Grasping ideas with the motor system: Semantic somatotopy in idiom comprehension

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Embodied Cognition

Semantic mechanisms draw upon and are grounded in action-perception systems of the brain (Barsalou, 2007; Glenberg, 2007; Martin, 2007; Pulvermüller, 2005)
Tettamanti et al. (2005) found somatotopic activation during processing of action-related words and sentences.

Hauk et al. (2004) observed that only simple referential meaning of words and sentences has been examined. Does semantic somatotopy persist during processing of abstract/idiomatic sentence meaning?
Predictions

If the grounding of semantics in the sensory-motor system is a universal feature of the human cognitive system:

action-perception information should play a role in determining the landscape of semantic brain activation to sentences, even if their meaning is highly abstract.

Our study

Pattern of fMRI activation during reading of idioms that include arm- and leg-related action verbs

« He grasped the idea »
« He kicked the habit »
Methods

Participants
18 healthy right-handed English native speakers

Stimuli
76 English idiomatic expressions
76 literal sentences
  including arm- or leg-related action verbs

« John grasped the IDEA » vs. « John grasped the OBJECT ».
« Mary kicked the HABIT » vs. « Mary kicked the BALL ».

Action word  “Critical word”

Methods

Stimuli
Critical words were matched for relevant psycholinguistic variables.

Arm- and leg-related action words were matched for the same variables.

76 baseline stimuli (### ####### ###)

6 probe sentences (e.g. « He opened the door »)
Methods

Experimental procedure

Sentences were presented word by word (500 ms)

- Silent reading task
  + Answer to simple yes/no questions about probe sentences (e.g. « Did he open the door? ») with left fingers
  - measure of error rates

- Motor Localizer task
  perform small movements of left and right index fingers and feet (4 times for 20 s each time)

Methods

fMRI data analysis

Metabolic activity related to semantic integration at the sentence level was found to be maximal at about 6-8 s after sentence completion (Humphries et al., 2007) or even later (Simmons et al., in press).

Two time-windows for analysis:
- Early: HRF response time-locked to the onset of critical words
- Late: HRF response time-locked to a point delayed by 3 s after critical words
**Methods**

**fMRI data analysis (1)**

- 2 left-lateralized ROIs from the « motor localizer task »
  - « hand motor area »
  - « foot motor area »

Four-way ANOVA:

- Time-Window (early vs. late) x
- Idiomaticity (idiomatic vs. literal) x
- ROI (hand area vs. foot area) x
- Semantic Reference of verbs (arm vs. leg)

**Methods**

**fMRI data analysis (2)**

- 2x9 ROIs along the motorstrip (central sulcus and precentral gyrus; 25 ≤ z ≤ 76 mm)

Four-way ANOVA:

- Time-Window (early vs. late) x
- Dorsality (dorsal vs. lateral regions) x
- Idiomaticity (idiomatic vs. literal) x
- Semantic Reference of verbs (arm vs. leg)
Results

Behavioral Results

Error rates for probe sentences = 8.3 % (SE 2.45)

Participants paid attention to the task

Results

fMRI Results: « motor localizer »

Time-Window x ROI x Reference interaction (p = .013)
ROI x Reference interaction (p = .014) in the late analysis window
Results

fMRI Results: « motor localizer »

Idiomatic sentences including leg-related action words activated more strongly the left foot motor area vs.

Idioms including arm-related action words activated more strongly the left hand motor area

Results

fMRI Results: Motorstrip

Time-Window x Dorsality x Reference interaction (p < .001)

Cortical activity along the motorstrip was modulated by semantic reference of the verbs differently for the 2 time-windows

Dorsality x Reference interaction (p <.001) in the late analysis window
Results

fMRI Results: Motorstrip

Dorsal regions (z ~ 75 mm): cortical activity was stronger for sentences including leg-related action verbs vs. Lateral regions (25 ≤ z ≤ 50 mm): stronger activity was observed for arm-related sentences

Discussion

- Silent reading of idioms that include action words recruits the motor cortex somatotopically
- Semantic somatotopy was evident in the late analysis window, where sentence level meaning is computed
- Our results support theories that view abstract semantics as grounded in action-perception systems (Barsalou, 2007; Pulvermüller, 2005)
- Time-course of motor activity during idiom processing using MEG
Conclusion

The orchestration of abstract meaning is not solely explained by the activation of unspecific semantic centers in fronto-temporal cortex, but it involves late complementary activations in the motor system. These referentially grounded activations may play a specific role in the composition of sentence meaning.

Thank you