

Research Article

GESTURE, SPEECH, AND LEXICAL ACCESS:
The Role of Lexical Movements in Speech Production

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Abstract—In a within-subjects design that varied whether speakers were allowed to gesture and the difficulty of lexical access, speakers were videotaped as they described animated action cartoons to a listener. When speakers were permitted to gesture, they gestured more often during phrases with spatial content than during phrases with other content. Speech with spatial content was less fluent when speakers could not gesture than when they could gesture; speech with nonspatial content was not affected by gesture condition. Preventing gesturing increased the relative frequency of nonjuncture filled pauses in speech with spatial content, but not in speech with other content. Overall, the effects of preventing speakers from gesturing resembled those of increasing the difficulty of lexical access by other means, except that the effects of gesture restriction were specific to speech with spatial content. The findings support the hypothesis that gestural accompaniments to spontaneous speech can facilitate access to the mental lexicon.

Conversational gestures are unplanned, fluent hand movements that often accompany spontaneous speech. The prevailing view is that they enhance communication by conveying information that amplifies and modulates information conveyed in the speech channel (Birdwhistell, 1970; Graham & Argyle, 1975; Kendon, 1983, 1987). However, recent research casts doubt on the communicative importance of conversational gestures, at least insofar as the semantic information they convey is concerned (Feyereisen, Van de Wiele, & Dubois, 1988; Krauss, Dushay, Chen, & Rauscher, 1995; Krauss, Morrel-Samuels, & Colasante, 1991), leading several investigators to speculate about possible noncommunicative functions they may serve (Feyereisen & deLannoy, 1991; Hadar, 1989; Krauss et al., 1991; Morrel-Samuels & Krauss, 1992; Rimé & Schiaratura, 1991).

One possibility is that conversational gestures are generated as part of the speech production process, and play a role in the retrieval of words from lexical memory. The general idea that gestures enhance a speaker's ability to access obscure or unfamiliar words is not a new one, having been proposed by a remarkably varied assortment of writers over the past 60 years (DeLaguna, 1927; Dobrogaev, 1929; Ekman & Friesen, 1972; Freedman, 1972; Mead, 1934; Moscovici, 1967; Werner & Kaplan, 1963). The earliest empirical study is probably that of Dobrogaev, who asked speakers to curb facial expression, gestures, and head movements while speaking. He reported that this restriction resulted in decreased fluency, impaired articu-

lation, and reduced vocabulary size. Unfortunately, the article, like many written in that era, provides little in the way of procedural details and describes results in an impressionistic, non-quantitative fashion.

More recently, three studies have examined the effects of preventing gesturing on speech. Lickiss and Wellens (1978) found no effects of restraining speakers' hand movements on verbal fluency, but it is unclear exactly which dysfluencies were examined. Using a varied set of linguistic indices, Graham and Heywood (1975) examined the speech of 6 subjects describing abstract line drawings on trials during which they were permitted to gesture and trials during which they were not. Although statistically significant effects of preventing gesturing were found on some of the indices, Graham and Heywood concluded that "elimination of gesture has no particularly marked effects on speech performance" (p. 194). Given their small sample of speakers and the fact that statistically significant or near-significant effects were found for several contrasts, failure to reject the null hypothesis seems a weak justification for so strong a conclusion. In a rather different sort of study, Rimé, Schiaratura, Hupet, and Ghysselsinckx (1984) compared the content of subjects' speech while their heads, arms, hands, legs, and feet were restrained with the content of their speech under normal circumstances. Less vivid imagery was observed when speakers could not move.

In considering functions gestures might serve, it is useful to distinguish between two different types of what we call conversational gestures.¹ Although gestural typologies abound in the literature, virtually all researchers recognize a category of conversational gestures that are simple, brief, repetitive, coordinated with the speech prosody, and apparently unrelated in form to the conceptual content of the speech they accompany. We refer to such gestures as *motor movements* (Hadar, 1989). They also have been called "batonic gestures" (Bull, 1987) and "beats" (McNeill, 1987, 1992). A second category of conversational gestures consists of movements that are more complex, less repetitive, more varied, and of longer duration than motor movements and that seem related in form to the ideational content of the accompanying speech. We refer to this second category of gestures as *lexical movements* (Hadar, 1989). They also have been called "illustrators" (Ekman & Friesen, 1972) and "representational gestures" (McNeill, 1992). Our central hypothesis is that such gestures play a role in lexical access.

How might gesturing affect speech? Speech production begins with the formulation of a communicative intention—a con-

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1. Conversational gestures differ from the gestural hand signs with conventionalized meanings (e.g., "thumbs-up," "A-OK") often referred to as emblems. Emblems can be used in the absence of speech and clearly convey semantic information.

ceptual structure to be conveyed by the utterance.² Levelt (1989) calls this stage of the process *conceptualizing* and refers to its output as a *preverbal message*. The preverbal message specifies the semantic features to be used in lexical selection, and in constructing it the speaker may draw upon knowledge represented in memory in any of a number of representational formats. In the second stage of the speech production process, which Levelt calls *formulating*, the preverbal message is transformed into a linguistic structure. As part of this process, elements of the preverbal message activate entries in the mental lexicon, permitting the speaker to select lexical items that satisfy the previously determined semantic specifications. The output of this stage is a surface structure, which is then further processed by a *phonological encoder* into a set of phonetic instructions or an articulatory plan. We believe that lexical movements derive from knowledge that is encoded in a spatial format, and that the spatial features of the conceptual structure that are expressed in a lexical movement facilitate lexical access by cross-modally priming the semantic features that enter into lexical search.³

If lexical movements facilitate lexical access, preventing speakers from gesturing should make lexical access more difficult. Problems in lexical access often are reflected in slow, dysfluent speech. For example, unpredictable (hence, less accessible) words in spontaneous speech tend to be preceded by silent and filled pauses (Goldman-Eisler, 1958; Tannenbaum, Williams, & Hiller, 1965). The rate of filled pauses in a speech corpus is positively correlated with its lexical diversity, an indication of the range of alternatives from which lexical selection is made (Schachter, Christenfeld, Ravina, & Bilous, 1991). Artificially increasing the difficulty of lexical access (e.g., by asking the speaker to avoid using words that contain a particular letter) increases the frequency of filled pauses (Boomer & Dittmann, 1964).

Of course, not all pauses, filled or silent, reflect problems in lexical access. From time to time, speakers must pause to breathe. They also pause to plan the ideas they want to convey (Butterworth, 1980). In addition, speakers may insert pauses for communicative reasons—as a kind of audible punctuation to guide listeners' comprehension. In spontaneous speech, about 60% to 70% of the pauses fall at grammatical clause boundaries (often called *juncture pauses*), but speech read from text (for which neither planning nor lexical access is problematic) contains many fewer pauses, with nearly all of them falling at junctures (Henderson, Goldman-Eisler, & Skarbek, 1965). Although it is difficult to determine a juncture pause's origin, pauses that fall within grammatical clauses (often called *hesitations* or *nonjuncture pauses*) typically reflect problems in

speech production. One of the effects of rehearsing speech material is to increase the proportion of pauses that fall at grammatical junctures (Butterworth, 1980). In one study (Chawla & Krauss, 1994), about 72% of the filled and silent pauses in rehearsed narratives fell at grammatical junctures; in the spontaneous versions of these same narratives, the rate was 40%. If our conjecture about the function of conversational gestures is correct, preventing speakers from gesturing should increase the relative frequency of nonjuncture pauses and other dysfluencies.

In the experiment reported here, we examined the effects of preventing speakers from gesturing as they described animated action cartoons to a listener. We also artificially manipulated the difficulty of lexical access by constraining what they could say. We expected that the effects of preventing speakers from gesturing would parallel those of constraining their speech.

METHOD

Subjects

Forty-one undergraduates (20 males and 21 females) participated to satisfy a course requirement. All were fluent speakers of English, and all but 1 were native speakers.

Apparatus and Materials

The experiment was run in a small room furnished with two armchairs, a video monitor, and a video camera. The chair used by the subject was fitted with arm extensions and what were described as "electrodes" positioned to contact the palms of the subject's pronated hands. Wires from the electrodes ran to a port in the wall, ostensibly connected to a polygraph in the next room.

Six videotaped excerpts averaging 2 min 45 s in length, edited from Warner Brothers' *Road Runner vs. Wile E. Coyote: The Classic Chase*, were used as stimuli. Each excerpt depicted an episode in which the coyote hatched an elaborate plan to destroy the roadrunner, only to end up hoise by his own petard. The six excerpts were taken from different cartoons and did not portray a coherent sequence of events.

Procedure and Experimental Design

The experiment was described to subjects as a comparison of different psychophysiological recording sites in people experiencing and subsequently describing an event. Subjects were told their skin conductance response would be monitored both while they viewed the cartoons and later as they described the cartoons to a confederate.⁴ Presentation orders for both cartoons and conditions were randomized. In a 2 × 3 within-subjects factorial design, subjects were videotaped as they de-

2. Our description of the speech production process is based on the model proposed by Levelt (1989). The description omits many details of what is an extremely complex process, and many of these details are matters of considerable contention. However, virtually all of the speech production models that have been proposed draw a distinction between conceptualizing and formulating stages of the process.

3. We also believe that conceptual contents encoded in other formats (e.g., motoric) can be represented gesturally, but the data we present concern only spatial content. For a more detailed exposition of this model, see Krauss, Chen, and Chawla (1996).

4. In actuality, no psychophysiological measures were taken; the electrodes were used to provide a credible reason for immobilizing the subjects' hands and arms. The deception, and the reason for it, was revealed in a postexperiment debriefing.

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scribed the cartoons in six experimental conditions. They were told that electrodermal activity would be recorded from their palms for three of the cartoons (*no-gesture* condition) and from their ankles for the other three (*gesture* condition). They were instructed to keep their hands in contact with the electrodes in the no-gesture condition. Gesture condition was crossed with three speech conditions in which the difficulty of lexical access was varied: One (*normal-speech* condition) placed no constraints on the subjects' speech; in the other two, the subjects were instructed either to try to use as many obscure words as possible (*obscure-speech* condition) or to avoid using words that contained a specified letter (*constrained-speech* condition).⁵

Subjects' narratives were transcribed verbatim, and the locations of all filled pauses, silent pauses, truncated sentences, word fragments, and repeated words were marked. The narratives were partitioned into sequences of phonemic clauses—short word strings each marked by a single intonation contour and a primary stress (Boomer, 1965; Dittmann & Llewellyn, 1967). The frequency, duration, and location of gestures were coded from the videotapes using a locally designed computer-aided system.

RESULTS

Effects of Obscure- and Constrained-Speech Conditions

Did the instructions for the obscure- and constrained-speech conditions affect the language subjects used in their narratives? Because a word's frequency and its syllabic length tend to be inversely correlated (Zipf, 1935), we would expect to find longer words in the obscure condition than in the other two speech conditions, and that was indeed the case. The mean for the obscure condition was 1.40 syllables, compared with 1.26 and 1.29 syllables in the normal and constrained conditions, respectively, $F(2, 78) = 9.86, p < .0001$. The three speech conditions differed reliably from each other in their mean syllabic lengths: normal versus obscure: $F(1, 40) = 12.41, p < .001$; obscure versus constrained: $F(1, 40) = 6.49, p < .02$; normal versus constrained: $F(1, 40) = 4.94, p < .05$.

We also would expect the obscure and constrained instructions to have produced speech that was lexically more diverse than normal speech. The type-token ratio (TTR: the ratio of the number of different words in a sample [types] to the number of words [tokens]) is a commonly used measure of lexical diversity. Mean TTRs for the normal, obscure, and constrained conditions were 0.350, 0.386, and 0.374, respectively, $F(2, 78) = 5.92, p < .01$. The normal condition differed from both the obscure condition ($F[1, 40] = 14.42, p < .001$) and the constrained condition ($F[1, 40] = 6.34, p < .02$); the obscure and constrained conditions did not differ ($F < 1$). It appears, then, that our instructions in the obscure- and constrained-speech conditions accomplished the intended purpose of making lexical selection more difficult.

5. The design systematically varied *c* and *d* as the letters to be avoided in the constrained condition. Because no differential effects were found, the two letters are treated interchangeably in the analyses.

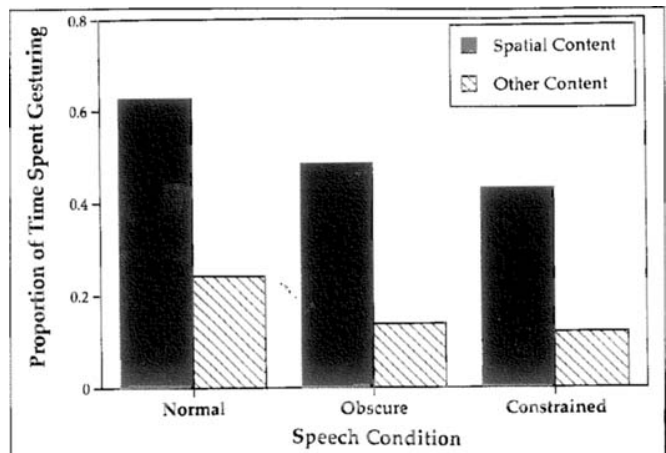


Fig. 1. Proportions of speaking time spent gesturing for spatial and nonspatial content. Rates are shown for the normal-, obscure-, and constrained-speech conditions.

Gesturing and Speech Content

If lexical movements reflect spatial mental representations, we would expect gesturing to be most frequent when the conceptual content of the speech is spatial. In English, spatial content often is associated with spatial prepositions. We identified all of the phrases in our subjects' narratives that contained spatial prepositions; we refer to these phrases as *spatial content phrases* (SCPs).⁶ Then, for each narrative, we calculated the proportion of the speaking time that the speaker spent gesturing during SCPs and during other phrases. Overall, gesturing occurred about three times more often during SCPs ($M_s = .514$ vs. $.167$; $F[1, 40] = 333.98, p < .0001$). The means for the three speech conditions are shown in Figure 1.

Content and fluency

Because gesturing is so strongly associated with spatial content, we would expect preventing gestures to have particularly marked effects on fluency in SCPs. Speech rate (words per minute) varied reliably as a function of speech condition ($F[2, 80] = 75.90, p < .0001$) and content ($F[1, 40] = 8.02, p = .007$). Overall, speakers spoke more rapidly in the normal-speech condition than in the obscure- or constrained-speech conditions, and when the content was nonspatial than when it was spatial. The effect of preventing the speaker from gesturing depended on content, $F(1, 40) = 13.91, p < .001$. The mean speech rates are shown in Figure 2. With spatial content, speakers spoke more slowly when they could not gesture. However, when the content was nonspatial, speakers spoke more rapidly when they could not gesture. This latter result is puzzling to us, and we have no explanation for it.

Content and dysfluency

For each narrative, we counted the total number of dysfluencies that occurred in SCPs, and divided that total by the

6. About 30% of all phrases in our corpus were spatial content phrases, and their relative frequency did not differ as a function of speech condition ($F < 1$).

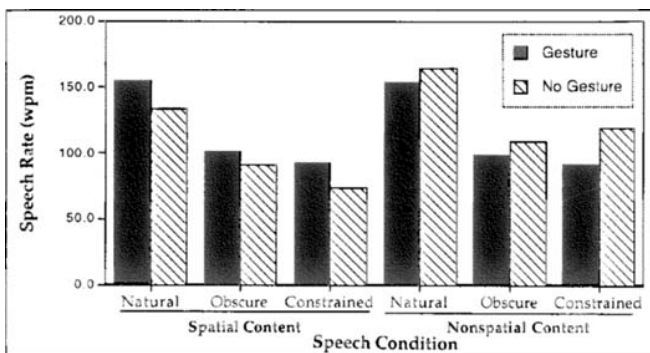


Fig. 2. Speech rate (words per minute) in the normal-, obscure-, and constrained-speech conditions. Rates are shown for spatial and nonspatial content and when subjects were and were not allowed to gesture.

number of words in spatial phrases in that narrative; we did the same for dysfluencies in phrases without spatial content. The results of this analysis parallel those found for speech rate. Speakers were more dysfluent overall in the obscure- and constrained-speech conditions than in the normal condition ($F[2, 78] = 38.32, p < .0001$), and they were more dysfluent during SCPs than during other phrases ($F[1, 39] = 18.18, p < .0001$). Content and speech condition also interacted significantly, $F(2, 78) = 11.96, p < .0001$. Finally, a significant Gesture \times Speech Condition \times Content interaction ($F[2, 78] = 4.42, p = .015$) indicates that the effects of preventing gesturing depended on whether the conceptual content of the speech was spatial or nonspatial. When the content was spatial, preventing gesturing increased the rate of dysfluency (.291 vs. .266 dysfluencies per word; $F[1, 40] = 3.58, p < .066$), but for nonspatial content, dysfluency rates with and without gesturing did not differ (.227 vs. .221 dysfluencies per word, respectively; $F < 1$).

Filled Pauses

Preventing speakers from gesturing adversely affected their ability to produce fluent speech when the content of that speech was spatial. However, a variety of factors can cause a speaker to speak slowly and dysfluently. Is it possible to ascertain whether the adverse effects of preventing gesturing were due specifically to increased difficulty with lexical access? The measure that most sensitively reflects problems in lexical retrieval is the way filled pauses are distributed with respect to grammatical junctures. When lexical access is difficult, we should see an elevation of the relative rate of nonjuncture filled pauses.

We calculated the conditional probability of a nonjuncture filled pause (i.e., the probability that a filled pause would be a nonjuncture filled pause) in SCPs and found reliable main effects for both speech condition ($F[2, 80] = 49.39, p < .0001$) and gesture condition ($F[1, 40] = 8.50, p < .006$). Making lexical access more difficult by requiring speakers to use obscure words or to avoid words containing a particular letter increased the proportion of nonjuncture filled pauses. In speech with spatial content, preventing gesturing increased the likelihood that

filled pauses would fall within grammatical clauses rather than at the clause boundaries. The means are shown in Figure 3.

DISCUSSION

Speakers are more likely to gesture when the content of their speech is spatial than when it is not. When they cannot gesture, they have more difficulty producing speech with spatial content. The effects of restricting gesturing parallel the effects of making lexical access more difficult by other means, except that restrictions on gesturing seem to affect mainly speech with spatial content. Speech contains more dysfluencies, and a greater proportion of filled pauses are intraclausal, when speakers are prevented from gesturing than when they are allowed to gesture. We believe that these data implicate conversational hand gestures in the speech production process—specifically, in lexical access. According to our theory, lexical movements derive from spatially encoded knowledge, and they facilitate lexical retrieval by cross-modally priming the semantic features that enter into lexical search during grammatical encoding.

An alternative possibility is that gesture suppression affects the conceptualizing, rather than the formulating, stage of the speech production process. Certainly, it is possible that gesturing helps the speaker conceptualize the spatial relations that will be expressed in speech, and it would not be surprising if difficulties at the conceptual level resulted in slow and dysfluent speech. However, although we cannot definitively reject this alternative hypothesis, our results argue against it. Requiring speakers to use obscure or constrained speech decreased the likelihood that a filled pause would fall at a grammatical juncture. Preventing speakers from gesturing accomplished the same thing. Such intraclausal (nonjuncture) dysfluencies are widely believed to be associated with problems in word finding. Hence, although we believe speakers probably do employ gestures for conceptual as well as for lexical purposes, we think it unlikely that such uses played an important role in our study.

It might be argued that remembering to keep one's hands still while talking requires some cognitive effort, and that our results simply reflect diminished processing capacity. Such a cogni-

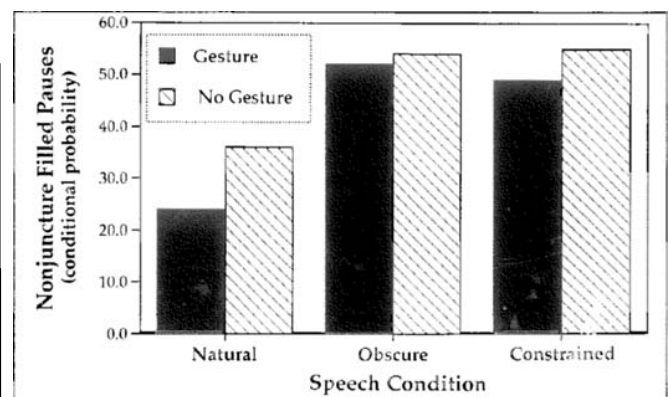


Fig. 3. Probability of a nonjuncture filled pause given a filled pause in spatial content phrases. Mean rates are shown for the normal-, obscure-, and constrained-speech conditions when subjects were and were not allowed to gesture.

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tive-overload explanation fails to account for the fact that the deleterious effects of preventing gesturing are specific to speech with spatial content. When the content of speech is nonspatial, preventing gesturing may facilitate speech rate.

Recently, several investigators have addressed the question of how the gesture production and speech production systems are related (Kendon, 1983, 1987; Levelt, Richardson, & La Heij, 1985; McNeill, 1992; Rimé & Schiaratura, 1991), and have produced quite different accounts of the relation. Our findings bear directly on this issue. An autonomous view, put forward by Levelt et al. (1985), holds that "the two systems are independent during the phase of motor execution, the temporal parameters having been preestablished in the planning phase" (p. 133). Previous work examining the time course of gestures and their lexical affiliates has undermined the tenability of this position (Morrel-Samuels & Krauss, 1992). The present study's finding that preventing speakers from gesturing affects their ability to produce fluent speech further strengthens the view that the speech production and gesture production systems interact.

Our results also raise questions about the widespread assumption that the speech processor consists of a set of self-contained modules. According to one proponent of the modularity view (Levelt, 1989), the grammatical and phonological encoders are encapsulated within the formulator module and receive no outside input apart from that passed on by the conceptualizer module. However, speech production is affected by whether or not the speaker is able to gesture, and that finding seems inconsistent with a strong version of the modularity assumption.

Although it seems reasonably clear that what we call lexical movements facilitate a speaker's ability to produce speech with spatial content, our account of how they accomplish this is both highly speculative and underspecified. For example, it is far from clear how a set of movements can represent spatial conceptual relations, and whether these representations are holistic and noncompositional, as McNeill (1992) claimed, or composed of a set of elementary spatial features, as we contend. Another important question is the role lexical movements might play in the production of speech with conceptual content that is not spatial. Although in our study speakers gestured at a considerably higher rate during spatial content than during other content, people also gesture when talking about such abstract matters as justice, love, finances, and politics, and it is not obvious how conceptual contents of this sort can be represented gesturally. Finally, as we noted earlier, the functions of gestures at the conceptual stage of speech production are not well understood.⁷ Nevertheless, despite these (and other) lacunae in current understanding of the way conversational gestures affect speech, we believe there is adequate reason to conclude that their use benefits speakers as much as or more than it does their addressees.

7. For more extended discussion of these and other unresolved issues, see Krauss, Chen, and Chawla (1996).

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