EMG-recorded hand motor response during passive action sentence processing

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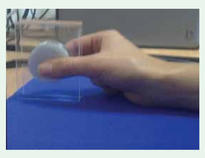
Introduction

Functional neuroimaging [1,2], EEG [3] and TMS [4] studies have shown an implication of the motor system during action language processing such as action verbs (e.g. «to nail») and tool names (e.g. «hammer»). Peripheral motor activity modulations, believed to result from central motor modulations, have also been recorded during action language processing through a force sensor [5].

Recent evidence suggests that the motor implication is modulated by linguistic [6,7] as well as conceptual [8,9] parameters.



There is, however, debate regarding whether or not the motor system is necessary to comprehend action language, and whether it plays a role in an online or a post-comprehension process [10].

This study aims to determine whether :

(1) hand EMG can capture modulations of peripheral motor activity (reflecting activity in the motor cortex) in relation to manual action language processing
(2) motor activity is modulated by specific linguistic parameters: sentence type, linguistic context, prosody
(3) these modulations vary for tool noun and action verb, located in different phrases of the sentence

Method

Participants: 20 (10 women) healthy adults, aged 20 to 50 years, right-handed, native speakers of French Canadian, with no prior history of neurological, psychiatric or language disorders.
Pre-testing: hearing (Figure 1), cognitive abilities (MoCA), prosody discrimination (Figure 2)

Task: passive auditory language processing while performing a distractor task (visual detection). Participants were instructed to indicate, by a left foot movement, any change in a visual pattern.

Stimuli: 180 manual action sentences

«With her scissors, Sarah cuts the newspaper.»

associated to manual action

bisyllabic

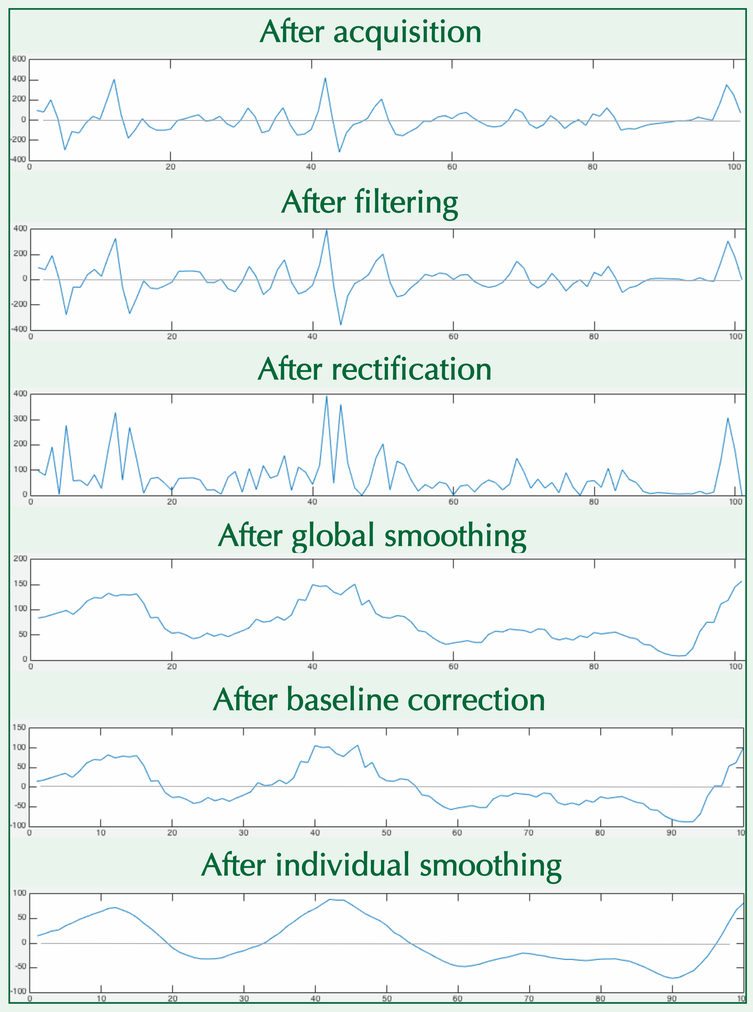
Tool names / Action verbs

ciseaux	découpe
cuillère	mélange
crayon	dessine
couteau	épluche
guenille	essuie
mouchoir	frotte
pinceau	peint
marteau	cloue
raquette	frappe
stylo	signe

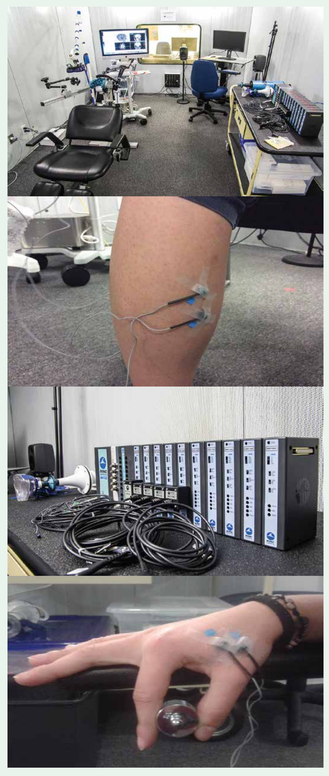
associated to same manual action

controlled number of syllables

controlled frequency of occurrence



Variable			
Sentence type	Affirmation … Sarah découpe …	Simple Negation … Sarah découpe pas …	Double Negation … Sarah ne découpe pas …
Semantic context	Positive Avec ses ciseaux, …	Neutral Dans le jardin, …	Negative Sans ses ciseaux, …
Prosody	Rising		Falling



Electromyography:

- Biopac, 4mm Ag/AgCl pairs of reusable electrodes
- Measure of action potentials at surface of first dorsal interosseus (FDI) of right hand
- Direct measure of peripheral motor responses
- High temporal resolution
- No artificial induction of motor responses

Acquisition:

- Gain: 5000Hz
- Sampling rate: 1000Hz
- Low-pass filter: 500Hz

Signal processing:

- 10Hz order 2 Butterworth high-pass filter
- 55-65Hz order 2 Butterworth band-stop filter
- Artefacts rejection
- Signal rectification
- Signal segmentation in 300ms time windows
- Whole signal 9-point width moving average smoothing
- Baseline correction (percent change)
- Individual 9-point width moving average smoothing

Measure:

Mean amplitude in 2 time windows for noun and verb:

- During target word: 0-300ms after word onset
- After target word: 300-600ms after word onset

Results

Figure 1 Pure tone thresholds

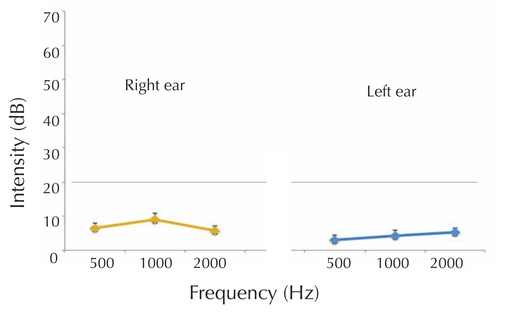


Figure 2 Prosody discrimination

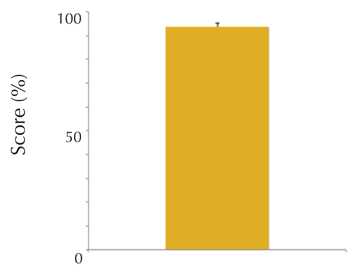


Figure 3 Motor response during tool noun

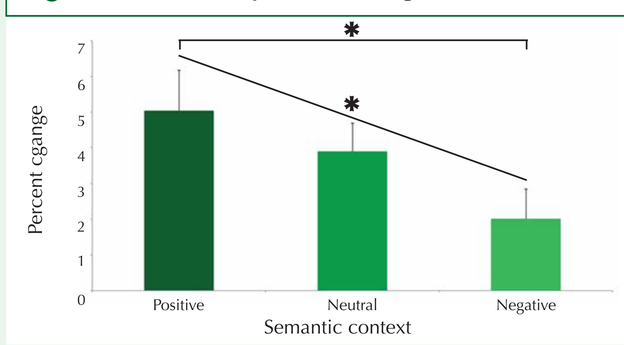
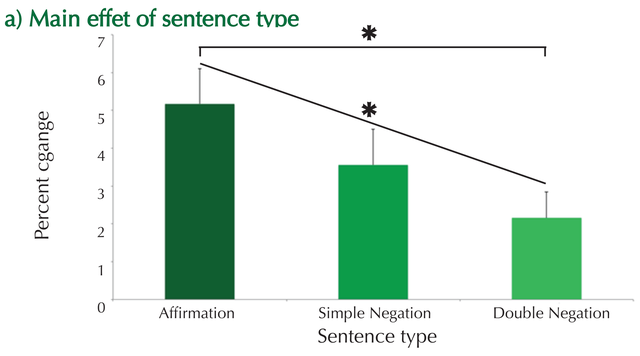
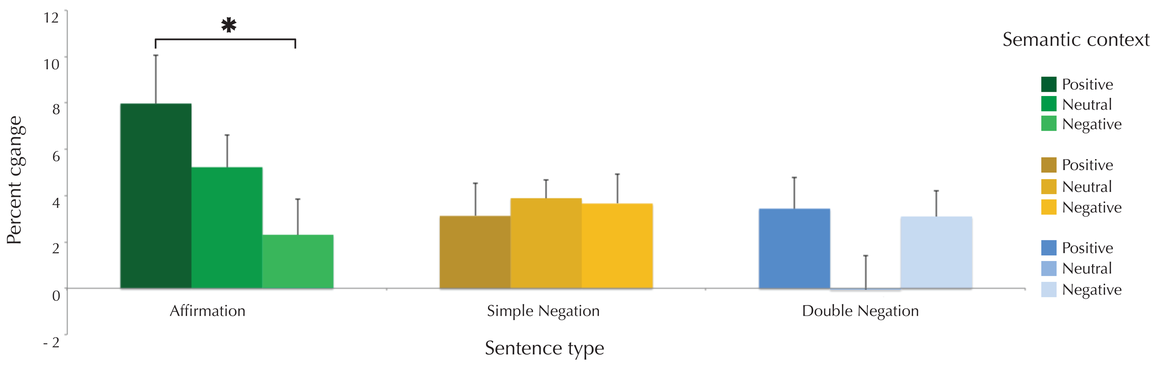


Figure 4 Motor response during action verb

a) Main effet of sentence type



b) Sentence type x Semantic context interaction



Discussion

Semantic context effect during noun processing (Figure 3)

During tool noun processing, motor response in FDI is significantly higher when semantic context is positive than when it is negative. A significant linear trend shows that motor response in FDI decreases linearly from positive, to neutral to negative semantic contexts.

Sentence type effect during action verb processing (Figure 4)

During manual action verb processing, motor response in FDI is significantly higher when the sentence is affirmative than when it is a double negative sentence. A significant linear trend shows that the motor response decreases as a function of negativity (Figure 4a). The interaction between sentence type and semantic context (Figure 4b) reveals that the semantic context effect is present in affirmative sentences only during the processing of the manual action verb.

These results suggest that the implication of the motor system in semantic processing of action language can be proximal: early context has an impact on motor response during the processing of the tool noun (both occur in the first phrase of the sentence), while sentence type influences motor response during the action verb processing (both occur in the second phrase of the sentence). Early semantic context can also have a distal impact on motor response during action language processing (i.e. on action verb in second phrase of sentence).

There was no effect of prosody on the motor response, despite the fact that it was accurately heard and interpreted by the participants, as shown by our hearing assessment and prosody discrimination task (Figures 1 & 2).

Conclusion

These results support the notion of an implication of the motor system during action language processing. Here we show for the first time that EMG can capture modulations of peripheral motor activity in relation to language processing. We also show that the impact of linguistic factors on motor response can be proximal (e.g. effect of semantic context during tool noun processing), as well as distal (e.g. effect of semantic context during action verb processing in affirmative sentences).

Further research aiming to determine which linguistic, but also conceptual parameters (such as attentional focus or motor imagery abilities) may influence motor activity is needed to continue uncover the neurobehavioral and neurophysiological mechanisms underlying motor and language interactions.

References

[1] Tremblay & Small (2010) Cerebral Cortex. [2] Hauk et al. (2004) Neuron. [3] van Elk (2010) Biological Psychology. [4] Tremblay, Sato & Small (2012) Neuropsychologia. [5] Frak et al. (2010) Plos One. [6] Aravena et al. (2012) Plos One. [7] Aravena et al. (2014) Frontiers in Human Neuroscience. [8] Moody & Gennari (2010) NeuroImage. [9] van Dam et al. (2012) Human Brain mapping. [10] Mahon & Caramazza (2008) Journal of Physiology.

Acknowledgments

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