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Research report

Is the coupled control of hand and mouth postures precursor of reciprocal relations between gestures and words?

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ABSTRACT

We tested whether a system coupling hand postures related to gestures to the control of internal mouth articulators during production of vowels exists and it can be precursor of a system relating hand/arm gestures to words. Participants produced unimanual and bimanual representational gestures expressing the meaning of LARGE or SMALL. Once the gesture was produced, in experiment 1 they pronounced the vowels "A" or "I", in experiment 2 the word "GRÀNDE" (large) or "PÌCCOLO" (small), and in experiment 3 the pseudo-words "SCRÀNTA" or "SBÌCCARA". Mouth, hand kinematics and voice spectra were recorded and analyzed. Unimanual gestures affected voice spectra of the two vowels pronounced alone (experiment 1). Bimanual and both unimanual and bimanual gestures affected voice spectra of /a/ and /i/ included in the words (experiment 2) and pseudo-words (experiment 3), respectively. The results support the hypothesis that a system coupling hand gestures to vowel production exists. Moreover, they suggest the existence of a more general system relating gestures to words.

1. Introduction

Gesture is a universal feature of human communication. In every culture speakers produce gestures, although their extent and typology vary. Some gestures, called gesticulation, are produced simultaneously with speech. Gesticulations can be representational when they specify features of the conversation object, or deictic when they indicate an object, a person, a direction, a location, and more abstract referents such as "past time", or, finally, they can be motoric when they emphasize some parts of the conversation. Other gestures are usually produced alone even if some of them can be produced associated with the word of the same meaning. They are iconic if they derive from pantomime of transitive (i.e. directed to an object) actions, or symbolic (emblems) when they have no apparent relation to objects or actions they represent, or signs, i.e. the "words" used by deaf people [1,2].

There are two views about the relationships between gesture and speech. The first posits that gesture and speech are two different communication systems [3–5]. According to this view, gesture works as an auxiliary support when the verbal expression is temporally disrupted or word retrieval is difficult. An alternative view [1,2] posits that gesture and speech form a single system of communication, since they are linked to the same thought processes even if they differ in expression modalities.

The link between gesture and speech (and in general language) may be the result of the activity of a system evolved from a class of neurons recorded in monkey premotor area F5. This class discharges when commanding a grasp with the hand or the mouth [6]. This system (the dual hand–mouth command system), by controlling both hand and mouth actions, can be involved in transferring aspects of the meaning of manual actions to mouth postures, and, vice versa, aspects of meaning of mouth actions to hand postures. The function of understanding the meaning of hand and mouth actions can be carried out by a system developed from the class of the mirror neurons, recorded in the monkey premotor area F5 [7,8]. This class discharges when the animal performs a hand (or mouth) action and it observes the same action performed by another individual. Rizzolatti and Craighero [9] proposed that, by matching the visual representation of the action with the motor representation of the same action, the mirror neurons could be involved in understanding the action meaning.

A system reciprocally relating hand and mouth is active in humans. Gentilucci et al. [10] found that the grasp with the hand (or the mouth) of either a large or a small object affected the simultaneous opening of the mouth (or hand fingers): this was larger when grasping the large than the small object. Similarly, Gentilucci and Campione [11] found that postures of hand (or mouth) pantomiming the holding of a large or a small object affected the successive grasping of an object. This effect consisted in an increase

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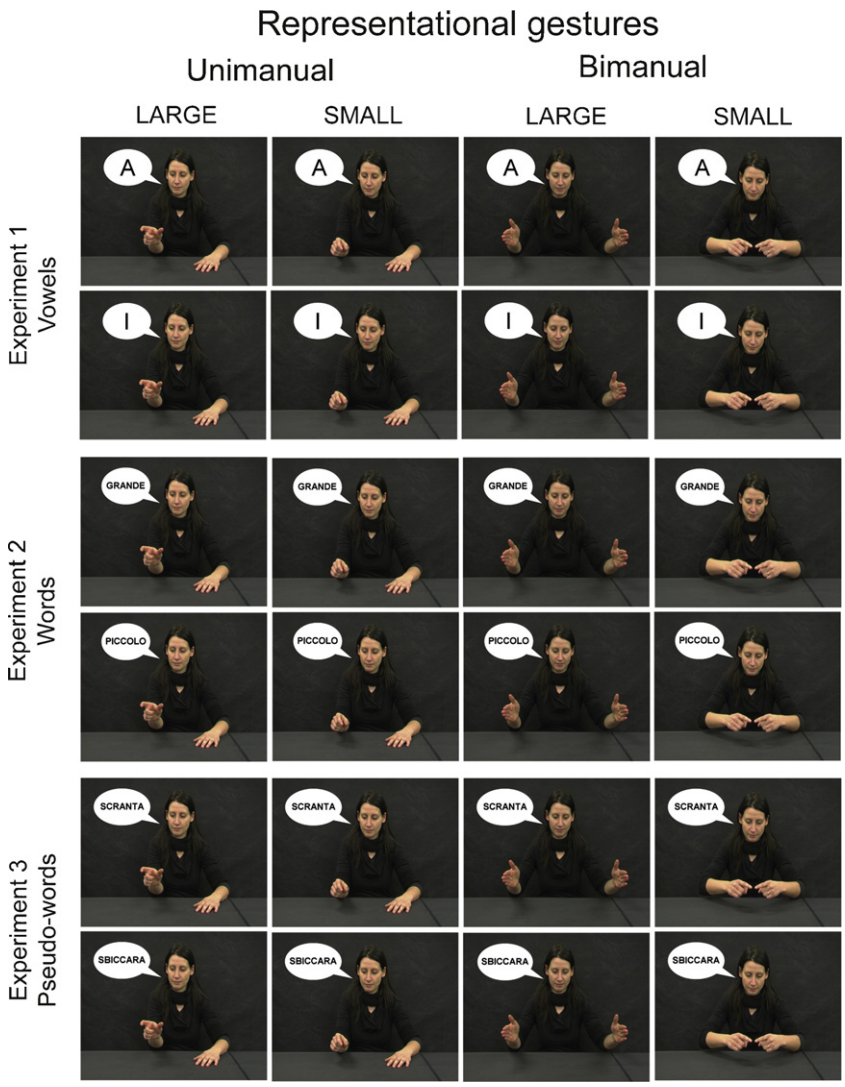

Fig. 1. Stimuli presented in experiments 1–3. The panels show all the combinations between gestures and printed vowels ("A" and "I", experiment 1) or gestures and printed words ("GRÀNDE" and "PÍCCOLO", experiment 2) or gestures and printed pseudo-words ("SCRÀNTA" and "SBÌCCARA", experiment 3). The representational gestures LARGE and SMALL could be executed with the right hand (unimanual gestures) or both hands (bimanual gestures).

and decrease in hand (or mouth) shaping when the mouth (or hand) pantomimed the holding of a large and a small object, respectively.

If the hypothesis that the system reciprocally relating hand and mouth is precursor of a system reciprocally relating gestures and speech is true, then parameters of vowel voice spectra, and in general phonemic units, which are related to postures of mouth phonatory organs [12], should affect and should be affected by the control of the grasp. Indeed, this occurred: Gentilucci and Campione [11] found that when pronouncing the open vowel /a/, which is characterized by a larger aperture of the internal mouth, the finger shaping of a simultaneous grasp was larger than when pronouncing the closed vowel /i/, which is characterized by a smaller internal mouth aperture. Conversely, Gentilucci et al. [10] found that the hand grasp of a large object induced an increase in voice parameters of simultaneously pronounced syllables if compared to the hand grasp of a small object.

The next problems to be solved in order to validate this hypothesis are whether hand postures expressing meaningful gestures affect vowel production and whether the same or similar effects are also observed during pronunciation of words whose meaning was related to the gesture. We addressed these problems in the present study. We chose to study the effects of the representational gestures LARGE and SMALL, produced by aperture/closure of the fingers of the right hand (unimanual gesture) or both the hands (bimanual gesture, Fig. 1), on vowel pronunciation (/a/ and /i/, experiment 1) and pronunciation of the words /'grande/ (large) and /'pikkolo/ (small) (experiment 2). Since we hypothesized that the system relating hand and vowel is the precursor of a system relating hand and word, we expected similar effects of hand gesture on /a/ and /i/ of the vowels produced alone and the same vowels included in the words. Specifically, the gestures LARGE and SMALL will be associated to larger and smaller internal mouth aperture and consequently to higher and lower formant 1 (F1) [13], respectively. We chose unimanual and bimanual gestures in order to test whether a different size representation could be constructed when presenting vowels and words. Specifically, we expected a relation between unimanual gesture and pronunciation of vowels alone (experiment 1). This could be consequent to the hypothesized existence of a simpler system coupling aperture of fingers of the same hand with mouth aperture [11]. Concerning the relations between gesture and word (experiment 2), we hypothesized a size representation of gesture influenced by semantics, which could be unrelated to the effectors producing the gesture. If this was the case, by the comparison of the absolute sizes presented by the