

# Gesture and right hemisphere involvement in evaluating lecture material\*

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This study investigated hemispheric lateralization in comprehending and evaluating lecture material with and without nonverbal hand gestures. Participants watched a lecture with and without gesture under conditions of cognitive load in the left or right hemisphere. There were no effects of gesture or load on lecture comprehension, but gesture and load influenced how participants evaluated the lecture. Specifically, presence of gesture significantly influenced participants' affective evaluations of the lecturer in both load conditions. However, gesture influenced cognitive evaluations of the lecture material only when the right hemisphere was free from cognitive load. The results suggest that the right hemisphere may be specialized for processing information conveyed through hand gestures.

**Keywords:** Gesture, speech, comprehension, lateralization, right hemisphere

Why do captivating speakers gesticulate while they pontificate? It's true. Visit any lecture given by a popular professor, and you will likely see and hear gestures and words whipped together in a flurry of activity. Could it be that these hand gestures are precisely what make the speaker so captivating?

Previous research has demonstrated that hand gestures do make communication clearer for listeners (Beattie & Shovelton, 1999; Cassell, McNeill, & McCullough, 1999; Goldin-Meadow, Wein, & Chang, 1992; Kelly, Barr, Church, & Lynch, 1999; Kelly & Church, 1998; McNeill, 1992). For example, Kelly et al. (1999) found that people understood ambiguous utterances much better when they were produced with versus without gesture (e.g., saying, "It's cold in here" while pointing to an open window). Moreover, Kelly and Church (1998) discovered that adults used gestural information to make more complete assessments of children's knowledge than adults who only had access to speech.

Some researchers have explored the educational implications of these findings (Alibali, Flevaris & Goldin-Meadow, 1997; Gauger, 1952; Goldin-Meadow, Kim, & Singer, 1999; Goldin-Meadow & Singer, 2003; Kelly, Singer, Hicks, & Goldin-Meadow, 2002; Valenzeno, Alibali, & Klatzky, 2003). For example, Valenzeno et al. (2003) found that children who watched videos of a teacher learned more when the video contained teacher's gestures than when it did not. Moreover, Kelly et al. (2002) demonstrated that training people to be more aware of gesture actually helped people make more thorough and accurate assessments of a communicator's knowledge. In one of the earliest studies of this kind, Gauger (1952) had high school students attend a lecture in a face-to-face situation or hear that same lecture over a public address system. The students in the "gesture" condition showed better comprehension of the material than the students in the audio only condition.

Thus, there is solid evidence that gesture plays an important role for students in educational interactions. The present study aims to extend these findings in two ways. First, it explores how gestures affect people's subjective interpretation and evaluation of an educational message. The knowledge that students acquire from teachers is only part of the overall learning experience in the classroom. The way that students think and feel about what they learned, and how they learned it, most likely also contributes to students' overall experience in the classroom. There is research suggesting that certain nonverbal behaviors — such as, facial expression, tone of voice, eye gaze, and body posture — influence affective evaluations of a teacher and a teacher's content (Knapp, 1972; Neill & Caswell, 1993). However, there is little research on how hand gestures, specifically, influence students' evaluations of the learning process. The present study attempts to fill this gap in the literature.

The second goal of the present study is to investigate one possible neural mechanism that may allow gesture to affect comprehension. Specifically, the study investigates the role that the cerebral hemispheres play in gesture processing during comprehension of lecture material. It is commonly accepted that the left and right cerebral hemispheres process information in different ways (for a recent review, see Hellige, 2001) With particular regard to speech and gesture processing, the left hemisphere is believed to be specialized for processing verbal information, and the right hemisphere is thought to be specialized for processing non-verbal information (Buck & Van Lear, 2002; Corina, Vaid, & Bellugi, 1992a; Corina, Poizner, & Bellugi, 1992b; McNeill, 1992; McNeill & Pedelty, 1995). In one study focusing on speech and gesture comprehension, Corina, Vaid, & Bellugi (1992a) found that comprehension of spoken (and signed)

language was processed in the left hemisphere. Interestingly, they did not find comprehension of non-linguistic hand gestures to be lateralized to either hemisphere. However, in another study, Corina, Poizner, and Bellugi (1992b) described a left-lesioned deaf signer who had disruptions to his sign language abilities, but no disruptions to symbolic gesture abilities. This suggests that linguistic abilities are localized to the left hemisphere, whereas non-linguistic gestural abilities are localized to the right hemisphere.

The technique used in the Corina, Vaid, and Bellugi study (1992a) to measure hemispheric activity is a type of cognitive load procedure called a “concurrent activities paradigm” (Kinsbourne & Cook, 1971). The procedure requires participants to perform a primary task while simultaneously performing a secondary task. For example, in the study by Corina et al. (1992a), participants watched videos containing speech or gesture (primary task) while they concurrently tapped a button with a finger on either the left or right hand (secondary task). The rationale was that if the primary task exerted demands on one hemisphere more than the other, tapping behavior on the contralateral hand would decrease. In the case of the study by Corina et al. (1992a), participants exhibited greater decrements in tapping behavior while comprehending linguistic material when the right versus left hand was tapping.

One of the limitations of the Corina study was that the gesture stimuli were artificial and detached from a verbal context. The two types of gestures were emblems (e.g., waving good-bye) and arbitrary hand movements taken from the Kimura and Archibald Movement Copying Test (Kimura & Archibald, 1974). Unfortunately, these gestures bear little resemblance to the spontaneous gestures produced with speech in natural discourse. For this reason, the present study aimed to build on this previous work by using gesture stimuli that were more natural and ecologically valid.

To summarize, there were three goals of the present study. First, it attempted to replicate previous studies demonstrating that hand gestures enhance comprehension of lecture material. Second, it aimed to determine whether lectures accompanied by hand gestures influenced participants affective and/or cognitive evaluations of the lecturer and the lecture content. And third, it explored whether the neural mechanisms underlying these effects were lateralized to the left or right hemisphere.

## Method

### *Participants*

Thirty-nine college undergraduates (13 men and 26 women) participated in the study for course credit. They ranged in age from 18 to 22.

### *Procedure*

Participants were tested in groups of one to five. After they read and signed a consent form, they were told that they would be watching a short neuroscience lecture on action potentials. They were told that while they watched, they would engage in a hemispheric cognitive load task. The “concurrent activities paradigm” has been used successfully in previous research to measure interference between a primary task and a secondary hemispheric load task (Corina, Vaid, & Bellugi, 1992a; Kinsbourne & Cook, 1971). The load task required participants to synchronize to a metronome (set to 40 beats per minute) and mark a piece of paper with a pencil with either the left or right hand. The rationale of the secondary task was to interfere with either the left hemisphere (right hand mark) or the right hemisphere (left hand mark) while the participants performed the primary task (i.e., watching the video). Note that the present use of the “concurrent activities paradigm” differed from previous studies. Rather than use performance on the secondary task as the dependent measure (as previous studies have done), the present experiment used performance on the *primary task*. That is, by having all participants mark a pencil 40 times per second across all conditions, we ensured that the secondary task would “load” participants equally while they watched the video. This allowed us to determine how loading the right and left hemispheres affected comprehension of the material with and without gesture. Participants were given practice with the marking task prior to watching the video. Participants then watched the experimental stimulus in either the gesture-present or gesture-absent condition (described below). Participants were randomly assigned to the hemisphere load and gesture conditions.

Following the video, participants were asked several questions about the content of the lecture and were asked to provide their affective and cognitive evaluations of the lecture. Following these questions, participants were debriefed and the rationale of the experiment was explained.

### *Materials and Stimulus*

Participants watched a normal VHS video on a typical VCR that projected onto a movie screen in an empty classroom. The video (5-and-a-half minutes in length) showed a neuroscience professor giving a short lecture on action potentials. The lecture on action potentials was specifically chosen because this topic is rich in visuo-spatial imagery — for example, it presented concepts about how ions enter and exit cell walls, how electrical charges change inside and outside cells, and how neurotransmitters cross synapses and bind to receptors. The material was familiar to the students, but none of them had seen this particular lecture previously. There were two versions of the video that corresponded to two levels of the Gesture condition. In the gesture-present condition, the video depicted the entire head and torso of the professor so that his hand gestures were visible. The lecturer was not given any special instructions to gesture — rather, he was instructed to give the lecture as he normally would in the classroom. The result was a lecture that was rich with iconic, deictic, and metaphoric gestures (McNeill, 1992). In the gesture-absent condition, the video was digitally edited so that only the head of the professor was visible, thus blocking access to his gestures. In this way, the only difference between the tapes was what the participants saw, but what they heard was identical across conditions.

The questionnaire asked two types of questions. The first set of questions probed about the specific content that participants gleaned from the lecture (Appendix A). The second set of questions required participants to make evaluations about the material and the lecturer. Specifically, one sub-set of questions (termed “affective evaluation”) asked participants to rate how they felt about the material and lecturer. The second sub-set of questions (termed “cognitive evaluation”) asked participants to evaluate their understanding of the material (Appendix B).

### **Results**

The experiment was based on a 2 X 2 between-subjects design, with Gesture (present vs. absent) and Hemispheric Load (LH load vs. RH load) as the two factors. The data were analyzed with multivariate and univariate ANOVAs. Dunn-Šidák *t tests* were used for all contrasts.

### *Forced choice*

The forced choice items tapped participants comprehension of the lecture material. There were no significant main effects of Gesture ( $F(1,35)=0.33$ , ns) or Load ( $F(1,35)=1.63$ , ns), and there was not a significant Gesture by Load interaction ( $F(1,35)=0.08$ , ns). Refer to Table 1 for the means and standard deviations. These results suggest that participants did not differ in their ability to glean information from the lecture across all conditions. This is important because it suggests that any differences in the remainder of the dependent measures were not due to how well participants actually comprehended the material.

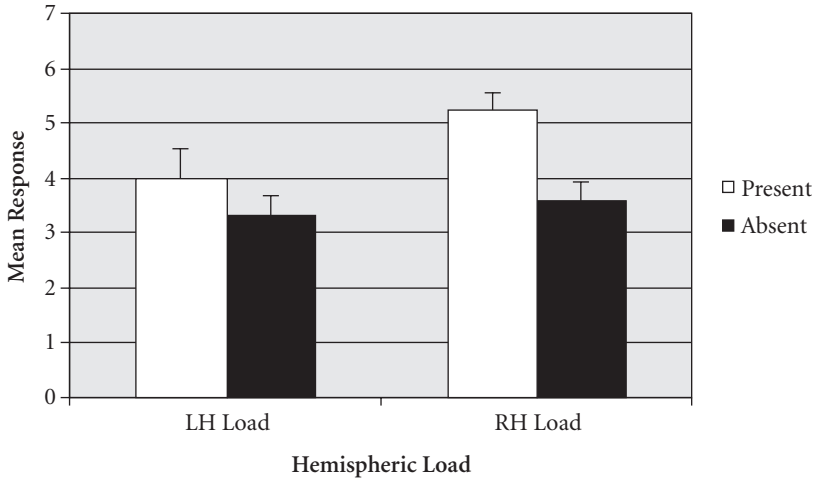
### *Affective evaluation*

This measure reflects how participants felt about the material and lecturer. The first part of this measure tapped how connected participants felt toward the lecture material. Specifically, this measure subsumed the “like lecture”, “lecture interest” and “stimulation” questions. These items were highly correlated ( $\alpha=0.79$ ). A multivariate ANOVA on these three items revealed no significant effects of Gesture ( $F(3,33)=0.34$ , ns), Load ( $F(3,33)=0.67$ , ns) or Gesture by Load ( $F(3,33)=0.25$ , ns). See Table 1. These results suggest that the experimental manipulations did not influence how participants felt about the lecture and lecture material.

The second part of this measure reflected how participants felt about the lecturer. The univariate ANOVA on the “lecturer” question yielded a main effect of Gesture ( $F(1,35)=6.14$ ,  $p<.05$ ) but no main effect for Load ( $F(1,35)=2.35$ , ns)

**Table 1.** Mean Ratings of Questionnaire Items across Load and Gesture Conditions

	Left hemisphere load				Right hemisphere load			
	Gesture absent		Gesture present		Gesture absent		Gesture present	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Forced choice	6.11	2.47	6.78	1.64	5.42	2.23	5.63	2.13
Like lecture	2.67	1.22	3.33	1.55	3	1.04	3.25	1.16
Lecture interest	2.67	1.44	3.17	1.55	2.88	1.48	3.31	0.65
Stimulation	2.89	0.93	3.11	1.23	3.75	1.86	3.63	1.06
Lecturer	3.33	1.12	4	1.7	3.58	1.24	5.25	0.89
Material difficulty	3.22	1.12	4.67	1.24	4.17	1.21	3.31	0.8
Understand lecture	3.08	0.92	5.06	0.97	3.96	1.32	3.75	1.04
Previous knowledge	3.78	1.56	5.79	1.35	4.83	1.34	4.75	0.89
Confidence	1.77	1.09	4.78	1.27	2.92	1.38	3.38	1.06



**Figure 1.** Mean ratings for the “lecturer” question across load and gesture conditions.

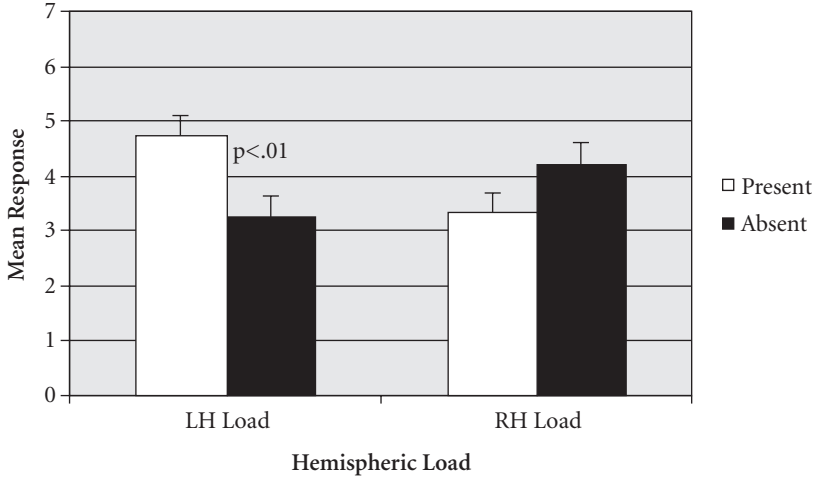
and no Gesture by Load interaction ( $F(1,35)=2.76$ , ns). Figure 1 shows that participants liked the lecturer more in the gesture-present condition than the gesture-absent condition across both load manipulations.

### *Cognitive evaluation*

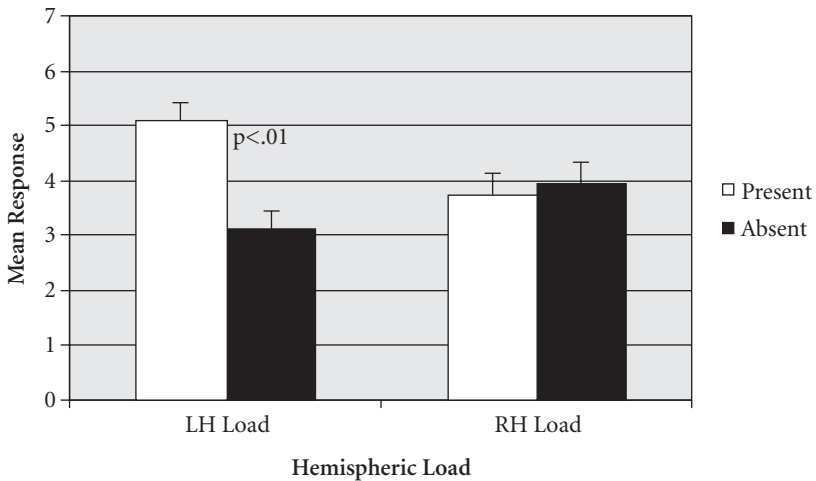
This measure reflects participants’ cognitive evaluation of the content of the lecture material and how well they understood that content. Specifically, this measure included the “material difficulty”, “understand lecture”, “previous knowledge” and “confidence” questions. These items were highly correlated ( $\alpha=0.85$ ). A multivariate ANOVA on these four items revealed significant effects of Gesture ( $F(4,32)=4.14$ ,  $p>.01$ ) and Gesture by Load ( $F(4,32)=3.67$ ,  $p<.05$ ), but no significant effect of Load ( $F(4,32)=0.69$ , ns).

Follow-up univariate test were performed on each of the measures. For the “material difficulty” item, there were no main effects of Gesture ( $F(1,35)=1.24$ , ns) or Load ( $F(1,35)=0.58$ , ns), but there was a significant effect of Gesture by Load ( $F(1,35)=10.30$ ,  $p<.01$ ). Post-hocs revealed that LH load participants rated the lecture material as easier when gesture was present versus absent ( $tDS(2,18)=2.99$ ,  $p<.01$ ), but there were no differences for RH load participants ( $tDS(2,18)=1.52$ , ns) (see Fig. 2).

For the “understand lecture” item, there was no main effect of Load ( $F(1,35)=0.10$ , ns), but there were significant effects of Gesture ( $F(1,35)=4.82$ ,



**Figure 2.** Mean ratings for the “material difficulty” question across load and gesture conditions.



**Figure 3.** Mean ratings for the “understand lecture” question across load and gesture conditions.

$p < .05$ ) and Gesture by Load ( $F(1,35) = 7.75, p < .01$ ). Post-hocs revealed that LH load participants said that they better understood the lecture material when gesture was present versus absent ( $tDS(2,18) = 4.06, p < .01$ ), but there were no differences for RH load participants ( $tDS(2,18) = 0.37, ns$ ) (see Fig. 3).

For the “previous knowledge” question, there was no main effect of Load ( $F(1,35) = 1.40, ns$ ), but there were significant effects of Gesture ( $F(1,35) = 5.90,$



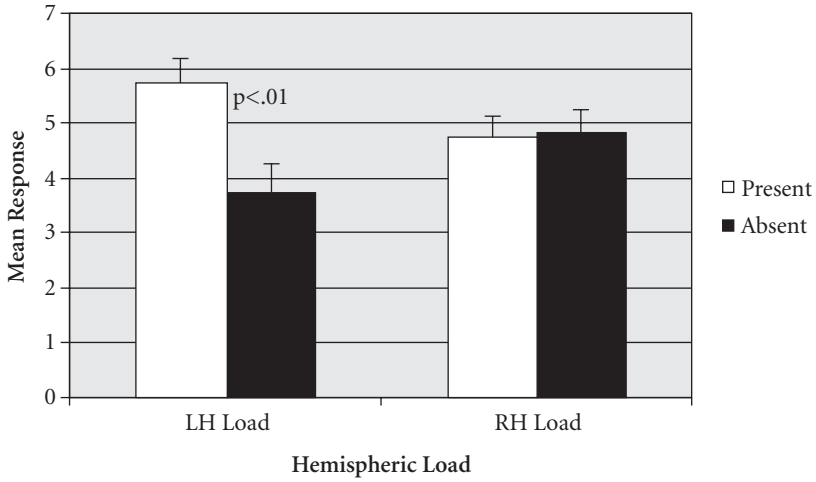


Figure 4. Mean ratings for the “previous knowledge” question across load and gesture conditions.

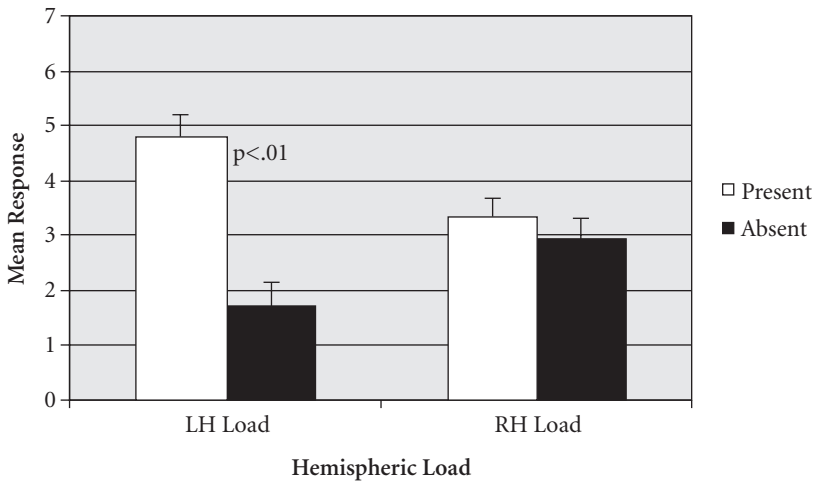


Figure 5. Mean ratings for the “confidence” question across load and gesture conditions.

$p < .05$ ) and Gesture by Load ( $F(1,35) = 10.30, p < .01$ ). Post-hocs revealed that LH load participants claimed that previous knowledge helped them understand the problems more when gesture was present versus absent ( $tDS(2,18) = 4.98, p < .01$ ), but there were no differences for RH load participants ( $tDS(2,18) = 0.79, ns$ ) (see Fig. 4).

Finally, for the “confidence” question, there was no main effect of Load

( $F(1,35)=0.01$ , ns), but there were significant effects of Gesture ( $F(1,35)=15.97$ ,  $p<.01$ ) and Gesture by Load ( $F(1,35)=8.09$ ,  $p<.01$ ). Post-hocs revealed that LH load participants were more confident in their answers when gesture was present versus absent ( $tDS(2,18)=2.57$ ,  $p<.01$ ), but there were no differences for RH load participants ( $tDS(2,18)=0.15$ , ns) (see Fig. 5).

To summarize the results from the cognitive evaluation, when the left hemisphere was under cognitive load, the right hemisphere was particularly sensitive to lecture material accompanied by gesture. Specifically, the right hemisphere sensitivity strongly influenced how participants' evaluated the content of the material and how well they claimed to understand that content.

## Discussion

The data from the present study failed to replicate previous research showing that hand gestures enhance comprehension of lecture material. However, the results suggest that gestures played an important role in participants' affective evaluations of the lecturer across both load conditions. Moreover, the right hemisphere played a greater role than the left hemisphere in the cognitive evaluations when gesture was present versus absent.

### *Gesture and lecture comprehension*

Why did the present experiment fail to replicate past research? One possibility is that the gestures did indeed affect comprehension, but our dependent measure was not sensitive enough to uncover this effect. The present study used a questionnaire method to tap comprehension of the lecture material. This technique has been used in previous research on gesture comprehension and was determined not to be as sensitive as more open-ended, free recall measures (Kelly, Singer, Hicks, & Goldin-Meadow, 2002). Thus, it could be that gestures did affect comprehension, but our questionnaire technique simply did not tap that comprehension.

Although this is a possibility, there is reason to believe that the questionnaire accurately measured comprehension of the material. The students in the study were all recruited from an Introductory Psychology course, and although the course has a neuroscience component, most students find this section to be the most difficult to grasp. Consequently, this could have created a floor effect in the response to the questionnaire items. In contrast, previous research on

gesture comprehension has used material that is very familiar and accessible to participants (Gauger, 1952; Goldin-Meadow, Wein, & Chang, 1992; Kelly & Church, 1998; Kelly, Singer, Hicks, & Goldin-Meadow, 2002).

If, in fact, the material was too challenging for participants, and the gesture and load conditions did not have any effect on the comprehension scores, it actually makes the results from the evaluation measures more valid. For example, if the comprehension scores were better in the gesture condition, one might expect that any positive evaluation of the lecture in the gesture condition might simply reflect a better understanding of the material. However, because the comprehension was the same under all conditions, different evaluations in different conditions more meaningfully reflected true effects of the gesture and load conditions on the evaluations of the lecture material.

### *Evaluation of lecturer and lecture material*

Although there were no effects of load and gesture on comprehension of the lecture material, these conditions did affect how participants evaluated the lecturer and lecture material. With regard to the affective evaluation, the presence of gestures appeared to cause participants to like the lecturer more than when gesture was absent. This finding is consistent with previous research claiming that nonverbal expressivity positively influences people's impressions of communicators (Abrami, Perry, & Leventhal, 1982; Allport, 1961; Basow & Distenfeld, 1985; Riggio & Friedman, 1986). For example, Riggio and Friedman (1986) had participants make evaluations of nonverbally expressive and unexpressive people who were explaining a procedure on a video. They found that the evaluators rated the communicators as most likeable when the communicators emphasized their speech with body movements and facial expressions. Researchers have found similar results in educational settings. For example, Basow and Distenfeld (1985) discovered that college students gave higher likeability ratings when professors were more nonverbally expressive compared to less expressive.

Whereas much of this research has placed hand gestures into a larger category of nonverbal expressiveness, some researchers have focused specifically on the role that hand gestures play in making evaluations of a communicator (Cassell, Bickmore, Campbell, Vilhjalmsson, & Yan, 2001). Cassell et al. (2001) discussed the effectiveness of "embodied interface agents" in human-computer interaction. Specifically, they argued that computer agents depicting whole body actions (e.g., hand gestures toward objects) were evaluated more positively

by users than computer programs that were not embodied (e.g., disembodied talking heads). One explanation for this finding is that gestures may make the computer program more life-like and allow the users to positively relate to the computer image. Similarly, the gestures of the speaker in the present experiment could have made the lecturer appear more natural and approachable, and this could have caused participants to have more positive feelings about the speaker (gesturer). Future research will investigate what specifically about gesture makes people have an affinity toward communicators who gesture when they speak.

The most robust effects in the present experiment were found with the cognitive evaluations of the lecture material. When the lecturer produced gestures, participants were more likely to rate the material as understandable, and they were more confident that they had answered the questions correctly. In other words, gesture appeared to help participants reflect on what they *knew* about the lecture material. These results are consistent with McNeill's theory of how hand gestures relate to speech in communication (McNeill, 1992). McNeill (1992) argues that representational hand gestures — like many of the ones used in the present study — are deeply rooted in the cognitive processes that underlie speech production and comprehension. Although gesture did not affect the comprehension of speech in the current study, it may have activated meta-cognitive systems that were involved in evaluating how well individuals understood that speech. To our knowledge, previous studies on gesture's role in learning have not differentiated between effects that gesture has on learning and the effects that gesture has on meta-cognitive evaluations of that learning.

The affective and cognitive evaluation findings have important educational implications. If gesture builds a connection between students and teachers in addition to making students feel confident that they understand the material, gesture might facilitate learning simply by getting students more comfortable with the learning process. Moreover this facilitation most likely would be bolstered when gesture actually improves comprehension and learning in educational contexts (Alibali, Flevaris, & Goldin-Meadow, 1997; Gauger, 1952; Goldin-Meadow & Singer, 2003; Kelly, Singer, Hicks, & Goldin-Meadow, 2002; Valenzeno, Alibali, & Klatzky, 2003). The facts that gesture enhances learning (previous studies) and increases positive evaluations of that learning (present study) strongly suggest that that teachers could improve their teaching simply by moving their hands naturally while they spoke in the classroom.

### *Hemisphere effects*

One of the more intriguing results in the present study is that gesture influenced the cognitive evaluations more strongly under left hemisphere load than right hemisphere load. This suggests that the right hemisphere was more sensitive to the gesture information when it was free to process the lecture material compared to the left hemisphere. This is consistent with previous research suggesting that the right hemisphere may be responsible for processing representational hand gestures (Buck & Van Lear, 2002; McNeill, 1992; McNeill & Pedelty, 1995). One explanation for this lateralization effect is that the right hemisphere is traditionally believed to be specialized for global visuo-spatial processing (Hellige, 2001; Levy, Trevarthen, & Sperry, 1972), and hand gestures are extremely rich with precisely this type of information (McNeill, 1992). This makes sense considering the nature of the stimulus used in the present study. Because the lecture was rich in global visuo-spatial imagery, and the instructor's gestures were an additional medium to convey this type of information, the right hemisphere could have been more active during the gesture-present versus gesture-absent condition.

It is interesting that the present experiment uncovered a right hemisphere gesture effect using the “concurrent activities paradigm” whereas the previous study by Corina et al. (1992a) did not. However, this discrepancy makes sense when one considers the differences in the stimuli used in both studies. Recall that the Corina study utilized a large number of arbitrary gestures that were presented in isolation from speech. Perhaps these movements did not activate the right hemisphere because their visuo-spatial meaning was unclear. Indeed, McNeill (1992) has argued that representational gestures have communicative meaning precisely because they are so closely and deeply integrated with speech during production and comprehension. Perhaps that is why the natural and spontaneous gestures used in the present study caused a right hemisphere effect — the right hemisphere could have been sensitive to the lecture in the gesture condition because the visuo-spatial meaning of the gesture was grounded in the meaning of the accompanying speech.

### **Conclusion**

Although the present study did not uncover any effects of hand gesture on comprehension, gestures did influence affective evaluations of the lecturer and

cognitive evaluations of what people learned from the lecture. Moreover, the right hemisphere appeared to be an important mechanism for using gesture to make these cognitive evaluations. In this way, it may be right hemisphere involvement in gesture processing that allows us to be so captivated by speakers who gesticulate while they pontificate.

## Note

\* This paper is based on the senior research project of the second author. We thank Colgate University for making research a crucial component to educating their undergraduates.

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## Appendix

### *Appendix A: The Forced Choice Questionnaire Items*

Please answer the following questions to the best of your knowledge after having heard the lecture on the videotape:

1. Which units make up the structure of a neuron?
  - a. sodium and potassium ions
  - b. dendrites, cell body, and an axon
  - c. positive and negative charges within the axon
  - d. pre-synaptic terminal and post synaptic terminal
2. Which direction does the action potential move?
  - a. down the axon
  - b. across the axon
  - c. up the axon
  - d. inside the axon
3. The ions and charges are where when the neuron is at rest?
  - a. sodium outside, potassium inside, negative outside, positive inside
  - b. sodium inside, potassium outside, negative outside positive inside
  - c. sodium inside potassium outside, negative inside, positive outside
  - d. sodium outside, potassium inside, negative inside, positive outside
4. What kind of signal is an action potential?
  - a. chemical
  - b. neurological
  - c. electrical
  - d. magnetic
5. What is the relationship between the flow of ions and the up-shoot of the action potential?
  - a. sodium in causes the up-shoot of the curve
  - b. sodium out causes the up-shoot of the curve
  - c. potassium in causes the up-shoot of the curve
  - d. potassium out causes the up-shoot of the curve
6. During the action potential, where are the ions located?
  - a. potassium out, sodium in
  - b. potassium in, sodium out
  - c. potassium in, sodium in
  - d. potassium out, sodium out
7. An excitatory signal is caused by what?
  - a. sodium flowing into the cell
  - b. potassium flowing into the cell
  - c. sodium flowing out of the cell
  - d. potassium flowing out of the cell



8. The pump moves the ions in which directions?
  - a. sodium in, potassium out
  - b. sodium out, potassium in
  - c. sodium in, potassium in
  - d. sodium out, potassium out
  
9. What is the relationship between the flow of ions and the fall of the action potential?
  - a. potassium in causes the fall of the curve
  - b. potassium out causes the fall of the curve
  - c. sodium in causes the fall of the curve
  - d. sodium out causes the fall of the curve
  
10. What is the purpose of the ion channel?
  - a. to selectively let certain ions back and forth across the membrane
  - b. to openly let ions flow back and forth across the membrane
  - c. to make sure certain ions do not flow into the cell
  - d. to make sure certain ions do not escape from the inside of the cell

*Appendix B: Affective and Cognitive Evaluation Questionnaire*

Please rate the following questions based solely on your opinions. There are no right or wrong answers:

1	2	3	4	5	6	7
not at all			somewhat			very much

*(Affective Evaluation)*

**Like Lecture**

How much did you like the lecture? \_\_\_\_\_

**Lecture Interest\***

How interesting did you find the lecture? \_\_\_\_\_

How bored did you get during the lecture? \_\_\_\_\_

**Stimulation**

How intellectually stimulating did you find the lecture? \_\_\_\_\_

**Lecturer**

How much did you like the lecturer? \_\_\_\_\_

*(Cognitive Evaluation)*

**Material Difficulty**

How easy did you find the lecture material? \_\_\_\_\_

**Understand Lecture\*\***

How well did you understand the lecture? \_\_\_\_\_

How confused did you get during the lecture? \_\_\_\_\_

**Previous Knowledge**

How much previous knowledge did you have of this material? \_\_\_\_\_

### Confidence

How confident were you in answering the questions correctly? \_\_\_\_\_

\*These two items were combined into one score by taking the inverse score of the “bored” question and averaging it with the “interesting” question. After inversion, the answers to the two questions had an alpha coefficient of .70.

\*\*These two items were combined into one score by taking the inverse score of the “confused” question and averaging it with the “understand” question. After inversion, the answers to the two questions had an alpha coefficient of .67.

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