Cognition 132 (2014) 174–180

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Verbal working memory predicts co-speech gesture: Evidence from individual differences

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ARTICLE INFO

Article history:
Received 2 October 2012
Revised 9 February 2014
Accepted 28 March 2014
Available online 8 May 2014

Keywords:
Gesture
Language production
Working memory
Lexical access
Individual differences

ABSTRACT

Gesture facilitates language production, but there is debate surrounding its exact role. It has been argued that gestures lighten the load on verbal working memory (VWM; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001), but gestures have also been argued to aid in lexical retrieval (Krauss, 1998). In the current study, 50 speakers completed an individual differences battery that included measures of VWM and lexical retrieval. To elicit gesture, each speaker described short cartoon clips immediately after viewing. Measures of lexical retrieval did not predict spontaneous gesture rates, but lower VWM was associated with higher gesture rates, suggesting that gestures can facilitate language production by supporting VWM when resources are taxed. These data also suggest that individual variability in the propensity to gesture is partly linked to cognitive capacities.

1. Introduction

People often gesture with their hands while speaking. There is considerable evidence that listeners can benefit from speakers' gestures, particularly if the gestures reinforce the information conveyed in speech (e.g., Valenzeno, Alibali, & Klatzky, 2003). However, speakers often gesture in the absence of an audience (Alibali, Heath, & Meyers, 2001), and speakers who are blind from birth gesture – even to blind listeners (Iverson & Goldin-Meadow, 2001). These findings suggest that in addition to a communicative function, gesture may serve speaker-internal needs. At the same time, there is individual variability in the propensity to gesture and, currently, the sources of this variation are largely unknown (Alibali, 2005; cf. Hotsetter & Alibali, 2007). Understanding what drives some speakers to gesture more can thus help to elucidate the types of cognitive processes that gesture may benefit and the mechanisms by which those benefits accrue.

Here we test two prominent hypotheses explaining how gesture might aid language production. One is that gesturing aids speakers by "lightening the load" on verbal working memory (VWM) during language production (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Ping & Goldin-Meadow, 2010; Wagner, Nusbaum, & Goldin-Meadow, 2004). Speakers are more likely to recall a word list if they can gesture during a description task that separates the encoding and retrieval of the list suggesting that gesturing can free up VWM resources during speech (as well as spatial working memory; Wagner et al., 2004), which allows for better maintenance of the load during the description phase (Goldin-Meadow et al., 2001). This effect has been observed independent of whether the items being described in the intervening task are present, suggesting that the memory benefits afforded by gesture

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http://dx.doi.org/10.1016/j.cognition.2014.03.012
0010-0277/

are not solely due to speakers using gesture to index objects in the immediate environment (Ping & Goldin-Meadow, 2010). Wagner et al. (2004) suggest that gesture reduces working memory load by providing an organizing framework for language production that affords better use of VWM resources (e.g., chunking); cf, Kita, 2000.

A second hypothesis is that gesture supports lexical retrieval by facilitating word activation (Krauss, 1998; Krauss, Chen, & Gottesman, 2000, Rauscher, Krauss, & Chen, 1996). Krauss and Hadar (1999), Krauss et al. (2000) Lexical Retrieval Hypothesis (LRH) argues that some iconic gestures,[1] i.e., those that reflect the meaning of the speech, specifically aid in lexical access through cross-modal priming: The motor representation of the activated concept primes the phonological form of the associated word via semantics. Some evidence for the LRH comes from the timing of gestures in relation to speech. The initiation of gestures precedes the articulation of their lexical affiliates by approximately a second, and gestures terminate at approximately the same time at which the articulation of the associated word begins (Morrel-Samuels & Krauss, 1992). Relatedly, late-talkers (i.e., children with delayed onset of productive, expressive vocabulary) use communicative gestures more than typically developing children (Thal & Tobias, 1992), suggesting that gesture rates may be related to vocabulary size as well as lexical retrieval.

The "lightening the load" hypothesis and LRH similarly predict benefits of gesture for language production, and, indeed, these hypotheses are not necessarily mutually exclusive. In this paper we test the predictions of these two accounts by examining whether individual differences in speakers' tendencies to spontaneously gesture during a language production task are related to their working memory resources and/or lexical access abilities. If individuals who are less verbally fluent or have smaller vocabularies produce more iconic gestures, then this would support the hypothesis that lexical retrieval difficulties are a primary driving force for gesture production. If individuals with lower working memory capacity gesture more overall, this supports the "lightening the load" hypothesis and, importantly, extends it by suggesting that a driving force for the spontaneous production of gestures during speech may be points in which working memory is taxed.

The current study used two complex span tasks to measure individuals' VWM capacities. We assume that lexical retrieval is associated with at least two factors: the number of words a speaker knows and how quickly those words can be retrieved from the mental lexicon (for a similar suggestion see Bialystok, Craik, & Luk, 2008). Therefore, lexical retrieval abilities were measured using a standard vocabulary test, and phonemic and semantic verbal fluency tasks (Tombaugh, Kozak, & Rees, 1999), which require speakers to retrieve words from a particular letter or semantic category under time pressure (see Hotsetter & Alibali, 2007). Vocabulary has been found to be highly correlated with measures of confrontation naming (e.g., the Boston Naming Test, $r = .83$; Hawkins and Bender, 2002), which are commonly used to index word finding abilities in older adults and clinical populations (e.g., Calero et al., 2002; Schmitter-Edgecombe et al., 2000), but which, in educated young adults, yield scores that cluster around the mean, producing low sensitivity for indexing individual differences (Hamby, Bardi, & Wilkins, 1997). Fluency tasks, which are used in a wide range of neuropsychological assessments, are complicated and known to be associated with multiple cognitive processes. However, performance on verbal fluency tasks (and especially semantic fluency) has regularly been used to measure lexical retrieval abilities among various populations (bilinguals: Bialystok et al., 2008; Gollan, Montoya, & Werner, 2002; Luo, Luk, & Bialystok, 2010; children: Riva, Nichelli, & Devoti, 2000; schizophrenics: Allen, Liddle, & Frith, 1993; Vinogradov et al., 2003) and has been shown to be correlated with both vocabulary size (Bialystok et al., 2008; Luo et al., 2010) and picture naming abilities (Calero et al., 2002; Schmitter-Edgecombe et al., 2000). Thus, verbal fluency has been assumed to be tied to at least some of the processes involved in normal lexical retrieval.

2. Method

2.1. Participants

Fifty University of Illinois Urbana-Champaign undergraduates (18 male) participated in the experiment. All participants were native English speakers and received course credit for their participation.

2.2. Individual differences battery

2.2.1. Listening span

This task was a computer-based version of the Listening Span task used in Stine and Hindman (1994). Critical trials began with participants listening to a recorded sentence. As soon as the recorded sentence ended, they were prompted to determine whether the sentence was true or false, and made responses by a keypress. Between each sentence a letter was presented auditorily. At the end of a set of sentences, participants were asked to recall the letters that they heard in order by typing the letters. Participants completed 10 critical sentence sets in a random order (2 each at set sizes of 2–6). Two practice trials at set size 2 preceded the critical trials. The task was scored according to the Partial-Credit Unit-Weighted method (Conway et al., 2005).

2.2.2. Subtract two span

The task was a computer-based version of the Subtract Two Span task in Salthouse (1988). Critical trials began with a set of digits (0–9) presented one at a time for one second each on a computer screen. Participants read the digits aloud as they appeared. Immediately after digit presentation, participants were required to mentally subtract two from each of the digits retained in memory and recall the resulting answers in the order in which the digits were presented. Set sizes ranged from 2 to 7 and were presented in a random order. Two practice trials at set size 2 preceded the critical trials. The task was scored according to

[1] Krauss (1998) refers to these gestures as lexical gestures.