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THINKING THROUGH TALK:
AN ETHNOGRAPHIC STUDY OF A MOLECULAR BIOLOGY LABORATORY

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THINKING THROUGH TALK

Laboratory studies are a recent development in social studies of science, yet students of scientific laboratories tend to report some very similar experiences: what they observe in scientific practice does not lend itself easily to an analysis in terms of existing logical, epistemological, and methodological concepts of scientific inquiry; and what they are looking for in terms of these notions is not found in the "right" places, that is, where our shared beliefs would lead us to expect a feature of science.[1] Perhaps the feature most widely attributed to science and yet not "found" in its proper place is intellectual labor, a component of scientific pursuits commonly conceived of as a mental process located in individual minds. Common sense notions portray scientists as high-power though perhaps slightly mad intellectuals, and represent intelligence as a precondition for a successful scientific career. Several traditions within science studies construe scientific activity primarily in terms of mentalistic concepts. For example, models of scientific discovery tend to rely on mentalistic notions such as "genius", "insight", "gestalt switch", or "conceptual interaction", and they do so even when the argument appears to be from culture, as the idea of "Zeitgeist" in cultural maturation theories of innovation suggests.[2] Theories of scientific growth in twentieth century philosophy have tended to assume that science is a rationally well-founded system of inquiry, and have searched for models of rational choice and logical procedure that might explain the apparent success of science. Historical approaches predominantly portray the history of science as a history of ideas and, to a degree, sociology of science also utilizes mentalistic notions when it distinguishes between the properly "scientific", that is, "intellectual" or "conceptual" aspects of science and its institutional or social components. We argue against these approaches, that in actual scientific inquiry *much of what one would be inclined to call scientific "thinking" appears to be a public, socially organized activity not restricted to individual minds.* Conversely, much problem pondering in the mind, when it occurs...if one can believe verbal protocols of authors obtained during such performances--has the character of an incoherent intellectual fumbling that gives little indication of the presumed complexity and acuity of human intelligence.

To avoid misunderstandings, we would like to stress that there is, of course, no question that human conduct involves intracerebral physiological processes. The question is whether we have to think of these processes mainly as *internal acts.* As Ryle (1971) has argued, intelligence is also exercised in practical performances which need not incorporate the "shadow act" of contemplating propositions in what he called "the secret grotto in the head". Central cerebral operations cannot be ^problematically identified with the performance of mental computations. Moreover, intracerebral processing may have its own limitations, thus posing the question whether "thought" does not involve vehicles of thinking other than, or in addition to, central cerebral operations.

A possible scenario for such a situation is offered by what Dennett (1985) calls "the orange theory of mind",[3] Accordingly, the mind consists of a series of input analyzers and a central processing unit. The input analyzers are domain-specific modules that serve to interpret the incoming information and to make it available to central processes. The central arena itself remains pretty much obscure. The theory assumes that the modules are somewhat encapsulated or less than perfectly interconnected. The tip-of-thc-tongue phenomenon provides an example of this encapsulation of modules: In order to continue with a train of thought one may have to drive a module which needs a word as its input, a word one has momentarily no access to because of a barrier between the module one has been driving and the module that needs to be activated. To overcome such barriers, that is, to get the right kind of interaction between modules, modules may have to be stimulated externally rather than internally, for example via the visual or auditory system—by listening, that is, to one's own voice or to that of another speaker, by drawing a picture to oneself or by going and "seeing for oneself (by exposing oneself to visual stimulation):

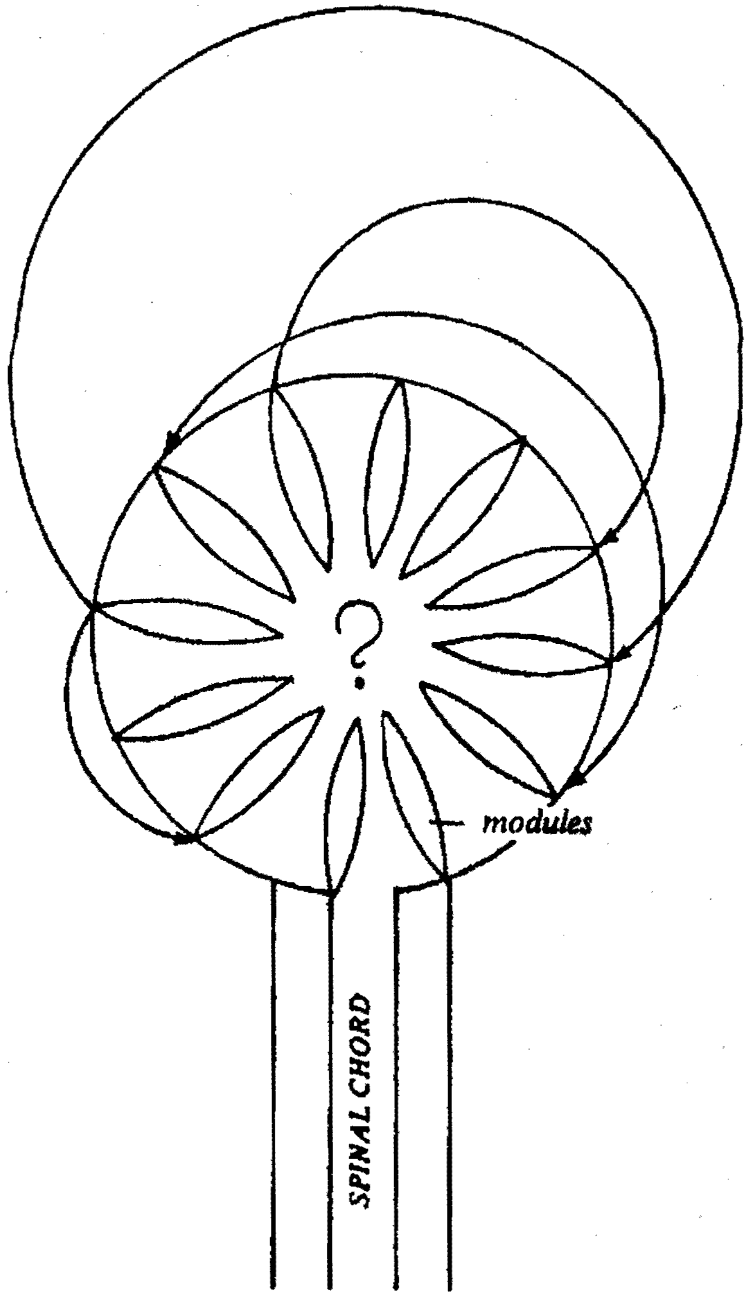


Figure I. The Orange Theory of the Mind

Evolutionary speaking, externally stimulated, and peripherally (in interaction with the environment) performed thinking may have preceded central inference processing in the mind. Accordingly, visualization with the help of the "mind's eye" may be a trick our less than perfect central processors have learned over time to simulate external stimulation and thereby achieve the appropriate interconnections in the brain.

Let us assume that human beings for whatever reason have always depended upon peripherally performed inference processing. Then it is plausible to assume that they will have evolved cultural *vehicles of thinking* other than thought that routinely supplement and replace their central operations. If Gehlen (1962) is right, then many social institutions perform functions which can be seen to substitute for or improve upon the anthropological equipment of human populations. Are there any cultural candidate machineries of thinking ostensibly at work in human groups? We think there are. We submit that in the science we study, *spoken discourse* is one such machinery, besides others to be dealt with at a different occasion.[4]

Having studied the two groups of scientists described below for several years, we are inclined to say that the natural habitat of scientific thinking is talk. Thus, cerebral mechanisms aside, thought in scientific inquiry appears to have not so much a cognitive structure (in the sense of mental calculations) but rather ^*speech act* and particularly a *dialogue* structure. Thinking has, of course, often been associated with language faculties, to the degree to which it is still a matter of contention whether something like "visual thinking" not involving language as described by Ferguson (1977) actually exists, However, what we find in observing scientists at work is not just a link between thinking and language, but a link between thinking and talk, more precisely shop talk. What difference does this make? When embedded in talk, thinking is *interactively accomplished.* It exploits the power of discourse to *bring forth* features of the phenomena which, once on the table, may be very suggestive, and thus may facilitate or simply imply certain conclusions. Loosely put, the move is from inference to conversational implicature[5]: what we get instead of mentally-induced problem solutions are conversationally-induced utterances which, among members of the appropriate science culture, may trigger certain previously nonobvious interpretations or performance recommendations. This observatlon was not expected. Though the phenomenon of shop talk has been noted in earlier laboratory studies (particularly Lynch 1985a), neither we nor others have perceived it as a vehicle of scientific thought.

In this paper, we will focus on several interactionally accomplished inference machineries at work in the groups observed: procedural implicalure, optical induction, the oppositive device, and thinking aloud patterns. Most of the data presented are derived from an ongoing laboratory study of molecular genetics conducted since September 1984 at the Center for Molecular Genetics in Heidelberg, FRG. The group studied works on transcriptional control mechanisms: on DNA regulatory elements which can dramatically increase transcriptional activity during the transcription of DNA into RNA, and which are, for that reason, relevant to the understanding of normal and abnormal cell growth. The group publishes regularly in journals such as *Nature* and *Science* and is one of the leading research units in the area. The leader of the group, who is also a professor at the University of Heidelberg, and its core-members spent several years in the United States, and there were two American post doctoral personnel employed in the group during observations. The Center is largely financed by government sources; the research is done by post doctoral personnel, doctoral students, and students working toward the equivalent of an MA. Most of the examples presented in this paper are derived from a series of interconnected experiments involving a particular method of RNA preparation ("SI analysis"). The results obtained from the study of this group are confirmed by data from a university-based research unit in atomic physics,[6] from which we will include one example. They are currently being examined and extended in a study of particle physics.[7]

THE LABORATORY IS A VILLAGE SQUARE

Clifford Geertz (1973) and Latour and Woolgar (1979) have characterized scientists as compulsory writers: Scientists are said to be very concerned with taking notes and writing papers, and the whole enterprise of research is seen to turn around written products. But if this is true, then it seems all the more correct that many scientists are compulsory talkers: Surely the time they spend on verbal exchanges by far exceeds the time spent on taking notes or writing papers. In many ways, the scientific laboratory resembles a *village square*—it offers a kind of public forum in which laboratory members can watch each other's activities and join each other in daily gossiping rounds.* Typically, the doors of offices and labs are left wide open; they are locked only when scientists are absent or when potentially hazardous instruments are involved. In this open environment, talk is facilitated in many ways, for example through spatial arrangements or the occurrence of specific events.

Consider talk occasioned by spatial arrangements. Laboratory and office conditions are nearly always crowded, la the Center observed, participants desks are placed next to each other alongside the windows of the labs. When participants work at their desks there is little room to pass behind them; one must pass within what Hall (I96S) called "intimate distance.*[1] Intruders deal with this potential embarrassment by making a comment or asking a small question, which may lead to a more extended exchange. A number of laboratory facilities including apparatus such as centrifuges or refrigerators are shared, When they line up to me the equipment, participants meet and talk. Apart from spatial arrangements, there are certain events which nearly invariably occasion talk.

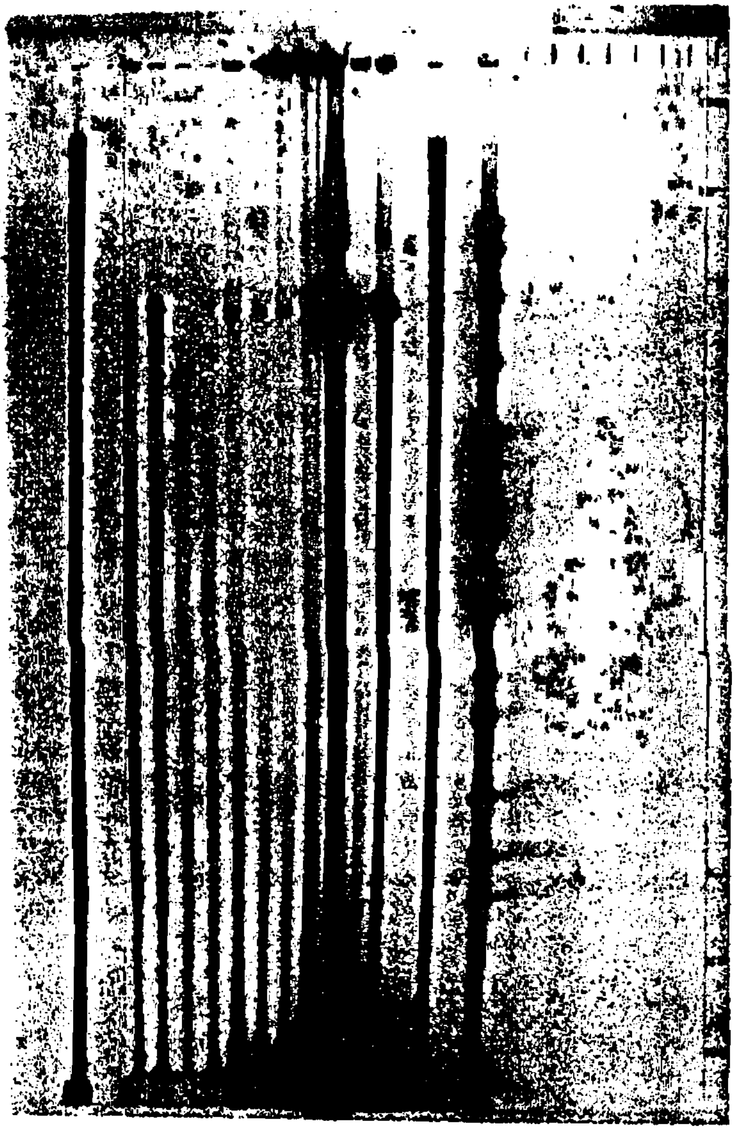


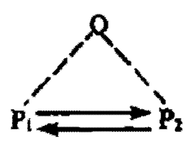
Figure 2. Example of an Unedited Autoradiograph Film
(as it appears in the laboratory)

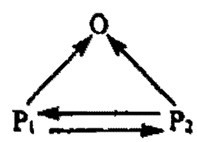
In the molecular genetics laboratory, most of the data are autoradiograph data.[9] They are generated by radioactively-marked DNA or RNA fragments separated in an electrophoresis gel on which an X-ray film has been exposed, and they look like transparencies which display grey and black bands. Figure 2 provides an example of such a film.

Characteristically, these "films[11] appear in the laboratory when an author retrieves them from the room in which they have been exposed and starts to inspect them against the light. Others present are attracted by such events, gather around the visual material, move their fingers and gaze about its surface, and begin a series of verbal exchanges. The leader of the group exerts a similar attraction. He often .stands in the laboratory, seemingly without purpose, or strolls through the lab without any noticeable'goal. Almost invariably, some member of the group will approach him, and ask a question or offer a comment. Once the leader is engaged in an exchange, other participants gather around the group and listen or take over the conversation. Leaders also "make their rounds" through the lab, like doctors in wards, in a more structured and purposeful manner, and initiate talk by asking: "What's new?" or "How are things arc going?"

What are some of the characteristics of shop talk thus initiated in these manners? First, much of shop talk is *occasioned talk;* it comes about through participants waiting for, and actively seizing, opportunities for talk. As occasion talk, shop talk does not have a predetermined profile of activities, unlike many institutional encounters. A medical interview, for example, typically includes an opening identity and recognition sequence, the delivery of a complaint, an interrogative series, and a medical recommendation (Eglin and Wideman 1986). Counselling service encounters have similarly been found to accomplish prestructured sequences of tasks (Kallmeyer 1985). In contrast, the sequence of activities in scientific shop exchanges appears to strictly depend on the occasion. This lack of a preset sequence of tasks may be reflected in the *variability of Ore time frame* of shop talk exchanges. In general, these rounds of talk take anywhere between 30 seconds and an hour, with longer exchanges being usually arranged in advance as formal "meetings". A third characteristic of shop talk is its *special form of reciprocity,* by which we mean a joint orientation to the technical task tit hand and the relative absence of identity casts through which parties are distinguished from each other in terms of institutional roles. It is rare that the parties to a shop-talk encounter pursue recognizably different agendas, or attempt to influence the response of the other in relation to some personal goal. Thus, shop-talk exchanges do not typically follow a pattern of strategic interaction in which parties try to wrest desired responses from each other. The joint orientation to the technical task at hand presumably also accounts for the relative scarcity of excursions into "conversations" (chats on nontechnical matters). Conversations do occur, of course, but they have preferred occasions and locales. Technical exchanges, on the other hand, do not have preferred occasions: They account for much of the talk during lunchtime and coffee breaks, and they even occur during physical exercises, for example in fitness training or when participants go running together.

A further characteristic of shop talk is its *embeddedness m a series of exchanges* made possible through the mutual accessibility of participants to each other while they work in the laboratory. The possibility to take up an issue repeatedly adds to the temporary and incipient character of tasks accomplished in shop exchanges: To the tendency of participants to leave conversational tasks incomplete, and to put into question, in subsequent exchanges, conclusions they have reached in earlier rounds of talk. Finally and significantly, most shop talk appears to be *attached to objects,* mostly displays, apparatus, or specimens of some sort. Phrased differently, much shop talk recorded has a tripartite structure which involves two participants and an object toward which these arc oriented. This sort of shop talk is not just, as most talk is, *about* an object; it is directed to a concrete material object which participants hold in hand. Participants(P) interact so to speak not only with each other but also with the object(O) they address:





Talk "about" an object

Talk "attached" to objects

Significantly, the objects addressed by participants are indeed manipulated during talk: For example, a data display may be held up and turned around, fingers search it, gazes lock on to some of its details. The attachment to objects contributes to the gestural quality of shop talk. The operation performed, the detail observed, complement as concrete "phrases" (and not just as generalized references to context) the verbal exchange.

TOOLS OF THINKING

When we call the attention to rounds of talk in the laboratory: Are we referring to scientists' *verbal business transactions!* What is achieved in these transactions is substantive work and not, to use a distinction made by Goffman (1971, pp. 147-148), "ritual" or "relationship" work (though the latter may be done within and simultaneously with the former, and business transactions have, of course, their own ritual aspects). In mentalist terminology, the tasks achieved in these transactions are the making of inferences, the pondering, rejection and acceptance of propositions, and the projection of explanations—all matters customarily associated with processes in the mind. The shop talk discussed in this paper is a *production device* for generating knowledge out of the manual and technical dimensions of laboratory work. Talk must be considered a *technical instrument* in the laboratory just like the more familiar laboratory equipment. Talk achieves what these more familiar devices do not: For example, it provides the machinery through which scientists "fix" the evidence, arriving at (temporarily) definitive readings of the sense data their equipment turns out.[10]

What machinery? In the science we observe, there are at least four interactional devices which participants employ routinely in performing the above work. We call them *procedural implicature,* the *oppositive device, optical induction,* and the *thinking aloud* pattern. These devices have two characteristics. They are marked by a "conversational score" (a distinctive pattern of interactional organization) and they involve an induction mechanism. Both characterizations are exemplified below.

Procedural Implicature

Consider first the *procedural implicature* device." This pattern is used to derive nonobvious conclusions from mute experimental outcomes by means of an inquiry into the procedures through wlu'ch these outcomes have come about. In a nutshell, the exchange consists of a scries of question-answer and/or assertion-confirmation adjacency pairs (pairs of utterances in which the first utterance constrains the second, *as* in a question which "demands" an answer). These access and make public information regarding the history of a phenomenon. Adjacency pairs are produced in u stepwisc, sequential fashion and result in a mapping of the procedural biography of a phenomenon and its reactions. The pattern may be followed by a conclusion in the form of an interpretation ("this means...") or of n performative recommendation ("I would. ...", "youVe got to. ...*), and ii is frequently initiated by a statement which discloses some problematic occurrence or information. Schemaf'cally speaking, the pattern looks as follows:

OPENING (DISCLOSURE)
repeat n ACCESS-TELL (CONFIRM)
CLOSING (PERFORM/ENTAIL)

The following example is a little more complex in that it includes replay or check of the opening statement (In. 644-46) which the addressee, Qe, had apparently not completely understood. The interrogatory (ACCESS-TELL or CONFIRM) sequence begins in in, 647 and continues through In. 671, after which a conclusion (PERFORM) is offered. The exchange also includes an insert which equally consists of an interrogatory sequence but reconstructs an earlier case (ln. 649-54). The excursion makes apparent differences and similarities between the earlier and the currently explored experiment, thus serving to detail further ongoing procedural reconstructions (->):

(190904 841n640)

	640	Ja	and yesterday I happened to find out from Mu that GTC is perhaps not the real thing, 0 that yield that quality is good, Sn told me this much, but yield is less good
	644	Qe	quality is good but
	645	Ja	right
	646	Mu	uh-hu. Because
->	647	Qe	0 without neo? or with neo'
	648	Mu	without neo, but with 2% FCS
->	649	Qe	uh, yea, slowly now, Didnt Ka once cotransfect with PSV2 neo and with this MSV-LVP'
	651	Mu	uh-hu
->	652	Qe	and from this he raised the mixture, or what'
->	653	Mu	yes, and from this he picked a few clones
	654	Qe	okay
->	655	Mu	and now I made it once more without neo and simultaneously LPB in pBr. That is LPV only
->	657	Qe	so in principle youVe got this same MSV-LPV and LPV only[1]
	658	Mu	uh-hu
->	659	Qe	and you transfected them on NIH 3T3'
	660	Mu	uh-hu
->	661	Qe	and you picked foci(?)'
->	662	Mu	(and mouse? too)
	663	Qe	okay
->	664	Mu	and I let them grow in a 2% serum
->	665	Qe	yes, and what is the result'
->	666	Mu	and a great many died and a some went soggy and also Formed some kind of foci (?)
	667	Qe	aha
->	668	Mu	and from them Th picked five to ten clones
	669	Qe	very well, very well
->	670	Mu	and now we're letting them grow and then I will make another blot
	672	Qe	you've got to make an immunofluorescencc, you can do it now, this week already
			((Etc.))

Note that the conclusion reached or the inference drawn at the end of such rounds of talk responds to the procedural mapping which lies between initial statement and conclusion. The point of the pattern is that participants rely on the development of their interaction *to produce an inference, or to produce* *features of the events- which suggest a conclusion.* As a consequence, the conclusion need not provide an answer to the opening sequence which may have been a problem statement. Thus, in the above transcript the performance recommendation (to make an immunofluorescence) has less to do with the initial problem statement (that GTC does not work too well, In. 640ff) than with the fad that Qe wants to build the results of the test into a paper he is to present at a conference in the week that follows the exchange, a possibility that became apparent during the exchange. The continuation of the exchange confirms this reading of the conclusion. In the following transcript, Mu first objects to performing the lest immediately as Qc had urged her to do, arguing that there are not enough clones and that she does not have the necessary antiserum. In response to this, Qe explains that he would like to include the results in his presentation (In. 685) and that they would score for two points he would like to make (In. 690ff):

(190994 84 In672)

672 Qe you've got la make an immunofluorescence, you can do it right now, this week already
674 Mu but there are only a few now. Next week
675 Qc okay, but whatever it is, I would directly-, that is when you split them the first time, or the second time. When you split them the second time then you split about one-half in a bowl and the other
679 Mu when is An coming buck'
680 Qc she's coming back, next week
681 Mu because she has the antiserum
682 Qc oh
683 Qc youVe really got to look whether something shines there
684 Mu imd what I did in addition
685 Qc because that would be great, that could somehow be built into it ((his presentation of« paper next week))
687 Mu thatV something else
688 Qc well-, that's nothing else
689 Mu well-, but one c&n make something new out of it
690 Qe that makes for two points. That make* for two points, first there is a transforming gene that transforms easily if you place an enhancer in front of it, that is if you enhance it through transcription. One point. Tb« uccorvd point: There is no negative control. Whatever nits on it from the LPV control* docs not control it negatively.

Note that in contrast lo other conversations described in this paper, the above exchange is not an inference-producing exchange. Rather, the exchange consists of a series of negotiations between participants who know what they want but whose goals are at crass-purpaies, Qc wishes the ijTutmnofiuorescence test to be done quickly in order to include its results in his presentation, Mu wants to delay the lest and finish ongoing work. Consider how Ma's contributions divert from Qe's request: She points out obstacles to making the test (In. 674, 679-8), attempts to turn the conversation around to another topic (In. 684), and disagrees with Qe's reasoning (In. 687-89). The whole episode has the character of a postexchange (Edmondson 1981)—of an exchange that serves to firm, detail, and sometimes put into question a conlcusion reached in a prior segment of the conversation. Compare this exchange^ with inference-producing, adversarial exchanges exemplified in the next section.

One last example of a procedural implicature. It is drawn from an experiment in atomic physics on the ionization of helium by positron impact. The example includes two short excursions into procedural reconstructions which are framed and divided by formulations of gist. The procedural reconstruction is initiated when Di starts to report that the real count of particles decreases when he lowers the blind count:

	21	Di	(. . .) I think that until now we've just discussed something that's pretty incorrect. Therefore, I made some control measurements and now it's gone. And now if I lower the blind count from 20 to approximately 5.5/
->	25	Ra	by turning off the magnetic field or what'
	26	Di	no, by changing the threshold
	27	Ra	yes!
	28	Di	uh, this means that I have lowered the blind count by a factor of 4 and the real count decreases by a factor 2. I've got only 100 real ones
	31	Ra	(is this) is this *expected*'. Or
	32	Di	yes, yes. That's the way it is. Sad but true
->	33	Ra	the blind count decreases by a factor 4. Because you did what'
	34	Di	because I changed the threshold
->	35	Ra	of what'
	36	Di	of/okay, the discriminator threshold for the pulses
->	37	Ra	okay. Then what decreases only by a factor of 4'
	38	Di	the real count
	39	Ra	but that's good!
	40	Di	well, it's better than if it decreased by a factor of 8, but it would still be, still be better if it wasn't decreasing at all
	42	Ra	no, this would mean, wouldn't it, no, no, this is a clue, isn't it, for the fact that the events which lead to the background count are physically different from those which/when we count our primary positrons.

In these examples, the reconstruction performed by participants determines for them the kind of issue at stake and the consequences with respect to ongoing laboratory work. This procedure does not conform to standard formulations of deductive reasoning in science nor to patterns of inference presumed by the problem solving model. For example, the exchange may result in a "solution** to a problem participants did not have while the problem which initiated the exchange may not find a solution. The pattern corresponds most closely, perhaps, to the logic of historical explanation through the reconstruction of idiosyncratic events by a kind of narrative interview technique.[13] Participants act as local historians interested in the details of a case—they do not elicit, for example, a global assessment of the situation or some theory about the events. In keeping with this method, "thinking through" the problem appears to be the *interactively accomplished* product of participants' historical research—not the result of an individual's purely mental workout of problem implications.

The Oppositive Device

The second inference device is called *oppositive* because of the *adversarial* nature of the exchange. In contrust to other patterns, the device is argumentative: Participants do not raise procedural questions in the fashion outlined above, or, as in the case of optical induction, draw inferences from what they see. Instead, they argue with, expand upon, and negotiate candidate accounts and formulations offered by another participant, the opponent in the exchange, In the following discussion, which Ls part of a longer, frequently adversarial exchange, the question is whether certain bands on a film are the probe or unspecific starts:[M]

(100104 851 n691

69	Jn	how do you mean, cut'
70	Ir	partially cut. ((Ja looks skeptical?)) Well, look, what is typical is that you've got these band* here. And youVc SI/
71	Ju	nnw, these could be other starts as well
72	Ir	in CAT
73	Ja	mtw. Unlikely
74	Ir	wherever there is u lot of RNA on it/
75	Jn	nnw but/the first we did together, there it went down there/the longer you exposed it, the more you got down there..,. Don't you remember[1]
78	Ir	(Iinaudible)) you dorrt need CAT-RNA
79	Ju	**thu/**
80	Ir	but CAT/ ((inaudible))
H	Ja	ify if *you* want to claim it a/ that this is a product of digestion/ product of partial digcttion of S1
83	Ir	yauVe ft&o gat *probe* in there. Always.
84	JH	but in different amount*. This for example/
85	Ir	((ironic?}) in different amounts, yta, yea
86	Ja	this U obviou* ((inaudible)) Otherwise thin would be/
87	Ir	(it) could be ... These were different RNAV nothing more than a claim. 1 mean if there/

89	Ja	you mean the amount of RNA has an influence on S1 digestion' what does this have to do with it' you're throwing lots of calfthymus-DNA in there even before the S1-digestion
92	Ir	sure, but if/ if for example here I had only/ if what you're saying was logical, okay'
94	Ja	okay'
95	Ir	then I should have least of the probe retained *here* okay'
96	Ja	((repeating)) least of the probe retained where'/
97	Ir	where there is most CAT-specific RNA
98	Ja	no, you always have too much of it
99	Ir	if any. But curiously enough where there/
100	Ja	you've got there where there is most, you've got/
101	Ir	where there is any RNA at all.
102	Ja	most specific/ not where there is any RNA at all, this doesn't have to be the case. ((Etc.))

Note that the point of such patterns is not, as one might assume, the persuasion of one participant by another or the negotiation of firmly held opinions until a compromise is reached. First, participants develop their contributions as they go along in response to problem features they become aware of; they may not hold the respective opinions in advance. Second, the purpose of these exchanges appears not to be to reach an agreement among opponents but to use their disagreement to produce novel (not previously obvious) features of the phenomenon discussed. For example, there is little effort on the part of participants in these exchanges to reconcile their differences. More generally speaking, there exists a *preference for disagreement* in contrast to the preference for agreement students of verbal encounters in other institutions, for example in doctor-patient interactions, have found.[15] Significantly, many adversarial exchanges do not end with an agreement but nonetheless produce a conclusion on which participants can proceed. Furthermore, even when an agreement is reached this does not mean that the problem has been solved, as illustrated by the frequency of what one might call "negative solutions "—ways of undoing the problem without solving it. For practical purposes, results can be achieved which do not require a solution to the conceptual problem involved. Examples of such forms of remedial measures are proposals for different kinds of redressive action, such as for not showing the problem in a publication. Remedial measures are often proposed as free-standing solutions, that is as solutions which are not logically derived from the preceding exchange. In the continuation of the above example, participants arrive (after a brief interruption by a colleague) at a temporary conclusion (ln. 121ff) which proposes a redressive action:

(100105 851nI19)

119	Ir	IVe probably different amounts of probe in there/ had different amounts of probe in there.
120	Ja	this is something else again

((brief interruption by another speaker))

121	Ja	I would just expose it for a shorter period of time. But you can cut it off unyway

((Pause))

123	Ir	now sure/ 1 cun follow Chambon ((points to a small section on his film suggesting that for publication, he can cut off the rest))
124	Ja	well, you should have seen those/ Picard, Schaffner in the latest volume of the EMBO journal/ also everything ((cut)) off. You could sec that there was a lol of dirt down there. Everything cut off. YouVc got the advantage, youVe got ((laughs briefly)) free space in between ((to cut between bands))

Optical Induction

The third device employed by participants, *optical induction,*[6] is more specifically relevant to talk embedded in work with visual materials. Procedural implicaturc uses the assumption of a causal relationship between the biography of an experimental result and its qualities to bring out features of the phenomenon which suggest a conclusion. For the same purpose, the oppositive device relies on differences of experience, judgment, and opinion expressed in adversarial exchanges. Optical induction, on the other hand, draws upon visual materials to prompt, extend, or control contusions. In the example given below, these conclusions relate to the identifying characteristics of the bands on a film. The conversational means, in this case, are neither question-answer adjacency pairs as with procedural inquiries nor posits and counters as with the oppositive device, but sequences best characterized as *formulations* (mixed with confirmations): utterances which formulate the identity of various traces on film based upon how these traces look and where they are located, upon visible similarities and hypothetical starting points. In the following example, Ir and Ja resort to a series of such exchanges after they get stuck with the question of the length of the "marker" (In. 27), a construct whose pattern of bands on the film is supposedly known and can serve as a kind of measuring stick for other bands. Going back and forth between the bands of the "probe" and the marker-bands, participants infer from what they see what the length of certain bands might be:

(100105 85p32)

24 Ir (...) in any case, there is another marker. No problem, this is a hind f marker

26 Ja and how/how long is it'

27 Ir I can still figure this out. But I mean, this is the probe, okay'

28 Ja okay

29 Ir there on top. And the probe I know how long it is. 420

30 Ja 420, is this, this is 500'

31 Ir could also be 500, couldn't it. Could also be 600

32 Ja well if *this* is 600... and *this* 400. 300 was here. ((Ir appears to shake his head?)) No

34 Ir no see, the way the gel ran blue was *there,* and this is 130

35 Ja *130's there*

36 Ir and then 250 is ***there***

37 Ja there is 250

38 Ir there is another one (?)

39 Ja okay. 499 ... and the other ones here are still going to appear'

((Etc.))

In many respects, an autoradiograph film is like a maze. To find a way out of this maze, different parties point out where it goes along (by noting, for example, the possible identity and length of certain bands). This is partly a visual problem, in which the parties employ visual clues to accomplish the task. Since the induction mechanism relies on visual clues which are collaboratively recognized in talk, optical induction is not bound up with a particular conversational pattern. In other words, formulations are just one of several conversational devices with the help of which optical inductions may be performed, a device adapted to the specific pictorial problems presented by autoradiograph displays. This raises the possibility that optical induction might be considered a strictly visual tool of judgment rather than as a discursive mechanism of thinking relying on talk. On the other hand, in the sciences observed, visual inspections and optical induction appear embedded in verbal exchanges, which indicates that talk plays a role in these cases as a mechanism of thinking, as in the first two patterns mentioned above, Nonetheless the connection between the conversational "score" and the induction mechanism is clearly more loose in optical induction than in the first two devices, with which the conversational patterns are the sole vehicles of inductions.

Thinking Aloud

A similar point can be made about the last pattern to be mentioned, the device of *thinking aloud.* It appears to be used both when participants work by themselves and in the presence of others, though perhaps not as frequently as other patterns mentioned. When thinking aloud participants seem to exploit the stimulating effects of hearing their own voice perform in front of an audience—a role in which they may cast a colleague or themselves (when someone talks to him/herself). As in the case of optical induction, it is not clear that thinking aloud patterns must have a particular conversational form, with some exceptions: Like other shop-talk routines they tend to produce conclusions or performance recommendations and thus exhibit closure points (note the conclusion in In. 113ff. of the transcript below). And they have a monologic structure which reduces the hearer to making listening noises and gives the speaker the privilege of long, elaborate turns. However, the hearer (who is sometimes cast in the role of a learner) is nonetheless important in these exchanges. First, thinking aloud patterns are often interspersed with short periods of dialogue and with accounts which directly respond to the presence of a listener. Second, they are frequently initiated by someone silently joining a participant or by someone joining and making a request for information. Thus, thinking aloud patterns are interactively accomplished conversational patterns despite their monologic structure. The following excerpt begins after a three-turn dialogue betweeen Ar and Ir inserted in a more extended exchange in which Ir had alternately given accounts and "lapsed" into thinking aloud about the film he holds in hand. In line 89, Ir lapses again into thinking out loud, as indicated by his ignoring Ar's questions:

(150106 85p81)

87	Ar	once more, how arc they different[1] ((from each other, he means RNA preparations))
88	Ir	((Pause; Ir looks at his film and does not react to question)) ((inaudible)) must be shorter the other one. This band is shorter. The problem is... that's why I put it in, it's got a different promoter ((inaudible)). If I measure it with the same probe as mine is (then all of it is shortened) up to the beginning of CAT. All that's different is gone. As if you had a start down there, 50 bases. Okay, that means I would have some control, a correct start there, correct start, and there a marker with RNA
96	Ar	((repeats his question))
99	Ir	((still does not respond to the question)) and you don't even see (what does it mean) more sensitive. I mean this is a simple statement because I say it's more sensitive in as far as I sec on this film ((exposed)) overnight this thick blob and with this method after an appropriate
103	Ar	((inaudible))
104	Ir	((Pause)) my problem is whether I've got the right start side. Because if one discounts the marker, then one sees 6..5,4,6,5,4, there, the starts should be *there* ((Pause)) IVe got 3 different ones in there now

((Pause))
where the start is, ((is)) a general start
((Pause))
113 (that means, I surely have) starts from here on. That's the one in CAT. Up there. But in the end it doesn't matter. However many there may be. I mean, IVe got to see whether there is going to be such a start in the virus, which is 70 bases above, at around 100. ((inaudible)) Which one sees, if one. . .. uh, T-antigcn ((inaudible)) I've got this with small t too ((inaudible)),
((end of the exchange))

EPISODIC REASONING

One final note. From the transcript, it is plain that thinking aloud patterns tend to be argumentative, like exchanges taking an oppositive course. One characteristic of argumentative talk is that reasoning is often *episodic,* by which we mean it is continually attached to—and indeed relies for its substance on—concrete historical occurrences (episodes). These may be experimental procedures, ways experiments have turned out or problems have been handled in the past, or other experiences of the group or of scientists known to its members. More precisely one should say that experiences made by group members or gleaned from the literature and from reports of other scientists become formulated as episodes ("what Chambon did. . .," "what Schaffner did. , .," "what happened when we did the experiment last time. . .," "what I got when I last tried the procedure.,.," etc.), And these episodes are recalled as a possible resource in "firming" conclusions and in arguing for candidate interpretations. As an example, consider once more the conclusion of the oppositive exchange noted above:

(100105 851 nl21)
121 Ja I would just expose it for a shorter period of time. But you can cut it off anyway
-> 123 Ir now sure/1 can follow Chambon
-> 125 Ja well, you should have seen those/ Picard, Schaffner in the latest volume of the EMBO journal/ also everything ((cut)) off, You could see that there was a lot of dirt down there. Everything cut off. You've got the advantage, youVe got ((laughs briefly)) free space in between.

Or consider ln. 75ff. of the same exchange:

-> 75 Ja naw but/ the first we did together, there it went down there/ the longer you exposed it, the more you got down there... Don't you remember[1]

Though episodic reasoning is more common in argumentative exchanges, it is not limited to them. For example, episodes also appear in procedural reconstructions, as the excursion into the reconstruction of an earlier experiment in the first transcript presented above indicates. In this case, the episode is "dissolved" in a series of question-answer adjacency pairs; it displays the same form of interactional organization as the encompassing sequence of talk:

(190904 84 In649)

649	Qe	uh, yeah, slowly now. Didn't Ka once cotransfect with PSV2 neo and with this MSV-LPV[1]
651	Mu	uh-hu
652	Qe	and from this he raised the mixture, or what'
653	Mu	yes, and from this he picked a few clones
654	Qe	okay

Episodes are recalled not only to back up arguments, firm conclusions, or simply to extend the available range of information. They also serve to instruct and entertain. In such cases they take on the character of *atrocity stories*[11] told by authors for the benefit of participants who report—or worry about—some unnerving event. In the following example, Ir tells the story of the kind of problems he once experienced when he tried to run an electrophoresis gel:

(170102 85pIO2)

1	Ir	(...) then he told me you have to let it cool down. Then it hardened when I poured it ((and could not be poured))
3	Na	yes
4	Ir	next lime 1 thought: ha, this trick is not going to do me in a second time
5	Na	((laughs))
6	Ir	I poured it in boiling hot and then it ran out ((of the apparatus)) below. It wasn't tight down there. Well, be it, now you've gone that far, I juat heated it up once more and in 1 put it ((laughs aloud)). Then the plate burst ((laughs)).
10	Na	haha, this is really
11	Ir	and so on all the time. And then I finally had it ready, it was done. Then I ((inaudible)) and I took off the label* and then (laughs again)) then the thing burst with KH ((laughs)). And things like that. The worst was, I found out later/ because it took a few days until I had it, there wasn't any microwave oven around, you always had to first boil it
19	Na	yesyes

Ir I had it ready, then I let it run ((laughs out)), then it/ when I took
it apart the glass outside was so slippery ((the gel spilled)) into the
lower tank of the electrophoresis chamber. I was lucky that there
was somebody there on a Saturday morning, he helped me to
wash it off and to catch it with a glass plate
Na I mean, happens to everybody ((etc.))

Experience travels through these episodes, it circulates among the members of a group and is accumulated by some as a form of procedural capital (knowing who has tried what with what success or knowing what happened to X when he or she did Y) upon which one can draw when the time comes. Thus episodes, in a more structured way than shop talk in general, are a means of keeping the crucial information alive which might otherwise be stacked away in protocols or buried in memories.[18]

CONCLUSION: THE PROSTHETIC STRUCTURE OF SCIENTIFIC THINKING

Scientific thinking as it appears in scientific work has *& prosthetic* structure.[19] It employs devices other than thought to elicit and facilitate conclusions. One such device is the interactional inference machinery of shop talk. The pervasiveness and the sheer amount of shop talk is striking in the sciences observed. It is plain that work gets accomplished in shop talk, and that shop talk must be considered a technical instrument of knowledge production just like the more familiar experimental apparatus and machines. In working through examples of scientific shop talk, we found several recurrent patterns of talk that ostensibly accomplish inference tasks, Most widespread among these appear to be procedural implicatures and the oppositive device. Two of the devices identified are argumentative, the thinking aloud pattern and the oppositive device, with the latter being adversarial while the former is not. To some extent, argumentative patterns "feed upon" or overlay other conversational patterns; the patterns described are not mutually exclusive. For example, participants may draw visual inferences and make optically-derived claims in the service of their argument. Arguments are often backed by episodic reasoning, as are conclusions in all devices. Episodes are one of several narrative elements in scientists' spoken discourse, other elements being stories and reports (not examined here). Two shop-talk routines are more heavily than others attached to the object around which the conversation turns: optical induction and thinking aloud. In thinking aloud, speakers turn away from hearers and face the object while they sketch out arguments, identify issues ("problems"), and formulate experiences or conclusions—all apparently in taking their clues from the object. In optical induction, the same close connection between object and talk occurs in a more literal sense: by the way it looks, how it is positioned in relation to other observables, etc., the object "suggests" a conclusion. Yet both patterns rely, like the first two mentioned, on the presence of other speakers: They are realized through talk (sometimes through talk to oneself).

In identifying the above patterns of talk, we paid attention to the phenomenon that complex problem situations tend to become *interactively dissolved* in shop talk. This leaves unconsidered other forms and functions of shop talk, as well as habitats of scientific thinking other than talk. It is plain that the patterns of talk exemplified above do not exhaust participants repertoire of shop-talk routines. Equally, we must assume that "thinking" may become located in a variety of locations other than verbal interaction, once we consider that there is not just one single habitat of thought such as the mind. We have tried in this study not to miss the interactional organization of scientific thinking exhibited in natural scientific practice. It remains for a future study to examine other vehicles of scientific thinking and forms of talk.

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NOTES

1. For some of the major laboratory studies published so far sec Latour and Woogar (1979); Knorr Cclina (1981); Zenzen and Rcstivo (1982); Lynch (1985a); Trawcek (1988). For an overview of recent developments in science studies, see Knorr Cetina and Mulkay (1983).

2. The notion "Zeitgeist" is a mcntalislic concept, meaning "spirit of the time." Characteristically, culture is described in analogy to the individual as a "superorganism" by one of the originators of the "Zeitgeist" theory, Alfred Krocbcr (1917). For areview of received theories of discovery see Brannigan (1981, Chs. 2 and 4),

3. In u scries of lectures presented at the Conter for Interdisciplinary Research, Bielefeld, Spring 1985. Dennet was referring to Fodor* model of the modularity of mind (Fodor 1984).

4. One other machinery is the human body, on whose Information processing potential participants rely when they insist that they must see a phenomenon "with their own eyes" and perform certain tasks "themselves."

5. This way of putting the matter draws upon a possible but not very clear distinction between inferences" as logical accomplishments and what Orice (1975) calls "conversational implicaturc," which in our reading rest* upon convention and cultural knowledge.

6. The unh works at the University of Bielefeld and has been selected and studied as a "control group" for variable periods of lime since 1984.

7. In a study begun in 1987 at the UA2 experiment at the CERN, Geneva. For the instrumental shape of the laboratories we currently study as well as for a discussion of the devices these laboratories use in constructing natural objects, see Knorr-Cetina (1988).

8. For a comment on how seemingly solitary types of fieldwork in earlier historical epochs nonetheless "embody the integration of solitary seeing, thinking and doing into a larger fabric of social interaction," see Rudwick (1985, p. 432). Rudwick echoes George Herbert Mead's (1967) notion that "thinking" can be conceived of as an inner dialogue and for this (and other) reasons as a social act. He argues that the geologist carried with him an "inward microcosm of the larger world of geological debate" that became visible when joint field work provided an occasion for "outward" and open debate. Compare also our finding of the "thinking aloud" pattern in laboratory research.

9. For an introductory description of autoradiograph daia and the methods through which they are produced, see any textbook in molecular genetics, for example, Alberts cl a!. (1983).

10. For an example of how the conversational devices described in the following arc applied to the problem of fixation of evidence, see Amann and Knorr-Cetina (1988a). For a sludy of how consensus is reached on the results of aseriesof experiments, sec Amann and Knorr-Cetina (198Kb).

11. The name of the pattern borrows from Grice's notion of "conversational impliealure" (1975) mentioned before and from Cicourel's work on "procedural knowledge" (e.g. 1974; 1975; 1978).

12. By conversation analysis standards, the following data nre fairly grossly transcribed. We have omitted indications of overlaps and of the length of pauses, and not transcribed explosive aspiration, "latching" or prolonged prior syllables. We believe, however, that the transcriptions are adequate for the level of analysis we attempt, and that the omissions do not fiffect this anulysis. The following transcribing conventions were used:

/	"Interruption"
( )	Single parentheses indicate the transcriber was not sure about the words contained within parentheses. Empty parentheses indicate talk inserted in or before passages relevant to the case presented.
(( ))	Double parentheses indicate comments by the transcriber
'	Rising intonation

13. The narrative interview is a technique which attempts lo get the respondent to relate in detail the particulars in a sequence of events, and to prevent him/her from offering the interviewer his/her theory or summary account of what happened (SchUtzc 1976).

14. "Starts" indicate molecules that have separated in the gel run. They are the expected bands on a film. The "probe" is a radioactivcly labelled DNA fragment to which RNA is hybridised and which appears in all lanes of the film as a band in a specific position.

15. The notion "preference for agreement" is used in two ways in the relevant literature: On the one hand, it refers to formal agreement, as in sentences beginning with "Ycs, but..." which are usually polite versions of disagreements. On the other hand, the notion also refers to a more general tendency to express agreement with a speaker's utterance and to keep to oneself possible disagreements with his/her opinion (compare Sacks 1973; Pomerantz 1975).

16. We owe the name of the pattern to Karl Hcinrich Schmidt.

17. See Strauss (1985) for examples of atrocity stories in a medical setting.

18. For the role of stories in particle physics and for findings similar to ours, see Tmweek (1987).

19. For an interesting study of "prostethic" forms of thinking in lay persona solving everyday arithmetic problems, see Lave (1987). For a study orhow practices of congtituting wricntific exhibits make up an "externalized retina" for scientific perceptions, see Lynch (1985b). For a study of how "seeing" is realized through routinized conversational practices in the laboratory, *net* Amann and Knorr-Cetina (1988a).

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