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7

"When I come down I'm in the domain state": grammar and graphic representation in the interpretive activity of physicists[1]

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"I" is not the name of a person, nor "here" of a place, and "this" is not a name. But they are connected with names. Names are explained by means of them. It is also true that it is characteristic of physics not to use these words.

L. Wittgenstein, *Philosophical Investigations* (1958: 123)

7.1 Linguistic resources for practicing science

This paper explores how scientists build meaning through routine interpretive activity involving talk, gesture, and graphic representation. In the course of making sense of their own and others' scientific research, scientists sometimes combine these semiotic resources in ways that seem to blur the distinction between scientist and the physical world under scrutiny. We shall argue in this paper that in scientific interaction, (1) grammar works together with graphic representation and gesture to construct a referential identity which is both animate and inanimate, subject and object, and that (2) the construction of this indeterminate referential identity plays an important role in scientists' efforts to achieve mutual understanding and arrive at a working consensus.

Our study is intended to be of cross-disciplinary interest. The analysis is motivated by cultural, philosophical, sociological, and historical research on scientific practice (e.g., Bloor, 1976; Lynch, 1985, 1993; Shapin and Schaffer, 1985; Pickering, 1992; Biagioli, 1985, 1993); anthropological and linguistic approaches to lexical and grammatical structure (e.g., Duranti, 1990; Hanks, 1990, 1992; Silverstein, 1993); interactional studies of conversational discourse (e.g., Schegloff, 1991; Goodwin, 1994); and psychological paradigms that take activity as a locus of human cognition (e.g.,

Voloshinov, 1973; Vygotsky, 1978; Leontyev, 1981; Bakhtin, 1993). Each of these enterprises imposes somewhat different methodological criteria for the interpretation of data. In our study, we attempt to synthesize these methodologies as a way of approaching and understanding grammar as constitutive of and constituted by the activities of working scientists. As such, we utilize detailed transcripts annotated with cultural glosses and provide ethnographic background that contextualize and render the interactions more meaningful to readers outside the field of physics.[2]

For nearly as long as science has been recognized as a profession, the character of scientific discourse and interpretive activity has been a topic of intense scholarly interest. Considerable attention has focused on the discursive representation of the triadic relationship between scientist, scientific findings, and members of the scientific community, especially in terms of the political, religious, and other socio-cultural forces that may structure this relationship and its representation over historical time (e.g., Kuhn, 1962; Fleck, 1979/1935; Shapin and Schaffer, 1985; Biagioli, 1990a, 1990b, 1992). An over-arching concern throughout studies of scientific discourse has been the manner in which scientists verbally portray their own or other scientists' subjective involvement in the world of physical events. A number of scholars have argued that the stances of relative involvement or detachment in scientific discourse are culturally constructed and historically situated, with detachment being the preferred stance in Western science (e.g., Latour and Woolgar, 1979; Gilbert and Mulkay, 1984; Shapin and Schaffer, 1985; Latour, 1987; Bazerman, 1988; Lynch, 1988; Traweek, 1988, 1992; Biagioli, 1993; Collins and Yearling, 1992; Gooding, 1992; Knorr-Cetina, 1992). Arguing against the view that scientific discourse represents "matters of fact," these scholars assert that scientists employ linguistic and other symbolic resources (such as illustrations and graphic displays) both to construct worldly entities, processes, states, relations, and outcomes as "matters of fact" and to mitigate their own role in producing these phenomena.[3]

Of particular relevance to these studies has been the observation that the discursive practices of scientists vary across informal scientific discussions and formal, especially written, scientific texts. According to these observations, whereas in more public and formal discourse, mention of scientists' involvement in research activities is minimal or nil, in everyday informal scientific discourse in laboratory interactions and in informal accounts of those interactions, scientists often refer to themselves as agents in the production of scientific knowledge (see especially Latour and Woolgar, 1979; Gilbert and Mulkay, 1984; Latour, 1987; Gooding, 1992). These studies suggest that the more impersonal style characteristic of public scientific texts helps render scientific accounts as objective and factual. On the other hand, they assert, the more personal style characteristic of informal laboratory talk renders scientific accounts as subjective, context-sensitive, and as somewhat like narratives of personal experience wherein particular protagonists (i.e., scientists) think, feel, and act to overcome obstacles and resolve problems.

This broadly dichotomous treatment of discourse repertoires in scientific communication, which threads through constructivist studies of scientific practice and knowledge, tends to be semantically conservative. It suggests that scientists have only one referential practice for expressing subjective involvement, namely, reference to discrete persons (scientists) acting in relation to some other discrete phenomena (physical or natural entities) in the world. Indeed, this sense of discreteness is implied in all discussions of scientists as agents who construct physical/natural entities and events, because agents are, by definition, separate forces affecting objects in the world.

But what about other practices for indexing subjective involvement, in particular ones in which scientists use referring expressions to identify with the objects they study? We propose that scientists express their subjective involvement not only by foregrounding their role as practitioners of scientific activity, they also express involvement more extremely by taking the perspective of (empathizing with) some object being analyzed and by involving themselves in graphic (re)enactments of physical events. Examples of these forms of reference can be seen in Segments (1a) and (1b) below:[4]

(1a) RO LAB (11-14)

```
Ron:   .hhh But as you go belo:w the first order (0.5)
       transition you're [still in the domain structure 'n
                         [((leans upper body to right))
       you're trying to get [ou:t of it.
                            [((sweeps right arm to left))
```


(1b) ROLAB (1-3)

```
Ron:   Well you also said [(the) same thing must happen here.
                          [((moves to board; points to diagram))
       [When [I come down [I'm in  [the domain state.
       [((points to right part of diagram))
             [((moves finger to left))[
                          [((moves finger to right))
                                   [((moves finger to left))
```

We suggest that in using such forms of reference with predicates that describe entities as changing location/state or as attempting to do so, scientists are not referring exclusively to themselves as scientists nor exclusively to the object of scientific concern but rather to a conflation of both, and, in so doing, structure their relation to – that is, their subjective involvement in – aspects of the physical world in ways not explored in previous studies of scientific discourse. The present discussion will explore this referential possibility in scientific discourse through an examination of referential encoding in the laboratory deliberations among physicists. Specifically, we consider what a group of physicists might be communicating when they use a particular set of linguistic resources, namely, constructions consisting of *personal pronominal subjects* (especially "I" and "you") and *predicates of motion/change of state* (e.g., "go," "break up").

Our study is practice-centered, interaction-centered, and activity-centered in the sense that it views scientists' language behavior as (1) a set of historically rooted practices having the potential to alter social order and cultural structures of knowledge and belief (Bourdieu, 1977; Hanks, 1990, 1992); as (2) a form of social interaction (Bakhtin, 1981; Goodwin and Goodwin, 1992; Schegloff, 1972, 1991) having the potential to recontextualize past and to precontextualize future interactions;[5] and as (3) a form of social activity having the potential to recontextualize past activities and to precontextualize future ones.[6] Indeed, social activities are jointly achieved through interaction and rely on tools, including symbolic tools like language, to coordinate participants' actions and accomplish goals (Vygotsky, 1978; Leontyev, 1981; Engeström, 1987, 1990).[7] We thus consider how grammatical constructions and other symbolic tools, such as graphic representations, mediate between and symbolically bring together not only scientists in joint activity but also scientists and the objects they study. We examine scientists' talk and their (re)construction of graphic representations as finely integrated practices and draw on both these types of interactionally produced symbolic practices in our exploration of how meaning may be assigned to utterances.[8]

7.2 Ethnographic context

Located within an American university, the physics laboratory that is the field site of our ethnographic and linguistic study carries out research within the area of solid state physics. The laboratory undertakes research comprising theoretical, experimental, and theoretical-experimental collaborative work on condensed matter phenomena, including spin glasses and random magnets. The group is, in this sense, unusual in that (1) its members are both theoreticians and experimentalists, (2) the principal investigator (PI) is a theoretician mentoring experimentalist graduate students and (3) holds a high-level full-time administrative position within the university. In general, the research pursued by this laboratory represents a move throughout the field of solid state physics in recent decades to study disordered systems (Fleury, 1981; Ford, 1982; Hurd, 1982).

Our study involved six months of participant field observations, concurrent and subsequent interviews with each regular member, and audio- and videorecordings of members of the physics group interacting in various work settings, including the experimental laboratories, small group meetings, and the weekly group meetings. Approximately sixty hours of interaction were recorded and transcribed according to the conventions of conversation analysis (see note 4), and particular segments of interaction have been further transcribed to include eye gaze, hand, head, and body movements, as well as gestures to the graphic displays produced or shown in the course of these interactions.

In addition, copies of versions of overhead transparencies ("viewgraphs") and most of the printed materials which members brought to the meetings were collected. We also have a corpus of electronic messages sent between a member of this group and a colleague in Europe concerning a particular coauthored research project which was often discussed in the group meetings. An archive of the members' research papers, published articles, and dissertations arising out of their research activities was also assembled. Finally, several tutorial sessions, during which members of the physics group explained the concepts and principles behind their research, were audiotaped for future reference, and background articles on relevant topics, which they recommended, were consulted.

The analysis presented here draws from videorecordings of the group meetings in which members present experimental or theoretical findings to the PI ("Ron" in our transcripts). During these presentations, the presenter, the PI, and, on occasion, other members of the group discuss and evaluate the experimental findings or theoretical calculations in light of their current understanding of physical phenomena and in comparison with the work of other physicists, try to arrive at a working consensus, and plan the next steps of a particular project. At times, members may move to the blackboard or the overhead projector to present, suggest, or otherwise probe physical phenomena (Ochs, Jacoby, and Gonzales, 1994). They also often come to the meetings with various types of printed materials, including published articles, computer printouts of experimental data, facsimile transmissions, and other sorts of correspondence.

To provide background to the interactions analyzed in this chapter, we briefly summarize the research topic under discussion.[9] The analytic thrust of this laboratory is the physics of atomic spins (magnetic moments) in a crystalline lattice. One project focuses on how atoms in a disordered alloy system interact with one another as a result of internal physical processes which have been affected by magnetic fields and temperature changes. This project relies, in part, on experiments carried out by Miguel, one of the advanced graduate students. For several months, he designed and conducted a series of experiments to test a computer-simulated model published by Grest et al. (1986). Figure 7.1 is our own schematic representation of the main argument of this model.[10]

Grest et al.'s (1986) theoretical argument is that, depending on the combination of temperature and strength of magnetic field, atomic spins in a diluted antiferromagnet will exhibit different kinds of order.[11] At a given magnetic field at high temperatures,

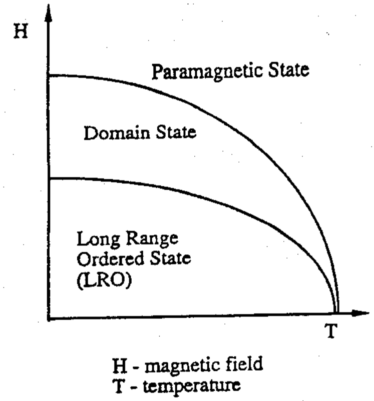


Figure 7.1 Phase transitions in a diluted antiferromagnet (based on Grest et al., 1986)

atomic spins in a diluted antiferromagnetic system are uncorrelated, i.e., in a randomly disordered ("paramagnetic") state. As the magnetic field decreases and/or the temperature lowers, the system undergoes a phase transition and moves into a partially ordered ("domain") state.[12] At a certain point, at even lower fields and lower temperatures, the system undergoes another phase transition and moves into a "long range ordered" state.[13] The paramagnetic, domain, and long range ordered states are separated in Figure 7.1 by "phase transition" lines. Figure 7.2 schematically represents these three different phases of atomic order. We have adopted the physicists" convention of using arrows to represent atomic spins.

This introduction to the ethnographic setting and content of one of the group's projects is sufficient, we feel, for readers to get a sense of the local work culture of the physicists and the ideas which inform their conversations, excerpts of which appear throughout this chapter.

7.3 Grammatical realizations of subjective involvement

In the interactions we have analyzed, members of the physics group use a number of referential practices for grammatically encoding their subjective involvement in scientific practice. Among these practices are the two discursive practices which have received the bulk of attention in rhetorical, sociological, and anthropological

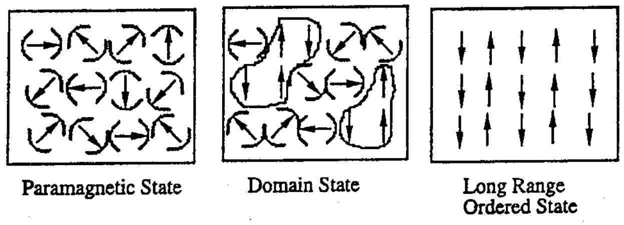


Figure 7.2 Long range ordered, domain, and paramagnetic states in a diluted antiferromagnetic system

studies of scientific life (e.g., Latour and Woolgar, 1979; Gilbert and Mulkay, 1984; Bazerman, 1988; Traweek 1988, 1992; McCloskey, 1990). In the first kind of grammatical realization, said to be typical of private, informal scientific discourse, scientists construct a "physicist-centered" account of scientific phenomena by referring to themselves as the thematic agents and experiencers of these phenomena. In the second kind of grammatical realization, said to be typical of public, formal scientific discourse, scientists make no explicit reference to themselves as physicists but rather construct a "physics-centered" account of scientific phenomena, i.e., an account which foregrounds the physical constructs of research interest and masks human involvement in the manipulation of nature. (We use the term "physics" here in one of the senses in which it is routinely used by members of this group: to refer to properties and processes of the physical world.) "Physics-centered" discourse is often characterized by using agentless passive structures or syntactically active structures in which the thematic subject of an utterance is a physical entity or process.[14]

7.3.1 *Physicist-centered grammar: physicist as thematic focus*

Segments (2) and (3) below illustrate utterances in which the grammatically encoded thematic focus is on the physicist as active participant in the making of science and scientific discovery, whether as agent or experiencer.

Physicist as agent. Segment (2) illustrates physicists referring to themselves as agents in relation to physical phenomena, acting upon physical entities through manipulations of experimental conditions:

(2) RO LAB (1-3)

```
Miguel: Yeah: not only that u- [we did experiments
                                   [((points to diagram))
         [where we (.) we uh:(0.2)  [we (.) brought the
         [((Ron backs away from board))  [((moves left hand to diagram))
         system: uh: [(0.8) [here
                     [((hand to chin))
                            [((points to diagram))
Ron:     Mm hm
Miguel: [And then we uhm (0.2) °or was it there?,°
         [((moves hand lower on diagram then moves left hand to chin))
         (0.2) [uh: that's right.
               [((moves left hand to board))
         [Here.  [Then we lowered the field, (0.2)
         [((points to diagram))
                 [((lowers hand on diagram; looks at Ron))
         [raised the field,
         [((raises hand on diagram))
```

Physicist as experiencer. Segment (3) illustrates physicists referring to themselves as experiencers, perceiving, understanding, or reacting to physical phenomena and measurements:

(3) RO LAB (1-3)

```
Ron:     Is there a po:ssibility that he hasn't
         [seen anything real?,
         [((points to equation on board))
         (0.5)
Ron:     [>(I) mean< is there a
         [((points to lower part of diagram, upper, lower again))
         possibil[ity
Miguel:         [I- i- it is possible and there [i-
                [((vertical headshakes))         [((horizontal
                                                   headshakes))
         [(0.2) [I'm ama:zed by his measurements because when=
         [((Ron moves from board to other side of table))
```


(3) RO LAB (1-3) continued

```
Ron:              [(The-)
Miguel: =you quench: (.) from five to two tesla (.) a magnet a
         superconducting magnet [.hhh e:: [(.)
                                [((mild vertical headshakes))
                                          [((moves head forward))
Ron:     °That's what I'm wondering.°
```

7.3.2 *Physics-centered grammar: physics as thematic focus*

Segments (4) through (6) illustrate physicists foregrounding inanimate physical entities as the thematic focus and grammatical subject of clauses. In such utterances, the physical entities are assigned two related semantic roles through predicates which refer either to a motion/change of state event or to a cognitive experience.

Physics + motion/change of state. Segment (4) illustrates how physicists grammatically construct physical entities (e.g., an atomic system) as moving through space and/or undergoing changes of state:

(4) RO LAB (1-3)

```
Miguel: So: (.) what I was saying is the following [At h- high
                                                   [((gestures
                                                   high on board))
         fields (i-) or high temperatures, [the system is in
                                           [((looks at Ron))
         the paramagnetic reg[ime.
                             [((looks at board))
         [(.)
         [((Miguel puts hand on board))
Miguel: Then (.) it crosses [to a: domain state.
                            [((looks at Ron))
         [.hhh (.) [ A::nd (.) there's also
         [((looks at board))
                   [((puts hand on board))
         a: long range (.) ordered state [at
                                         [((looks at Ron))
         [low fields and low  [temperatures
         [((hand traces diagram)) [((drops hand to side))
```

Physics as experiencer. Although we do not normally think of inanimate entities as capable of cognition, Segments (5) and (6) illustrate how physicists also grammatically construct physical entities as experiencers, by selecting predicates of sentience and understanding:

(5) RO LAB (1-3)

```
Ron:    [If this were a first order [pha:se transition, (0.2)
        [((moves to board; points to diagram))
                                     [((looks at Miguel))
Miguel: Mm hm?
Ron:    [Then that means [that- that- this system has no
        [((looks at board)) [((Miguel looks at board))
        knowledge of [tha:t system.
                     [((looks at Miguel))
```

(6) RO LAB (11-14)

```
Miguel: Let me uh: tell you why I'm raising the question. .hh uh-
        [this is a modest field.
        [((points & circles pen towards table))
        (0.5)
Miguel: Ts! So the [region, .hhh [where the system is
                   [((places fingers on narrow area of diagram))
                                 [((moves hand down diagram))
        experiencing random fields is very narrow in
        temperatures.And if you [coo:l extremely fast (1.2)
                                [((stretches out right arm))
        the system may [never have the time to experience
                       [((rapid horizontal headshakes))
        those random fields and therefore you
        [have a long range ((losing breath)) ordered state at
        [((places both arms palms up at side of body))
        the low temperatures (.) in low fields.
```


7.3.3 *Commonality of physicist-centered and physics-centered discourse practices*

Although much has been made of the different rhetorical effects created by that discourse practice which draws attention to the scientist (physicist) as the thematic focus of an utterance and the other discourse practice which draws attention to the object of inquiry (a physical entity or system) as a thematic focus, these two discourse practices actually share a common perspective. In particular, *both practices presuppose scientist and objects of inquiry as separate and distinct entities.* This is perhaps more easily seen in physicist-centered discourse, in which the physicist is encoded as a distinct agent (e.g., "when you cut the field") or experiencer (e.g., "we observe the drop at high fields") separate from the object of inquiry.[15] But it is important to note that physics-centered discourse presupposes the same separateness and distinction between physicist and the object of inquiry precisely because the physicist is nowhere to be seen. Moreover, while frequently not referentially present in physics-centered discourse, the physicist is implied as a distinct referent in constructions such as agentless passive clauses (e.g., "it still (is) the case that they [the measurements] were obtained at different temperatures").

7.3.4 *Physicist and physics as blended thematic foci: the problem of indeterminacy*

Do these two discourse practices exhaust the possibilities for grammatically structuring the relationship between physicist and physics? As we indicated briefly at the outset, we think not because we have noticed that, in addition to the varied grammatical realizations of physicist and physics as distinct entities, our data are full of utterances which encode an *indeterminate* referent, as in "as you go below the first order transition you're still in the domain structure and you're trying to get out of it" (1a) and "when I come down I'm in the domain state" (1b). That is, the referent constructed in these utterances appears to be neither exclusively the physicist nor the object of inquiry but rather a blended identity that blurs the distinction between the two. Such utterances cannot, of course, be literally understood as indexing events in which physicists participate. Nevertheless, they appear to be completely unproblematic for the physicist interlocutors. Indeed, no one ever stops an interaction to ask, "What do you mean "*I'm* in the domain state"?" or "How could *you* possibly "go below in temperature"?" Moreover, they are also ubiquitous in our data.

Several co-occurring linguistic properties of these indeterminate utterances work together to convey a sense of indeterminacy. First, their verb forms tend to be realized in the simple present or present progressive, which depict events as generic, enduring, or iterative rather than as specific, unique, and punctual. Second, the pronominal subjects, generally "I" and "you," do not appear to be restricted to either the speaker or addressee, but rather to a class of referents who may participate in these generic, enduring, or iterative events (e.g., "As you [or any entity] go below the first order transition"). Third, while the pronominal subject of these utterances presupposes an animate referent, the predicate appears to refer to a physical event or state attributable to an inanimate referent (i.e., the physical object under consideration), as represented below:

Personal Pronoun$_{animate}$ || **Predicate**$_{inanimate}$

These utterances thus seem to have a semantically schizoid, illogical character which blurs the boundaries between the animate subject (physicist) and the inanimate object (physical entity/system).

Segment (7) presents a typical sequence in which all three types of thematic foci – physicist-centered, physics-centered, and indeterminate – alternate in rapid succession. The segment begins with Ron and Miguel at the blackboard, with Ron articulating a problem he is having in understanding the results of Miguel's recent experiments. The ensuing discussion[16] centers on (1) differences between Miguel's results and those of the computer-simulated model proposed by Grest et al. (1986); (2) differences between Miguel's experiments and those found by another experimental group (headed by Kleeman); and (3) differences in Miguel's measurements obtained from two different experimental procedures (zero field cooled vs. field cooled).[17]

Throughout this interaction, Ron and Miguel point, gesture, and add to a freehand abstracted sketch of the Grest et al. phase transition model on the blackboard (see Figure 7.1). The progressively

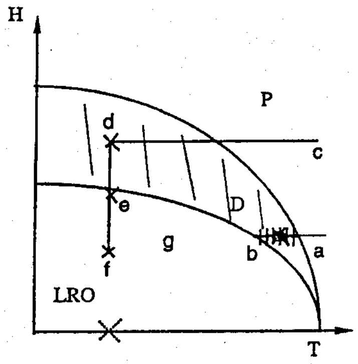


Figure 7.3 Key to nonverbal gesturing within blackboard sketch

annotated graphic display is thus constituted as a highly intertextual representation through which the participants can move fluidly from a discussion of one set of results to another (Ochs, Jacoby, and Gonzales, 1994). Figure 7.3 represents the graphic display. We use lowercase letters to identify places which the participants point to or touch in the course of their conversation.

Here, then, is the sequence between Ron and Miguel:

(7) RO LAB (1-3)

```
Ron:   When I approach a phase transition
       line [in different
             [((looks at board; points to 'X' between a and b))
       [directions.  That I understand.
       [((looks at Miguel))
       (.)
Ron:   [But what I [(.) tryin to- what I can't
       [((looks at board; points to e))
       [((Miguel looks down; moves away from board))
                   [((Miguel looks at board))
       figure out is if this is truly
       [a phase transition line
       [((looks at Miguel))
       (0.2) [why [don't I [go: [(0.2) to the
             [((looks at board))   [
                   [((moves finger to d))
                             [((moves finger to f and holds))
```

(7) RO LAB (1-3) continued

18 [((looks at Miguel))
19 long range ordered phase in the Kleeman experiment.
20 (1.0)
21 Ron: [Cause you're telling me [that [I
22 [((looks at board)) [((points to d))
23 [((moves finger to f))
24 go [here [and there's still a decay (present).
25 [((looks at Miguel))
26 [((Miguel looks down; turns body away from board))
27 .hh [But you're telling me that [if I
28 [((looks at board)) [((points to a))
29 [come in [this way [(0.5) and [go he:re there's
30 [((moves finger to b))[[
31 [((looks at Miguel)) [
32 [((Miguel looks at board))
33 [((moves finger to g))
34 no decay.
35 (1.0)
36 Ron: [Nothing happens.
37 [((slight shrug))
38 (0.2)
39 Miguel: [Yeah well eh: I [I don't know. [I: (.) nu-
40 [((moves to board)) [[
41 [((Ron steps back from board)) [
42 [((picks up chalk))[
43 [((looks at Ron))
44 (if from) I'm going to throw ideas in the pot.
45 Uh [HEre (.) (when) you reach this point
46 [((points to c))
47 [here (0.5) [u- prior to cutting the field we
48 [((marks 'X' at d)) [((with other hand, points to d))
49 are in (the) domain state.
50 Ron: Yes
51 Miguel: [And [as- when you cut the field [(0.8) you
52 [((points to d)) [((points again))
53 [((moves finger to f and lowers hand))

54 uh reach the [long range order state.
55 [((looks at Ron))
56 (.)
57 Miguel: [So maybe the domains need to grow.
58 [((raises both hands into air with upward motion))
59 (.)
60 Miguel: [Although that's not what we observe
61 [((looks up))
62 really experimentally.
63 Ron: Well you also said [(the) same thing must happen here.
64 [((moves to board; points to b))
65 [When [I come down [I'm in [the domain state.
66 [((points to a)) [[
67 [((moves finger to b)) [
68 [((moves finger to a))
69 [((moves finger to b))
70 Miguel: Yeah.

Table 7.1 shows more clearly how, within this single strip of interaction, interlocutors switch among physicist-centered, physics-centered, and indeterminate perspectives within and across turns. The table follows the segment in time and is to be read from left to right, returning to the next leftmost utterance as one gradually moves down the table.

The compact character of this constant perspective-switching seems to preclude topic as influencing the use of indeterminate constructions. What does seem influential, however, is that indeterminate constructions seem to be a referential resource especially suited to the activity of thinking through research problems together. Indeed, it does seem, in our data, that in contrast to physics- and physicist-centered constructions, indeterminate constructions tend not to appear outside of this activity. More specifically, these constructions primarily appear *after* graduate students or post-doctoral fellows have initially presented research findings to the PI, and that the PI is the main producer of these constructions as he struggles to understand and evaluate the findings of the junior members. Nevertheless, other members produce these constructions as well when they participate in the ongoing discussion. When the PI uses these constructions, he typically uses the first person singular

Table 7.1 Switching among alternative perspectives in unfolding interaction (from segment 7)

PHYSICIST FOCUS	PHYSICS FOCUS	INDETERMINATE FOCUS
Ron:		When I approach a phase transition line in different directions.
That I understand.		
But what I tryin to-		
what I can't figure out is	if this is truly a phase transition line	why don't I go to the long range ordered phase in the Kleeman experiment.
Cause you're telling me that		I go here
	and there's still a decay (present).	
But you're telling me that		if I come in this way and go he:re
	there's no decay.	
	Nothing happens.	

Table 7.1 (continued)

Miguel: Yeah well eh I I don't know. I nu- (if from)		
I'm going to throw ideas in the pot.		Uh here (when) you reach this point here
u- prior to cutting the field		we are in (the) domain state.
Ron: Yes		
Miguel: And as- when you cut the field		you uh reach the long range order state.
	So maybe the domains need to grow.	
Although that's not what we observe really experimentally.		
Ron: Well you also said	(the) same thing must happen here.	When I come down I'm in the domain state.

pronoun "I," as in "when I come down I'm in the domain state," or "why don't I go to the long range ordered state in the Kleeman experiment." When graduate student and post-doctoral presenters use indeterminate constructions, they tend to use either the second person pronoun "you" or the first person plural pronoun "we," as in "uh here when you reach this point we are in the domain state."

7.4 Two interpretive strategies

In trying to understand these physicists' use of indeterminate constructions, we consider two main interpretive strategies. As will be shown, we ultimately align with the second strategy because it widens the basis for assigning meaning beyond the utterance to include the referential gestural practices which accompany the linguistic stream and which are integral to the activity in scientific practice of collaboratively interpreting graphic representations.

7.4.1 Interpretive strategy 1: pronominal referent = physicist

One strategy for understanding indeterminate utterances is to posit that they have an underlying logical form containing a causal predicate. Thus, (8a) might be interpreted as having the underlying logical form of (8b):

(8a) I'm in the domain state.

(8b) I cause some physical entity to be in the domain state.

With Strategy 1, the pronominal form refers exclusively to the *physicist* who functions in the semantic role of *agent*, i.e., as a physicist carrying out an experimental protocol. Such an interpretation treats the construction as a physicist-centered locution and preserves the rhetorical and philosophical distinction between scientist as subject and the physical world as the object of inquiry: it is understood that the scientist is a separate entity who causes some change in the physical world.

Support for this interpretive strategy comes from similar constructions in English, such as "I remodeled my house," the interpretation of which may depend on interlocutors supplying background

knowledge so as to evaluate whether or not the referent of the pronoun has actually physically carried out the action. Thus, while "I remodeled my house" could mean that the speaker physically carried out the remodeling, it can also mean that the speaker caused someone else to remodel his/her house. An interlocutor would need to supply cultural and personal knowledge to interpret such utterances, including knowledge of the speaker's right, ability, and/or predilection to be the referent which causes some other entity to participate in the event.[18]

However, positing an underlying causal predicate is problematic for at least two reasons:

(1) As we have shown, physicists explicitly express causality through both transitive physicist-centered constructions such as "And then I lower the temperature" and indeterminate constructions such as "If I go below in temperature" in alternation within the same activity. Is there a cognitive advantage perhaps? We think not because the positing of an underlying form would require the comprehender to supply abstract causal predicates to understand them, whereas transitive forms do not.

(2) Indeterminate constructions pragmatically imply that the subject pronoun referent is more directly involved in the change of location or state of a physical entity than the subject pronoun referent in an underlying causal proposition. For example, the pronominal referent of "I" in "If I go below in temperature" seems involved to a greater degree in the change of state between temperatures than does the pronominal referent of "I" in "I cause some physical entity to go below in temperature." Thus, indeterminate constructions create a zone of *ambiguity* which allows the interpretation that the referent could actually be doing the activity described.

7.4.2 Interpretive strategy 2: pronominal referent = blended identity

A more satisfying way to understand the meaning of indeterminate constructions, then, is to posit a more extreme form of subjectivity in which the distinction between the scientist as subject and the physical world as object is blurred. In this interpretation, the pronominal referent (the referent of "I" in, for instance, "When I come down I'm in the domain state") is a blended identity composed of both the animate physicist and the inanimate physical entity undergoing some change of state. Whereas Strategy 1 attempts to resolve the apparent semantic contradiction (of an animate subject linked to a predicate which presupposes an inanimate subject), Strategy 2 accepts the schizoid character of such constructions as a linguistic resource used non-problematically by scientists in their everyday interpretive work. Strategy 2 thus acknowledges that referential ambiguity is a necessary poetics of mundane scientific problem-solving in that by using indeterminate constructions as a linguistic heuristic, scientists constitute an empathy with entities they are struggling to understand. Such a referential poetics allows interlocutors to symbolically participate in events from the perspective of entities in worlds no physicist could otherwise experience. Moreover, scientists take such "interpretive journeys" (Ochs, Jacoby, and Gonzales, 1994) in two intertwined constructed realms: (1) the world of physical events, and (2) the world of visual representations of those events.

The constructed world of physical events. When physicists use indeterminate constructions, they may be symbolically repositioning themselves in an imagined realm of physical events (Bühler, 1990/1934; Hanks, 1990, 1992). In so doing, they evoke a referent of "I" which is subjectively involved in the world of physical events. Rather than causing events, as Strategy 1 would have it, the referent of "I" in Strategy 2 is experiencing physical events from the perspective of physical entities. Thus, for example, the pronominal referent of "I" in "I'm in the domain state" (1b) is understood to be directly experiencing the domain state. In example (1a), the pronominal referent of "you" is understood to be "go[ing] bel<u>o:w</u> the first order transition . . . <u>still</u> in the domain structure 'n' . . . trying to get out of it." In other instances of indeterminate constructions, the pronominal referents "go into the long range ordered phase," "break[ing] up into domains," and "go below in temperature."

In the poetics of interpretive Strategy 2, therefore, the referent indexed by the pronoun "I" or "you"[19] travels through temperature and magnetization conditions, crosses phase transition boundaries, and experiences the effects of these changes. But who or what

is participating in these physical events? Strategy 2 suggests that it is both physicists and the inanimate physical matter which they study (e.g., sub-atomic particles, random magnets). Indeterminate constructions are thus a resource which enables physicists to routinely manifest an extreme form of subjectivity by stepping into the universe of physical processes to take the perspective of physical constructs (i.e., to symbolically live their experiences). Like actors playing characters or reporters quoting others, however, while both voices are heard, the voice of the physicist is backgrounded, and that of the physical construct is foregrounded (Voloshinov, 1973; Bakhtin, 1981, 1993).

Referential displacement of this sort seems especially suited to the scientists' efforts to think through physical problems. Indeed, as noted earlier, indeterminate constructions frequently appear when one physicist (especially Ron, the laboratory director) is trying to retrace and interpret what may have transpired in the course of experiments carried out by another physicist in the laboratory. Support for this interpretive strategy also comes from mythic accounts of scientists' flashes of insight concerning physical phenomena in the universe. It is reported, for example, that when Einstein was sixteen, ten years before formulating the theory of relativity, he "tried to imagine what he would observe if he were to travel through the ether with the same velocity as a beam of light" (Whitrow, 1972: 105). Similarly, Jonas Salk recalls that early in his life he developed a technique in which he would picture himself "as a virus, or as a cancer cell, for example, and try to sense what it would be like to be either in order to better understand the viruses" (Salk, 1983: 7). Further, members of the laboratory team acknowledge using language to identify with the objects they are trying to understand. An especially revealing statement came from an interview with Ron, the most prolific user of indeterminate constructions, when he was asked what he thought these kinds of utterances meant:

(9) Interview with Ron (8-2-91)

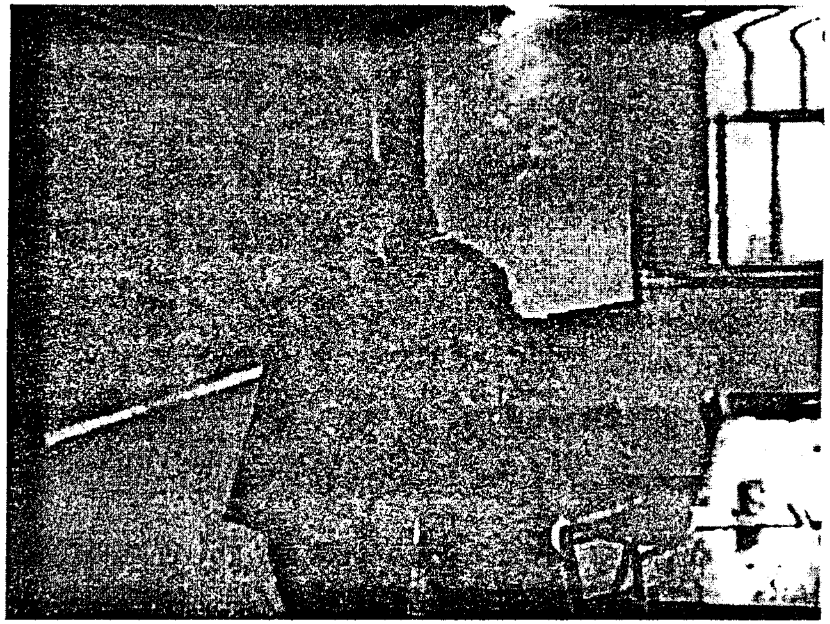
Sally: Elinor is very interested in all the phrases like . . . "When I cross over that line"[20]. . . This is her favorite line in the whole corpus . . . "When I cross over that line" . . . Who's I? ((*lines omitted*))

Ron: This comment that Elinor picked up is certainly true . . . that we personalize inanimate objects. That's a very common physical phenomenon ((*laughter*)) or, I should say, a phenomenon among physicists.

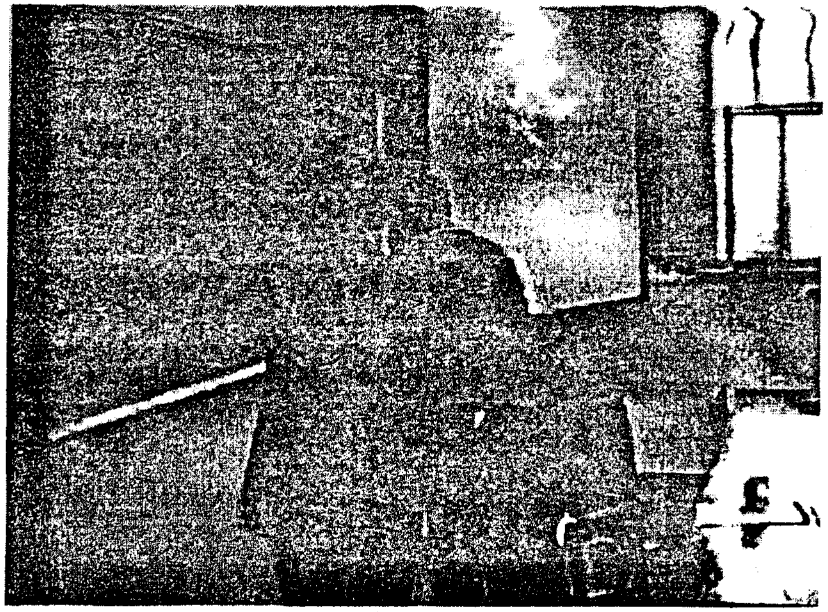
Two things especially strike us about Ron's response. The first is that he volunteers an interpretation of indeterminate constructions as utterances in which "we [physicists] personalize inanimate objects." This comment emphasizes more the propensity of physicists to animate or anthropomorphize physical objects rather than to take on their identities.[21] The second striking aspect of Ron's comment which reflects a Strategy 2 interpretation is his displayed awareness of his own blurring of identities (of physicist and physical entities) in the phrase "physical phenomenon." After laughing, he disambiguates this phrase (through self-repair) by reformulating it as "a phenomenon among physicists."

The constructed worlds of visual representations. While indeterminate utterances may help to displace physicists into constructed worlds of physical events, they do so as part of embodied interpretive practices. To understand such constructions, it is therefore crucial to pursue an analysis that integrates the language, gestural practices, and visual arrays which comprise physicists' interpretive activities.[22] For example, in Segment (7), when Ron says, "I approach a phase transition line in different directions" (lines 1–4) and "come in this way and go here" (line 29), the meaning of "line," "this way," and "here" are interpretable not only as places on the blackboard in the meeting room but also as symbolic places on the graph, which conventionally represent states and events in the physical world.[23]

Graphic displays thus provide physicists with a cognitive and spatial domain to inhabit and wander in. They also transport physical phenomena into the perceptual presence of physicists[24] and serve as a locus in which physicist and physical phenomenon can be brought into physical and symbolic contact with one another (Ochs, Jacoby, and Gonzales, 1994).[25] This intertextual and multimodal process is depicted in Figure 7.4. As can be seen in this series



[If I . . .
[((*points to a*))



. . . [come in this way (0.5) and . . .
[((*moves finger to b*))

. . . [go he:re . . .
[((*moves finger to g*))

Figure 7.4 "If I come in this way (0.5) and go he:re"

of video stills, when Ron says, "If I come in this way," he points his finger first to the rightmost limit of Miguel's measurements at the upper phase transition line (point [a] in Figure 7.3), then to the leftmost limit of Miguel's measurements at the lower phase transition line (point [b]), and then looks at Miguel who has turned his face and body away from the blackboard. After Ron's slight pause pulls Miguel's gaze back to the board (Goodwin, 1980), Ron adds, "and go here," simultaneously moving his finger further left into the long range ordered portion of the graph (at point [g]).

The meaning of "If I come in this way" is thus built simultaneously from (1) the sensori-motor action involving Ron's fingers and hand on the blackboard and within the graphically defined space, and (2) from the symbolic meanings which have already been assigned to the marks, lines, and areas of the conventionalized graphic representation in this and previous interactions. Moreover, indexical gestures are so much a part of the physicists' discourse practices, it appears that physicists come to their understandings

and interpretations of physics partly through such sensori-motor and symbolic re-enactments of physical events and that the collaborative thinking-through process requires that this sensori-motor involvement be witnessed and evaluated by others present.[26]

This characterization of the role of sensori-motor re-enactments is not mere musing on our part. Segment (10), taken from the same meeting as Segment (7), suggests that the physicists themselves are aware of how important sensori-motor re-enactments within graphic spaces are to collaborative interpretive activity:

(10) RO LAB (1-3)

```
Ron:      ((resting head on right hand)) Now let's just s- (.) take your
          finger and start abo:ve the the:: upper transition line.
Miguel:   Yes. ((turns toward board))
Ron:      You're going to say I'm in the paramagnetic state
Miguel:   [Mm hm? ((turns to Ron))
          [((vertical headshakes))
Ron:      Just draw your line. ((Miguel turns to board))
Miguel:   [O[kay.
          [((moves finger from a to b; hand to chalk ledge))
Ron:        [Okay.
Miguel:   (       )
Ron:      I've reached that point. ((Miguel looks at Ron)) And by the
          fact that- (.) the time scale appears to set in right at-
          right when I cross that line,
Miguel:   [Mm hm
          [((vertical headshakes))
Ron:      You're gonna tell me that the random field
Miguel:   M[m
Ron:       [then uh:: (0.2) has caused a domain (.) structure (0.5)
          whi:ch uh itself is [growing in time in some way,
                              [((opens right hand; horizontal headshakes)
Miguel:   Mm hm?,
Ron:      Because of presumably there's [a nucleation and uh it has
                                        [((makes squeeze motion
                                              with fingers))
          to reach an [equilibrium (.) [on the domain side.
                      [((hand to head))  [
```

Miguel: [(Yes it does.)
[((vertical headshakes))
[Yeah.
[((vertical headshakes))
Ron: [Which you may never get to.
[((hand opens to side; hand to head))
(0.5)
Miguel: [Mm hm
[((vertical headshakes))
Ron: A*nd I'm [purposely putting words in your mouth.
[((waves right hand toward Miguel; hand to head))
Miguel: [Y:es.
[((vertical headshakes))
Ron: AND now I [continue down in temperature.
[((moves index finger through air, right to left))
Miguel: [Mm hm.
[((vertical headshakes))
Ron: .hhh [Those domains have some physical: (.) si:ze by
[((opens hand, moves it right))
now. [They're grow[ing?,]
[((moves open hand right))
Miguel: [Correct.] That's right.
[((vertical headshakes))
Ron: [When I cross the [lower line,
[((points to board; lowers head))
[((Miguel turns to board))
Miguel: [Yes:
[((turns to Ron))
Ron: you're gonna tell me [that I jump then, (0.2) to a state
[((snaps fingers))
where [I- m- I have large correlated regions, but the
[((opens hand; horizontal headshakes; head tilts right))
[domains have [no necessary relationship to
[((head straight)) [((moves hand left))
(.) [the domains in the crossed hatch region.
[((points to board; hand to head))

There are several observations to be made concerning Segment (10) with regard to the relationship between the thinking-through process, gestural practices in a graphic space, and the frequent occurrence of indeterminate constructions. One is that, in line 1, Ron interrupts what appears to be the beginning of a hypothetical reasoning sequence ("Now let's just s-") to direct Miguel to place his finger on the line in the graph. When Miguel subsequently contributes a verbal compliance ("Yes"– line 3) to this directive and a continuer ("Mm hm"– line 5) to Ron's resumed reasoning-through process without placing his finger on the graph (lines 3-6), Ron redoes a directive to "Just draw your line" (line 7). Only when Miguel gesturally complies with this second directive (line 9) does Ron fully resume his reasoning-through process. A second observation is that the gesturing is topicalized as a heuristic procedure in the talk itself and is not merely an accompaniment to the deliberation between the participants about physics. A third observation is that in the early part of the segment (lines 12–14), Ron uses "I" in indeterminate constructions even though it is Miguel who has gestured to the board. Since Ron is sitting at the table, at some distance from the blackboard, his directives to Miguel are, in some sense, a way of constituting Miguel as an extension of Ron's own body into the graphic space.[27]

Finally, we note that the occurrence of indeterminate constructions are generally concentrated in two places in Segment (10): in the opening of the segment (lines 1–15) and towards the end of the segment (lines 41–63). Between these two parts of the segment, Ron switches to "physics-centered" constructions as he hypothesizes what might be occurring physically in the domain state phase given the argument he is following. It seems that the indeterminate constructions in this interaction come into the talk in those parts of the narrative about the experiment in which the system is moving from the paramagnetic state to the domain state and from the domain state to the long range ordered state, precisely at the phase transition boundaries represented on the graph by the large curved lines (see Figure 7.3). Ron's stopping and then resuming his use of indeterminate constructions, coupled with Miguel's gestures, thus lends an enhanced dynamism to the physical processes narrated through the talk and represented by the static graph.[28]

Similarly, let us return to Ron's utterance "When I come down I'm in the domain state" (Segment 7, lines 65-69):

```
Ron:    [When [I come down [I'm in [the domain state.
        [((points to a))   [       [
              [((moves finger to b))  [
                           [((moves finger to a))
                                  [((moves finger to b))
```

The presence of the blackboard sketch provides a locus for Ron to perspectivize simultaneously not only what happens when a magnetic system "come[s] down [in temperature]," but also what happens when Ron, as a physicist in the here-and-now interaction, iconically "come[s] down [in temperature]" along a particular trajectory within the graph. Ron's movement is iconic with the graph in that when he "come[s] down [in temperature]," he moves his finger inside the graph from right to left along a horizontal line representing change in temperature. Note that within the conventions of the blackboard sketch (see Figure 7.3), the horizontal axis represents temperature and, thus, a movement leftward represents a decrease in temperature. Ron can therefore linguistically say he is coming "down" yet gesturally move his finger with respect to *how the graph represents a decrease in temperature* (i.e., horizontally, right to left). Ron can also iconically locate himself "in the domain state" by moving his finger back and forth within the area of the graph designated as the "domain state."

Segments (7) and (10) suggest that indeterminate constructions draw interlocutors into an intersection of multiple worlds, including the world of here-and-now interaction, the world of graphic space, and the world of physical events symbolically represented by the graphic display.[29] It is as if interlocutors are able to situate themselves simultaneously on three referential planes through their talk and interaction yet never experience referential confusion as a result of this multi-leveled distribution of attention: physicists (1) attend to people and objects (especially graphic displays) in their meeting room, (2) carry out symbolic gestural motions within graphic representations, and, facilitated by these graphic representations and their own gestural enactments, (3) imagine themselves as physical systems in different physical states. All these practices (and more) not only contribute to the meanings of the personal pronouns in

indeterminate constructions, they also help to constitute the social, cognitive, and linguistic activity of interpreting procedures and findings in scientific discourse.[30]

It is important to point out that while the presence of a visually accessible representation appears to promote the use of indeterminate constructions, such constructions are also used when physicists are not actually gesturing within a graphic representation. We have already noted that one physicist may be speaking while another is doing the gesturing (see discussion of Segment (10)). Secondly, there may be an interactional history of gesturing and orienting to a graphic representation, which gives meaning to indeterminate constructions. This is especially relevant to our data in which discussions of the same topic can continue for more than an hour, with participants occasionally moving to the blackboard, then returning to the table to continue deliberating, using indeterminate constructions without further gesturing to the graph. Finally, a graphic representation may be nowhere in sight but may exist as a virtual reality by dint of its being part of the background knowledge base of the participants. Once knowledge of the model is part of their cognitive apparatus, physicists may speak of upper and lower phase transition lines, for example, without having to draw or hold in their hand a graphic representation of a phase transition model.

While these other scenarios are possible and do occur in our data, we cannot stress strongly enough that the pervasive context for the emergence of indeterminate constructions is participants' orientation to a visibly available graphic representation. Overwhelmingly, interlocutors are looking at, gesturing towards, and/or touching locations within these graphic spaces as they say utterances such as "And now I continue down in temperature," "If I come in this way (0.5) and go he:re there's no decay," or "Why don't I go: to the long range ordered phase in the Kleeman experiment." Indeed, the interlocutors appear to have difficulty sustaining interpretive activity without either jumping up from the meeting table to sketch out what they mean through diagrams and graphs on the board or leaning over printed materials on the table to relate their argument to graphically defined spaces. It may be that this frequent gestural referencing of graphic spaces may serve to reinvoke the mediating role of the graphic display in the participants' creation of meaning.[31]

7.5 Conclusion

This paper brings scientific practice to bear on the understanding of referential meaning in the interactions of physicists. It also examines how referential practice organizes scientists' subjective involvement in simultaneously relevant worlds. Our study has focused on a type of indeterminate utterance: one that combines a personal animate pronominal subject (e.g., "I") with an inanimate physical event predicate (e.g., "am in the domain state"). Such constructions appear syntactically cohesive but are semantically disjunctive in that an entity which is "in the domain state," "breaking up into domains," or "going to the long range ordered state" is not usually considered capable of being encoded as an "I" or "you" who is conscious, reflective, and able to give verbalized descriptions of its physical state.

We have considered two interpretive strategies which might be employed to resolve the semantic incongruity of these indeterminate constructions. The first, which we found to be lacking, attempts to resolve the semantic incongruity by positing an unrealized causative predicate. This strategy allows the personal pronoun to be understood as literally referring to the physicist as agent (e.g., "I'm in the domain state" -> "I cause a physical entity to be in the domain state"). The other, more satisfying strategy attempts to resolve the semantic incongruity by first positing a referential displacement of the identity of the physicist onto the identity of the physical entity or event. Such a displacement allows the personal pronoun to be understood as figuratively referring to the physical entity as if the physical entity were imbued with the capability of conscious self-description (e.g., "I'm in the domain state" -> "I, as physicist assuming the perspective of the physical entity, am in the domain state").

This second figurative strategy was modified further by bringing into the discussion the gestural practices and graphic representations because they are also part of physicists' activity of thinking through physics problems together. In this modified strategy, indeterminate constructions can be understood as literal predications about physicists in the here-and-now world of the interaction who gesturally locate themselves in the world of graphic representation. At the same time, because the world of graphic representa-

tions indexes a world of physical events, these same utterances can be understood as referring to physical entities experiencing the physical events represented by the graph. That graphic representations mediate between scientists and the physical entities they are struggling to understand is old hat to scholars of scientific practice. What is not old hat or obvious, however, is that *graphic representations can referentially constitute scientists and physical entities as simultaneous, co-existing participants in events.*

This analysis of indeterminate constructions contributes to the discussion of subject/object relations in science by illuminating how words, gestures, and graphic representations structure multiple relations between scientists and their objects of inquiry. It hopefully puts to rest the reductive notion, often voiced in studies of science, that scientists have but two discursive alternatives through which they communicate their subjective involvement: either topicalizing themselves as agents or actors who cause physical events, or suppressing their role in favor of topicalizing scientific instruments, systems, results, and other non-human constructs. We hope to have demonstrated that scientists routinely blur the boundaries between themselves as subjects and physical systems as objects by using a type of indeterminate construction which blends properties of both animate and inanimate, subject and object. Indeed, referential indeterminacy created through gesture, graphic representation, and talk appears to be a valuable discursive and psychological resource as scientists work through their interpretations and come to consensus regarding research findings.

Our analysis of referential meaning in the discourse of physicists also suggests that linguistic structures and the shapes of utterances cannot be adequately described without widening the scope of inquiry to include the participants' interaction. Indeed, what we mean by "grammar" may require a reconceptualization. Specifically, we are proposing that grammar cannot be merely a finite set of computational rules or operations in the brain, nor is it to be found only in the verbal sound stream of talk. Instead, "grammar" must also encompass the possibility that grammatical structures and their meanings are constituted through interlocutors' larger activities, tool use, and gestural practices.[32] Benveniste (1971: 220), arguing for a semiotic approach that collapses the distinction between *langue* and *parole*, suggests that grammatical forms such as pronouns and verbs are "an inextricable part of the individual instance of discourse: [they are] always and necessarily actualized by the act of discourse and in dependence on that act." Arguing for a social interactional approach to language, Sacks (1992: 31) similarly observes that "Grammar, of course, is the model of closely ordered, routinely observable social activities" (Lecture 4, Fall 1964 – Spring 1965, p. 31). It behooves us, therefore, to approach grammar as the interactional achievement of participants who creatively adapt language to their larger communicative needs.

Notes

1 We are grateful to Asif Agha, Mario Biagioli, Alessandro Duranti, Charles Goodwin, Marjorie Harness Goodwin, William Hanks, John Heritage, Greg Kenning, Marcos Lederman, Jay Lemke, Emanuel Schegloff, Jonathan Selinger, Michael Silverstein, Marja-Leena Sorjonen, Carolyn Taylor, Sandra Thompson, and two anonymous reviewers for their helpful comments at various stages in the development of this paper. This study is part of a larger project, "The Socialization of Scientific Discourse," directed by Elinor Ochs and funded by the Spencer Foundation (Grant no. M900824, 1990-1993). Additional funding has been provided by a UCLA Faculty Senate Grant. Earlier versions of this paper were presented at the Interaction and Grammar Workshop at UCLA (May, 1992) and at the International Conference on Discourse and the Professions, Uppsala, Sweden (August, 1992).

2 The reader is directed to Schieffelin (1979) for an explication of this endeavor.

3 It should be noted that there is considerable discussion of the philosophical underpinnings and socio-historical accuracy of constructivist studies of scientific discourse. For example, see the debates in Pickering (1992) and Schaffer (1991).

4 Segments of our recorded data are transcribed according to the conventions of conversation analysis (e.g., Atkinson and Heritage, 1984: ix-xvi). Detailed explanations of these notation conventions are included in a glossary at the end of this volume. There is, however, one additional convention used in this chapter:
bolded text indicates the phenomenon of focus

5 This point rests on the essential notion of "conditional relevance" (Sacks, Schegloff, and Jefferson, 1974) which argues that because certain types of utterances warrant other types of utterances as relevant next conversational moves, interaction is orderly and conventional.

6 An activity, in this sense, for example, could be "presenting narratives of experiments." But this activity can be undertaken as a reevaluation of past experimental activity, for instance, or as a precontextualization of projected new experiments.

7 Activity theorists are primarily concerned with the impact of tool-mediated, joint activity on thinking. In this perspective, scientists' thinking develops as an outcome of tool-mediated interactions with people and inanimate objects (including abstractions).

8 Goodwin 1994, 1995 and Goodwin and Goodwin (forthcoming a, forthcoming b) demonstrate the highly coordinated character of gestural and vocal symbolic practices in a variety of work settings, including the operations room of an airport, geochemical laboratories, archaelogical digs, and courtrooms. See also Lynch and Woolgar's recent (1990) collection which examines the interface of talk and figurative representation in constituting scientific "reality."

9 In the discussion of laboratory research that follows, we use descriptive terms and arguments drawn from the interviews, tutorial sessions, and informal conversations we have had with the laboratory members. We are aware that such descriptions may minimize the subjective involvement of the physicists in their own research and interpretive processes. We also realize that we are summarizing as "matters of fact" concepts which the physicists are well aware have not yet achieved "canonical" status within the field and which may eventually be shown to be "wrong."

10 Figure 7.1, and Figure 7.2 which follows, are diagrams which we are introducing into this discussion for the purpose of making it easier for our readers to understand the basic concepts informing the talk and interaction of the physicists we studied. We are aware, therefore, that these figures have the status of "working conceptual hallucinations" (Gilbert and Mulkay, 1984) typical of illustrations in introductory science textbooks and popular science journals. We have constructed these figures based on our reading of several theoretical and experimental articles and on our consultations with members of Ron's lab.

11 An antiferromagnet is a magnet in which the neighboring atomic spins are all antiparallel. An example of an antiferromagnet is FeF_2. A diluted antiferromagnet is a "dirty" antiferromagnet in which a large percentage of the atoms of one of the elements has been replaced by atoms of a third element. For example, $FeZnF_2$ is a diluted antiferromagnet in which zinc atoms have replaced a large percentage of the iron atoms.

12 According to Grest et al. (1986), a domain would be a pocket of atomic spin order within an otherwise disordered crystalline lattice. A domain state, therefore, would be a dynamic state in which previously randomly ordered domains grow in size as a function of time in a crystalline lattice. Until long range order is achieved (see

note 13), there would be order within each domain, but from one domain to the next there would be disorder.

13 According to Grest et al. (1986), in a long range ordered state the atomic spins throughout the crystalline lattice would be arranged in an orderly manner, and would remain so forever unless acted upon by other forces.

14 But see Traweek (1992) for an impassioned plea not to draw a sharp line between these two value-loaded discursive alternatives but to allow scientist-centered accounts to be as credible as science-centered accounts.

15 We don"t mean to give the impression that agent and experiencer exhaust the semantic possibilities which scientists have for referring to themselves. Scientists may be represented/constructed grammatically as interlocutors (e.g., "I would have said that y:er in the domain state"), possessors (e.g., "you have a number for the magnetization"), patients (e.g., "what I"ve been trying to do is to-f:force you into a (.) a position"), recipients (e.g., "Let me tell you how I'm picturing things."), recipient/benefactors (e.g., "I have this preprint for you"), and other semantic roles.

16 The discussion illustrates the observations of sociologists and ethnographers (e.g., Lynch, 1985; Latour, 1987) concerning the ways scientists deal with "trouble" by deciding if it is (a) inconsequential to the meaning of the results, (b) an artifact of the procedure (which renders the results meaningless), or (c) an original discovery.

17 In the zero field cooled procedure, a heated sample of prepared matter is cooled in a zero magnetic field. A field is then applied at a low temperature, and the magnetization is measured as the temperature is raised in incremental steps. In the field cooled procedure, a heated sample is slowly cooled in a magnetic field. The magnetization is measured while cooling is under way.

18 Hanks (1990, 1992) discusses similar utterances in Mayan and the set of assumptions about a candidate referent's status which are needed to interpret them. For example, Mayans need to know that the utterance "In this ditch I'm making, two rows will it take" means that the speaker is controlling the ditch-making but others are doing the physical work. Hanks speaks of the situation as follows: "DP's first person singular reference to what he was doing, when actually he was sitting watching us work, was a clear instantiation of his rank as the head, not only of the current undertaking, but of the household in which we all resided and the *solar* [homestead] in which we were working. Regardless of who wields the hoe, it is DP who is making a ditch to plant peppers" (Hanks, 1990: 124–5).

19 In indeterminate constructions, the pronoun "you" could refer specifically to the addressee in the interaction or to a generalized, unspecified referent (the impersonal "you").

20 The phrase "that line" refers to a phase transition line.

21 Anthropomorphization of physical objects in scientific discourse can be accomplished through a wide variety of physics-centered constructions, in which a physical system is imbued with intentions, knowledge of other systems, and the ability to experience random magnetic fields. As Lemke (1990) notes, such "humanized" scientific discourse appears to facilitate scientific problem-solving in classroom settings.

22 Bühler (1990/1934: 18–19) notes:

> It goes without saying that linguistics cannot get along without observation... Of course, only what is *audible* in the concrete speech event can be fixed on records, and this first only weighs heavily in the methodological discussion. For there is more to the full speech event – we could just as well call it the "significant" or "meaningful" speech event – than just what is audible. But how is the rest of what belongs to the speech event also registered and made accessible to exact observation? However the matter is twisted and turned, the observer who is researching language must (whether from within or without, as the usual distinction has it) undersand what is registered with his eyes and ears...

Since the introduction of video technology, there has been a growing interest in the relationship between gesture, tools, and talk in discourse, in everyday as well as worksite settings (see, e.g., Goodwin, 1984, 1994, 1995; Heath, 1984; Schegloff, 1984; Egbert, 1991; Goodwin and Goodwin, 1992, forthcoming a, forthcoming b; Whalen, 1995).

23 Given that a graphic representation such as the blackboard sketch relevant to segment (7) (see Figure 7.1) can also be highly intertextual (Ochs, Jacoby, and Gonzales, 1994), deictic references such as "here" and "this way" may index multiple symbolic spaces in distinct graphic "texts." A graph may thus be an example of what Bühler (1990/1934: 156) calls "a systematized play of fiction supported by a thousand conventions."

24 Sociologists, anthropologists, and historians of science (e.g., Fleck, 1979/1935; Lynch, 1985; Latour and Woolgar, 1979; Latour, 1987) have noted that figures and graphs are "inscriptions" which make visibly present physical phenomena that cannot otherwise be directly seen by the naked eye, and thus they play a role in enhancing the reality status of physical constructs. But see also Gilbert and Mulkay (1984) who point out that scientists are well aware of the fictional status of many of the inscription devices they employ.

25 We are not saying that graphic displays *necessarily* lead to such symbolic contact. As can be seen in segment (7), physicists may use a graph to represent their actions as experimentalists ("When you cut the field") or they may treat the graph as an object to be known, understood, or otherwise experienced. Our point is that the graph affords physicists the *possibility* of symbolically engaging in physical events.

26 This practice recalls discussions of "witnessing" in the early periods of modern science (see, for instance, Shapin and Schaffer, 1985;

Bazerman, 1988), when scientists wishing to prove the factual status of their findings invited ratified colleagues to witness experiments with their own eyes. When colleagues could not be present to witness first-hand, they were invited to "virtually" witness the experiment by reading detailed accounts which included detailed drawings of instruments and other relevant objects. Our point here is that when the physicists in Ron's lab depict physical events verbally and gesturally within a graph, those co-present "virtually" witness experimental findings and theoretical physical events which took place (or could take place) at some other time or location.

27 This observation is very similar to the observations made by Hanks (1990) concerning referential practices in a ditch-digging worksite in the Mayan community he studied. See note 18 for a fuller description of the interaction he analyzed.

28 It also appears that the semantic incongruity of indeterminate constructions is effective because it is offset by a spate of semantically unproblematic "physics-centered" utterances. Thus, periodically switching from one type of utterance to the other reinforces and regrounds the interpretive possibility that the physical constructs could also be the referent of the animate pronoun.

29 Silverstein (personal communication) has suggested that the intersection of worlds is even more complex when we take into consideration that indeterminate constructions are often couched within metapragmatic predicates, such as "what I can't figure out is" and "cause you're telling me that," which we have categorized in Table 7.1 as a physicist-centered discourse practice. In addition, multiple worlds and multiple time frames are indexed and overlaid through the use of the simple present tense in indeterminate utterances such as "why don't I go to the long range ordered phase in the Kleeman experiment" (Segment 7, lines 14–19).

30 In advocating Strategy 2, we have pursued a perspective that is integral to the work of scholars in a number of related disciplines who explore linguistic structures as rooted in social practices and activities, including, among others, Sacks, Schegloff, and Jefferson's (1974) consideration of the interrelationship of syntax and turn-taking, Sacks and Schegloff's (1979) discussion of linguistic resources for person reference in talk-in-interaction, Duranti's (1990) study of agency in Samoan interaction, Hanks' (1990, 1992) work on Mayan deixis as a referential practice, Goodwin's (1994) treatment of the collaborative construction of categorization in professional interaction, Schieffelin's (1992) work on the impact of evidentials in constructing literacy practices and cultural change among the Kaluli, Sorjonen and Heritage's (1992) study of *And*-prefaces as agenda markers in interaction, Silverstein's (1993) work on shifters and creative presupposition, and Haviland's (in press) analysis of transposition in Tzotzil and Guugu Yimidhirr speech events.

31 Participants' frequent return to graphic displays as a way of grounding and regrounding subsequent talk about physical entities and processes may be similar to their use of and shifting to "physics-centered" constructions which, we suggested earlier, may serve to ground and reground the referential meaning of indeterminate constructions.

32 While we are calling for a wider scope of inquiry into language, we are by no means suggesting that grammatical categories have no sociological or psychological reality. Indeed, we take issue with Lee (1991: 224), who has called for "dissolving the conceptually un-analysed notion of "language" and language form" and for "seeking to locate structures . . . without preconceived notions of what these structures look like." The study of anything, including the ethnomethodological study of social order, is never free of "preconceived notions" and is inescapably constrained to some extent by its own vernacular and ideology (cf. Fleck, 1979/1935), and may even be enriched by constructs developed elsewhere. More importantly, the findings of conversation analysis (e.g., the work on collaborative completion, appendors, and repair initiation) provide ample evidence that interlocutors (and even sociologists) are oriented to and cognitively monitor many of the linguistic structures which linguists have named and analyzed.

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