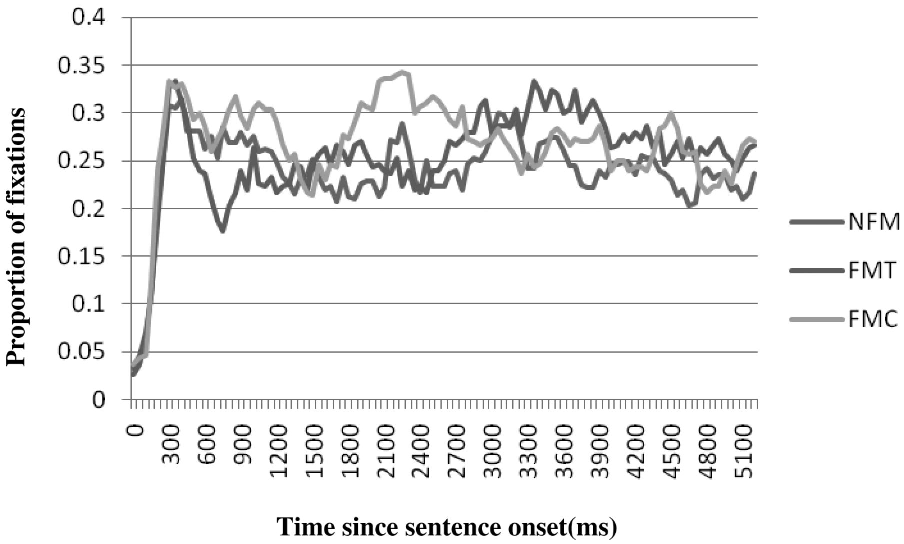


FIGURE 2 The change in proportion of fixations to the area of interest for different sentences since onset of the sentence.

the design similar, participants had to see a scene and then listen to a sentence about it, that is, FMC, FMT, or NFM in the absence of the screen. This design allowed examining the magnitude of motion simulation during imagery. We predicted that if subjects can simulate motion even when the scene is no longer present in their perceptual world, then we would see similar eye movement patterns for different sentence types as in Experiment 1. We predicted that the number of fixations, number of saccades, and gaze durations would be longer for fictive motion sentences (FMC and FMT) as compared to NFM sentences. However, we predicted the effect of word order would be similar to that of the first experiment. Alternatively, if it is the case that the simultaneous presence of a scene is necessary in the visual field for illusory motion simulation to take place and affect eye movements, we would not see extended gaze durations or an increase in the number of fixations for fictive motion sentences.

Method

Participants. Sixty participants (mean age 23 years) from the University of Allahabad took part in the experiment. Thirty eight were men and 22 were women. All were native Hindi speakers with corrected-to- normal vision. Informed consent was obtained from each participant prior to the experiment. None of them had participated in Experiment 1 or in any rating studies. Subjects were naïve to the purpose of the experiment. Participants were randomly assigned to three experimental conditions as in Experiment 1.

Stimuli and procedure. The visual and auditory stimuli were same as used in Experiment 1. The experiment began with a calibration process that was automatic as participants looked at the fixation cross presented at 13 different locations on the monitor. Participants were instructed that a scene would be shown on the screen which would remain for some time .They were free to look anywhere on the presented scene. They were informed that the scene would be replaced by a blank screen and they would be presented with a spoken sentence. Participants were given instruction to listen the sentence very carefully as they would be asked to judge later whether sentence and scene were related or unrelated. While listening to the spoken sentence they were free to look anywhere on the blank screen.

After successful calibration the experimental trial began with a fixation cross at the center of the screen for 750 ms. After the fixation, a scene was presented for 5000 ms and was followed by a blank screen. Onset of the auditory sentence occurred 1000 ms after presentation of blank screen (Altmann, 2004; Altmann & Kamide, 2009). Auditory sentences were presented via speakers located on both sides of the monitor and equidistant from the subject. The blank screen remained until 3000 ms after offset of the auditory sentence (Figure 3). After the end of each trial participants were required to perform a judgment task in response to the question of whether the picture shown and the spoken sentences were compatible or not. This was to ensure that while listening to the sentences they were imagining the scene shown before.

Data analysis. The dependent eye movement variables used were the same as used in the first experiment, that is, total number of fixations, average duration of fixations, number of

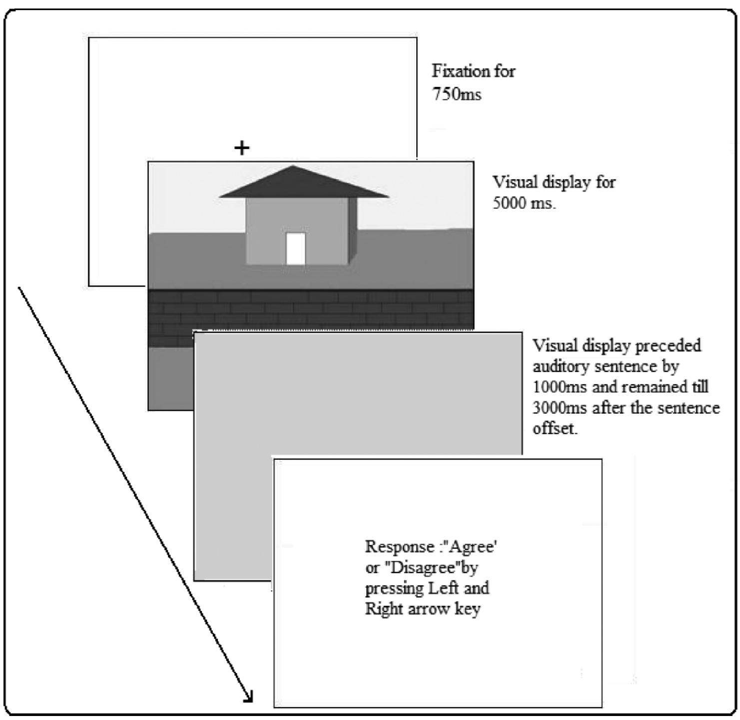


FIGURE 3 Presentation sequence of experimental trials in the blank screen paradigm.

saccades, and total gaze duration. However, these eye movement variables were measured on the part of the blank screen that was previously occupied by the object depicting the noun phrase. These variables were measured only within a prespecified AOI. The AOIs remained the same as those in the first experiment but were imposed on the blank screen instead of the scenes themselves. However, viewers did not see any contours during the trials.

Results and Discussion

Analysis of variance with sentence type as a factor revealed a significant effect of sentence type on number of fixations, $F_1(2, 57) = 6.31$, $p < .005$. The effect was not significant by item, $F_2(2, 42) = 3.46$, $p < 0.05$. Further, a significant linear trend was observed, $F(1, 57) = 6.83$, $p < .01$, indicating that the total number of fixations decreased from NFM to FMC sentences (Table 2). Planned comparisons revealed a significant difference between the fictive motion and nonfictive motion conditions, $t(57) = 3.47$, SEM = 1.27, $p < .001$, but not between the two forms of fictive motion sentences, $t(57) = .70$, SEM = 3.12, $p > .05$. Sentence type did not have any effect on number of saccades, suggesting that a similar number of eye movements were triggered toward AOIs for different conditions.

The effect of sentence type on average duration of fixation was, however, significant, $F_1(2, 57) = 6.75$, $p < .001$, and $F_2(2, 42) = 14.8$, $p < .001$. There was a significant linear trend, $F(1, 57) = 12.8$, $p < .001$, indicating that average gaze duration decreased proportionately from NFM to FMC sentences. Planned comparisons revealed significant difference between fictive motion conditions and nonfictive motion conditions, $t(57) = 3.51$, SEM = 302.91, $p < .001$, but not between the two forms of fictive motion sentences, $t(57) = 1.13$, SEM = 179.24, $p > .05$.

Similarly, sentence type had a significant effect on total gaze duration, $F_1(2, 57) = 8.86$, $p < 001$, and $F_2(2, 42) = 11.96$, $p < .001$. Again there was significant linear trend, $F(1, 57) = 9.77$, $p < .001$, indicating a proportionate decrease in total gaze duration from NFM to FMC sentences. Planned comparisons revealed significant differences between both types of fictive motion sentences and nonfictive motion sentences, $t(57) = 4.12$, SEM = 461.35, $p < .001$. However, there was no significant difference between fictive motion canonical and fictive motion topicalized conditions as far as total gaze duration was concerned, $t(57) = .79$, SEM = 272.99, $p > 0.05$.

TABLE 2
Means and Standard Deviations for Number of Fixations, Number of Entries, Average Fixation Duration, and Total Gaze Duration on the Area of Interest for Different Sentence Types During Concurrent Scene Presence

	Number of Fixations Sentence Type		*Number of Entries*		*Average Duration of Fixation (ms)*		*Total Gaze Duration (ms)*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
NFM	6.92	3.22	2.14	.94	1365.15	585.85	2799.83	768.40
FMT	4.44	1.47	1.95	.61	910.56	714.54	1712.95	869.76
FMC	5.07	2.04	1.99	0.79	714.41	271.05	1943.67	905

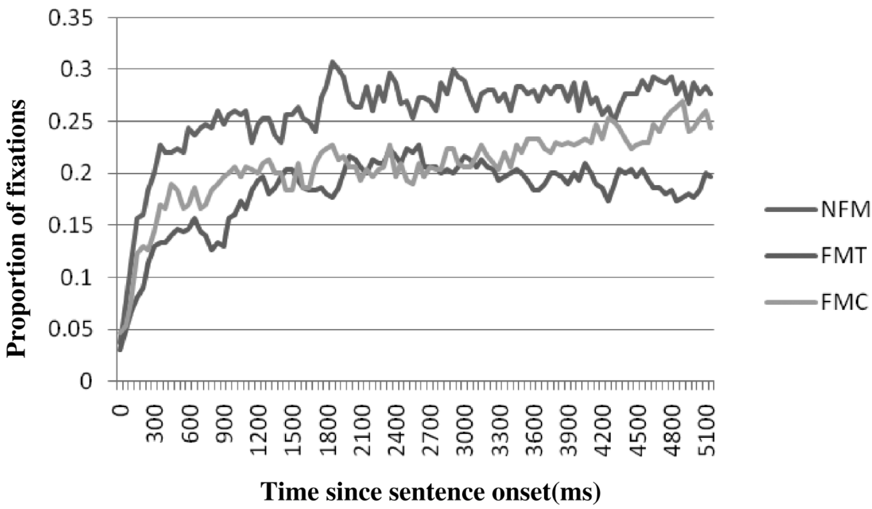


FIGURE 4 Proportion of fixation to the area of interest for different sentence types from onset of the sentence till its offset.

Time course of simulation of motion. For this analysis we counted proportion of fixations to concerned AOIs on the blank screen. We divided the total gaze record into 100 slots and each slot was of 50 ms, spanning a total duration of 5000 ms (see Figure 4).

The aim of this experiment was to explore simulation of motion during imagery. The findings of this experiment were strikingly different from those of Experiment 1. The number of fixations, average duration of fixation, and total gaze duration for NFM sentences were significantly higher than for either of the fictive motion sentences. The results also showed that there was no significant difference between these eye movement variables for canonical and topicalized fictive motion sentences. The results suggest that the physical presence of a scene is necessary for motion simulation to take place. Interestingly, the time course plot (Figure 4) showing the proportion of fixations indicates constant deployment of higher visual attention for the fictive motion canonical sentences as compared to topicalized sentences, although the overall differences were not statistically significant.

GENERAL DISCUSSION

The study investigated the effect of sentence structure on implicit motion simulation as in fictive motion sentences during perception and imagery. The paradigm employed recording participants' eye movements during processing of fictive and literal sentences while they viewed static displays (Experiment 1) and in the absence of such displays (Experiment 2). We found increased visual attention to the depicted scene during comprehension of fictive motion sentences in Experiment 1.The results replicate previous findings of mental simulation for fictive motion sentences (Matlock & Richardson, 2004; Richardson & Matlock, 2007) and are consistent with embodied (Barsalou, 1999; Gibbs, 2006b; Masson, Bub, & Warren, 2008) and simulation-based theories of language comprehension (Fischer & Zwann, 2008). For the same sentences in Experiment 2, participants deployed higher visual attention during comprehension of literal sentences as compared to either form of fictive motion sentences. This suggests that during imagery mental simulation of motion is minimal for fictive motion sentences.

Of importance, word order manipulation had a significant effect on the magnitude and time course of motion simulation, as seen during comprehension of fictive motion sentences in both experiments. Higher visual attention was deployed during comprehension of fictive sentences that had trajectors as subjects. This suggests that the extent and magnitude of motion simulation was dependent on that element which had a sentential focus. This finding extends earlier findings by showing that some aspect of observed simulation is due to the information structures of sentences. Therefore, if eye movement data is to be considered as evidence for mental simulation of movement, then sentence structures on which such data were elicited must be looked at carefully. Time-course plots clearly indicate a higher proportion of fixations during the comprehension of noun phrases that were subjects. These findings support the theoretical conjectures concerning figure-ground distinctions in sentences affecting attentional mechanisms (Talmy, 2000). Future studies may look into how much mental simulation arises because of "fictivity" alone and out of events associated with sentence structures. Overall, these results support more dynamic theories of language processing for figurative language (Barsalou, 2003; Gibbs, 2006a).

In Experiment 2, subjects allocated higher visual attention to the trajectory during comprehension of the literal sentences as compared to both types of fictive motion sentences. The results suggest that for mental simulation to occur during comprehension of fictive motion sentences, presence of the scene is required. This indicates a qualitatively different level of processing for figurative language as compared to literal language during imagery. The pattern of results suggests that subjects retrieved the information concerning the spatial layout of the object described by the sentence and not the embodied experiences associated with the fictive motion elements. Eye movements to the spatial location of objects have been found by others for literal sentences (Altmann & Kamide, 2009; Hoover & Richardson, 2008; Richardson & Spivey, 2000). We argue that presence of a scene is a necessary condition for embodied simulation to take place and for relevant perceptual motor systems to become activated during figurative language processing in imagery.

Eye movements during visual perception involve both linguistic and nonlinguistic representations (Knoeferle & Crocker, 2006, 2007; Mishra, 2009). Event structures (Altmann & Kamide, 2009) and affordances (Gibson, 1979) drive eye movements to locations in the scene. However, in our study, inanimate nouns that were combined with motion verbs could not afford any motion themselves. Thus, what listeners could create as a mental representation (Zelinsky, 2008; Mishra & Marmolejo-Ramos, 2010) while listening to the sentences was the illusory motion, that is, a temporary assignment of mobile agenthood to subjects that are not capable of any motion in the real world. Therefore, in the presence of the scene, as in Experiment 1, subjects simulated motion and looked longer but did not do so when the scene was absent. The magnitude of simulated motion arising from a figurative understanding of fictive motion sentences probably temporarily overrides constraints of affordance, as in Experiment 1. This forces language comprehenders to look longer and to deploy continuous visual attention to the scene even when the sentences are meaningless with respect to what is depicted. In contrast to this, during imagery only spatial locations are remembered, indicating an effect of affordances. Although theories differ as to the exact nature of the contents of scenes after they are withdrawn from the visual field (see Rensink, 2000, and Henderson & Hollingworth, 2003, for contrasting viewpoints).

Alternatively, it is possible that a working memory limitation might have prevented efficient recollection of the scene and the objects for further saccadic eye movements that would reveal simulation of motion (Melcher & Kowler, 2001). Scene memory has been suggested to be both abstract and detailed (Tatler, Gilchrist, & Rusted, 2003). Therefore, subjects did have a spatial layout of the scene in mind during the blank-screen state, but this representation was not sufficient to generate further sensory-motor effects when a figurative sentence was comprehended. The results suggest that in motion simulation during comprehension of fictive motion sentences, what the subject has observed earlier (e.g., Richardson & Matlock, 2007, or as in our first experiment) can affect eye movements only when the scene is present.

In sum, these results demonstrate that figurative language is indeed processed differently than literal language and affects overt motor behavior as seen in eye movements. This throws important light on the ongoing debate about basic processing differences between these two types of language use. Our study builds on earlier findings in showing the effect of information structure on illusory motion simulation during comprehension of figurative language. Finally, the study advances understanding of the nature of mental simulation during perception and imagery while showing an effect of sentence structures on simulation.

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APPENDIX A

1.

FMC*: Yeh pul nadi ke upar se hokar guzarta hai.*
[This bridge goes across the river.]
FMT: *Nadi ke upar se hokar yeh pul guzarta hai.*
[Across this river goes the bridge.]
NFM*: Yeh pul nadi ke upar hai.*
[This bridge is across the river.]

2.

FMC: *Yeh baada khet ke beech se hokar guzarta hai.*
[This fence goes through the middle of the field.]
FMT: *Khet ke beech se hokar yeh baada guzarta hai.*
[Field the middle goes this fence.]
NFM: *Yeh baada khetke beech main hai.*
[This fence is in the middle of the field.]

3.

FMC: *Yeh sadak registaan se ho kar guzarti hai.*
[This road goes through the desert.]
FMT: *Registaan se hokar yeh sadak guzarti hai.*
[Desert through this road goes.]
NFM: *Yeh sadak registaan main hai.*
[This road is in the desert.]

4.

FMC: *Yeh imaarat asmaan tak jaati hai.*
[This building goes up to the sky.]
FMT: Asmaan tak yeh imaarat jaati hai.
[Sky up to this building goes.]
NFM: *Yeh imaarat oonchi hai.*
[This is a tall building.]

5.

FMC: *Yeh raasta pahado ke beech se hokar guzarta hai.*
[This way goes through the mountains.]
FMT: *Pahado ke beech se hokar yeh rasta guzarta hai.*
[Mountains through is this way goes.]
NFM: *Yeh raasta pahado ke beech main hai.*
[This way is between the mountains.]

6.

FMC: *Yeh jaal is kambhe se guzar kar us khambhe tak jaata hai.*
[The net goes from this pole to that pole.]
FMT: *Is khambhe se guzarkar yeh jaal us khambhe tak jaata hai.*
[From this pole goes the net to that pole.]
NFM: *Yeh jaal do khambho ke beech main hai.*
[This net is between the two poles.]

7.
FMC: *Yeh rail ki patari gaon se hokar guzarti hai.*
[This rail track goes through the village.]
FMT: *Gaon se ho kar yeh rail ki patri guzarti hai.*
[Village through this rail track goes.]
NFM: *Yeh rail ki patri gaon main hai.*
[This rail track is in the village.]

8.
FMC: *Yeh phoolon ki kyari maidaan se hokar guzarti hai*.
[This row of flowers goes through the field.]
FMT: *Maidaan se hokar yeh phoolon ki kyaari guzarti hai.*
[Field through this row of flowers goes.]
NFM: *Yeh phoolon ki kyaari maidaan main hai.*
[This row of flowers is in the field.]

9.
FMC: *Yeh kinaara nadi ke bagal se guzarta hai.*
[The bank flows along with the river.]
FMT: *Nadi ke bagal se hokar yeh kinaara guzarta hai.*
[River beside this bank goes.]
NFM: *Yeh kinaara nadi ke bagal main hai.*
[This bank is beside the river.]

10.
FMC: *Yeh bijli ke taar is khambhe se guzarkar us imaarta tak jaatein hai.*
[These electric wires go from this pole to that building.]
FMT: *Is khmabhe se guzarkar yeh bijli ke taar us imaarat tak jaatein hai.*
[From this pole go electric wires to that building.]
NFM: *Yeh bijli ke taar is khambhe aur imaarat ke beech main hai.*
[These electric wires are between the pole and the building.]

11.
FMC: *Yeh pagdandi jungle se ho kar guzarti hai.*
[This road goes through the jungle.]

FMT: *Jungle se hokar yeh pagdandi guzarti hai.*
[Jungle through this road goes.]
NFM: *Yeh pagdandi jungle main hai.*
[This road is in the jungle.]

12.

FMC*: Yeh patthar ki kataar samudra ke beech se hokar guzarti hai.*
[This row of rocks goes through the middle of the sea.]
FMT: *Samudra ke beech se hokar yeh patthar ki kataar guzarti hai.*
[Sea through the middle of this row of rocks goes.]
NFM: *Yeh patthar ki kataar samudra ke beech main hai.*
[This row of rocks is in the middle of the sea.]

13.

FMC: *Yeh pedo ki kataar nahar ke kinaare se hokar guzarti hai.*
[This row of trees runs along the river bank.]
FMT: *Nahar ke kinaare se hokar yeh pedo ki kataar guzarti hai.*
[River beside goes this row of trees.]
NFM: *Yeh pedo ki kataar nahar ke kinaare hai.*
[This row of trees is beside the river bank.]

14.

FMC: *Yeh pahad samudra ke kinaare se hokar guzarta hai.*
[This mountain runs along the sea coast.]
FMT: *Samudra ke kinaare se hokar yeh pahad guzarta hai.*
[Sea coast beside goes this mountain.]
NFM: *Yeh pahad samudra ke kinaare hai.*
[This mountain is beside the sea.]

15.

FMC*: Yeh dewaar ghar ke saamne se hokar guzarti hai.*
[This wall runs in the front of the house.]
FMT: *Ghar ke saamne se ho kar yeh dewaar guzarti hai.*
[House in front runs this wall.]
NFM: *Yeh dewaar ghar ke saamne hai.*
[Their wall is in the front of the house.]

APPENDIX B