

# Symbolic Gestures enhance Foreign Language Vocabulary Learning

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## Introduction

Vocabulary acquisition represents a major challenge in foreign language learning. A long tradition in cognitive psychology has shown that verbal information is better retained if accompanied by self-performed co-speech gestures [1]. Similarly, recent studies have also demonstrated an enhancing role for gestures in foreign language learning [2]; specifically, the use of gestures during word learning facilitates new vocabulary retrieval even if the words are abstract and must

be combined with an arbitrary gesture [3]. This is consistent with a growing body of evidence indicating that multisensory training has an impact on learning [4]. However, if gestures are only observed, i.e., not self-performed, the impact on memory diminishes [5]. If the memory gain due to gesturing resides only in the motor component, random gestures might show the same effects as symbolic gestures by adding motor complexity to the verbal code.

## Hypothesis

Symbolic co-speech gestures accompanying new words have an impact on memory. Random gestures might show the same effect as symbolic gestures.

## Predictions

Symbolic gestures accompanying new words in the foreign language enhance learning. They create sensorimotor networks. Random gestures being inconsistently paired with the words might show the same behavioral effect and also create sensory motor networks.

## Behavioral Study

### Methods

#### Participants

33 subjects (mean age 23.17, M = 25, SD = 1.61, 17 females, 16 males)

#### Task

Foreign language vocabulary learning

#### Stimuli

92 single words from Vimmi, an artificial corpus conforming with Italian phonotactic rules

#### Training material

5-sec instruction videos representing an aspect of the word's semantics and 1-sec audio files in foreign language (Vimmi)

Design: within subjects design

#### Training conditions

Symbolic gestures and random gestures accompanying the single words in the foreign language

#### Training procedure

Participants cued to imitate 5-sec instruction videos for a total training time of 2 hours daily for four days. 46 words were trained with symbolic gestures and 46 were trained with random gestures.

### Behavioral testing

Retrieval assessed daily through single-word translation tests.

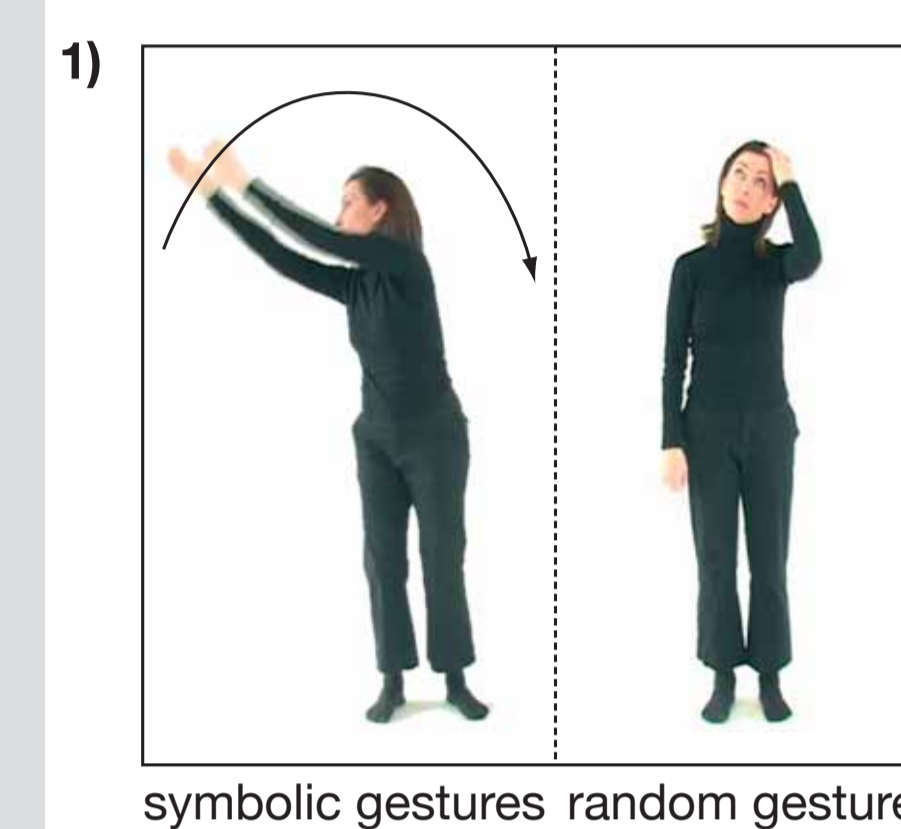
### Results

Items encoded with symbolic gestures were significantly better retrieved in both translation directions at all time points,  $F(1,32) = 20.40$ ,  $p < 0.001$  (aggregated data).

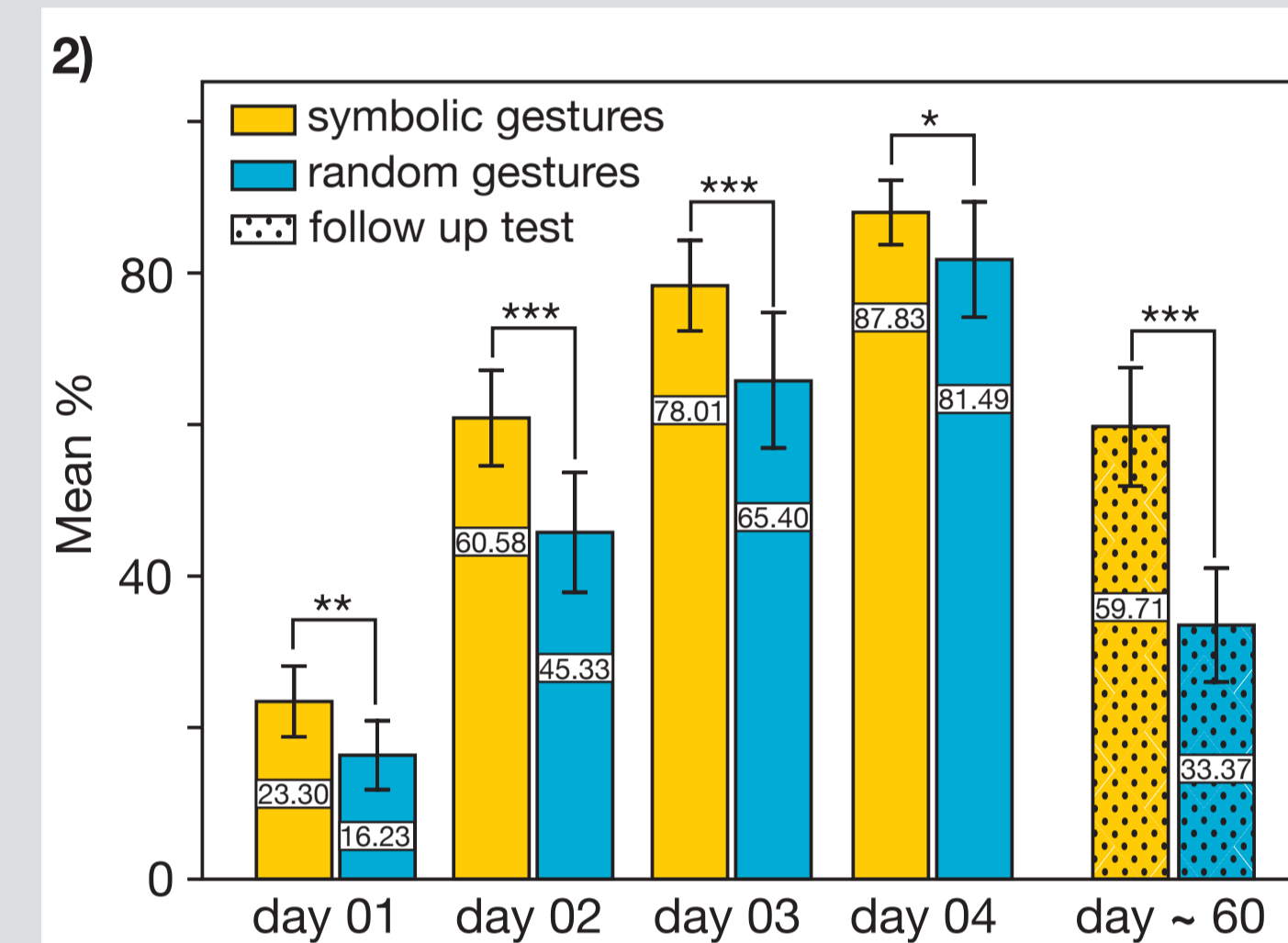
A follow-up test after ~60 days revealed dramatic information decay for the words encoded through random gestures.

### Conclusion

Performing symbolic gestures during learning has a significantly better impact on memory for new vocabulary items (1st to 4th day and after ~60 days) compared to using random gestures.



**Fig. 1:** Images from the videos used for the two training conditions: symbolic (here the word *bridge*, a bow with both hands) and random gestures. The videos showed an actress performing the gestures to be imitated. The written word appeared at the bottom of the screen with its German translation and was played aloud.



**Fig. 2:** Participants' retrieval of the learned items was assessed through written translation tests ~24 hours after every training session and approximately 60 days after the first training. The data in the graph are aggregated and averaged for translation direction. Figure error bars represent +/- 2 SE. \*P < 0.05, \*\*P < 0.01, \*\*\*P < 0.001.

## fMRI Study

### Methods

#### Participants

18 randomly selected subjects who participated in the behavioral experiment (mean age 23.44, M = 25, SD = 1.38, 10 females, 8 males).

#### Stimuli

Written words and audiofiles. 96 learned words, 23 unknown items, 23 silent periods; no training videos shown.

#### Task in the scanner

word recognition. Instruction: "If the word you hear and read is unknown to you, press the key with your left hand".

#### fMRI Data Acquisition & Analysis

3-T scanner (Bruker Medspec 30/100)

20 axial slices, 4 mm thick, 1-mm interslice distance, FOV 19.2 cm, data matrix of 64 x 64 voxels, inplane resolution of 3 x 3 mm; every 2 sec during functional measurements, BOLD sensitive gradient EPI sequence, TR = 2 sec; TE = 30 msec; flip angle = 90°; acquisition bandwidth = 100 Hz. high-resolution whole-head 3-D brain scans: 128 sagittal slices, 1.5-mm thickness, FOV 25.0 x 25.0 x 19.2 cm, data matrix of 256 x 156 voxels.

#### fMRI data analysis

LIPSIA software package [6], Bayesian probability analysis [7]

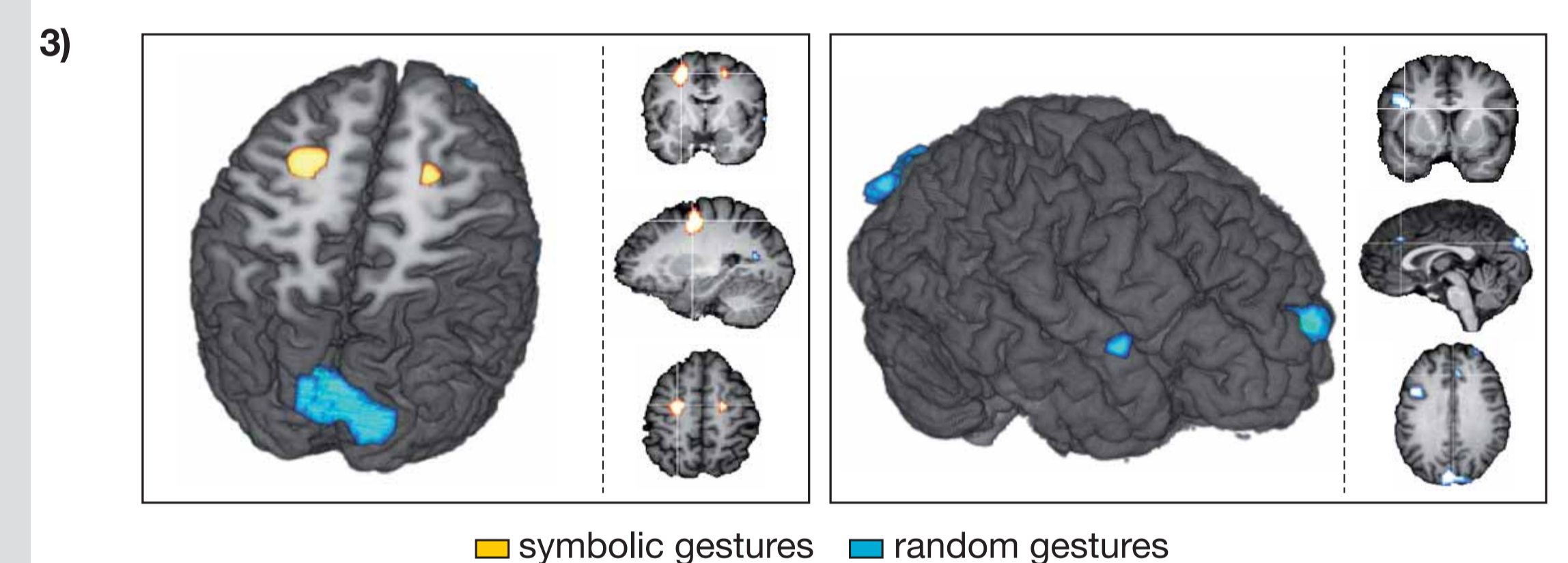
### Results and Discussion

**Symbolic gestures** connected with words map motor programs in motor cortices in a somatotopic way [8].

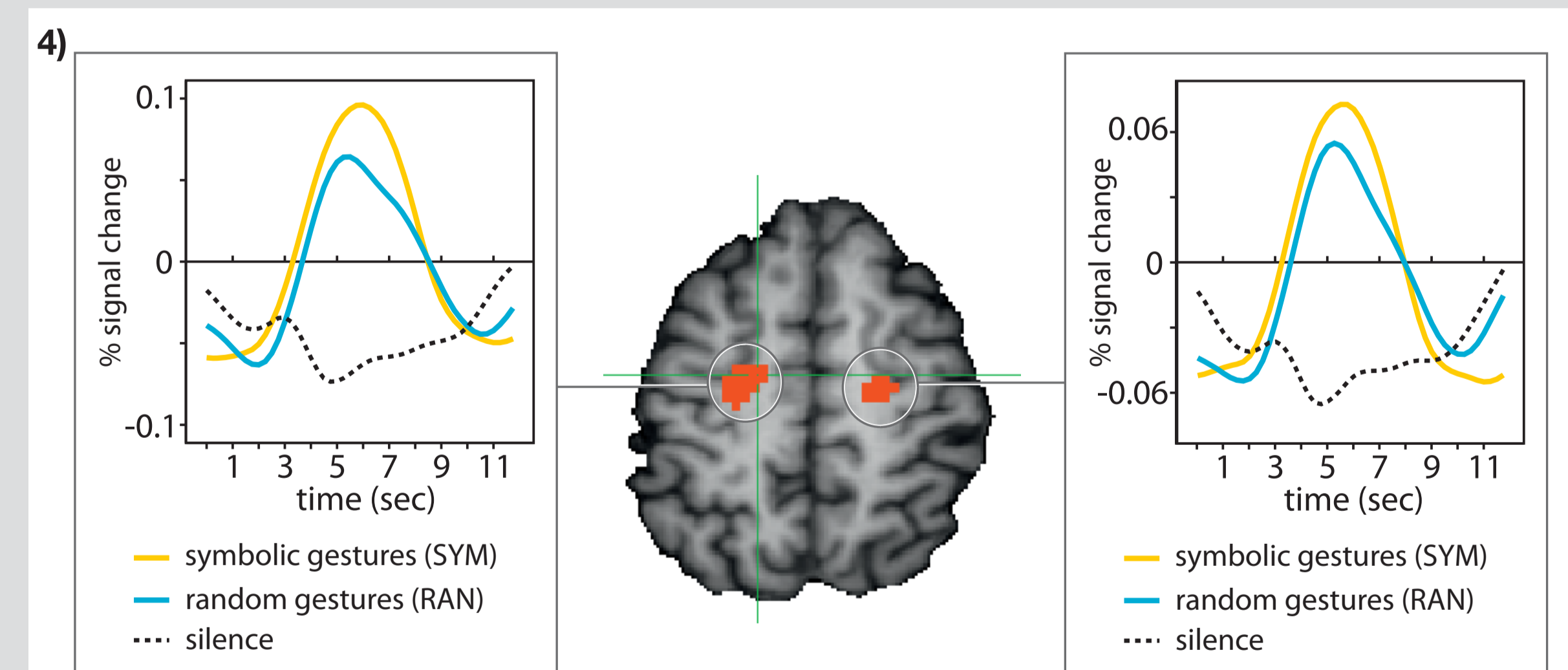
- Activity in premotor cortex is induced by unintentional motor simulation processes occurring even without visual cue of the action [9].
- Activity results from resonance of the network [10].

**Random gestures** connected with words cause interference and activate a network for cognitive control.

- The brain detects conflicting factors and incongruence (anterior cingulate gyrus, BA 32 [11], posterior cingulate gyrus, BA 18, inferior parietal junction BA 9 [12]).
- The brain tries to integrate the different sensorial information components (cuneus, BA 19 and superior temporal gyrus, BA 22).
- The brain does not succeed in integrating the information and suppresses [13] the conflicting information component (frontopolar cortex, BA 10), i.e. the random gesture.



**Fig. 3:** fMRI study results: Main contrast for symbolic gestures vs. random gestures. Motor encoding through symbolic gestures elicits activity in the dorsal pre-motor cortices (BA6). Random grooming gestures create a bilateral large-scale network mirroring cognitive control. Color-coded regions show clusters with high Bayesian posterior probability of condition.



**Fig. 4:** Areas in the motor cortices of significant signal intensity changes (in red). Time courses are given for the most significant voxel of each cluster.

## Conclusion

The behavioral part of this study has shown that co-speech gestures must be congruent, and hence have symbolic value, in order to enhance verbal learning.

The fMRI-experiment has demonstrated that symbolic gestures create a motor program connected with the word. Random gestures accompanying words fail to do this: instead they cause interference and involve brain

areas engaged in cognitive control. These areas detect and suppress conflicting information components.

### Acknowledgements

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### References

- Zimmer, H.D., *Memory for action: a distinct form of episodic memory?* 2001, Oxford: Oxford University Press, ix, 205 p.
- McCafferty, S.G. and G. Stam, *Gesture: second language acquisition and classroom research*. ESL and applied linguistics professional series. 2008, London: Routledge, xii, 327 p.
- Macedonia, M., *Voice Movement Icons. Sensorimotorische Encodierungsstrategie zur Steigerung der quantitativen und qualitativen Lerneffizienz bei Fremdsprachen*. Doctoral Dissertation, University of Salzburg, Austria, 2003.
- Shams, L. and A.R. Seitz, *Benefits of multisensory learning*. Trends in Cognitive Sciences, 2008, 12(11): p. 411-417.
- Hornstein, S.L. and N.W. Mulligan, *Memory for actions: Enactment and source memory*. Psychonomic Bulletin & Review, 2004, 11(2): p. 367-372.
- Lohmann, G., et al., *LIPSIA—a new software system for the evaluation of functional magnetic resonance images of the human brain*. Comput Med Imaging Graph, 2001, 25(6): p. 449-57.
- Neumann, J. and G. Lohmann, *Bayesian second-level analysis of functional magnetic resonance images*. Neuroimage, 2003, 20(2): p. 1346-1355.
- Hauk, O., I. Johnsrude, and F. Pulvermüller, *Somatotopic representation of action words in human motor and premotor cortex*. Neuron, 2004, 41(2): p. 301-307.
- Umiltà, M.A., et al., *I know what you are doing, a neurophysiological study*. Neuron, 2001, 31(1): p. 155-65.
- Tettamanti, M., et al., *Listening to action-related sentences activates fronto-parietal motor circuits*. J Cogn Neurosci, 2005, 17(2): p. 273-81.
- Melcher, T. and O. Gruber, *Decomposing interference during Stroop performance into different conflict factors: An event-related fMRI study*. Cortex. In Press, Corrected Proof.
- Brass, M., et al., *The role of the inferior frontal junction area in cognitive control*. Trends in Cognitive Sciences, 2005, 9(7): p. 314-316.
- Depue, B.E., T. Curran, and M.T. Banich, *Prefrontal regions orchestrate suppression of emotional memories via a two-phase process*. Science, 2007, 317(5835): p. 215-219.

LOBE	Left hemisphere					Right hemisphere				
	BA	x	y	z	mm <sup>3</sup>	BA	x	y	z	mm <sup>3</sup>
<b>Frontal</b>										
Middle frontal gyrus	6	-24	-9	48	1,971	6	18	-9	51	216
Inferior frontal gyrus	9	-45	9	30	1,107					
Superior frontal gyrus						10	24	57	24	837
<b>Occipital</b>										
Cuneus	19	-6	-90	30	2,835					
<b>Limbic</b>										
Cingulate gyrus						32	3	30	33	243
Posterior cingulate gyrus	18	-27	-66	15	135					
<b>Temporal</b>										
Superior temporal gyrus						22	60	-3	3	108

**Fig. 5:** fMRI main contrast result [Symbolic Gestures – Random Gestures]