



## Research report

## A facilitating role for the primary motor cortex in action sentence processing

Melody Courson<sup>a,b</sup>, Joël Macoir<sup>a,b</sup>, Pascale Tremblay<sup>a,b,\*</sup><sup>a</sup> Département de Réadaptation, Université Laval, Québec, QC, Canada<sup>b</sup> CERVO Brain Research Center, Québec, QC, Canada

## ARTICLE INFO

## Keywords:

Language embodiment

Context sensitivity

Semantic polarity

Electromyography

## ABSTRACT

The involvement of the motor system in action language comprehension is a hotly debated topic in cognitive neuroscience and psychology. Recent studies suggest that primary motor cortex (M1) response to action language is context-sensitive rather than automatic and necessary. Specifically, semantic polarity (*i.e.* affirmative/negative valence) appears to modulate the intensity of this response, which is stronger for affirmative action sentences. The aim of our study was to examine further the context sensitivity of M1 response. More specifically, we aimed to determine whether M1 response follows semantic polarity or the core meaning of the sentence using two-part action sentences containing interacting polarities. Modulations of M1 activity were recorded using surface electromyography of the first dorsal interosseous muscle of the right hand in 22 healthy participants. Our results show an increase in M1 activity during the first part of the sentence, regardless of semantic polarity. This response was then modulated by the polarity of the second part of the sentence, which carried crucial information regarding the action. These observations suggest that M1 differentially responds to different aspects of action sentences, one response being automatic and the other following the core meaning of the sentence. Our results thus contribute to clarifying the nature of the motor response to action language, which is key to develop more comprehensive and plausible neurobiological models of language processing.

## 1. Introduction

In the last two decades, the existence of a response of the motor system during action language processing has repeatedly been shown by a large number of groups using various cognitive neuroscience methods (*e.g.* [1–7]). However, the precise role of the motor system in action language processing remains a hotly debated topic (*e.g.* [8–10]). The theoretical issue is to determine whether action language processing is embodied, that is, if the motor system takes part in this semantic process or not. For the upholders of a strictly embodied cognition, “specific action representations are activated during action word understanding” [11], a mechanism that is viewed as automatic and necessary to action language comprehension [12,13]. A different view proposes that the motor system does not contain conceptual knowledge of action [14], and that motor activation is due to a spreading from semantic processing areas [5].

Zwaan [10] has proposed that this question will be solved by investigating the conditions under which the motor system is involved in language comprehension. Attentional, lexical, emotional and linguistic contexts have been shown to have an influence on motor response [1,15–17]. Specifically, semantic polarity (*i.e.*, affirmative/negative valence) is a linguistic factor that modulates the amplitude of the motor

response during action language processing. For instance, paired-pulse transcranial magnetic stimulation (TMS) applied over M1 during passive reading of action and control sentences induced a modulation of motor evoked potentials for affirmative action sentences only [18]. Furthermore, by measuring variations in finger pressure, Aravena and colleagues showed that listening to action verbs induces a motor response when they are embedded in affirmative sentences (*e.g.* “Fiona lifts her luggage”), but not in negative sentences (*e.g.* “Fiona *does not* lift her luggage”) [1], thereby confirming that semantic polarity can modulate motor responses during action verb processing. Further characterization of the flexibility of the motor response to action language as a function of polarity will lead to a better understanding of the role of the motor system in action language processing.

The aim of this study was to investigate the time-course of M1 response during the processing of two-part action sentences containing interacting polarities in two different experiments. In study 1, we developed and validated the experimental material that was used in study 2. In study 2, using time-locked electromyography (EMG), we recorded hand motor activity, a proxy for M1 activity, during passive listening of two-part action sentences, composed of a prepositional phrase and a main clause, each containing an action word. Polarity was modulated in the prepositional phrase (Positive, Neutral and Negative) and in the

\* Corresponding author at: Département de Réadaptation, Université Laval, Québec, QC, Canada.  
E-mail address: [pascale.tremblay@fmed.ulaval.ca](mailto:pascale.tremblay@fmed.ulaval.ca) (P. Tremblay).

main clause (Affirmative, Negative). This experimental design allowed us to investigate whether M1 response strictly mirrors polarity throughout the sentence processing, or whether it follows the main polarity of the sentence, conveyed by the main clause. If the polarity of each sentence part modulates the motor cortex response, it would suggest that M1 responds automatically to the polarity context of action language, regardless of the core meaning of the sentence. If, however, the motor response is solely modulated by the main-clause polarity, it would be evidence that this response follows the core meaning of action sentences.

## 2. Study 1

This preliminary study aimed to validate the sentences used in the main experiment (study 2), by determining whether they were semantically understandable and plausible.

### 2.1. Participants

Healthy native speakers of Canadian French were recruited through emails sent to Université Laval students and employees, employees of CERVO, as well as posters distributed in the community. All participants were right-handed [19], had normal or corrected-to-normal vision and no self-reported history of speech, voice, language or neurological disorder. Participants were screened for cognitive functioning (score  $\geq 26/30$ ) using the Montreal Cognitive Assessment (MoCA) [20]. Normal hearing ( $< 25$  dB of hearing loss) was assessed *via* pure-tone audiometry (PTA) at 0.5, 1 and 2 kHz using an AC40 Interacoustics clinical audiometer in a soundproof room. Informed written consent was obtained for each participant. The study was approved by the Committee on Research Ethics of CERVO (project #2013-349). Two participants were excluded from the semantic judgment task analyses because their performance differed from the group performance by over  $\pm 3$  SD of the group mean. The final group consisted of eighteen (18) participants (mean age 26.82 years  $\pm$  6.93; range 20–40 years; 11 women).

### 2.2. Stimuli

All stimuli were produced by a 24-year-old female Canadian French speaker in a double-walled soundproof room. Stimuli were 240 auditory two-part manual action sentences containing a noun in the prepositional phrase and a manual action verb in the main clause (e.g. “Avec ses ciseaux, Sarah découpe le journal”/“With her scissors, Sarah cuts the newspaper”). Ten different action word pairs were created that consisted of matching tool nouns and manual action verbs (e.g. “scissors” and “cuts”) that were conjointly used in 160 sentences. Ten action-neutral nouns (e.g. “kitchen”) were used in the remaining 80 sentences and were randomly matched to the main clause manual action verb. All nouns were two-syllable long. Half of the manual action verbs were one-syllable words while the other half were two-syllable long. The spoken frequency of occurrence of nouns and verbs was controlled using the French database Lexique [21]. The frequency of occurrence of tool nouns and manual action verbs did not significantly differ ( $t_{(9)} = -3.48, p = 0.74, d = 0.18$ ), neither did the tool and neutral-action nouns ( $t_{(9)} = -2.029, p = 0.07, d = 0.91$ ), or the neutral-action nouns and manual action verbs ( $t_{(9)} = -2.053, p = 0.07, d = 0.93$ ). Semantic polarity was manipulated (Fig. 1a). Specifically, prepositional phrases were either positive (e.g. “Avec ses ciseaux”/“With her scissors”), neutral (e.g. “Dans la cuisine”/“In the kitchen”) or negative (e.g. “Sans ses ciseaux”/“Without her scissors”), while main clauses were either affirmative (e.g. “..., Sarah découpe le journal”/“..., Sarah cuts the newspaper”) or negative (e.g. “..., Sarah ne découpe pas le journal”/“..., Sarah does not cut the newspaper”). In this validation study, each participant was presented with 180 of the 240 sentences. The stimuli were pseudo-randomized across participants.

### 2.3. Procedure

Participants were comfortably seated in a Faraday, double-walled soundproof room, facing a computer screen. They were instructed to answer as rapidly as possible by pressing one of two buttons on a Cedrus response pad RB-830 (Cedrus Corporation, San Pedro, USA) with their index and middle fingers of the right hand. Participants were asked to make two judgments on the sentences in separate runs: a semantic judgment and a plausibility judgment. In the semantic judgment task, participants were asked to determine whether an action was carried out or not in each sentence. In the plausibility task, they were asked to indicate whether they were surprised by the outcome of the sentence. Stimuli were presented auditorily through a high-quality headset (Beyerdynamic, DT 770 Pro, Heilbronn, Germany) at an individually adjusted intensity.

### 2.4. Data analysis

For each task, a 2-way repeated-measure analysis of variance ( $3 \times 2$  ANOVA) with prepositional-phrase polarity (positive, neutral, negative) and main-clause polarity (affirmative, negative) as within-subject factors was performed on the percentage of correct responses using SPSS (IBM) for Macintosh (version 23).

### 2.5. Results

In the semantic judgment task, the percentage of correct responses (mean 98.36%; SD 3.37) showed no significant effect of prepositional-phrase polarity ( $F_{(2,30)} = 0.23, p = 0.80, \eta_p^2 = 0.02$ ), or main-clause polarity ( $F_{(1,15)} = 0.38, p = 0.55, \eta_p^2 = 0.03$ ), nor any significant interaction effect ( $F_{(2,30)} = 1.21, p = 0.31, \eta_p^2 = 0.08$ ). In the plausibility task, percentage of correct responses (mean 58.01%; SD 31.48) showed no significant effect of prepositional-phrase polarity ( $F_{(2,34)} = 0.86, p = 0.43, \eta_p^2 = 0.05$ ), or main-clause polarity ( $F_{(1,17)} = 0.18, p = 0.68, \eta_p^2 = 0.01$ ), nor any significant interaction effect ( $F_{(2,34)} = 1.19, p = 0.32, \eta_p^2 = 0.07$ ).

### 2.6. Discussion

Study 1 demonstrated that the sentences are well understood. Although results from the plausibility task showed that sentences were moderately surprising, the semantic judgment task revealed that sentences were very well understood. Importantly, semantic and plausibility judgments did not vary across conditions, revealing that clause polarity does not influence the comprehension of the sentences. Thus, these analyses validate the use of these sentences in the main experiment (study 2).

## 3. Study 2

### 3.1. Participants

Participants were 26 native speakers of Canadian French, recruited through emails sent to Université Laval employees and students, employees of the Institut universitaire en santé mentale de Québec, and flyers distributed in the community. Inclusion and exclusion criteria, as well as the preliminary auditory and cognitive assessments were identical to those of study 1. Two participants were excluded due to technical difficulties, one for a lack of task compliance and one during statistical analyses (see Section 3.5.2). The final group consisted of 22 participants (mean age 35.27, SD = 9.19; range 21–50 years of age; 11 women). Informed written consent was obtained. The study was approved by the Committee on Research Ethics of CERVO (project #2013-349).

Download English Version:

<https://daneshyari.com/en/article/5735040>

Download Persian Version:

<https://daneshyari.com/article/5735040>

[Daneshyari.com](https://daneshyari.com)