lucinations, the patient hears voices that are experienced as coming from an external entity (Chadwick & Birchwood 1994). With other positive symptoms, too (e.g., thought intrusion, delusions of alien control, paranoid delusions, and reference delusions patients may declare that they are being acted on by alien forces, as if their thoughts or actions were controlled by external agents (Frith 1992).

Positive schizophrenic symptoms offer a specific model of dissociation between different aspects of explicit representation or knowledge of self-generated actions. They suggest a dissociation between the explicit representation of the content (or consciousness) of action, and the explicit representation of agency (i.e., reflective representation or metarepresentation). According to D&P, metarepresentation corresponds to explicit representation of the self as the holder of an attitude and it relies on an explicit representation of the attitude, that is, higher-order thoughts. We suggest that metarepresentation should also be considered as a form of consciousness of action. It is by generating metarepresentation that the self can become aware of its own actions. This is how one's mental productions (thoughts or representations; i.e., inner reality) are distinguished from the perception of external events (external reality) and how one's actions are distinguished from those of other people (i.e., how the self is distinguished from other selves). These properties relate to how an action is attributed to its proper origin, in other words, how a subject can make a conscious judgement about who is the agent of that action (an agency judgement).

D&P make a broader use of the "what" and "how" systems in vision. At a higher level, subjects may accurately attribute the origin of an action to themselves, yet ignore many aspects of their motor performance (Fourneret & Jeannerod 1998). This suggests that there are dissociable levels in actions with regard to access to consciousness. The signals used for controlling motor execution would be different from those used for generating conscious judgements about an action. Questions accordingly arise about the possible cognitive systems underlying the explicit or metarepresentational levels of knowledge of action.

We suggest that in schizophrenic symptoms the dissociation between the explicit content of action and its metarepresentation does not correspond to the classical dissociation between implicit procedural and explicit declarative knowledge (such as in blindsight), and could not be considered as simply included in the classical distinction between the explicit declarative system (ventral path) and the implicit visuo-motor system (dorsal path). Recent work has shown that the dorsal-ventral dissociation can be tracked further rostrally, up to the prefrontal cortex. Dorsal and ventral inputs to this structure seem to be segregated (Rossetti 1998). In addition, according to Frith (1992; 1995), disconnection between prefrontal (action command) and posterior associative areas result in a failure to anticipate sensory reafferents resulting from action, which may then be misattributed (Frith 1992; 1995). This suggests that more complex brain networks seem to be involved in consciousness of action than in conscious perception. These data deal directly with the agency problem.

Analysis of brain activity during several forms of action (active, passive, mentally simulated) has revealed a network common to all these conditions, to which the inferior parietal lobule (area 40), part of the supplementary motor area (SAM), and the ventral premotor area contribute (Jeannerod 1994; 1997). This cortical region is somewhat homologous with monkey ventral area 6 where one can record from "mirror neurons," not only when the animal performs a specific goal-directed hand movement (e.g., a grasping movement), but also when the immobile monkey watches the same movement performed by a conspecific (Rizzolatti et al. 1996a). Rizzolatti has proposed that monkeys recognize a motor action by matching it with a similar action motorically coded in the same neuronal population. We have suggested that this system could be a framework for studying dysfunctions of the mechanisms for answering the question "Who?" (e.g., the schizophrenic alteration of agency; Georgieff & Jeannerod 1998). This mechanism could be for our relationships with other individuals the counterpart of the "What?" and "Where?" mechanism for our relations with objects. To summarize, the reflective representations allowing the self to adopt a holder attitude require a representation of others. The implications of such a social system need to be developed in Dienes & Perner's model.

Does the hand reflect implicit knowledge? Yes and no

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Abstract: Gesture does not have a fixed position in the Dienes & Perner framework. Its status depends on the way knowledge is expressed. Knowledge reflected in gesture can be fully implicit (neither factuality nor predication is explicit) if the goal is simply to move a pointing hand to a target. Knowledge reflected in gesture can be explicit (both factuality and predication are explicit) if the goal is to indicate an object. However, gesture is not restricted to these two extreme positions. When gestures are unconscious accompaniments to speech and represent information that is distinct from speech, the knowledge they convey is factuality-implicit but predication-explicit.

Dienes & Perner (D&P) make an excellent case that the distinction between implicit and explicit knowledge is many-layered. The challenge comes in finding the most useful way to characterize the layers. We focus here on the distinctions made within the "Content" box (Fig. 1), using them to identify the layer that best characterizes knowledge expressed in gesture.

Spontaneous gestures at times convey information that differs from that conveyed in the speech they accompany (Church & Goldin-Meadow 1986; Goldin-Meadow 1997; Goldin-Meadow et al. 1993). In section 4.3., D&P suggest that when gesture conveys information different from the information conveyed in speech, it reflects "thoughts about reality that have not yet been recognized as being about reality" – in short, gesture is factuality-implicit.

D&P draw a parallel between gesture-speech discordance and the dissociation between the knowledge bases underlying children's understanding of false belief. At a time when children display no understanding of false belief in their verbal responses they demonstrate a reliable understanding of false belief in their visual orienting responses (Clements & Perner 1994). Children *look* at the place where the protagonist thinks an object has been moved, even though they fail to *say* that this is the correct place. D&P argue that such visual orienting responses are factuality-implicit.

Two problems arise. First, this analysis puts gesture on a par with visual orienting responses. On intuitive grounds, this seems incorrect because gesture is symbolic, eye glances are not. Second, in Clements and Perner (1994), the pattern of gesture was not like visual orienting responses but like speech. When asked where the protagonist would look, children indicated the incorrect place with *both* words and gestures.

D&P's framework can be used to resolve both problems. We begin by considering gesture in relation to visual orienting responses. We agree that both may be factuality-implicit (although we return to this question below). We suggest, however, that gesture differs from eye glances at the level of prediction – gesture may be predication-explicit, whereas eye glances are not. Information that is "useable by different parts of the system" (sect. 4.3) is predication-explicit. We offer two examples to show that spontaneous gestures can meet this criterion.

First, when asked to describe algebra word problems that they have read, adults sometimes convey different information in gestures and speech. In such cases, adults subsequently solve the problem using a strategy compatible with their spoken description 32% of the time. But 43% of the time, they solve the problem using a strategy compatible with their *gestured* description (Alibali et al. 1999). In these instances, the information expressed uniquely in gesture "previews" the subsequent problem solution. Thus, gesture represents information that can be referenced by different parts of the system.

Second, children often express strategies for solving mathematical equations in gesture that they do not express in speech (Alibali & Goldin-Meadow 1993; Perry et al. 1988). When later asked to rate the correctness of solutions generated by different problem-solving strategies, children rate solutions generated by strategies that they conveyed uniquely in gesture *higher* than solutions generated by strategies they did not express at all (Garber et al. 1998). Thus, the information children convey uniquely in gesture is not tied to the hands but can be accessed by other systems – gesture is consequently predication-explicit.

We are currently attempting to ask the crucial question – is information conveyed uniquely through eye glances also accessible to other systems? Is it predication-explicit? Using an eye-tracker, we are able to determine the pattern of eye glances children produce when asked to solve equations. If children convey patterns through visual orienting behaviors that are *not* found in either their speech or gesture, we can then ask whether the patterns unique to eye-glances predict their subsequent ratings as well as patterns that are unique to gesture (cf. Garber et al. 1998). We suspect that they will *not* – that visual orienting behaviors will not be predication-explicit, and thus will be distinct from spontaneous gesture.

We now return to factuality. We agree with D&P that spontaneous gesture is factuality-implicit – that is, speakers do not recognize their gestured comments as being about reality. One way to test this claim is to encourage speakers to be aware of their gestures. When gestures are truly spontaneous, they sometimes tap knowledge that cannot be expressed in words. If speakers are made aware of their gestures, this could change – gesture should become factuality-explicit, and should no longer convey different information from speech.[1] Indeed, in Clements and Perner (1994), children were asked to indicate where the protagonist would look, and many responded by pointing. These children were aware of having gestured. Gesture and speech were therefore both factuality-explicit (as well as predication-explicit) and, perhaps as a result, patterned together.

To summarize, gesture does not have a fixed position within D&P's framework. Instead, its position depends on the nature of the knowledge it expresses. If the goal is to move a pointing hand to a target (a visually guided movement[2]; Bridgeman 1991; Bridgeman et al. 1997, sect. 4.1), neither factuality nor predication is explicit, and the knowledge reflected in gesture is fully implicit. In contrast, if the goal is to indicate an object (a declarative act; Clements & Perner 1994), both factuality and predication are explicit, and the knowledge reflected in gesture is therefore explicit. However, gesture is not restricted to these two extreme layers of the D&P framework. When gestures are unconscious accompaniments to speech and represent information that is distinct from speech, the knowledge they convey is factuality-implicit but predication-explicit.

In some contexts, spontaneous gestures access a knowledge base that is distinct from the knowledge base that informs speech. Gesture may be abstracted from perception or action (e.g., Alibali et al. 1998) but is not itself perception or action. Hence, gesture extends beyond knowledge that is embedded in action. However, gesture is not recognized as being about reality, and is therefore not fully explicit. We argue that gesture reflects an important way-station in the progression from implicit to explicit knowledge – one that offers unique insight into implicit thought.

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NOTES

1. We thank John Cacioppo for suggesting this study.
2. It is important to point out that visually-guided behaviors and visual orienting behaviors do not always pattern in the same way (although they appear to do so in false belief tasks, cf. Clements & Perner 1996). A salient example is the young infant's knowledge of objects, which appears more sophisticated when measured via visual orienting responses (Baillargeon 1987; Spelke et al. 1992) than when measured via visually-guided reaching (Piaget 1954). Bertenthal (1996) suggests that this discrepancy can be resolved by acknowledging two distinct knowledge bases – one that subserves the perceptual control and guidance of actions, and one that subserves the perception and recognition of objects and events. As far as we can tell, the D&P framework does not capture this distinction – both knowledge bases are fully implicit. It might be worth incorporating into the framework a dimension that could distinguish the two.

Implicit knowledge in engineering judgment and scientific reasoning

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Abstract: Dienes & Perner's theoretical framework should be applicable to two related areas: technological innovation and the psychology of scientific reasoning. For the former, this commentary focuses on the example of nuclear weapon design, and on the decision to launch the space shuttle Challenger. For the latter, this commentary focuses on Klayman and Ha's positive test heuristic and the invention of the telephone.

Dienes & Perner (D&P) outline four areas of application of their ideas to research. In this brief commentary, I want to add a fifth: the psychology of science (Feist & Gorman 1998) and technology (Gorman 1998). Consider an example. Mackenzie and Spiniardi (1995) argue that a great deal of implicit knowledge is involved in the development and maintenance of nuclear weapons and that much of this knowledge may be lost when the current generation of weapons designers retires. Similarly, Gusterson has written about the "group of senior scientists who have experienced many nuclear tests and who therefore "really understand" how the weapons work. Other scientists speak of these men as irreplaceable, because so much of their knowledge is tacit knowledge that is not, and probably cannot be, written down" (Gusterson 1996, p. 106).

D&P remind us of the degrees and types of explicitness a statement like, "this is a nuclear weapon" might have. Scientists might know that this is an effective weapon now, and might know how they knew that – by what test, or facts, or evidence, or experience; this level of explicitness corresponds to all the levels in Figure 1 of the target article. Or scientists might know that this is not an effective weapon anymore, even if it was one in the past, and be unable to articulate precisely why they feel that way. In this case, the content box in D&P's Figure 1 would be explicit, but not the attitude box, because attitude includes justification. Or does attitude just incorporate that "feeling of knowing"?

Consider a different example. Roger Boisjoly had seen the damage to the O rings on the space shuttle from previous flights, and was sure that they would blow at the low temperature projected for the Challenger launch. But the data he presented were ambiguous (Vaughan 1996). Boisjoly's judgment was hard to make explicit – when pressed, all he could say was that the decision to launch was a "step away from goodness." Boisjoly appeared to be at level 1 in Table 1 – he knew that the shuttle was not safe at this particular temperature, but could not articulate all the reasons behind his judgment.

Like many experts, Boisjoly and the weapons designers have to make judgments under uncertainty. Boisjoly did not know that the Challenger would blow up if launched; he merely felt that this kind of a disaster was significantly more likely at a lower launch