

MENTAL SIMULATION IN LANGUAGE COMPREHENSION  
AND SOCIAL COGNITION

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ABSTRACT

Current theories in social cognition and cognitive psychology conceptualize understanding of actions and of language describing actions as the performance of sensorimotor simulations. Although there is emerging empirical evidence for these theories, they are currently underspecified and the evidence is correspondingly coarse. Language is a sensitive tool that allows us to construe actions in myriad ways. This article discusses several challenges that face simulation theories aimed at capturing the subtlety of language.

More than a decade ago, Bargh, Chen, and Burrows (1996) reported an interesting experiment in which subjects created sentences out of words that were provided by the experimenter. In one condition, all of the words were associated with the elderly—e.g., *Florida*, *grey*, *sentimental*, *wise*, and *bingo*—but words explicitly referring to old age were omitted. In the other condition, control words unrelated to the elderly were used. The fascinating part of the experiment came next. After subjects had completed what they thought was the experiment, the experimenter surreptitiously recorded the time it took the subject to walk down the hallway. Interestingly, subjects who had previously composed sentences using words associated with the elderly walked more slowly than subjects who had used the control words. The explanation for this effect was that exposure to the elderly-associated words activated an “elderly stereotype,” which then caused the subjects to adopt a stereotype-consistent walking speed.

What is one to make of results such as these? One option is to examine what kinds of other stereotypes can influence behavior. Many social psychologists have indeed chosen this option (see Bargh, 2006 for a recent review of the extensive literature on stereotypes and priming). Another possibility is to obtain a better understanding of the mechanism that led from exposure to and manipulation of a certain kind of semantic information to modulated walking behavior.

When presented with the results of Bargh et al.'s Experiment 2, we might wonder what it was during the sentence unscrambling task that gave rise to the modulation of walking speed. One could easily imagine a cottage industry developing over this question, in which ever-increasing numbers of research teams explore whether all the words were necessary, only one, or any number in between. Other researchers would wonder whether it was nouns rather than verbs causing the effect. Next, researchers would start to wonder about the order in which the words were presented. They would examine if presentation speed matters and whether the effect would be larger or smaller under an external memory load, or with an auditory instead of a visual presentation of the words, and so on. In short, there is a plethora of questions that could be posed here.

From the theoretical perspective of embodied cognition, the interesting aspect of the Bargh et al, (1996) and related findings (see Bargh, 2006 and Niedenthal et al., 2005 for recent reviews) is that a linguistic stimulus, which was previously thought to be arbitrary, amodal, and abstract, apparently triggers a particular kind of motor behavior that is irrelevant to the task that the subject was ostensibly performing with the stimuli. In the embodied-cognition framework, the subjects' behavior would be explained by positing that they were performing a mental simulation of an elderly person. In Barsalou's (2008, p. 618) definition, a mental simulation is "the reenactment of perceptual, motor, and introspective states

acquired during interaction with the word, body, and mind.” Zwaan (2004) calls these states “experiential traces.”

There are many studies in the literature now that show a close connection between linguistic stimuli and sensorimotor activation. For example, exposure to action words or sentences leads to activation of cortical motor areas that overlap with areas that are active when the action is actually being performed (e.g., Buccino et al., 2005; Pulvermüller Shtyrov, & Ilmoniemi, 2005; Tettamanti et al., 2005). Also, sentences about specific motor actions such as moving your hand toward or away from the body or turning a knob interact with the performance of such actions (Glenberg & Kaschak, 2002; Zwaan & Taylor, 2006). Importantly, the action-word motor activation effect is bidirectional. Prior stimulation of relevant motor areas leads to speeded language processing (Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005; see Fischer and Zwaan, 2008, for a recent review).

The Bargh et al. (1996) experiment and many other experiments in social cognition raise questions for theories of mental simulation. Most studies have examined immediate interactions between linguistic cues and the sensorimotor system, but the effect here occurred after some delay. How to account for this lingering effect? To begin answering this question, one might consider the parameters of motor performance that are affected by the manipulation. Did the subjects just walk more slowly, or did

they also have a different gait and did they also mimic the posture of older adults? To take a more extreme example, if the subjects had had to unscramble sentences with words associated with infants, would they start crawling out of the lab? Most likely not. The effect is presumably more quantitative in nature than qualitative, such that it is less detectable by the individual and thus less correctable. A motor program is activated that is consistent with the subjects' experience of seeing older adults and this affects the parameter settings that control walking speed, but does not drastically alter the motor program that subjects routinely activate to navigate the hallway.

#### Interpreting language-induced sensorimotor effects

Theoretically, there are several ways to interpret language-induced sensorimotor effects. The first possibility is to simply discount these effects as the result of conscious imagery strategies. It is well documented that people are able to generate detailed sensorimotor simulations with conscious effort (e.g., Jeannerod, 1994; Kosslyn, 1980). However, it is unlikely that such conscious imagery was involved in many of the experiments showing sensorimotor effects, for example because there was no reason for participants to engage in motor imagery (e.g., during their stroll through the hallway in the Bargh et al. experiment), or because the observed sensorimotor effects were sufficiently immediate to rule out more time-consuming conscious imagery processes.

The second possibility is to accept that non-conscious language-induced motor effects do routinely occur during language processing, but to relegate these effects to an ornamental role, while arguing that the core cognitive tasks are performed by abstract, arbitrary, and amodal representations, as Mahon and Caramazza (in press) propose. In their "grounding by interaction" account, activation cascades down from abstract representations to sensorimotor systems, which accounts for the sensorimotor effects observed in so many experiments. Sensorimotor activation is not irrelevant in this process, but serves to "enrich" the representation. Such a scheme is definitely a logical possibility. The problem at this point, however, is that there is no independent evidence for an abstract layer of representation. In fact, Mahon and Caramazza (in press, p. 9) argue that "(e)xperiments are not required to demonstrate that the scope of the embodied cognition hypothesis is sharply limited up front." This is so, they write, because there are concepts such as "300, 012, incredulous, astute, theory, embodied, false and on an on." The implication is clear: there cannot be an embodied account of such concepts. However, this ignores the fact that proposals for embodied accounts of abstract concepts are already in the literature (e.g., Arbib, in press; Barsalou, 1999; Barsalou, and Wiemer-Hastings, 2005; Gallese & Lakoff, 2005). For example, Barsalou (1999, pp. 601-602) offers an embodied account of the concept "false," among other concepts. Whether or not these

accounts will have sufficient explanatory power and will stand up to empirical scrutiny is a different question, but a defeatist attitude might be premature, and so might be the need to assume an layer of abstract symbols.

The third possibility is to assume that sensorimotor activation is the “stuff” of language comprehension (e.g., Barsalou, 1999; Glenberg & Kaschak, 2002; Rizzolatti & Arbib, 1998; Zwaan, 2004) and consider the motor activation shown in these experiments as functional and an inherent part of language understanding: the simulation view. A strong version of this view would claim that sensorimotor simulations are necessary for comprehension. A more cautious version of this approach might be to adopt the simulation view until proven otherwise (e.g., by data showing direct evidence for abstract symbols), at which point the grounding-by-interaction view would become a viable candidate. Thus, the tack here would be to take the simulation view “as far as it can go” before perhaps (or not) concluding that there are aspects of language comprehension that it cannot account for. Given that there does not exist any convincing empirical evidence against the simulation view, it is the best theoretical tool at our current disposal to understand language comprehension and social cognition, but it may very well have its limitations.

So the question becomes: how far can the simulation view take us, both in terms of accounting for the uniquely and universal

human feat of linguistic communication and in terms of understanding social cognition in general? In order to begin to address this question, it is necessary to first (1) consider the special nature of language, particularly its capacity for displacement, and (2) put the simulation view in a historical context.

### Language and displacement

All human languages allow users to communicate not only about the present, but also about the past and the future, and even about nonexistent or even impossible events and entities. Hockett (1960) called this capacity for displacement one of the design features of human language. It is useful distinguish between embedded language use, in which language is used to refer to the communicative situation (Spivey & Richardson, in press), and displaced language use in which language refers to a situation removed in time and/or space from the communicative situation, or even to an impossible situation (e.g., in a Gedankenexperiment, in counterfactual reasoning, or in fantasy). In embedded language comprehension, the relation between language and perception/action appears clear and immediate. When someone yells "fire" we all look (and run) for the nearest exit. However, even here mental simulation is at work. A recent finding attests to the role of mental simulation in embedded comprehension. For example, when hearing "He has drunk the beer" subjects fixate an empty beer glass in a visual scene rather than a full one, even

though the content of the full glass corresponds to the meaning of the word "beer" (Altmann & Kamide, 2007). Thus, visual attention is driven by a mental simulation of the described situation, rather than merely by the referential links between individual words and potential referents in the environment.

The role of mental simulation is more immediately obvious in displaced comprehension as there is nothing in the comprehender's environment that is relevant to the comprehension process, which forces the comprehender to rely on sensorimotor experiences already in long-term memory. Displacement makes language a powerful tool for mental simulations, for language is the medium by which mental simulations are shared and shaped across people and cultures. Although there is no need or possibility to map the simulation onto the immediate environment in displaced comprehension, such a mapping can occur at later times and in different environments. The mental simulation is stored in long-term memory and is re-activated at a later point in time, where it influences behavior, much like the walking speed of the subjects of Bargh et al.'s (1996) experiment was modulated by prior exposure to elderly-related words. Displaced language gives rise to mental simulations that reflect potential courses of action, either actual or mental, which can be used to shape later behavior. This is consistent with the idea that language comprehension is not comprehension for comprehension's sake, but is used to better act

in the world (James, 1890; Semin, 2000; Zwaan & Kaschak, in press). For example, reading how a character in a novel solves a delicate interpersonal problem can help us solve similar problems in our own lives (Mar et al., 2006).

#### Putting the simulation view in context

It can be said that the simulation view is a logical extension of theorizing about language comprehension from the 1970s onward. Early theories viewed language comprehension primarily as forming a mental representation of the linguistic input, as for example argued in a very influential paper (Kintsch & van Dijk, 1978). However, in an equally influential book the same two authors argued later that language comprehension is tantamount to creating a mental representation of the state of affairs described by the linguistic input, a situation model, rather than to creating a mental representation of that input per se (van Dijk & Kintsch, 1983). There is a great deal of evidence for situation models (see Radvansky & Dijkstra, 2007 and Zwaan & Radvansky, 1998 for reviews). To mention just one out of many examples, when subjects read the sentence pair "The President left the building. A moment later, a bomb exploded" and are asked after the second sentence "Did you just read the word *left*?", they respond more quickly than when the second sentence said "An hour later, a bomb exploded" (Zwaan, 1996). This finding suggests that the event of the President leaving the building is more active in the subjects'

ongoing mental representation when the narrative is still in the same situation compared to when it has shifted to a new situation, an hour later. If subjects merely constructed a mental representation of the message itself, we would not expect such a difference, given that the target word was presented in the previous sentence in both cases. Thus, situation model theories assume that the comprehender's experience of events unfolding in time, space, and causation figures into the comprehension of a linguistic message.

Situation model accounts often lack specificity with regard to the nature of the mental representation. Most researchers seem to assume abstract propositional representations, in which the evolving situation model represents a fusion in working memory of propositions derived from the linguistic message with propositions retrieved from long-term memory, although some researchers also allow analog representations (e.g., Kintsch, 1998). There are different situation model theories, but the basic idea is clear: language comprehension is tantamount to situation-model construction. In this sense, language comprehension is a special form of social cognition, because social cognition itself can be regarded as situation-model construction (Wyer & Radvansky, 1999). Language comprehension is special, because situation-model construction is guided by symbolic input.

Simulation theories take the notion of language comprehension as guided situation-model construction one step further (Zwaan, 2004; Zwaan & Rapp, 2006). To see this, it is important to consider a limitation—perhaps “omission” is the better word—of situation model theories. Zwaan and colleagues (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998) developed the Event-Indexing Model, which was intended to model the construction and representation of situation models in terms of the connection strengths between nodes in a network that represented events in the situation. To the extent that an event took place in the same time frame, in the same location, involved the same protagonist(s), was causally related to, and was part of the same goal-plan structure as, the event(s) currently in working memory, the easier it was to integrate and the more strongly it ended up being connected to those events. Behavioral (Zwaan, Magliano, & Graesser, 1995; Zwaan, Radvansky, Hilliard, & Curiel, 1998) and neuroimaging evidence (Yarkoni, Speer, & Zacks, 2008) support this view. However, one drawback to this view is that the event nodes themselves are “empty”; they are merely labeled intersections of links and do not carry any representational information. For example, simply labeling an event node with “break” does not tell us anything about the action of breaking per se. Of course, the word carries meaning, but that meaning is not part of the representation the model has. As far as the model is

concerned, the label might as well be “hibernate”, “trebuchet”, or “Seinfeld.” The problem is that the event nodes are not grounded in experience. In contrast, simulation theories assume that comprehension entails the activation and use of experiential traces in long-term memory. In doing so, they provide an answer to the grounding problem (Harnad, 1990). Comprehension is not the manipulation of abstract, arbitrary, and amodal symbols, a language of thought. Rather, comprehension is the generation of vicarious experiences making use of the comprehender’s experiential repertoire (Zwaan, 2004). Thus, situation model theories tell us how events are related, but not how events are grounded in perception and action. Simulation theories fill this theoretical gap.

#### Challenges for the simulation view

As noted earlier, a great deal of empirical evidence seems to point to the close interaction between sensorimotor activation and language. But what does this mean? The situation is not unlike that of stereotype effects in social psychology. The field abounds with demonstrations but there are few theories to explain the findings (although the latter are emerging in social psychology, Bargh, 2006). Even more problematic is that most of the demonstrations involve rather small linguistic units, mostly words and sometimes sentences.

Just demonstrating *that* words or sentences activate experientially consistent sensorimotor areas (action words motor areas, color words color vision areas, motion words motion areas, and so on) is useful, but no longer sufficient. In order to make the case for simulation theories, it was important to demonstrate the close interactions between language and sensorimotor systems, but in the process, language has been reduced to a rather coarse mode of communication. To say, for example, that the leg area of the premotor cortex is activated when we read or hear the word “kick” and the word “walk” is interesting, but hardly does justice to the complexity and subtlety of language. The two verbs clearly describe different actions that are carried out for different purposes and in different manners. In which sensorimotor region are these differences represented? Also even if the leg area is activated after “He walked” and “They walked” there is a difference between these two events. And what happens when the actions are embedded within a protagonist’s perspective, as in *He walked vs. He watched Fred walk*? There are several challenges facing simulation theories of language and social cognition. Although there are different simulation theories in the literature, the challenges listed below apply across the different theories. I do not claim that the list is exhaustive<sup>1</sup>, but I do think that these are important challenges that need to be met to make real progress in theory development.

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<sup>1</sup> The most-often heard criticism of simulation theories is that they

The referential resolution challenge. Going by the extant neuroimaging studies of embodied cognition, one would arrive at the woefully erroneous conclusion that human language is a semantically low-resolution tool that allows us to tell hand actions from leg actions and tools from animals, but not much else. For example, languages such as English and Dutch have dozens of verbs denoting bipedal locomotion. Examples in English (Dutch in parentheses) are to *walk (lopen)*, to *trot (draven)*, to *run (rennen)*, to *step (stappen)*, to *stroll (slenteren)*, to *sprint (sprinten)*, to *saunter (slenteren)*, to *wade (waden)*, to *skip (huppelen)*, to *skate (schaatsen)*. A curious example from Dutch (originally from Frisian, a language spoken in the Dutch province of Friesland), is *klûnen*, which means to walk on ice skates (over a piece of land to get around a nonskatable part of a canal). Not only does this involve unusual shoe ware (ice skates), it also involves an awkward gait, since the shoe ware was not designed for the task of walking and does not allow one the biomechanically effective action of rolling one's feet. Just showing that the leg area of the premotor cortex is activated is obviously not enough to represent these various shades of ambulant meaning. What is needed at this point, is research showing the behavioral and neural differences produced by these

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cannot account for abstract concepts. There already are several proposals in the literature that shown how abstraction might be achieved in mental simulations (Arbib, 2008; Barsalou, 1999; Barsalou & Wiemer-Hastings, 2005; Gallese & Lakoff, 2005), so I will refrain from further discussing this challenge here.

verbs, differences that may very well not lie in motor areas but rather in sensory areas.

The issue of semantic granularity is obviously relevant for social cognition, because if mental simulations are shaded by subtle word choice, social behavior might be similarly shaped. Word choice, for example, is affected by group membership. The same undesirable event is described in more abstract language when it concerns an in-group member than when it concerns an out-group member (Maass, Salvi, Arcuri, & Semin, 1989). This is so presumably because concrete language construes the event as unique, whereas abstract language construes the event as general. The reverse pattern occurs when the event is a desirable one. Similarly, prior exposure to adjectives in an ostensibly unrelated task makes subjects perform differently on perceptual and categorization tasks than subjects who had been exposed to action verbs (Stapel and Semin, 2007). Specifically, whereas the former subjects tended to focus more on global aspects of the stimuli, the latter tended to focus on local aspects. These are effects of word class (adjectives versus verbs) but in view of the example just given, it stands to reason that there are even more subtle effects within word classes. So the challenge is to identify these effects and develop a more sophisticated simulation account of language.

The context challenge. Many cognitive psychologists and social psychologists have fashioned fine careers out of investigating

responses to individual words—cognitive psychologists to examine the factors that contribute to word recognition and social psychologists to examine the effects of words as triggers of stereotypes—but it is important to keep in mind that words are never processed in isolation. Not in the real world. Though the word STOP on a stop sign appears by itself, it is not processed in isolation, but in the context of traffic rules and its current location. It means “stop moving your vehicle here and now” and not, for example, “a red car stopped here yesterday at noon” or “stop talking inside your car.” But it only means this when situated on a street corner and not, for example, when placed in a museum. Not even in psycholinguistic experiments—the assumption is that randomization schemes neutralize any linguistic context effects.

Context can be something quite simple, such as the location of a word on a computer screen, or its location relative to another word. For example, subjects are able to judge more quickly whether words like *branch* and *root* are semantically related when they are presented like this:

BRANCH

ROOT

than when they are presented like this:

ROOT

BRANCH

because the relative positions of the words map onto the relative positions of their referents in the first case (branches are typically above roots), whereas they do not in the second case (Zwaan & Yaxley, 2003). These findings not only hold for concrete concepts, but also for more abstract ones. For example, the concept of power is commonly mapped onto the vertical dimension, with the more powerful being above the less powerful. Therefore, spatial effects such as those shown by Zwaan and Yaxley also hold for power relations, such as MASTER-SLAVE (Schubert, 2005).

So the challenge for simulation theories is to account more precisely for such context effects. One clue is that the simulation system appears to be unselective with regard to the information that it incorporates. Although the relative positions of the words are irrelevant to the semantic-relatedness judgment task, this spatial information apparently permeates the mental simulation, presumably leading to interference when it is inconsistent with the relative positions of the words' referents.

The conceptual combination challenge. Related to the notion of context is the notion of conceptual combination. Current theories of meaning no longer assume that meaning is compositional, i.e., that the meaning of a larger semantic unit can always be reduced to the meanings of its constituents and the way in which they are combined. For example, *large man*  $\neq$  *large* + *man*. This is easy to see if one considers *large envelope*. Here, the meaning of *large* is

different from that in the previous example. One cannot simply substitute the noun in the phrase and expect the meaning of the adjective to remain unchanged. Similarly, *red* takes on a different hue when applied to *balloon* than when applied to *wine* or *hair*. How will simulation theories account for cases such as these? Also, what is the simulation of *red* like before the listener has encountered *man* or *envelope* or does the comprehender hold off on simulating the adjective's referent before the noun's referent is known? In other words, how does the simulation unfold in time?

The perspective challenge. Language is used to convey a perspective or an attitude with respect to a certain person or situation. For example, tense and aspect are used to construe situations. Compare *He had started the car* with *He started the car* or with *He was starting the car*. If each of these sentences elicits the same kind of motor activation, then what does this mean? On the one hand one could say that it supports the simulation view, since motor resonance is needed to understand each of these sentences. On the other hand, one could argue that this shows the "Pavlovian" nature of the effect. Whenever a motor action is described, motor activation ensues, regardless of the nature of the construal in which the motor action occurs, which means that it cannot be the prime contributor to meaning.

By the same token, how do simulation theories account for perspective? There should be a difference between *You hit me* and *I*

*hit you*. More subtly, there is a difference between *He went into the room* and *He came into the room*. In one case, the situation is being construed from outside of the room and in the other case from within the room. Long before the advent of modern simulation theories, it was shown that such construals have behavioral effects (Black, Turner, & Bower, 1979). Recently, it was demonstrated that perspective taking is not solely determined by linguistic construals, but may also be influenced by culture (Leung & Cohen, 2007). However, precious little is known about the functional and structural mechanisms behind these effects.

The ontological status challenge. How do simulation theories account for construals such as negations, counterfactuals, hypotheticals, and so on? Researchers are beginning to address these questions. For example, Kaup et al. (2007) hypothesized that a negation involves three steps in a simulation theory. The first step is to simulate the situation that is explicitly stated not to be the case, that is, the part of the negation that is within the scope of the negation. The second step is to switch attention away from this simulation and now simulate the actual situation (if possible). The evidence for this hypothesis was mixed. Kaup and colleagues did find evidence for the simulation of the negated situation. For example, when subjects read a sentence about a door not being open, they subsequently showed facilitation in recognizing a picture of an open door. However, they did not obtain evidence for the

simulation of the actual situation, which would be evidenced by facilitation in the recognition of a closed door. Kaup and colleagues argued that this may be due to pragmatic considerations. The salient aspect of the situation is not that the door is closed, but that, for some reason, it was expected or desired to be open. If this reasoning is correct, then it suggests that mental simulation is not necessarily a simulation of an actual situation. It can also be a mental simulation of a desired situation. Of course, the question remains how negation is represented, as the experiment in question did not find any evidence of the representation of the actual situation. However, the results do point to the powerful effect of explicitly stating that something is not the case. It leads to a mental simulation of that which is supposedly not the case, whose effects linger on in memory. In the domain of persuasion, this ironic effect (Wegner, 1994) of negation is likely to thwart attempts to mitigate or even reverse the effects of stereotype activation. Repeatedly stressing that a certain stereotype is not true, in fact, strengthens it (Gawronski et al., 2008).

The combinatorial challenge. The same words can be combined in subtly different ways presumably to express subtly different thoughts. Compare *the red car* with *the car is red*. Showing that both constructions produce activation in the “red” area of the cortex is not going to be very helpful on its own. We would also want to know when this activation occurs. Also, what

color is the car in the predicative construction, *the red car*, before we learn that it is red? Do we momentarily simulate a colorless car or do we simulate a random color, perhaps that of our own car or of our favorite color only to replace it with red upon processing the adjective? And what happens when we hear *red wine*? Do we first activate the stereotypical red and then replace it with burgundy (see Zwaan, 2004 for a discussion)? And how can we make processes such as these yield to experimentation?

The social learning challenge. From the perspective of social cognition and social learning, it would be important to learn how mental simulations and thus vicarious experience is modulated by a complex naturalistic linguistic message. It appears, for example, that someone's literary diet affects their social skills (Mar et al., 2006). Mentally simulating the experiences of characters in narrative fiction appears to parallel the comprehension of peers in the actual world. Readers with a healthy diet of fiction may thus strengthen or even expand their repertoire of social abilities unlike frequent readers of non-fiction. Consistent with this view, Mar and colleagues found that fiction print-exposure positively predicted measures of social ability, whereas non-fiction print-exposure was a negative predictor. The tendency to become absorbed in a story also predicted empathy scores. So the question here is, what is it, exactly in these narratives that helps bring about these effects? And

can we somehow distill and bottle these linguistic structures to create optimal social learning environments?

### Conclusion

There is increasing evidence that mental simulation may be “the stuff of” (language) comprehension and social cognition. This evidence comes from both behavioral and neuroimaging experiments. However, it is time to take stock after the first wave of evidence has washed over us. In this article, I have tried to outline some of the challenges facing simulation theories in language comprehension and social cognition. The best way to address these challenges is by developing process models that give a detailed account of how mental simulations are orchestrated from moment to moment by the remarkable and often underestimated subtlety of human language; work along these lines is currently underway in my laboratory. Such process models could help explain how language can be used to help shape attitudes, behavior, and perhaps even personalities.

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