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Hemispheric inference priming during comprehension of conversations and narratives

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A B S T R A C T

In this study we examined asymmetric semantic activation patterns as people listened to conversations and narratives that promoted causal inferences. Based on the hypothesis that understanding the unique features of conversational input may benefit from or require a modified pattern of conceptual activation during conversation, we compared semantic priming in both hemispheres for inferences embedded in conversations and in narratives. Participants named inference-related target words or unrelated words presented to the left visual field-right hemisphere (lvf-RH) or to the right visual field-left hemisphere (rvf-LH) at critical coherence points that required an inference in order to correctly understand an utterance in the context of the conversation or narrative. Fifty-seven undergraduates listened to 36 conversations or narratives and were tested at 100 target inference points. During narrative comprehension, inference-related priming was reliable and equally strong in both hemispheres. In contrast, during conversation comprehension, inference-related priming was only reliable for target words presented to lvf-RH. This work demonstrates that priming for inference-related concepts can be measured with input in conversational form and suggests the language processing style of the RH is advantageous for comprehending conversation.

1. Introduction

Although language and communication takes many forms, spoken conversation has always been the primary setting in which people produce and understand language on a daily basis (Clark, 1996). Even comprehending a conversation as a bystander may emphasize different processes than comprehending narratives. Conversational speech contains a number of features that make it distinct from other types of language. For example, in contrast to written language, interactive spoken discourse is typically spontaneous, multimodal, and frequently rife with incomplete or disfluent utterances. Moreover, conversation and narrative language seem to have distinct grammatical organizations and semantic structures (Clark & Clark, 1977). For example, people use different discourse markers of cohesion in conversation than they do in narrative, producing relatively more elliptical statements and more referential expressions to pick out specific entities in the discourse context (Mentis & Prutting, 1987; Carter & McCarthy, 1995). In contrast, narrative includes relatively more conjunctions that express logical relations between sentences, and also contains more explicit lexical markers of coherence, including reiteration of previous references to bind narrative episodes together (Mentis & Prutting, 1987; Carter & McCarthy, 1995). Additionally, conversational speech is typically embedded in a particular time and place. That is, when people converse, they tailor their utterances in particular ways to accommodate aspects of the setting, such as their interlocutor's social status, the physical context, and concurrent feedback from their addressees (Brennan & Clark, 1996; Clark & Krych, 2004; Horton & Gerrig, 2002).

As a consequence of these features of spoken conversation, the processes that support the comprehension of conversational utterances may be qualitatively distinct from the processes involved in the comprehension of other forms of language. Comprehending conversation may emphasize different processes than comprehending narrative because it contains relatively more situational ellipses that require integrating extra-linguistic information to derive interpretations from utterances whereas the comprehension of monologic narratives, that include more explicit references relative to conversation, may involve interpretive processes that focus directly on linguistic meanings (Carter & McCarthy, 1995). If narrative and conversational language contexts differ in the way they convey information, it is likely that people need to use or emphasize different processes to understand each. In this paper we focus on the processes that underlie how people draw connective inferences during comprehension, which is important for understanding both conversational and

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narrative language. In order to capture specifically comprehension-related differences, we implement a passive comprehension task where participants listen to naturalistic conversations or narratives and do not interact in them. Because conversation is more interpersonal, tied more closely to a particular time and place, and more elliptical, people may rely on more distant semantic information to draw inferences when comprehending conversation compared to narrative. Distantly-related yet crucially relevant semantic information is contained within the social cues, verbal intonation, knowledge of the interlocutors, and other extra-linguistic information that potentially enriches a semantic context. We are interested in testing whether information from these broad associations is more readily available as people make inferences in the context of a spoken dialogue compared to the same inferences in the context of a narrative monologue.

1.1. Inference generation

Generating inferences is an essential part of comprehending language. Often in discourse, parts of the message are only implied, which requires a listener or reader to draw upon background knowledge, context, and speaker information as a means of obtaining a coherent idea of what is being conveyed (Graesser, Singer, & Trabasso, 1993). People so crucially rely on inferencing during discourse comprehension that during recall, they often report inferred information as factual (Bagget, 1975; Thorndyke, 1976). People also have problems determining if information was explicitly stated or inferred from discourse (Johnson, Bransford, & Soloman, 1973). Moreover, response times for naming words related to inferences generated from discourse are equally fast as those for explicitly stated words (Potts, Keenan, & Golding, 1988), which suggests that listeners reliably draw inferences during comprehension and incorporate inferential information into their discourse representations.

Theorists have suggested a variety of frameworks for differentiating between the types of inferences that people generate during comprehension (Graesser et al., 1993; Graesser & Kreuz, 1993; Kintsch, 1993; McKoon & Ratcliff, 1992). There is general agreement that generating causal bridging inferences is necessary during comprehension. Causal inferences are assumptions based on implied information about changing circumstances over successive events. Suppose someone says, "I had a full bottle of water when I started playing the game" and then says, "By the end of the game, it was completely empty, but it kept me refreshed." It is necessary to draw the causal inference that the water was drunk in order to understand why the speaker was refreshed during the game. The present study assessed the natural comprehension process by measuring semantic activation from causal inferences embedded in conversations and narratives. Transcribed examples of stimuli that promote causal inferences in both conversations and narratives are provided in Table 1.

1.2. Lateralized language processes

One important question has been the degree to which there are hemispheric differences in the activation and processing of linguistic meanings during comprehension. Both hemispheres participate when people comprehend language, but each operates on information in different ways (Federmeier, Wlotko, & Meyer, 2008; Lindell, 2006). Whereas the left hemisphere (LH) is always important, the contributions of the right hemisphere (RH) appear to vary, increasing as input gets more complex or more natural (for review, Jung-Beeman, 2005; Gernsbacher & Kaschak, 2003). For instance, people show many types of semantic priming, that is, they respond to target words more quickly and accurately following related than unrelated prime words. However,

Table 1
Example conversation and narrative that promote the same inferences. Identical questions are used to measure comprehension of both input types.

Example 1:

Conversation
Liz: My plan this weekend is to make a dent in this checklist.
Matt: Here, let me see that. Oh, you can check that one off.
Liz: You took care of the squeaky garage door?
Matt: Yup. I put a few squirts on the rusty hinge and now it's good as new. **(oil)**
Liz: Great! One thing down. Next do you want to help me go through this old box from the attic?
Matt: Sure. Wow, there's a lot of cologne bottles in here. What should I do with them?
Liz: Let's just get them out of the way for now. I'll take them downstairs.
Matt: Watch out, I think one of the bottles leaked out into the box so they're a little
slippery.
Liz: Ah crap!**(drop)**
Matt: Uh-oh. Did any of the bottles break on the floor?
Liz: Ummm, nope it doesn't look like it.
Matt: Oh good. Speaking of things breaking, did you find all those pieces to that broken vase?
Liz: Yes, thank goodness. I love that vase. It's been in my family for centuries.
Matt: What did you do with all the pieces? **Liz:** Check out the shelf over there.
Matt: Wow! You can't even see any of the cracks!**(repair)**

Narrative
Liz was not looking forward to her busy weekend of doing chores. While she stood in the kitchen deciding which task to do first, her husband Matt came in from the garage. Liz was reminded about her checklist and asked her husband if he'd taken care of the squeaky garage door yet. He told her that all it took was just a few squirts on the hinges to make it good as new. **(oil)** Moving forward with her checklist, Liz decided to go through an old box from the attic. She and Mark were surprised to see so many old cologne bottles and decided to put them down the basement. Unfortunately, Liz didn't notice that one of the bottles had leaked and made everything in the box slippery. She yelled out when she lost her grip as she walked down the stairs. Mark came to make sure everything was okay and was relieved to find that none of the bottles had broken.**(drop)** Liz gathered up the bottles and carefully carried them the rest of the way downstairs. She was reminded of the precious vase that had been in her family for centuries. Just last week, the vase was shattered from when Snowball, Mark's cat, had knocked it off of a shelf. Though she was devastated, she gathered up all the little pieces she could find. It took some patience but soon even the cracks were no longer visible.**(repair)**

Comprehension Questions
1. What does the woman plan to do over the weekend? (Do Chores; work on a checklist)
2. What did the couple find in the box from the attic? (Old cologne bottles)

the patterns of priming differ depending on whether people respond to words presented to the right visual field (rvf-LH) or to the left visual field (lvf-RH). The left hemisphere is especially suited for activating strong lexical associations within semantic contexts (Burgess & Simpson, 1988; Chiarello, 2003) whereas the right hemisphere is suited to activation of distantly-related, weak associates (Burgess & Simpson, 1988; Beeman et al. 1994; Chiarello, Burgess, Richards, & Pollock, 1990). For instance, people show more priming for strongly-associated target words presented to the rvf-LH, but they show more summation priming from three weakly-associated prime words for targets presented to the lvf-RH (Bottini et al., 1994). Moreover, the RH may contribute relatively more to comprehending metaphoric and nonliteral language than to comprehending straightforward language (Bottini et al., 1994; Mashal, Faust, Hendler, & Jung-Beeman, 2009). Such separate and distinct patterns of semantic priming in each hemisphere also demonstrate that both hemispheres actively participate in language processing; it is not the case that information presented to the lvf-RH is simply transferred to the LH for processing. Thus, both hemispheres participate in semantic activation, but relatively more distant semantic information is more strongly activated in RH.

Patterns of hemispheric activation from word primes have been replicated with priming evidence from more natural language contexts. When people comprehend connected narratives that promote inferences, they show facilitation when responding to visually presented inference-related target words compared to unrelated words (Shears, 2008; Long & Baynes, 2002), indicating that they are semantically processing information that could support the inferences. However, the amount of inference priming varies by both the time and hemifield to which the target word is presented (Beeman, Bowden, & Gernsbacher, 2000). People more quickly name (read aloud) inference-related target words presented to the rvf-LH at the coherence inference point, when it becomes necessary to draw the inference to maintain story coherence. Earlier though, at the predictive inference point, such inferences are optional or elaborative, as they are not yet necessary to maintain coherence, but information based on broadly-related semantic concepts could be integrated to make predictions about what would happen next in the story. At this point, people only show priming for inference-related words presented to the lvf-RH. Taken together, these findings coincide with a theory which posits that the RH utilizes relatively more coarse semantic information and the LH operates on fine semantic information when people comprehend language (Beeman et al., 1994). In particular, the LH is thought to strongly activate concepts which are close in semantic relation to a discourse, allowing only those concepts to enter people's conscious awareness for easy selection and integration into a discourse model. Semantic processing in the RH is characterized by weakly activated, non-dominant, semantically distant concepts that provide a broad or gist-like semantic interpretation from some context. The coarse coding style of the RH becomes advantageous when weakly active semantic fields, which are large due to their distant semantic relation to the discourse context, overlap and summate, bringing into awareness broad semantic information that people use to maintain coherence, draw inferences, and integrate complex contextual details into their momentary interpretation of a semantic context (Jung-Beeman, 2005). Alternatively, the LH may use moment-to-moment lexico-semantic information to predict upcoming linguistic input within sentences, whereas RH may represent linguistic input across multiple sentences and integrate supplemental background knowledge in order to draw generalized interpretations about the gist, theme, and topic of utterances (Federmeier, 1999; Federmeier, 2007).

1.3. Current study

The present study contrasts how both hemispheres contribute to drawing inferences during the comprehension of narrative monologues versus conversational dialogues. This comparison will help determine whether people utilize similar or distinct patterns of semantic activation while comprehending different types of input, controlled for other linguistic factors (e.g., semantic relatedness). Both types of language conditions are presented aurally, and we examine inference-related priming at critical coherence inference points. In line with previous reports, the LH is expected to show relatively more inference-related priming during comprehension of narratives. In contrast, we predicted that the RH will show greater inference-related priming than the LH during conversation comprehension. Finding different patterns of hemispheric priming across language types would suggest hemispheric roles in language processing change depending on the type of language input that is comprehended, even when other factors are controlled.

This experiment has two purposes: First, given that the vast majority of previous research on inference processing has used narrative texts, we are interested in establishing that conversational stimuli can be used to obtain reliable comprehension data. This is particularly important given that conversational speech plays a central role in how most people encounter and use language. Second, we test whether hemispheric priming patterns for inference-related concepts in conversation are different from those in narrative, and specifically, if inference priming patterns during conversation comprehension are relatively more right-lateralized. If coherence inferences are effectively promoted in both language contexts, inference-related words should be read faster than unrelated words regardless of the laterality of presentation and the type of stimulus, conversational or narrative. However, if the RH is especially important for processing conversational input, people should show greater priming for words presented to lvf-RH than those presented to rvf-LH while comprehending conversation.

2. Methods and materials

2.1. Participants

Fifty-nine Northwestern University undergraduate students participated in return for either course credit (54 people) or $10 (five people; two males heard conversations, two females and one male heard narratives). Because left-lateralized language processing is more stable in right-handed populations, only right-handed participants were recruited. All participants were native English speakers with normal or corrected-to-normal vision. One participant was removed for showing average overall priming more than 2.5 SDs from the mean; another participant was removed for showing reverse laterality that was greater than 2.5 SDs from the mean. (Naming words presented to lvf-RH faster than words presented to the rvf-LH demonstrates evidence of potentially reversed language laterality, which indicates a participant has an irregular organization of language in the brain). The final dataset included 57 students (25 Males) between the ages of 18 and 22.

2.2. Materials

Stimuli were 36 vignettes promoting 100 casual inference events (see examples in Table 1). Each vignette had two versions, a conversational dialogue and a narrative monologue. Each inference event had a premise, which established an initial state, followed by a critical coherence test point that occurred at the end of the clause or utterance that described the causally changed state of circumstances. In the first example in Table 1, the word "squeaky" sets the initial premise state of the garage door. Then, the coherence inference point occurs following "after a few squirts the door is good as new," when it must be inferred that the door was oiled in order to make sense of this statement. The test point was selected to capture any inference-related conceptual activation at the latest point in time when an inference could be generated to cohere the meaning of an utterance. Each vignette included from 1 to 5 target inferences, for a total of 100 inference points of interest across 36 vignettes (dialogues or monologues).

Stimuli were first written as inference-promoting conversational vignettes and were then converted to monologue by changing each set of conversational utterances into a monologic narrative vignette, as shown in Table 1. Inference-related content in each conversational vignette and corresponding narrative vignette contained identical lexical and semantic content to promote the same inferences, including the premise information and the subsequent change of state that was expected to necessitate the inference. This critical similarity between input types ensured that any response time differences were not due to differences in subject matter or lexical items across the two language inputs. Common disfluencies (e.g., pause fillers), interjected utterances, and relatively more pronominal references were incorporated into non-inference-related parts of the conversations to make them seem more natural. By contrast, narrative vignettes included more straightforward references. For example, in Table 1, Liz says, "Great. One thing down." after learning one of the items on the checklist was complete. In the narrative version of this vignette, the narrative states that Liz is "moving forward with her checklist," which more directly conveys a similar meaning. Additionally, we tried to compensate for information that may have been implied in a conversant's tone of voice. If the intonation during conversation potentially conveyed more than was explicitly stated, the narrative text was altered to convey the sentiment as well. For the sake of control, it would be optimal to have both the narratives and conversations contain the exact same utterances, but that design would sacrifice the natural differences between the two forms of language, which is of interest here.

In a pilot study, written versions of the vignettes were tested to gauge whether the inferences were effectively promoted and to verify that the dialogues sounded plausible. Thirty-two pilot subjects read each vignette up to the point when the material promoted a coherence inference. Subjects then summarized the events in the vignette in their own words. Responses were coded for use of the exact inference-related target words (direct hit) as well as for responses indicating subjects had drawn the promoted inference (indirect hit). If any subject used a word synonymous to the target or made a response that presupposed the inferred information, the response was also coded as an indirect hit. The proportion of target hits was the total number of direct and indirect hits divided by the overall number of responses for the inference-related word. The final stimulus set had an average overall hit rate of 34% ± 23%. This overall hit rate was likely due to the stringent coding schema applied to pilot responses. If a subject's response was worded exactly the same as the information in the vignette, it was not coded as a hit because it could not be determined whether the participant merely rewrote exactly what they read. Therefore, the inference-related concept could have been active for those participants and not included in the overall hit rate.

To obtain evidence for inference concept activation, we used a visual word-naming task that compares naming response latencies for inference-related target words and unrelated target words. Inference-related words were one-word descriptors of the causal inference event (see example in Table 1). These target words had an average frequency value of 57.83 ± 68.02 words per million (Brysbaert & New, 2009). Each target word was paired with a related target word from another vignette that was unrelated to its inference context. For each inference event, the paired target word was presented in the unrelated condition for that trial in another version of the material set. Participants were counterbalanced across material sets so they never named any word more than once during the experiment. In this way, potential influences of semantic relatedness from words presented in the unrelated condition would be controlled across trials and material sets. Latent Semantic Analysis (LSA) (Landauer, Foltz, & Laham, 1998) was used to assess the semantic relationships among all visually presented words to each other and in the context of the vignette in which they were presented. The mean LSA value for related words in relation to inference-promoting contexts was reliably higher than that of unrelated words ($t(98)=2.87$, $p<.005$) to the same context. Also, mean LSA values representing the semantic field of related targets in association with unrelated targets showed little semantic overlap among terms (mean relatedness = .09). Each vignette also contained up to six probe points at which participants were asked to respond to filler words. These filler words were always unrelated to the story context.

To control for the potential effect of simple lexical priming of target words from closely-associated words occurring prior to inference points, fourteen additional pilot subjects were asked to list the first three related words that came to mind after reading each inference-related target word. If the first word listed was provided by more than four respondents, the vignette was rewritten to remove that word from the prior context. Any words, regardless of order, that were listed by more than 7 respondents were also excluded from the conversations.

We recorded both the conversational and narrative versions of each vignette using a portable solid state recorder in a sound-attenuating booth with an omni-directional microphone. To perform the vignettes, we recruited eighteen paid actors (eight female and ten male), who were instructed to sound as natural as possible. For the conversational vignettes, there were 15 conversations with one male and one female speaker, 10 with two female speakers, 10 with two male speakers, and one vignette with two male and one female speaker. Corresponding narrative versions of each vignette were recorded by the same actors. For every conversation with both a male and female speaker, a version of the corresponding narrative was recorded by each speaker, and material sets for narrative versions were counterbalanced for speakers' genders (i.e., some participants heard the male version of a narrative vignette while other participants heard the female version of the same vignette). The most realistic-sounding clips of each vignette were chosen and edited with Adobe Soundbooth.

Relatedness and visual field presentations were counterbalanced across four sets of materials. The order of presentation of the 36 vignettes remained the same across all four material sets. Vignettes with similar themes and target words occurred as far from each other in the presentation sequence as possible. In all four materials sets, 50 test words were related to the promoted inference and 50 were unrelated; half were presented to the left visual field-right hemisphere (lvf-RH) and half were presented to the right visual field-left hemisphere (rvf-LH). Relatedness and visual field orders for target words were randomly assigned for each of the four conditions across the first half of the experiment and then repeated for the second half. In every material set, filler word presentations were interspersed among target words. The visual field assignment for filler words followed an alternating L- R pattern, with no more than three consecutive presentations to any one visual field allowed throughout the experiment. In total, 232 words were presented.

Participants listened to either conversational or narrative vignettes. Though a within-subject design is optimal, it would have required substantially more observations per participant. In the interest of collecting high-quality data by preventing fatigue, the duration of the experiment was limited to one hour and the effect of input type was measured between participant groups. During each trial, participants in both groups named eight visually presented words, and answered two comprehension questions. The duration of vignettes varied from 14 s to 115 s with a mean of 58 s.

2.3. Procedure

The study took place in a single session carried out in a sound-attenuated room. Participants sat in front of a computer monitor, wearing headphones and with the chair adjusted to align their eyes with the center of the screen. Participants were instructed to lean their head comfortably in a forehead rest that positioned their eyes 53 cm away from the center of the screen, and directly in front of a microphone that remained adhered in the same place on the table for every subject.

Participants heard pre-recorded instructions explaining how to complete both the listening and speaking tasks. For the listening task participants were told to pay close attention to what they heard in order to respond accurately to the comprehension questions. For the speaking task, participants were asked to attend to the computer monitor and to read out loud, as quickly and accurately as possible, the words that appeared. At the start of the session, participants completed practice trials containing 3 conversations or 3 narratives (depending on their condition), and named 16 visually-presented words. These practice items acquainted the participants with the two tasks. None of the words presented during the practice trials were related to the experimental stimuli.

The auditory stimuli were presented over headphones at a comfortable volume and the visual stimuli (i.e., words) were presented on a 19" LCD monitor (1024×768 resolution) connected to a laptop running Presentation software. Words were presented in black 24 point Arial font, on a light gray background. The proximal end of each word (right end for words presented to lvf-RH and left end for rvf-LH words) was 1.3° of visual angle from the center fixation point (25 pixels from the center of the screen). Stimuli subtended 3.8° of horizontal visual angle (range: 1.6° to 3.8°) and.76° vertical visual angle. A pattern mask composed of letter fragments was presented 180 ms after the onset of the visual stimulus presentation to ensure participants would not experience after image effects. The mask extended to 5.7° of horizontal visual angle and 1.3° vertically.

Each participant listened either to all conversations or to all narratives. The voice trigger function that is built into Presentation software was attached to a stationary microphone which captured response latencies. Before the practice phase and while in the headrest position, participants read a series of words aloud while the microphone trigger was calibrated. Participants were instructed to use the same volume throughout the experiment. Each trial began with a fixation cross centrally located on the screen for five seconds, after which, the auditory presentation of the next vignette began. Test words were presented at the offset of the final word at inference points within each vignette. The latency between target word presentation and voice onset for naming a target word was the response time measurement. Voice onset is ideal in this design because we compare response times for naming words when they are context-related targets to response times of other participants who name those same words when they are unrelated to the semantic context. By using the same set of words in both relatedness conditions across participants, we control variability in response latencies that is due to voicing of the words themselves. At the end of every vignette, participants answered auditorily presented comprehension questions aloud. The questions were open-ended and did not pertain to inference events. They were recorded by two actors, one male and one female, whose voices alternated with every question. Based on predetermined answers, response accuracy to comprehension questions was coded online by the experimenter. Participants were given no feedback. The questions encouraged participants to pay attention to the vignettes. If participants missed several questions, they were reminded to pay attention. Questions used similar or exactly the same wording as was used in the vignette and required one or two-word answers about factual details (See Table 1 for example).

Average response times and accuracy for naming related and unrelated targets in each visual field were computed for every subject. Correctly named target word responses within 3 SDs of a subject's overall average response times were scored as that subject's target hits. Percent accuracy was calculated as the number of correctly named targets divided by the total possible targets that could be named in each condition. Due to an error in the initial material set design, the first eight subjects who completed the study saw 13 repeated target words. Responses for the second presentation of those target words were not included in the dataset from those participants, and the condition totals for accuracy calculations were adjusted to reflect their accuracies for naming non-repeating target words. All participants with an overall naming accuracy of 60% or greater were included in the group analyses.

3. Results

3.1. Response times

Participants' mean response latencies for correct naming responses (see Table 2) were subjected to a $2 \times 2 \times 2$ mixed factor ANOVA with visual field (rvf-LH, lvf-RH), and relatedness (unrelated, related) as within-subject variables, and language input (conversation, narrative) as a between-subjects variable. Participant gender and material set were initially included as between-subject covariates but no reliable effects were detected; neither variable was used as a factor in further analyses.

Table 2
Average subject RTs and priming for word naming in all conditions at coherence inference points in conversation and narrative.

Response time (sd)	Conversation		Narrative	
	LH	RH	LH	RH
Related	686 (20)	703 (20)	639 (20)	662 (20)
Unrelated	690 (21)	728 (21)	659 (21)	680 (22)
Priming	4 (44)	25 (38)	20 (37)	18 (41)

Note. Naming latencies are in milliseconds. Priming reflects the actual average inference priming across participants. Due to rounding, this may differ slightly from the difference of related and unrelated mean naming latencies.

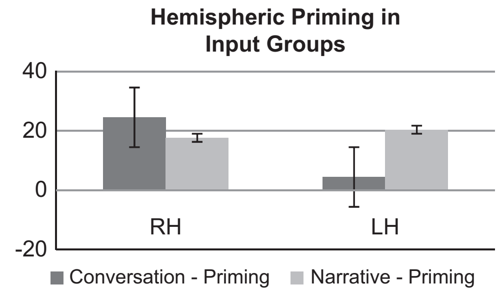

Fig. 1. A graph of relative hemispheric priming in both conversation and narrative input groups.

Overall, there was a left hemisphere response time advantage: Participants named target words presented to the rvf-LH more quickly (M=668 ms; SD=14 ms) than they named target words presented to the lvf-RH (693 ms; 14 ms), $F(1, 55)=58.52$, $p<.001$. Participants who listened to narratives named words presented to rvf-LH (649 ms, 16 ms) more quickly than words presented to lvf-RH (671 ms, 16 ms) ($F(1, 27)=22.876$, $p<.001$) and participants who listened to conversations named words presented to the rvf-LH (688 ms, 24 ms) more quickly than words presented to lvf-RH (715 ms, 23 ms) ($F(1, 28)=36.677$, $p<.001$).

There was also an overall main effect of relatedness: Participants named inference-related target words (672 ms, 14 ms) more quickly than they named words that were unrelated to the inferences (689 ms, 15 ms) ($F(1, 55)=16.83$, $p<.01$). This effect was reliable in each input separately: Participants in the narrative input group responded more quickly to inference-related (650 ms, 16 ms) than unrelated (669 ms, 16 ms) words ($F(1, 27)=13.190$, $p<.001$) and participants who listened to conversations named inference-related words more quickly (694 ms, 23 ms) than unrelated words (709 ms, 24 ms) ($F(1, 28)=5.397$, $p<.028$). These results show that both conversations and narratives were effective at promoting inference-related conceptual activation.

There was no main effect of language input type. Although participants from the narrative group named words more quickly (660 ms, 20 ms) than did the participants listening to conversations (702 ms, 20 ms), this effect was not reliable ($F(1, 55)=2.139$, $p<.15$), and is largely attributable to a few participants (the three slowest participants happened to be in the Conversation group, and the fastest in the Narrative group; removing these participants equated response times across conditions without changing the priming pattern across conditions).

There was a marginal three-way interaction between hemisphere, relatedness, and input type ($F(1, 55)=2.919$, $p=.093$). As shown in Fig. 1, the simple effect of relatedness within each visual hemifield differed for the two input groups: participants who listened to narratives named inference-related targets more quickly than unrelated words in both the rvf-LH and the lvf-RH, whereas the participants who listened to conversations only showed this priming effect for lvf-RH target words[1].

The priming effect in participants who listened to narratives did not interact with hemifield ($F<1.0$). Planned comparisons showed the inference priming (i.e., the difference between response times to related and unrelated words) was reliable in both hemispheres (lvf-RH: $t(27)=2.29$, $p<.03$, lvf-RH priming= 18 ms; rvf-LH: $t(27)=2.935$, $p<.007$, rvf-LH priming=20 ms). Similar priming in both hemispheres indicates that inference-related information is active in both the RH and LH during narrative comprehension.

Unlike participants listening to narratives, however, participants listening to conversations showed a reliable hemifield X relatedness interaction ($F(1, 28)=5.260$, $p<.03$). Planned comparisons revealed that participants comprehending conversations read inference-related words more quickly than unrelated words presented to lvf-RH (lvf-RH priming=25 ms, $t(28)=3.44$, $p<.002$), but this was not true of words presented to rvf-LH (rvf-LH priming=4 ms, $t<1.0$). Inference-related target words were only primed in the RH during conversation comprehension.

3.2. Accuracy

Because accuracy is highly susceptible to ceiling effects and less sensitive to the priming measure, interpretations are based largely on response latencies for correct naming responses. Nonetheless, for the sake of completion, we analyzed participants' mean accuracy data to parallel the response time analyses. Overall accuracy was 88%, which suggests that participants successfully apprehended the words despite rapid lateralized presentation.

Overall, there was a left hemisphere advantage in naming accuracy: Participants named target words presented to the rvf-LH more accurately (.912, .012) than they named target words presented to the lvf-RH (.847, .011), ($F(1, 55)=48.01$, $p<.001$). There was also a relatedness effect: Participants named inference-related target words (.896, .012) more accurately than they named words that were unrelated to the inferences (.863, .011) ($F(1, 55)=14.076$, $p<.001$. Finally, although participants from the narrative group named words slightly more accurately (.90, .02) than did the participants listening to conversations (.86, .02), this effect was only marginally reliable ($F(1, 55)=2.587$, $p<.085$).

Data from participants who listened to narratives, show they named words (both related and unrelated) presented to rvf-LH (.93, .01) more accurately than lvf-RH words (.87, .01) ($F(1, 27)=29.320$, $p<.001$). They also responded marginally more accurately to inference-related (.91, .01) than unrelated (.89, .01) words ($F(1, 27)=3.28$, $p=.081$). This inference priming effect slightly interacted with hemifield ($F(1, 27)=3.27$, $p=.082$) likely due to ceiling performance for naming rvf-LH targets. Ceiling-level accuracy for naming rvf-LH words precludes sensitivity to priming differences in that hemisphere, whereas accuracy below ceiling for naming lvf-RH words is sensitive to potential accuracy improvements. Thus, the marginal interaction is likely an artifact of limitations on accuracy improvement in the rvf-LH.

The participants who listened to conversations named words presented to the rvf-LH (.89, .02) more accurately than words presented to lvf-RH (.83, .02) ($F(1, 28)=20.424$, $p<.001$) as well. They also named inference-related words more accurately (.88, .02) than unrelated words (.84, .02) ($F(1, 28)=13.493$, $p<.001$).

[1] A post-hoc analysis that excludes participants with extreme LH advantage and mildly reversed advantage was computed to account for the slightly stronger LH advantage in one group. When unrelated response times were equated in the two groups, relative hemispheric priming patterns remained stable. This analysis is provided as supplemental material.

This group of participants showed no reliable hemifield X relatedness interaction ($F < 1$) in response accuracy.

There was no interaction between input type, hemisphere, and relatedness in accuracy ($F < 1$) and there were no speed-accuracy tradeoffs.

4. Discussion

This experiment measured relative asymmetries in semantic activation while people comprehended conversations or narratives. Participants who listened to narratives demonstrated reliable priming for naming inference-related target words presented to both visual hemifields. Participants who listened to conversations demonstrated response priming for target words presented to lvf-RH but not for those presented to rvf-LH. By showing inference-related patterns of hemispheric activity differ with conversational and narrative input, this work contributes to our understanding of lateralized language comprehension processes. In addition, these data demonstrate that natural sounding conversations can be used as stimuli for inference priming experiments.

An increased need for integrating broadly-related semantic cues in conversation was hypothesized to result in greater response priming in the RH at the inference point. Studies show people rely heavily on the RH for drawing inferences (Brownell, 1986; Beeman, 1993; McDonald & Wales, 1986), a cognitive process that is presumably augmented with broad scope of interpretation. The RH also maintains activation of alternative meanings and processes prosodic information during speech (Burgess & Simpson, 1988; Buchanan, 2000). Since conversation relies on inferred knowledge, alternative interpretation, and prosody more than narrative, more RH involvement may be necessary to comprehend the kinds of indirect meanings common in many conversational contexts. The critical finding, that participants listening to conversations are faster to name inference-related words only when they are presented to the lvf-RH, supports the hypothesis that understanding conversation emphasizes language processes of the right hemisphere. Thus, RH language processing may be especially important in comprehending meanings in conversational contexts.

The current findings were predicted by the coarse-coding theory of hemispheric activation, which posits that the RH plays an active role in language comprehension by facilitating integration of broadly-related semantic information (Beeman, 1993; see also Chiarello et al., 1990). The theory asserts that language is interpreted at basic and higher cognitive levels simultaneously, but each hemisphere of the brain processes the same information in different ways. Specifically, the RH processes language with a relatively broader scope of semantic association than LH.

Though the results are in line with the coarse-coding perspective, other interpretations should be considered. It is possible that the same scope of semantic information becomes active in both hemispheres, but at different speeds (Burgess & Simpson, 1988; Koivisto, 1997). In this view, LH is more adept at selective semantic activation and therefore does it more quickly than RH, which slowly builds semantic activation for use during post-lexical integration (Koivisto & Laine, 2000). This suggests greater RH priming for inferences in conversation compared with narrative are due to differences in the amount of time it takes for inferences to be promoted in dialogue compared with monologue. This view also predicts that inferences that take longer to promote from initial to changed state should show more RH priming than inferences that are promoted quickly. Post-hoc analyses show conversations (mean=56 s) were reliably shorter than the narratives (61 s; $t(34)=4.89$, $p<.01$). Because the narratives had the same inference-related content promoted over a longer period, the time-course view of hemispheric processing would predict greater RH priming during narrative comprehension. Yet in the present study, priming was only found in RH when people comprehended conversations. Thus, the hemispheric priming differences found here cannot be due solely to differences in the time-course of semantic activation.

Another theoretical perspective on language processing suggests the two hemispheres differ in how they use message-level semantic information to predict upcoming input as a discourse unfolds (Federmeier, 1999; Federmeier, 2007). LH, influenced by top-down predictions about upcoming language input, quickly activates and selects closely-related semantic information for more efficient comprehension. RH, on the other hand, driven by bottom-up integrative processes, slowly activates broadly relevant information. From this perspective, RH was likely more primed with inference-related concepts during conversation because they included more broadly relevant information. Though the materials controlled for semantic relatedness among target words and inference contexts across the input types, the narratives contained more explicit lexical information that made them potentially more predictable. In fact, a critical distinction between the narratives and conversations was the inclusion of fewer pronouns and more logical connectives in the narratives to express the same content. These are important features that distinguish narrative from conversation (Mentis & Prutting, 1987) that potentially lead to distinct hemispheric contributions during comprehension of each. Therefore, it is possible that coarse semantic coding, in conjunction with slow integrative semantic activation leads to more RH involvement in conversation comprehension; fine semantic coding, fast activation and selection of highly predictable semantic information by the LH facilitates comprehension of more lexically-rich, logically-connected narratives.

Because speakers in conversation often choose to implicate meanings that go beyond "what is said," conversational speech may appeal to a different "mode" of comprehension than understanding narrative texts. In a "conversational mode," people may get into a broader interpretational mindset wherein a wider range of both close and distantly-related concepts is weakly-activated. Dominant lexical-semantic interpretative processes in the LH might dampen, making more available weakly active concepts in the RH. As a result, a variety of alternative meanings, prosodic meanings, inferred meanings, and other interpretations based on information that RH is known to regulate during language comprehension may become more readily available. Those aspects of language associated with RH processing are also more characteristic of natural conversational language.

Alternatively, syntax or grammar distinctions between utterances of narrative and conversation could lead to differences in hemispheric processing during comprehension. Conversations typically take place in specific settings; the words uttered are chosen to convey particular meanings within the discourse context. Conversations are also spontaneous and therefore crucially dependent on moment-to-moment circumstances. Narrative monologues, on the other hand, are often pre-planned and may be less contextually constrained in a moment-by-moment fashion. Narrative sentences are more linguistically explicit and syntactically well-formed compared with the sometimes elliptical or incomplete utterances typical of many conversations. In the present study, we controlled for some of the linguistic distinctions between language in conversational and narrative form and found reliable hemispheric priming differences even though the vignettes were only minimally different. In real-world contexts, conversations and narratives likely have additional extra-linguistic qualities that could exacerbate differences in hemispheric contributions to their comprehension. Even so, it is not clear whether hemispheric differences during comprehension of narrative and conversation occur because people get into different comprehension "modes", if they pay more attention to particular linguistic elements when comprehending particular kinds of input, or some other possibility. Future studies will need to explore how mechanisms of language comprehension change based on the form of language input.

Another objective of the present work was to supplement current language comprehension research methods by demonstrating that a carefully controlled conversational context can yield interpretable patterns of hemispheric activation. This is especially important because conversations are a dominant mode of everyday language use. In the present study, participants' responses to visually presented words were faster if they were related to the inference-priming context, regardless of whether the input was presented as a conversation or narrative. Therefore, the conversational contexts were just as effective at promoting the relevant inferences as the narratives. Future comprehension research should consider using conversational stimuli to better simulate natural comprehension contexts.

This study approximated natural comprehension of conversation while circumventing issues that arise from a participant's having to produce responsive speech. One important limitation of this study, though, is that participants only listened to the conversations; they did not actually participate in them. Psycholinguistic work on language comprehension has sometimes been criticized for situating participants as "overhearers" to the linguistic input rather than as actual participants (Clark & Clark, 1997). It would be ideal to directly compare measures of listening comprehension (i.e., inference priming) with measures of comprehension while participants interactively produce and comprehend speech. More studies of how different language input influences comprehension are needed.

This work shows that language comprehension (i.e., inference priming) can be measured from conversational contexts. Since conversation instantiates a frequently-encountered language context, future research should more often be based on language in conversational form. The present study also shows people may rely more on inference-related conceptual activation in the right hemisphere than left hemisphere during comprehension of conversation compared with narrative. Increased demand for RH processing during comprehension of conversation compared with narrative could occur because of differences in the scope of semantic activation across the two hemispheres or because the RH is slower than LH at activating semantically relevant information as a discourse unfolds.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.neuropsychologia.2012.07.008.

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