

## Reply

### Language, interaction and embodiment

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Pickering and Garrod (this issue) provided an account of the cognitive processes underlying interactive language use (or dialogue). During language comprehension, people simulate (or covertly imitate) the form and the meaning of what they hear, and use those representations to predict what is likely to happen next. The term *form* refers to a range of linguistic levels, including sounds, words and grammar. People simulate form by using the language production system, and then let it 'run ahead,' so that they use what they would be likely to say next to predict what the speaker is likely to say, on the assumption that they share most of their knowledge of language with the speaker (Pickering & Garrod, 2007). They also simulate meaning, which we take to be at least partly derived from action-based representations (e.g. Barsalou, 2008), so that comprehending *shoot* simulates some part of the act of shooting. They can therefore predict what is likely to happen next. In addition, the covert imitation can lead to overt imitation, so that comprehension can lead to overt imitation of the form or meaning of what is uttered (an imitative response), or overt imitation of the form or meaning of what is likely to happen next (a complementary response). Such processes occur in isolated language comprehension as well as in dialogue, but they are likely to be most pronounced in dialogue, partly because interlocutors have to rapidly switch from comprehending to producing, and partly because interlocutors tend to align their representations (Pickering & Garrod, 2004) and thus their simulations of the speaker are most likely to be accurate.

Glenberg (this issue) outlines an account of imitation and prediction that makes similar claims about the activation of embodied representations in the construction of meaning (but which does not focus on imitation of form). He proposes that the account is a consequence of the mirror neuron system (e.g. Rizzolatti & Craighero, 2007) that is activated similarly when an animal performs an act or sees another perform the same act. Our account can also be explained in terms of mirror neurons, though does not need to be. Indeed, our framework is more closely related to proposals of action-based representations in perception of other people (Wilson & Knoblich, 2005) and behavioural mimicry (Chartrand & Bargh, 1999), which are similarly compatible with but uncommitted to the involvement of the mirror neuron system.

Glenberg's (this issue) model of the Action-Based Language theory is related to the model sketched in Pickering and Garrod (2007). In particular, his notion of gain control is closely related to our notion of Kalman Gain. However, he uses it to determine whether overt or covert imitation occurs, and we use it to determine the extent to which people base decisions about what they are hearing on the signal (e.g. a word heard in noise) and the extent to which they use their prediction of what is likely to occur. An interesting question for both approaches is how people decide the level at which to set the gain.

Finally, we agree that our approach can be applied to the relationship between language and emotion, as illustrated by Havas, Glenberg, and Rinck (Havas et al., 2007; see also Foroni & Semin, in press). Just as *shoot* can activate representations associated with the action of shooting, so it can activate representations associated with related emotions such as fear. Importantly, all of these representations are activated rapidly and automatically, in a way that is likely to be

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important to fast-moving interactive dialogue, particularly when that dialogue is 'situated' in the sense that it refers to matters at hand (e.g. when the comprehender has a gun).

Morsella, Lanska, Berger, and Gazzaley (this issue) point out that people do not generally have direct cognitive control of their mental states. For example, they cannot simply decide to be frightened. Instead, they need to bring about such states indirectly, either by deciding to experience a frightening event or frightening language (which could be self-generated). The event or the language then activates the perceptual symbols associated with fear (as in Barsalou, 2008), which in turn leads to the emotion. This proposal is again compatible with our account of the simulation of meaning, though we do not commit ourselves to the lack of a direct route from language to emotion. The absence of an effect of telling participants about a contingency between a subliminal stimulus and a fear response (Olsson & Phelps, 2004) may indicate that such learning is unresponsive to language, but it is also possible that telling people about a relationship does not activate the relevant perceptual symbols in a way that directly describing a frightening event might well do. Finally, the finding that some patients can name objects or recognise how those objects are used, but cannot act upon those objects themselves, does not prove that action-based representations are irrelevant to comprehending language or events. Instead, the deficit may occur at a later ('output') stage, and the patients may use action-based representations relatively normally.

In conclusion, we thank the commentators for their suggestions about how our framework couched in simulation and prediction relates to other approaches and may help explain other phenomena such as emotional responses. We believe that all approaches help explain why language comprehension sometimes leads to imitation and sometimes to complementary responses, and propose that the question of when and why one occurs rather than the other is of central importance to the understanding of language use in general and interactive language in particular. In any case, our approach provides an account of the foundations of language and interaction, which relates both to the cognitive psychology and psycholinguistics on the one hand, and to social psychology and social neuroscience on the other.

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