Verb Semantics modulates neural activity in the left Lateral Temporal Cortex

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Introduction:

How event concepts and the verbs conveying those concepts are represented in the human brain remains to be fully clarified. Romagno et al. (2012) found that telicity modulates neural responses to verbs in the posterior portion of the left middle temporal gyrus (lMTG). Other studies showed a higher activation for non-dynamic (state) verbs (e.g., to stay) than dynamic (action) verbs (e.g., to eat) (Peelen et al., 2012), and a somewhat related preference for low-motion relative to high-motion verbs (Bedny et al., 2008, 2012), in lMTG/superior temporal sulcus. Thus, while the left lateral temporal cortex (lLTC) has been consistently implicated in event knowledge and verb processing (Kemmerer et al., 2012; Kable et al., 2005; Bedny et al., 2012; Willms et al., 2011), how event and verb properties differentially modulate neural activity within the distinct lLTC subregions remains unsettled (Crepaldi et al., 2011; Vigliocco et al., 2011). The present study aimed at disentangling the roles of distinct event features, including telicity, dynamicity and agentivity in the modulation of neural activity within lLTC.

Methods:

Here, we re-analyzed a dataset from a previously reported study (Romagno et al., 2012). In brief, fMRI (GE 1.5T) was used to examine neural activity in 22 [6F; age (mean ± SD): 28 ± 5 years] right-handed native Italian healthy volunteers while they performed a match-to-sample task, unaware of the real aim of the study. Stimuli were telic (e.g., to die), atelic state (= non dynamic and non agentive: e.g., to exist) and atelic activity (= dynamic and agentive: e.g., to walk: Vendler, 1967) verb infinitives, matched for frequency, length, number of core arguments, durativity, animacy, arousal and valence. Blocks consisted of 4 stimuli, presented sequentially for 1.5s each, followed by a 7s-gap and a 1.5s-probe stimulus consisting of an inflected verb form (e.g., [they] walk). Volunteers had to answer whether the probe corresponded to one of the four infinitives included in the previous block. Data pre-processing and group analysis were performed with the AFNI package. Repeated-measures ANOVA and post-hoc comparisons identified how verb features were represented at a cortical level.

Results:

Group mean (±SD) performance accuracy was 95.0±0.1% and reaction times were 810.0±207.3 ms, with no differences across conditions. Brain regions showing a significant (corrected $p<0.05$) feature effect included left anterior and posterior MTG (laMTG, lpMTG), left inferior parietal cortex, left anterior fusiform/parahippocampal cortex and anterior cingulate (AC). Atelic state and activity verbs, unlike telic verbs (Romagno et al., 2012), elicited a stronger response in laMTG and AC, and in the left inferior parietal and anterior fusiform/parahippocampal clusters, respectively.

Conclusions:

Implicit processing of telicity, dynamicity and agentivity differentially modulated neural activity

across different brain clusters and, in particular, within lMTG. We found that selectivity for state and telic verbs identified the most anterior and the most posterior portion of lMTG, respectively. Furthermore, dynamicity and agentivity modulated brain responses in parietal and ventral extrastriate regions. The role of each property was clearly isolated, as the stimuli were specifically controlled for and the task design covertly assessed the representation of those properties. Different event types are differentially mapped based on their semantic representation and, in particular, lMTG represents conceptual semantic properties of verbs: specifically, that kind of conceptual information which is relevant to morphosyntax, i.e., telicity (Romagno et al., 2012), stativity, agentivity.

Language:

Language Comprehension and Semantics

Bedny, M. (2008), 'Concepts are more than percepts: The case of action verbs', Journal of Neuroscience, vol. 28, no. 44, pp. 11347–11353.
Bedny, M. (2012), 'Typical neural representations of action verbs develop without vision', Cerebral Cortex, vol. 22, no. 2, pp. 286–293.
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Kable, J. W. (2005). Conceptual representations of action in the lateral temporal cortex', Journal of Cognitive Neuroscience, vol. 17, no. 12, pp. 1855–1870.
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Verb Semantics modulates neural activity in the left Lateral Temporal Cortex

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INTRODUCTION

- The left lateral temporal cortex (lLTC) has been consistently implicated in event knowledge and verb processing *(1-4)*. However, how event and verb properties differentially modulate neural activity within the distinct lLTC subregions remains unsettled *(5,6)*
- We previously showed that telicity modulates neural responses to verbs in the posterior portion of the left middle temporal gyrus (lMTG) (*7*, Fig.1A-B)

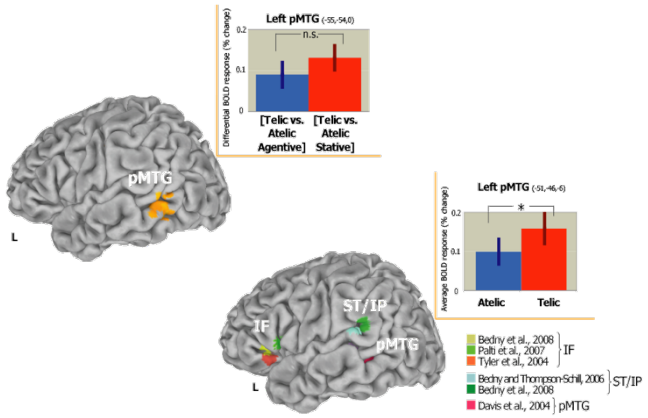

Fig. 1. Processing of Telic vs. Atelic Verbs *(7)*

- Other studies showed a higher activation for non-dynamic (state) verbs (e.g., *to stay*) than dynamic (action) verbs (e.g., *to eat*) *(8)*, and a somewhat related preference for low-motion relative to high-motion verbs *(9)*, in lMTG/superior temporal sulcus
- **The present study aimed at disentangling the roles of distinct event features, including telicity, dynamicity and agentivity, in the modulation of neural activity within lLTC**

METHODS

Participants

22 [6F; age (mean ± SD): 28 ± 5 years] right-handed native Italian healthy volunteers. The study was approved by the University of Pisa Ethical Committee. All participants signed a written informed consent prior to enrollment in the study.

Stimuli

– Telic (e.g., *to die*), atelic state (= non dynamic and non agentive: e.g., *to exist*) and atelic activity (= dynamic and agentive: e.g., *to walk*: *10*) verb infinitives , matched for cumulative frequency (663.01±813.75 (mean ± SD); p=0.81, Kruskal Wallis), word length in letters (8.36±1.72; p=0.94), number of core arguments, animacy of verb subject, durativity, emotional valence (6.30±1.35; p=0.076) and arousal (4.24±1.12; p=0.055).

Experimental Paradigm

– A match-to-sample task repeated for 60 blocks (20 per condition, one condition per block) across 6 different runs.
– In each block, 4 stimuli were presented sequentially for 1.5 s each (verb encoding), followed by a 7 s-maintenance gap and a 1.5 s-probe stimulus, consisting of an inflected verb form (e.g., *camminano, [they] walk*) (Fig. 2).
– Volunteers responded by button pressing on the match between the probe and one of the previous four infinitives.

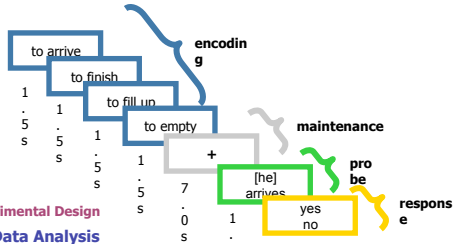

Fig. 2. Experimental Design

MRI Scanning and Data Analysis

– 1.5T GE scanner: GRE-EPI images (TR = 2,500 ms, 33 slices, 4-mm-thick axial images, FOV = 24 cm, TE = 30 ms, flip angle = 90, voxel size = 3.75 mm x 3.75 mm x 4 mm, 148 brain volumes for a total of 6 series), as well as high-resolution FSPGR images (124 slices, 1.2-mm-thick sagittal images, FOV = 24 cm).
– AFNI and SUMA packages (http://afni.nimh.nih.gov/afni)[11] for data analysis.
– Repeated-measures ANOVA and post-hoc comparisons to identify how verb features were represented at a cortical level
– Group-averaged Z scores for each verb class were used to weight RGB representation in Figure 3

RESULTS

Behavioral Results

Group mean (±SD) performance accuracy was 95.0±0.1% and reaction times were 810.0±207.3 ms, with no differences across conditions.

fMRI Results

Brain regions showing a significant (corrected p<0.05) feature effect included left anterior and posterior MTG (laMTG, lpMTG), left inferior parietal cortex, left anterior fusiform/parahippocampal cortex and anterior cingulate (AC). Atelic state and activity verbs, unlike telic verbs (7), elicited a stronger response in laMTG and AC, and in the left inferior parietal and anterior fusiform/ parahippocampal clusters, respectively.

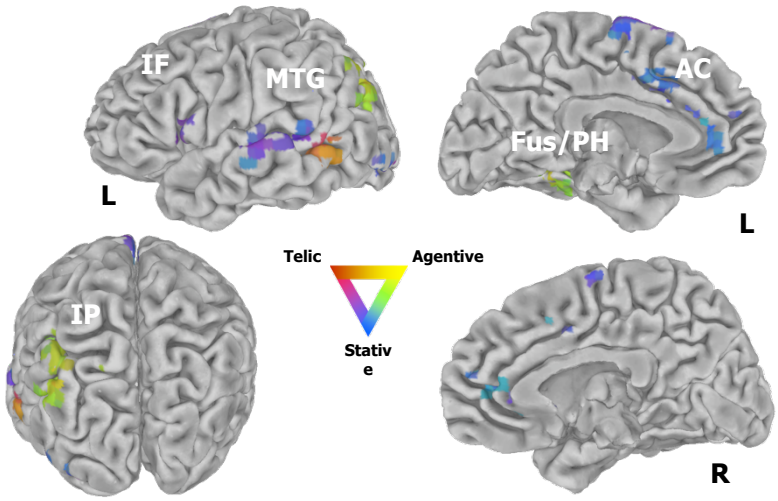

Fig. 3. Processing of Telicity, Stativity, Dynamicity and Agentivity

CONCLUSIONS

- **Implicit processing of telicity, dynamicity and agentivity differentially modulated neural activity across different brain clusters and, in particular, within lMTG.**
- We found that selectivity for state and telic verbs identified the most anterior and the most posterior portion of lMTG, respectively. Furthermore, dynamicity and agentivity modulated brain responses in parietal and ventral extrastriate regions.
- The role of each property was clearly isolated, as the stimuli were specifically controlled for and the task design covertly assessed the representation of those properties.
- Different event types are differentially mapped based on their semantic representation and, in particular, lMTG represents conceptual semantic properties of verbs: specifically, that kind of conceptual information which is relevant to morphosyntax, i.e., telicity *(7)*, stativity and agentivity, which unlike referential semantic features, and independently of them, govern morphosyntax in a specified way.

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