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

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Preliminary Note

- My main sources for this talk:
 - 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.

Outline I



Introduction

- Motor Resonance and Mirror Neurons
- Language Comprehension

2 First Experiment

- Method
- Design
- Results
- Discussion

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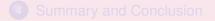
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Outline II



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- Goals
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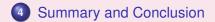
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Motor Resonance and Mirror Neurons Language Comprehension

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.

Motor Resonance and Mirror Neurons Language Comprehension

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]

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Motor Resonance and Mirror Neurons Language Comprehension

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.

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Motor Resonance and Mirror Neurons 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]

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Motor Resonance and Mirror Neurons Language Comprehension

Introduction Language Comprehension (2)

• **Question**: does language comprehension produces motor resonance ?

• The question can be posed at two distinct levels:

- 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.

⇒ This phenomenon is often called the Action-Sentence Compatibility Effect [Glenberg 02].

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Motor Resonance and Mirror Neurons Language Comprehension

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.

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Method Design Results Discussion

First Experiment

- 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).

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Method Design Results Discussion

First Experiment

- Three factors in the design of the experiment:
 - Implied rotation direction (clockwise or counterclockwise) expressed in the sentences;
 - 2 Match: congruence of the implied and manual rotation direction ;
 - 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 × 2 × 2 mixed analysis of variance (ANOVA).

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Method Design Results Discussion

First Experiment Results

- Most important result: the subjects responded more quickly when the rotation implied by the sentence matched their response rotation:
 - when there is a match: the mean (M) = 237 ms and standard deviance (SD) = 108;
 - 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.

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Method Design Results Discussion

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.

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Method Design Results Discussion

First Experiment

- 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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Goals Method Design Results Discussion

Second Experiment

- 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 ?

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Goals Method Design Results Discussion

Second Experiment

- 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.

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Goals Method Design Results Discussion

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:
 - A preverb region, which includes the seven frames preceding the verb frame;
 - The target region, which includes the verb implying the rotation;
 - The third region is the frame immediately following the verb;
 - The fourth region is the last frame of the sentence.

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Goals Method Design Results Discussion

Second Experiment

- We have four factors:
 - The sentence region ;
 - 2 The implied rotation direction in the sentence ;
 - The match between the implied and manual rotation direction ;
 - The list.
- The reading times were subjected to a 4 \times 2 \times 2 \times 2 ANOVA.

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Goals Method Design Results Discussion



- 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).

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Goals Method Design Results Discussion

Second Experiment

- 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 affordances¹ of referent objects have an *immediate* influence on sentence processing.

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

Summary and Conclusion

- 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.
- 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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- 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.
- 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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