Action-Sentence Compatibility Effect: Two Experiments on Motor Resonance in Language Comprehension

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Preliminary Note

- My main sources for this talk:

  1. This work is essentially a short **summary** of [Zwaan 06], focusing on the Experiments **2** and **4** ;

  2. See also
     - [Rizzolatti 99] on motor resonance ;
     - [Glenberg 02] on Action-Sentence Compatibility Effects;
     - and [Gallese 05, Barsalou 99] on issues of language understanding.

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Introduction
Motor Resonance and Mirror Neurons

- Many studies have shown the existence, in animal brains, of neurons firing both when an animal *performs* an action and when the animal *observes* the same action performed by another animal. [Wikipedia 07]
- Such phenomenon is called **Motor Resonance** and the neurons themselves are called **Mirror Neurons**, because they ”mirrors” the behavior of an another animal, as though the observer were itself performing the action.
- Motor resonance has been observed in a wide range of studies, both neurological (single-cell recordings on macaque monkeys) and behavioral.

Introduction
Motor Resonance and Mirror Neurons (2)

Definition

The phenomenon of **Motor Resonance**, which is mediated by the *mirror neuron* system, is characterized by the occurrence, upon *observation* of an action, of the *same neural pattern* that is activated while *performing* the observed action.
[Rizzolatti 99]

Introduction

Motor Resonance and Mirror Neurons (3)

- Mirror Neurons have been shown to be also responsive to an understanding of the *goal* of an action.
- All these findings have given rise to theories of **action understanding**: *"action understanding involves the mental simulation of the observed action"*.
- It is assumed that the skill to mentally simulate *other*'s actions derives from the ability to observe, predict, and control one's *own* actions.

Introduction
Language Comprehension

- Theories of action observation have been extended not only to the domain of action understanding but also to *language understanding* [Gallese 05].
- The idea is that people understand linguistic descriptions of actions by mentally *simulating* these actions.
- On this view, language understanding can be conceptualized as the language-induced **mental simulation** of the described actions. [Barsalou 99]

Introduction
Language Comprehension (2)

- **Question**: *does language comprehension produces motor resonance ?*
- The question can be posed at two distinct levels:
  1. *The* **form** *of the linguistic utterance:* **yes**, it has been demonstrated that hearing phonemes activates, in the listener's speech motor system, the same tongue muscles that are used to produce these phonemes.
  2. *The* **meaning** *of the linguistic utterance:* **yes too**, as some behavioral and neuroimaving studies have showed.

     $\Rightarrow$ This phenomenon is often called the **Action-Sentence Compatibility Effect** [Glenberg 02].

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Introduction
Language Comprehension (3)

Definition

The **Action-Sentence Compatibility Effect** (ACE) is defined as the facilitatory *priming* of manual actions by sentences denoting similar actions. [Bergen 05]

- The two experiments I will now present investigate the eventual presence of *motor resonance in language comprehension* in the specific context of *manual rotation*.
- ... or in other words, the eventual presence of an *ACE* for manual rotation.

First Experiment
Method

- 58 subjects listened to recordings of sentences and were asked after each one if it made sense to them;
- On critical trials, the sentences described **manual rotation actions** (eg. ”He turned down the volume”) ;
- The subjects indicated whether the sentence made sense or not by *turning a knob* with their right hand, either to the right for a yes response and to the left for a no response (half of the subjects) or the other way round (the other half of the subjects).

First Experiment
Design

- Three factors in the design of the experiment:
  1. Implied rotation direction (clockwise or counterclockwise) expressed in the sentences ;
  2. Match: congruence of the implied and manual rotation direction ;
  3. List.
- The implied rotation direction is counterbalanced *across subjects*, and the manual rotation direction is manipulated *between subjects*.
- The response times are then subjected to a $2 \times 2 \times 2$ mixed analysis of variance (ANOVA).

First Experiment
Results

- Most important result: the subjects responded **more quickly** when the rotation implied by the sentence matched their response rotation:
  1. *when there is a match*: the mean (M) = 237 *ms* and standard deviance (SD) = 108 ;
  2. *when there is a match*: the mean (M) = 275 *ms* and standard deviance (SD) = 133.
- It means a 38 *ms* difference, which is statistically significant: $F(1, 57) = 4.28 > 1$.

First Experiment
Results (2)

- The experiment also shows that clockwise manual responses are faster overall than counterclockwise responses: difference of 51 *ms*, which is significant: $F(1, 56) = 4.01 > 1$.

  $\Rightarrow$ Reason ? Apparently, a clockwise rotation can be made more quickly (or more conveniently) with the right hand than a counterclockwise rotation.

- No interaction between match and direction.

First Experiment
Discussion

- Sensibility judgements (ie. "Does this sentence make sense to you?") are hence made **more quickly** when the manual response to the sentence is in the *same rotation* direction as the manual action described by the sentence.
- This result allows us to **extends the ACE** to the domain of manual rotation.
- This experiment provides another evidence that *language processing recruit motor processes*.

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Second Experiment
Goals

- In this experiment, we seek to gain some insight into the *limitations* of the ACE analyzed in the last experiment.
- We are specifically interested in the **modulation** of motor resonance during online comprehension, ie. its *onset* and its *duration*.
- Is it a rather immediate and short-lived effect, or does it extend across word boundaries ?

Second Experiment
Method

- To this end, the subjects are asked to read a sentence *one frame at a time*, by rotating a knob:
  - Each frame shows between one and three words ;
  - each 5° of rotation makes the current frame disappear and a new one appear.
- As in the first experiment, the critical sentences describe actions involving manual rotation.
- The materials is constructed such that there is always one target region in the sentence, at which a specific manual rotation is implied.

Second Experiment
Method (2)

- **Example**: ”To quench / his / thirst / the marathon / runner / eagerly / opened / the / water bottle”.

  $\Rightarrow$ the target is here ”opened”, an action involving a counterclockwise rotation.

- The sentences are divided in four regions:
  1. A preverb region, which includes the seven frames preceding the verb frame;
  2. The target region, which includes the verb implying the rotation;
  3. The third region is the frame immediately following the verb;
  4. The fourth region is the last frame of the sentence.

Second Experiment
Design

- We have four factors:
  1. The sentence region ;
  2. The implied rotation direction in the sentence ;
  3. The match between the implied and manual rotation direction ;
  4. The list.

- The reading times were subjected to a $4 \times 2 \times 2 \times 2$ ANOVA.

Second Experiment
Results

- **Significant interaction** between region and match, due to a statistically significant $22\ ms$ match advantage in the verb region, with $F(1, 56) = 11.04$.
- On the other end, there is **no** match effect in the three others regions (ie. preverb, postverb or final regions).

Second Experiment
Discussion

- The data provide useful insight into the online modulation of sympathetic activation.
- The activation of the neural substrates involved in the actual manual rotation is thus an **immediate** and **local** affair.
- They are consistent with the finding that affordances[1] of referent objects have an *immediate* influence on sentence processing.

[1] generally described as *"an action that an individual can potentially perform in their environment"*

Summary and Conclusion

1. **Motor Resonance** is characterized by the occurrence, upon *observation* of an action, of the *same neural pattern* that is activated while *performing* the observed action.
2. The experiments investigated motor resonance in *language comprehension* in the context of *manual rotation*.
3. The first experiment supports the hypothesis that understanding sentences about manual rotation **activates** the neural substrates of manual rotation:
   - Indeed, we found that manual responses that were congruent with the action described in a sentence were faster than incongruent responses ;
   - This can be seen as an extension of other ACEs.

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4. The second experiment showed that the activation of the neural substrates involved in the actual manual rotation is an **immediate** and **local** affair:
   - Motor resonance was observed *only* on the region of the sentence that specified the rotation direction and did *not* extend beyond it.

5. All these results are consistent with recent theories of **action understanding**, which assume that "people understand others' actions by mentally simulating them through the covert use of their own action repertoire".

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