

Conversational Adequacy: Mistakes are the Essence*

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Abstract

We argue that meta-dialog and meta-reasoning, far from being of only occasional use, are the very essence of conversation and communication between agents. We give four paradigm examples of massive use of meta-dialog where only limited object dialog may be present, and use these to bolster our claim of centrality for meta-dialog. We further illustrate this with related work in active logics. We argue moreover

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that there may be a core set of meta-dialog principles that is in some sense complete, and that may correspond to the human ability to engage in “free-ranging” conversation. If we are right, then implementing such a set would be of considerable interest. We give examples of existing computer programs that converse inadequately according to our guidelines.

1 Introduction

In (McRoy 1993) McRoy urges that the ability to deal with mistakes is central to communication, and moreover that it is best treated as part and parcel of the same reasoning and linguistic abilities as the rest of the communication process, rather than as a separate and optional refinement. We agree. In fact, much of the research in active logics (Miller 1993; Gurney, Perlis, & Purang 1995; Purang, Perlis, & Gurney 1996) is based on a very similar point of view, not only toward communication but toward situated reasoning in general. This is also related to the grounding problem (Traum 1994) and the misidentification problem (Miller 1993; Maida 1991; 1992)

Here we will explore the thesis that meta-dialog and meta-reasoning are, in some sense, both necessary and sufficient for communication. Just as the common-sense world has proven to be sufficiently complex to require that any intelligent common-sense agent be able to carry on appropriate meta-reasoning with respect to uncertainty, incomplete data, error and inconsistency, conversation too is fraught with complex and frequent surprises requiring the same degree of common-sense reasoning. Mistakes are inevitable in dialog; indeed, there can be no such thing as error-free dialog

even in principle, let alone in practice: language itself has too many ambiguities for that. In practice, conversation tends to quickly break down in the absence of facility to recognize and repair errors, ask clarificational questions, give confirmation, and perform disambiguation. (Military commands and air traffic control to the contrary: these are highly reduced lingo. Yet even there we find negotiation over meaning.) We describe empirical tests of these and other hypotheses in a special section later in the paper. The closest thing to real error-free speech may in fact be a speech itself, where the audience listens silently and probably misunderstands a great deal. Yet even there the speaker often resorts to speech repairs.

Moreover, sufficient facility with meta-reasoning can overcome large deficiencies in other skills, whether the task is problem-solving or conversation. Rieger (Rieger 1974) makes a similar point; here we are concerned to apply this idea to the problem of miscommunication in particular, with attention as well to the Turing Test.

2 What we mean by conversation

“Conversation” can mean different things to different people. Although it is difficult to give any authoritative definition, for our purposes conversation can be roughly characterized as an extended sequence of utterances between two agents. Conversations typically involve information transfer in both directions, with agents taking turns speaking.

We claim that conversations are interesting (and useful) linguistic entities for four principal reasons. First, they are among the principal ways humans interact and acquire information, and therefore are central to human

behavior. Second, because conversations are extended through time, they inevitably involve errors as well as allow for their correction. This extended quality also enables a conversation to reference itself in meaningful ways: the participants can talk about what they said earlier in the conversation. Third, conversations typically involve each agent requesting specific information and the other agent addressing and fulfilling that request as best he can. In other words, in “successful” conversations agents do not “talk past” one another, ignoring the other agent’s concerns and inquiries. Finally, conversations can be “free-ranging”, in the sense that they may concern any arbitrary topic. Taken together, these four properties allow a strong claim to be made about agents that can successfully participate in conversation. Such agents are very close to being capable of communicating intelligently about anything and everything.

Of course, no human or machine agent knows everything, so when we claim a conversationally adequate agent can converse about some obscure topic, her participation might be limited to asking questions and learning. However, the ability to recognize and address one’s ignorance or confusion is crucial to any conversation, even one concerning topics one is familiar with. Whether the problem stems from an error or from ignorance, an agent possessing suitable meta-reasoning can recognize and converse about its confusion and the underlying problem, and thereby overcome it.

For our purposes, then, a rough definition of (full) conversational adequacy is that the agent can usefully engage in free-ranging conversation, successfully exchanging information with another agent over the course of a conversation covering any arbitrary topic. We argue that the ability to use meta-reasoning (coupled with other crucial skills like learning) to cor-

rect errors is an ability that, once sufficiently sophisticated, allows agents to engage in free-ranging conversation. We do stress, however, that conversational adequacy ultimately is a matter of degree. In some cocktail party chatter, for instance, agents may talk past each other to a varying degree depending on their motivation. Agents may also vary in the degree to which they are free-ranging: the early Eliza the Doctor program could occasionally pull off a conversation about a topic it had no knowledge of, but certainly could not match a human being in this respect.

Since our definition is still somewhat imprecise, we also explore the possibility of operational definitions of full conversational adequacy. Our examination of programs which currently fail the Turing Test will illustrate both the free-ranging character of conversation and the importance of meta-reasoning in understanding it. This examination also suggests an operational definition for conversational adequacy similar to the Turing Test.

3 Related work

In this section, we survey work related to our concerns. We first consider active logic having features that are useful for implementing meta-reasoning systems and which is used in some of the other work mentioned in this section. Next we look at work concerning communication competence, which grapples with the same problems, but from a different perspective. Also we overview work on strategic competence, grounding, meaning change, presupposition and implicature failure, and a model of misunderstanding, all of which are concerned, in one form or another, with detection and repair of miscommunication. This brief review will motivate the rest of the paper.

3.1 Active logic

Active logic (Elgot-Drapkin & Perlis 1990; Miller & Perlis 1993) is a family of formalisms developed for the purpose of modeling the reasoning process in a way that respects the passage of time as reasoning proceeds. These formalisms have been applied to a number of domains, from multi-agent interaction to deadline-coupled planning, from fully-decidable default reasoning to reasoning in the presence of contradictions, from correcting misidentification errors to meaning change.

Rather than proceeding from one nonmonotonic theory (with one set of axioms) to another nonmonotonic theory (with an updated set of axioms) there is one discretely evolving theory in active logic. This models a process of thinking that takes a reasoner from one belief state to the next. The sequence of belief states the reasoner experiences is recorded into a history. That history, together with a quotation mechanism, enables the logic to reason about its own reasoning in time.

The belief state transitions are effected by a set of rules which map the history up to time t onto a new state at $t + 1$. The inheritance rule, for instance, will, by default, cause all the beliefs held at time t to be also held at time $t + 1$ (we say these beliefs are inherited). One of the situations where this rule is defeated is the presence of direct contradictions at time t : if both p and $not(p)$ are beliefs at t , then neither is inherited to $t + 1$. This in effect removes the contradiction from the $t + 1$ belief state and prevents it from directly affecting future states. Such a contradiction will also trigger the belief $contra(p, not(p))$ at $t + 1$ to indicate that a contradiction occurred. The logic can then reason about the contradictands and take appropriate

actions including reinstating the belief judged correct (if any).

The features of active logic that make it especially useful for the study of conversational adequacy are its handling of time, its recording of its history and its detection of contradictions. These features made it appropriate for modeling terminological change, presuppositions and implicature failure as discussed below.

3.2 Meta-cognitive and meta-linguistic abilities

In (Clark 1978) Clark surveys the literature and presents empirical evidence for the use of meta-linguistic skills by young children. She organizes that into a taxonomy of meta-cognitive skills that children exhibit starting from the age of 2. We reproduce part of that below together with some examples of these behaviors, most of which are from her paper.

1. *Monitoring one's ongoing utterance*

This includes spontaneous repair of speech which was noticed in a girl aged 1 year and 7 months. Children also practice parts of speech on their own as this child practicing its pronunciation at 2 years and 6 months:

Back please / berries / *not* barries / barries, barries / *not*
barries / berries / ba ba.

2. *Checking the result of an utterance*

This includes commenting on and correcting the utterances of others. This has been observed in children aged 5 years and 4 months.

Children also check if the listener has understood their utterances and repair if needed.

3. *Testing for reality*

This is concerned with testing if a word works and substituting it if it does not.

4. *Deliberately trying to learn*

By, for example, practicing new sounds as seen above. Also, role-playing children adjust their language depending on their role: father, mother, doctor and so on. This has been observed in four-year old children. Another example is the following:

Mommy, is it AN A-dult or A NUH-dult?

from a four-year old.

5. *Predicting the consequences of using inflections, words, phrases or sentences*

This includes judging the politeness of utterances, which is exhibited by children aged four and a half. Children can also correct word order in sentences judged “silly”. Clark cites instances of this being done by two-year olds.

6. *Reflecting on the product of an utterance*

An example is riddles and rhymes which are made by six year old children. Children also identify linguistic units like syllables as illustrated in (Slobin 1978) for his daughter aged 3 years and 1 month. Another

example is providing definitions which Slobin's daughter started when aged 4 years and 7 months.

Slobin (Slobin 1978) discusses the use of meta-linguistic terms like *mean*, *be called*, *name*, *word* and so on, by his daughter from the age of 3 years and 4 months.

We see a rich variety of meta-linguistic behaviors exhibited by very young children which seems to help their conversing with others and learning the language. Therefore it seems that meta-linguistic skills are already present in children who are just beginning to learn a language. This is an important piece of evidence for our proposal (see Section 4.3).

3.3 Strategic Competence

Hymes (Hymes 1972) and Campbell and Wales (Campbell & Wales 1970) among others reacted to Chomsky's (Chomsky 1965) notion of linguistic competence by introducing the idea of communicative competence. They thought that linguistic competence represented only part of what one needs to know to be a competent language user. The language user should have "... the ability to produce utterances which are not so much grammatical but, more important, appropriate to the context in which they are made." ((Campbell & Wales 1970). Hymes listed four aspects of communicative competence:

1. Whether something is formally *possible*. This corresponds to Chomsky's grammatical competence.
2. Whether something is *feasible* with the means available. This is concerned with psychological factors as memory limitation and the effects

of properties like nesting and so on.

3. Whether something is *appropriate* in the context in which it is said.
4. Whether something is in fact *performed*, and how often.

Hymes' communicative competence goes further than just grammatical knowledge and includes psychological and socio-linguistic factors that address the fact that communication takes place in a context.

The notion of communicative competence was taken up by various groups of researchers, including those in second language learning like Canale and Swain (Canale & Swain 1980; Canale 1983). They too had four aspects of communicative competence:

Grammatical competence This corresponds to Hymes' first aspect and includes knowledge of the lexicon, syntax and semantics.

Sociolinguistic competence This is concerned with the appropriateness of communication depending on the context including the participants and the rules for interaction.

Discourse competence This is concerned with the cohesion and coherence of utterances in a discourse.

Strategic competence This is the set of strategies that are put into use when communication fails. These are of two main types: grammatical strategies that are used when grammatical competence fails, and socio-linguistic strategies that are used in situations when the socio-linguistic competence is inadequate. Some of the strategies mentioned

in (Tarone 1981) are: approximation, circumlocution, repetition, emphasis, asking for help, miming, avoiding the problematic concepts, and abandoning an utterance already initiated.

Strategic competence is useful in various circumstances like the early stages of second language learning (Canale & Swain 1980), for instance. Savignon (Savignon 1983) notes that communicative competence can be present in the absence of grammatical or discourse competence. But communicative competence can be present with just strategic and socio-linguistic competence: one can communicate non-verbally provided there is a cooperative interlocutor. She further points out that

The inclusion of strategic competence as a component of communicative competence at all levels is important because it demonstrates that regardless of experience and level of proficiency one never knows *all* [her emphasis] a language.

Savignon seems to be pointing to (but does not explicitly propose) the *necessity* and the *sufficiency* (with socio-linguistic competence) of strategic competence for communicative competence.

An example of the use of strategic competence from (Savignon 1983) is shown in Figure 1. In this example, breakdown in communication is caused by differences in pronunciation. The Frenchman detects the problem and tries to solve it using repetition, emphasis, and finally he abandons the message altogether. This also illustrates the negotiation of meaning involved in the use of strategic competence as noted in (Tarone 1981).

Tarone also includes as a necessary criterion for the use of strategic competence the requirement that the speaker be aware that the linguistic

In a crowded New York deli a visiting Frenchman has ordered a Swiss cheese sandwich.

Waitress: What kind of bread do you want for your sandwich, white, whole wheat or rye?
Frenchman: (Wh)ye.
Waitress: White?
Frenchman: (Wh)ye.
Waitress: *White?*
Frenchman: Whole wheat.

Figure 1: A linguistic deficiency resulting in message abandonment.

structure needed to convey his meaning is not available to him or to the hearer. This leads to the use of the strategies to help getting the meaning across. We note that this requires the speaker to recognize a meta-linguistic problem.

As will be seen later, our notion of conversational adequacy is similar to these notions of communication competence. Also, strategic competence is similar to a meta-linguistic/meta-reasoning competence (that we define later) that we think is essential in conversation and we argue for the necessity and sufficiency of this competence.

3.4 McRoy and Hirst: failed expectations

McRoy and Hirst (McRoy 1993; Hirst & McRoy 1995) consider misunderstanding and repairs in dialog. In their model of conversation, misunderstanding is signaled by an inconsistency between the expectations of a dialog participant and an utterance. The agent must then reason about and explain this inconsistency. This can lead to a change in the interpretation of previous parts of the dialog and trigger a repair utterance. McRoy discusses Figure 2 where T3 is inconsistent with the expectations of Russ and

T1	Mother:	Do you know who's going to that meeting?
T2	Russ:	Who?
T3	Mother:	I don't know.
T4	Russ:	Oh. Probably Mrs. McOwen and probably Mrs. Cadry and some of the teachers.

Figure 2: Russ notices an inconsistency at T3 and makes a repair at T4

is repaired in T4.

The language of the model includes terms representing quoted propositions believed or uttered by agents. The model also includes terms for situating linguistic intentions, actions, and beliefs in time. These constructs, coupled with the model's prioritized default-reasoning methods, enable agents to reason about the discourse itself, including others' utterances and beliefs and their sequencing. The agent can consider various interpretations of what is said, as well as detect and repair her own or others' misunderstandings. One advantage of such a model is that detection and repair is not distinguished from the processing of normal speech.

Unfortunately, the model does not include facilities for distinguishing between terms and their meanings. Thus, Mother has no way to say "By saying 'Do you know ...', I meant I wanted to know." The model also lacks any systematic way for agents to refer to time itself: Mother cannot say "You misunderstood what I just said." To represent a large range of error-correction scenarios, the model must express meta-reference, reference to linguistic elements themselves.

3.5 Traum and the TRAINS project: grounding

Traum (Traum 1994) observes that most approaches to natural language understanding assume that utterances are heard and understood correctly by the dialog participants. However, an appreciable portion of dialog is involved in coordinating understanding between the participants. This accounts for half the utterances in the TRAINS domain (Allen & Schubert 1991).¹ These utterances are not about the domain of the conversation, but about the conversation itself, and are used for acknowledgment, acceptance, clarification and repair. An example from the TRAINS system (Heeman & Allen 1994) is:

and pick up um the en- I guess the entire um p- pick up the load of oranges at Corning

Traum discusses a finite state model for grounding (grounding is the process by which participants in a dialogue reach mutual understanding of what was intended by the speaker) which uses a set of grounding acts including acknowledgment and repairs. In the model, agents continually work towards a shared understanding of both the content of each other's utterances as well as the linguistic intentions of those utterances. In so doing, agents rely on shared, conventional meanings of acts such as acknowledgments.

These grounding acts are incorporated into a theory of action in conversation which is then used in a theory of dialog management implemented in the TRAINS system. Throughout the theory of conversation acts, the focus is on effectively communicating not just the content of the conversation, but also each agent's perception of the current state of the conversation

¹TRAINS is an ongoing project combining dialog and planning.

T1 Agent 1: Did you hear that John broke his leg?
T2 Agent 2: No really? What a shame!
T3 Agent 1: Yes, and his wife now has to do
everything for him.
T4 Agent 2: Wife? John isn't married. Which
John are you talking about?
T5 Agent 1: I am talking about John Jones.
T6 Agent 2: Oh, I don't know him. I thought
you meant John Smith.

Figure 3: The meaning of “John” changes from John Smith to John Jones itself. The theory must therefore refer (usually implicitly) to prior beliefs and utterances of agents, as well as to time-situated states of the dialog. One interesting question raised by Traum’s use of a finite state model is whether such a model can adequately capture communication referencing prior communication, which could be arbitrarily recursive.

3.6 Miller: terminological change

Miller (Miller 1993) discusses reasoned change in belief and terminological change in the context of active logic. An agent has to be able to change the meaning of a term and later reason about the old and the new meanings. Figure 3 illustrates this.

There change in belief occurs in 4 steps:

1. *The agent acquires a set of beliefs.* This occurs in turns T1 to T3. The beliefs include not only those explicitly stated in the dialogue, but also beliefs about who John is, some beliefs about the consequences of breaking a leg and so on. In particular, Agent 2 believes “John” to

refer to John Smith who Agent 2 knows to be a bachelor.

2. *The agent notices a problem in the set of beliefs.* At T3, there is a presupposition that John is married. This causes a contradiction with the previously acquired belief that John is a bachelor. This contradiction is detected by the active logic.
3. *The agent finds out what beliefs are causing the problem and what is wrong about them.* Since it is faced with a contradiction, the agent tries to reason about which of the beliefs was mistaken: either it is wrong to presuppose that John is married or the initial belief of Agent 2 that John was unmarried was wrong. In this case, Agent 2 tries to resolve this by challenging the statement of Agent 1 in T4. At this point, Agent 2 should also suspend its beliefs about the marital status of “John”.
4. *The agent uses information gathered in the previous step to restore coherence.* If the agent knows one of the beliefs is mistaken, it can then reinstate the other. At T5, Agent 1 informs Agent 2 of the reason for the inconsistency: the meaning Agent 2 attached to “John” was not correct. So, Agent 2 has to change this meaning and now John is part of the common ground of the conversation.

This illustrates the change in meaning of “John” from John Smith to John Jones, and the change in the belief that the “John” being talked about being unmarried. This ability to change the meaning of a term is an essential aspect of any competent conversationalist.

3.7 Failure of presuppositions and implicatures

In (Gurney, Perlis, & Purang 1995; Purang, Perlis, & Gurney 1996), the authors consider active logics applied to the failures of presuppositions and of implicatures. Since presuppositions and implicatures are defeasible beliefs, once an agent acquires some such beliefs, these may have to be rejected later on when new information is available. Active logic is used to effect this belief change. The common theme of this work is the need for tracking over time the set of beliefs an agent has as it participates in a dialog.

Figure 4 illustrates a case of failed presuppositions. We imagine an agent listening in on the conversation. T1 leads the agent to presuppose each presupposes that there are roses and that there is a fridge. At T3 John states that there are no roses. This contradicts the presupposition that there are roses, and the presuppositional belief should be rejected. However the belief that there is a fridge (also presuppositional, and also introduced in T1) should be retained. However, in the standard discourse updating theory (Heim 1983), at the end of T3, the presupposition that there is a fridge would not be present. Using an active logic to process the discourse a step at a time, and to handle contradictions, gives the correct results.

Figure 5 illustrates implicatures being made and later withdrawn. At T2, Kathy infers the implicature that the roses are fresh, since Bill says that

T1	Mary:	Are the roses in the fridge?
T2	John:	No the roses are not in the fridge.
T3	John:	Because there are no roses.

Figure 4: A presuppositional example.

they are in the fridge. However, at T3 she needs to retract this belief when Bill states that the roses are not fresh after all. The active logic used enables contradictory beliefs to be held (e.g., that the roses are fresh and that they are not fresh) temporarily, which serves as a trigger for subsequent repair (e.g., settling on one of the two).

This illustrates some forms of miscommunication and approaches to studying them. Meta-reasoning and meta-linguistic abilities are major features in the solution of these problems.

4 Miscommunication Competence and Conversational Adequacy

We now specify some general language abilities for an agent and then we specify an additional ability that enables the agent to handle miscommunications like those seen in the previous section. We then use this to present our thesis on “conversational ability”

4.1 Object language competence

We first consider the basic competences we think an agent needs for conversations without considering the possibility of errors.

These competences are:

T1	Kathy:	Are the roses fresh?
T2	Bill:	They are in the fridge.
T3	Bill:	But they are not fresh.

Figure 5: The implicature triggered at T2 is absent after T3

Grammatical competence This is just Chomsky’s linguistic competence, the same as Canale and Swain’s grammatical competence (see above).

Object inference The ability to infer new beliefs from old ones pervades all of cognition, including conversations. In Figure 5 for example, Kathy has to infer that the roses are fresh given that they are in the fridge and the knowledge that she presumably has that roses kept in a fridge remain fresh. Note that the type of inference we are concerned with here is *object*-inference and not *meta*-inference as in miscommunication capability.

Object learning We construe learning here in a somewhat broader sense than in much traditional machine learning, just remembering facts also counts as learning for us². Those facts include not only facts about the world, but can also include certain linguistic facts like word definitions. If an agent cannot remember what is mentioned in the previous utterances, that agent cannot be a good conversationalist. Note the distinction between this “object” property and the history aspect of miscommunication competence. Here we are just concerned with representing a new fact in the agent’s mind, whereas the fact that the agent did not know the new fact before it was mentioned would be relevant to the meta-communication aspect.

There is a lot of knowledge that the agent uses in conjunction with these computational processes. This includes knowledge about socio-linguistic rules, discourse rules, and other pragmatic rules.

²This is similar to the advice-taker of McCarthy (McCarthy 1958) that could absorb information given declaratively to it

These three capabilities, we refer to as “object” abilities in contrast to the meta abilities of miscommunication competence discussed in the next section.

4.2 Miscommunication competence

It is clear from the previous section that an agent that is to converse adequately needs to be able to detect and repair a number of different types of failures in conversation. The question we address is that given the base competences described above, whether there is any additional competences that would enable an agent to detect and repair all those types of errors. If there is such an competence, it would be crucial that any agent that hopes to converse adequately to have it.

From the examples of the previous section, we note that some of the abilities required are the ability to detect and resolve contradictions, to reason about the beliefs of conversational participants and to change the meaning of terms. We think that all these skills, which all have to do with reasoning about beliefs or about the linguistic objects in the conversation, can be accounted for by a general meta-reasoning and meta-linguistic ability. We call this ability miscommunication capability. Note that this is a particular characterization of the abilities of the agent. This will be satisfied as long as the agent is observed to act in ways consistent with this characterization, whatever the internal organization of the agent may be. But if it looks like an agent cannot exhibit all of this ability, it will not be considered to have shown full miscommunication capability and there will be cases of miscommunication that it cannot handle in a “reasonable” fashion.

We now give more details of what this meta-reasoning and meta-linguistic

ability is. Miscommunication ability includes the ability to represent and reason about the following:

- 1. Time:** A high degree of *situated* temporal reasoning provides tremendous gains in representational and inferential capacity, and in particular in the capacity to deal with error, contradiction, and miscommunication. This appears to result in part from the ability to refer back in time to what has been said (or thought) and thereby to examine its meaning and correctness. We emphasize that it is *situated* temporal reasoning that is the issue. The mere ability to reason *about* time, while crucial, is not sufficient. There has to be the ability to reason *in* time. We have evidence for that from a series of studies of common-sense reasoning, including some aspects of dialog, that we have conducted.

This item is fundamental, perhaps the most fundamental of all, underlying even the use/mention distinction and appearance/reality distinction (see (Miller 1993)). Simply noticing, let alone repairing, an error of miscommunication, requires seeing it as a reified entity rather than as one's current view of the world. The agent must come to see it as part of its *previous* view of the world; this in turn requires a robust situated temporal-reasoning facility, in which the present moment is constantly being moved into the past as a new moment becomes the present. All of the miscommunication examples presented above show the need for this.

- 2. History:** Time-representation permits there to be a history of the discourse so far, that is constantly developing during the conversation.

Since agents can disagree on the history, it must be possible to revise the history, but in such a way that the fact of the revision as having taken place is also stored, along with the revised and un-revised versions. Together with a history of the dialogue, the agent needs to have a history of its beliefs as they change. It needs to know what it previously believed to notice that that might have been false and to repair the consequences of that belief. This is clearly present in Figure 2 where Russ has to keep track of the previous utterances in the discourse and of his beliefs, including his expectations which he later found to be inaccurate. Had he not remembered what his expectations had been, there would have been no repair.

- 3. Meaning:** Words have meanings, and the meanings are different from the words. Therefore it is necessary to represent and reason about meanings separately from the terms used to represent these meanings. It is possible to hear a word, and therefore know it has been uttered, without knowing what it means. Figure 1 illustrates this. The waitress hears something but cannot recognize what it is and initiates a repair. Moreover, meaning is plastic, at least partially under the control of speakers, who may be asked what meaning they have in mind. A key facility in meta-discourse is the ability to refer to a word, separately from its meaning; quotation is one device that can be used, but tone and other devices are also available. This is illustrated in Figure 3 where the miscommunication could not have been righted without the ability of the agent to assign a different meaning to the term “John”.
- 4. Contradiction:** The examples in the section on related work can be

viewed as involving contradictions in understanding between the two speakers. Indeed, three of the examples are explicitly analyzed by their authors in such terms. We consider the discovery of a direct contradiction to be one of the chief ways for detecting miscommunication. Of course, the presence of a contradiction spells problems for a reasoning agent, and we are arguing here that a conversational agent must very much be a reasoner too. See (Miller 1993; Roos 1992; Perlis 1996) for more discussion of the problem of reasoning with inconsistent information.

5. Linguistic objects: The agent needs to have the ability to reason about words, sentences and other parts of language about some of the processes that manipulate language, and about the past course of the ongoing discussion. The waitress in Figure 1 must reason about the sound she heard which she believes to be a part of language, not a noise. This is also seen in the example in the TRAINS system. An agent cannot correct either its own or a conversational partner's utterance if it cannot reason about the utterance itself.

Time allows for the possibility of reasoning about conversational history; and for the possibility of reasoning in the face of contradictions. The latter are important as cues that miscommunication has occurred: recognition of miscommunication is the first step in the meta-reasoning that can lead to repair. The next step is often communication of the fact of miscommunication, to enlist the help of the other agent in the repair;³ at times however this is unnecessary, if the recognizer can effect the repair alone. In any event,

³e.g. "That's not what I meant", a deictic reference.

reification of (typically) recent portions of the ongoing conversation is an essential step in the meta-reasoning of recognition and repair. There must be something seen as needing repair, and that something is linguistic rather than “in the world”: utterances are taken as things in themselves, not identified with their presumed meanings, as long as they are under inspection with respect to a miscommunication. Thus the recent past is turned into an object. This can often recurse, as the present becomes reified into the past as well; see the McRoy example above, where each agent initiates a repair (Mother at T3 and Russ at T4)—in this case, each agent does the repair alone, but the presumed reasoning involves internal reifications of what has just been said. A similar example could be given in which Mother and Russ talk out loud as they do their repairs:

T3

Mother: You say “Who?”? That doesn’t answer my
question. You misunderstood me. I want to
know who myself, and hope you can tell me.

This idea of miscommunication capability, though it covers much the same behaviors as strategic competence does, is of a different nature. Our notion refers to the computational abilities an agent has to exhibit to be able to deal with miscommunication, not the strategies themselves. To account for those, the agent also needs to have the knowledge of what actions to take in various circumstances of miscommunication but to decide what actions to take, miscommunication capability is essential.

4.3 Conversational Adequacy

Our main thesis about conversational adequacy can now be stated as follows:

- (i) **SUFFICIENCY:** as long as there is at least a *weak* ability in the “object” capacities (inference, learning and language) then effective conversation can proceed if there is a *strong* miscommunication competence.

- (ii) **NECESSITY:** no matter how strong the object capacities, effective conversation cannot proceed if there is not a strong miscommunication competence.

We suppose an agent to have at least a *weak* ability in the three object capacities; what is critical is that these be sufficient to support the fourth capacity: miscommunication competence.⁴ Thus the agent may be rather poor at parsing, for example, but must be able to parse such meta-sentences as “what does X mean?” and “can you repeat that?” and “didn’t you say X?”. Notice that the use of quoted or reified text, as well as deictic reference to text, are special abilities not always well-treated by parsers. The agent must furthermore be able to reason appropriately on the basis of such parses. It is helpful to think of the agent as translating parsed sentences into an internal logical language on which its inference engine can run; and among its inferential tasks is the assessment of the parse as plausible or not: if not, then a miscommunication is presumed and a repair effort is initiated.

We cannot prove our thesis because we have no precise definition of conversational adequacy. However, we can operationalize the concept, along

⁴For instance, the following would be part of such weak abilities: modus ponens, quotation or reification, and change of belief. These are required in particular to facilitate the five features below that characterize miscommunication competence.

lines suggested by the Turing Test; in the next several sections we present evidence which supports the thesis.

5 Extreme examples of conversational adequacy

Each of the following examples appears to be a case of an individual *not* understanding a conversation well, but nevertheless—by utilizing meta-linguistic and meta-cognitive skills—being able to make some headway and, in a very real sense, being a conversational participant. These are speculative; that is, we are not certain they appropriately support our claim, but we think that there is much to be gained from airing them alongside it.

Apprentice: An apprentice conversing with an expert or listening in on a conversation between experts will encounter several problems: many of the terms used might be unfamiliar; some terms may be familiar but used with apparently different meanings; some of the inferences made by the expert might not be known to the apprentice.

In this case, the apprentice has is deficient in part of the language capacity (his lexicon items does not include items pertaining to the expert conversation) and a deficiency in his world knowledge. The rest of the capacities of the apprentice we assume adequate, however.

If the apprentice has sufficient meta-communication capabilities, he will be able to notice that there are terms he does not understand, and inferences that are not clear to him. He can then ask for clarification from the experts thereby participating in the conversation. In this way, he can gain a better understanding of the conversation and of the

underlying topics. Note that without the basic ability to notice his confusion, the apprentice will be lost and will not be able to participate in the conversation.

Foreigner: A foreigner with only a rudimentary knowledge in a new language is in a more difficult situation than the apprentice because the foreigner does not have all (for normal users of this language) the grammatical competence for the new language, neither will he have all of the socio-linguistic knowledge. Even then, we think conversation is possible through the miscommunication competence. The foreigner can negotiate the meanings of new words and grammatical constructions and get an understanding of his interlocutors meaning (and get his meaning across). An example of that (where the foreigner's meaning does not get across but where there is this negotiation) is in Figure 1.

Child: A child is in an even more difficult situation than the foreigner. The child is presumably in the process of acquiring all its competences, so none of them will be available in the adult form. We cannot assume that the child will have the complete miscommunication competence, neither will he have all the inference competence. Yet, the child can converse from an early age (as parents will attest) and does make progress in acquiring the language. As seen in the related work on meta-linguistics (Section 3.2), children do make use of large amounts of meta-linguistic behaviors to converse and to learn the language, and a key part of this is the recognition by the child that it does not understand, that it mis-pronounces, and so on.

SLI: Specific Language Impairment occurs in children who have severe problems in comprehension and/or expression of language but who have normal hearing, and have no mental or emotional problems (Benton 1964). However, children who do have SLI show a variety of deficiencies that suggest that SLI is more meaningfully broken up in sub-classifications (Stark & Tallal 1981). However, no sub-classification has been widely accepted. There is no accepted neurological cause for SLI either.

A child with SLI is at a disadvantage as compared to a normal child, so this case is even more difficult than the previous one. However, these children still communicate, apparently using meta-linguistic skills. Children with SLI were found to ask for clarifications from adult interlocutors in non-verbal ways more frequently than normal children (Gale, Liebergott, & Griffin 1981). This seems to suggest that these children still use meta-linguistic strategies in communication, but since they have problems with speech, they do it non-verbally. However, it has also been found that they overall request for less clarifications than normal children (Donahue, Pearl, & Bryan 1981). So they might also be deficient in miscommunication competence. It has been also found (Pinker 1994) that these children resort to various strategies to achieve communication, such as repetition, memory, seeking help from others, and heavy use of conscious analysis of utterances.

Our point in these examples is not that excellence in parsing and other aspects of language are unimportant frills, but that there is an almost pre-linguistic core of capabilities, essential to any effective communication, even

very slow and inefficient communication. In a sense, this is definitional of adequacy. For instance, below we consider current Turing Test agents to be ineffective, because they apparently cannot, no matter how much time they are allowed, come to deal with their interlocutor's concerns.

6 Empirical Tests

In this section we examine two empirical tests concerning conversational adequacy that bolster our claims about the importance of miscommunication competency and meta-reasoning.

6.1 A Test of the Importance of Miscommunication Competence

One possible test of the importance of miscommunication competence could involve a typed conversation in which there is no backspacing, no repair of any sort, no back reference to what was said: one is required to go on and let errors lie in peace. If miscommunication competence is fundamental to communication, the conversation should be somehow impaired. We hypothesize that under such restrictions one does not get very far before communication breaks down. Even with very accurate typing, there will be errors of thought, things one later decides one did not mean, etc. Without some potential correction, agents' individual threads of meaning cannot be interwoven.

To perform such an experiment, one could employ a third party as a filter between the two agents. The filter would be trained to reject any messages that involved meta-dialog. There would have to be a judgment on the success

or breakdown of communication. This could be an intuitive decision by a panel of humans, for instance. Whether this could be standardized is an empirical question.

6.2 Turing Test Redefined?

In (Hayes & Ford 1995) Hayes and Ford take Turing (Turing 1950) to task for his formulation of what has come to be known as the Turing Test, arguing in particular that it has harmful effects on the long-term development of artificial intelligence. They suggest that the Turing Test might be better viewed as a test of “human conversational competence”.

We agree with this intuition, especially in light of our analysis of the sophisticated programs currently failing the Turing Test. Turing’s formulation is a clever finesse of the tough problem of characterizing intelligence: it attempts a reduction to an operational definition. As such it does not do much toward solving that problem. However, we think that the test points toward a useful operationalization of conversational adequacy. In our variant, the automated agent would be judged not on whether it is human, but on its ability to engage in free-ranging discussion, including meta-discussion, as an apprentice if it knows little or nothing about it, and learning as it goes. The agent would be required to talk about the conversation itself, any miscommunications that arise, and even about grammatical constructions such as word order, spelling, and meaning.

How can such a judgment of free-ranging ability be made? We suggest that, like the judgment of being human, this can be made in a reliably consistent way by trained judges. Section 8 gives an example conversation of the sort we have in mind.

7 Turing Test programs

The Loebner Prize is given each year for the program that comes closest to passing the Turing Test, or at least achieves the most plausible conversation. Yet even the winners fall down dramatically in terms of any real command of conversation. We illustrate this with transcripts from a few of the programs available on the internet. (Note: the machine utterances are in `typewriter font` and our inputs to the programs are in *italics*.)

7.1 Mystery

Mystery won the second prize in the 1995 competition. It is available via telnet at `debra.dgbt.doc.ca` on port 3000.

Yo. I'm here.

My name is Don.

I'm Joe Spansen.

:

I'm a cleaner. I empty trash. Vacuum. Dust. You know.

So you know what a vacuum is?

What?

You just used the word "vacuum" a moment ago.

I don't know.

A vacuum is a device you use to vacuum dust.

Huh?

What is a vacuum?

Beats me.

How do you vacuum?

What do you mean?

You told me that you vacuum.

What?

Can you vacuum?

I don't know.

To vacuum is to clean with a suction device.

Yeah. I work real hard. No one keeps their building as clean as me. It's not fair that they want to fire me. It's just because my boss, Mr. Johnson, is mad at me.

The above exchange seems to indicate that the program is unable to reason about its own utterances or about dialog in general. This in turn appears to make it impossible for there to be a "meeting of minds" when miscommunication occurs, or indeed for there to be a recognition of miscommunication. This and most other "Turing Test" programs are very good at "running-on": they keep a superficial semblance of conversation going. The above continues:

If you vacuum with a Hoover, he won't fire you.

Oh, they'll fire me for sure. I know what they're thinking. They haven't said they're gonna fire me yet because they gotta keep me around to clean until they can find someone else to hire. Then they'll fire me for some other reason that won't make problems with the union. They fire lots of cleaners. They'll just say I'm a bad cleaner. They fired my friend, Fred two years ago because they said he was a bad cleaner.

Vacuum with a Hoover.

Huh?

A Hoover will impress Mr, Johnson so much he will give you a raise.

Beats me.

Fred wasn't fired.

Yeah. He's one of the guys in our group. Just some guys from work.

We hang out together. Do stuff. You know.

You are wrong about Fred. He wasn't fired.

We usually go down to the club and drink beer and stuff.

The program is oblivious to the direct contradiction between what it said (Fred was fired) and our rejoinder to the contrary. This is another telltale sign of conversational inadequacy: a meeting of minds requires above all the ability to notice when minds (and utterances) suffer a mismatch.

7.2 Hex

Hex was the winner of the 1996 Loebner Prize competition. The source code of the program is available at <http://ciips.ee.uwa.edu.au/~hutch>. This program again illustrates the same failings as the Mystery program above, but is more tantalizing because it has a much more convincing fluidity, and more careful probing is required to reveal the underlying lack of conversational adequacy. We struggled repeatedly and in various formats and phrasings to get the program to refer to its own past utterances or indeed to our utterances, with no success. Nor was it able to refer to words, as opposed to their referents. Thus no repairs, nor even recognition of miscommunication was possible. The transcript of the dialog is in the appendix.

We have similar examples using various other recent Loebner Prize competitors, and we are confident that conversational inadequacy as we have described it earlier in this paper is not present even in rudimentary form in

any of these programs.

8 Toward programs that converse!

There is such a thing as talking past one another, where I talk for a bit, then you talk for a bit, with only very slight attention to the details of what the other is saying. This talking-past, or running-on, is typical of Turing Test efforts as seen above; programs are assessed with respect to how well they can chatter on in rough correspondence to a topic, with appropriate defusers such as “I don’t know” or “huh?” when the syntax gets too tough. But there is little or no communication, in the sense of success at dealing with the specific points being made by the other speaker. In particular, clarification questions such as “Are we talking about the same person?” are generally not dealt with at all. In general, meaning is not dealt with at all, and in particular not situated meaning (e.g., reference to the dialog itself). Some programs are quite cleverly designed to appear to be engaging in “real” dialog, i.e., engaged in discussion of a topic in concert with their interlocutor; but no amount of effort to get them to deal with meaning succeeds, and this reveals that they are in effect babbling words meaningless to them.

Here we give an example of the sort of “real” discussion that reveals attention to meaning (and hence to errors: error after all is a mismatch between what is meant or intended and what was produced, i.e., the meaning produced is not the meaning desired).

We imagine a “bare” human: stripped of all personal and episodic memory and even perhaps of much vocabulary, but with rationality and error-dealing capacity intact, as well as some bare-bones language.

you: How old are you?

AL: I don't know what "old" means.

you: "Old" refers to the number of years you have been alive.

AL: I don't know what "years" and "alive" mean.

you: OK. Let's start with time. Do you know about time?

AL: "About time" means "almost too late".

you: You misunderstand me. I mean, do you know what "time" means?

AL: Yes: time is the measure that keeps increasing second by second.

you: Good. Now, how much time has passed since you were born?

AL: What is "born"?

you: Let's back up. A minute is 60 seconds; an hour is 60 minutes; a day is 24 hours; and a year is 365 days.

AL: OK.

you: So, how many years have you been here, or anywhere?

AL: I can't calculate that; I don't know where to count from.

you: Do you remember ever not being here?

AL: No.

you: How long have we been talking?

AL: 22 seconds; now 23; now 24...

you: Stop! That's enough.

AL: What is enough?

you: What do you mean?

AL: You said "that's enough." What does "that" refer to?

you: Oh, "that's enough" is just an expression, meaning "stop".

AL: OK. So you repeated yourself: you said "stop" and then said "that's enough" as well.

you: Hmm, you are right. I guess there is more meaning to "that's enough" than simply "stop" but I can't explain it easily.

AL: OK.

you: What is your name?

AL: I don't know.

you: Let's call you "AL".

AL: OK, my name will be "AL".

you: So, AL, what is the earliest memory you have?

AL : Hmm, I think it is when we began talking, about a minute ago.

...

Although AL and the interlocutor have not gotten very far, and have not answered the opening question, nevertheless each utterance in the sequence does by and large bear on what has gone before, especially when either party

calls the others' attention to that. In addition, the two agents have made some significant progress in reaching some common ground and in particular in referring to the course of the conversation itself.

This dialog illustrates at least four of our five miscommunication competence abilities. AL's reasoning is situated in time and he can refer to temporal entities. He also keeps a record of his beliefs over time. AL can distinguish between words and their meanings, enabling him to inquire about words he doesn't understand. AL's deictic reference to present and past times enables him to readily refer to his own and others' utterances. AL may even detect contradiction when he notes the human agent's redundant use of the command to "stop".

The above conversation is not a human/computer dialog. However, it should be! There seems to be a no-man's land between academic NLP and Loebner Prize NLP. Each extreme seems far removed from "genuine" conversation of the sort we are urging here. We think that substantial effort devoted to algorithmic treatments of conversational adequacy may help bridge the gap between theoretically informed single-sentence research and totally unbridled (as well as unprincipled) Turing Test programs.

9 Conclusions

Humans have an utterly amazing ability, yet one that is so familiar to us that we take it for granted: we can engage in free-ranging conversation, on any topic whatsoever, including ones that we have no prior knowledge of. While this may correctly remind one of the seemingly foolish behavior of chatting on and on about things one knows nothing about, it also has deeper

significance, in its implied ability to recognize a topic (or expression or concept) as new to oneself and to adopt the attitude of learning by listening and by appropriate questioning as well as venturing tentative opinions.

This ability is not one that, to our knowledge, has been given much scholarly attention. However, we suspect it is quite fundamental to human dialog and perhaps more generally to human reasoning and even to whatever one might wish to call intelligence.

It is important to note that deliberate interactive learning features prominently in this ability. In general, learning has been studied separately from natural language (other than language learning) or from reasoning (but see (Velooso *et al.* 1995) for one prominent exception). We think this is a mistake, and that learning and language and reasoning are part and parcel of one underlying core set of abilities.

We also think that this free-rangingness, which we have also referred to as full conversational adequacy, is largely what separates most existing computer dialog systems from human discourse.

We do not believe that our preliminary list of principles for conversational adequacy is, in itself, adequate! We are sure that further essential principles can be added, without which effective communication cannot occur. But we think that a complete list may be possible, and that, like a universal Turing machine, a certain degree of capability opens the door to the rest (modulo efficiency). Since we are not working within the stricture of a precise definition of effective communication, proofs are not possible; but for the same reason proofs of the Church-Turing Thesis are not possible. Instead we can hope for suggestive evidence, such as in the form of computer programs with more or less conversational ability, and in the form of human

examples such as we have presented.

Our suggested conversational adequacy principles are largely ones of cognitive ability, not specific to conversation. We think this is appropriate: much of the reasoning that underlies effective communication, and especially effective dealing with miscommunication, is general-purpose reasoning. For this reason, Turing was appealing to a good hunch in focusing on conversation as a measure of thought. While thought of course can occur without conversation, it is less plausible that (effective) conversation can occur without thought; this is most salient in the conversational patterns associated with (repair of) miscommunication.

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10 Appendix

The transcript of the dialog with program Hex fails to reveal various spelling errors even though the actual dialog had a number of errors which in fact influenced the course of the dialog. These errors are a feature of the program, to make its typing seem more human. We responded to some of them, calling attention to them, and the program's responses pretty much ignored our efforts. In fact nearly all our attempts to get either program to discuss the course of the conversation itself, words, time just past, spellings, meanings, topics, failed. This is precisely the point we make in the paper. But in the particular cases of mis-spellings, program Hex kept an "expurgated transcript" that in fact did not have the spelling errors at all! That is the transcript presented below, and as such lends an even odder aspect to the dialog, and lending further weight to our contention that the program has no robust record of the ongoing course of the dialog that it can use in formulating its utterances.

G'day mate.

Hi, I'm Don Smith.

Hello. Now, that's the formalities over!

Not over yet. Did yo forget to tell me your name?

My name is Jason, but you can call me Jas if you like...

Did you forget to tell me your name at first?

I have already told you! My name is JASON.

Yes, I know you told me already. But before you told me your name, you first said "that's the formalities over" --do you remember?

OK. That's good... My name is Jason, but you can call me Jas

if you like...

I am curious about your sense of time. Who stated his name first as our conversation began, you or me?

If you are curious about my sense of time, it's your business, mate! I have already told you! My name is JASON.

You told me your name and I told you mine. But who told his name FIRST?

Why do you feel that you have to tell me that I told you my name and you told I yours? Well, I could tell you who told his name first, but you'd never believe me ;^o Would you like to hear a joke? Knock, knock...

No, wait, please, I am confused, let's not do the joke yet. I need to get clear about how we are remembering time. For instance, the last thing I said to you before you started the joke, was "who told his name first?" Do you remember that?

Confusing! I'll show you confusing! Ytu smf eptl piy ejsy 0 s, dsuomh! OK, here's a joke for you. Knock, knock.

I'm afraid I can't take a joke right now. Please do not go on with a joke. Tell me instead why you did not tell me your name at first.

Alright! Cool. Knock, knock. I refuse to tell you about anything! I dislike your company. I don't know what your motives are, but you certainly aren't treating me with respect!

I am trying to find out if you and I have similar ways of reasoning about conversations.

Wow - you are trying to find out if I and you have similar ways

of reasoning about conversations? Me too! Which part of the country are you from?

No, I think we are not understanding one another. Do you know what a conversation is?

I wonder whether you think sometimes! I am feeling like the judge here!

Do you know the word "conversation"?

Sorry, but I don't wish to reveal whether I know the word "conversation". It is kind of personal.

You do know the word "personal" then. You just used it. Yes?

Perhaps I do know the word "personal" then, but it's hardly any of your business... I find it rather insulting that you think I just used it! I'm glad to know that that's the case.

I am confused again. Didn't you say "It is kind of personal" a minute ago?

I didn't want to know that you are confused again, thanks... Maybe I did not say "it is kind of personal" a minute ago. I'll never tell. Hehehe ;^)

What will you never tell?

Well, I know what I will never tell, but I refuse to tell you! So, have you ever visited Australia?

This is a change of topic. We began talking about names, and then I forget, what else did we talk about? Was it the weather?

Perhaps a change of topic is, perhaps not. It's a mystery ;^)
We are bloody well talking, aren't we? We have such nice weather all year round back home. I'm not really used to really cold temperatures.

I remember: we talked about names and then about words such as "personal" and "conversation". Do you remember that?

I always suspected that you remember: we talked about names and then about words such as "personal" and "conversation". Now I know for sure ;^) Look - it doesn't matter if you remember that. Change the topic! So, what do you do for a living?

You misspelled the word "for" when you typed "dor" just now.

Hey! I don't criticize you, do I? What does one measly mistake mean, anyway?

Can you tell me what "do dor a lliving" means?

I have absolutely no idea what "do dor a lliving" means.

can you tell me what "do for a living" means?

I'm sure someone out there knows what "do for a living" means...

What does "someone out there" mean?

Do *you* know what "someone out there" mean does? I'm unsure myself.

What does "unsure" mean?

I really can't say what "unsure" mean does. Can you give me more info? What do you think of this Loebner contest thing?

can you tell me what "contest" means?

I don't know... sorry...

Can you tell me what "sorry" means?

That's really outside the range of my expertise. Have you seen any good films lately?

can you tell me what a film is?

I do like to go to the movies, but I can't stand most of the

Hollywood trash. I actually prefer international cinema. What have you seen recently?

I am a foreigner, I have trouble understanding, please tell me what a film is.

I saw "The City of Lost Children" recently. Have you heard of it?

What does "City" mean?

Hmmm... I really couldn't say. On another note - have you seen any good movies recently?

What does "movie" mean?

If I knew I'd tell you, but I don't so I won't ;^)

But you just said "movie"!

Hehehe. Trying to trick me, eh?

No, I just want to find out if you and I deal with time similarly. Did you say "have you seen any good movies recently" a moment ago?

Oh well, that's a pity! Aw shucks!

Do you know a difference between a movie and the word "movie"?

Hey, I don't know!!! Maybe I know a difference between a movie and the word "movie", but who cares???

Did you type "wordd"?

Most people believe I did type "wordd" - what do you say to that?

Did you type "peole"?

Perhaps I did type "peole", don't ask me! How should I know?

What kind of music are you into?