Chapter 9
Three Principles of Information Flow: Conversation as a Dialogue Game
Paul Piwek

Abstract

This chapter brings together the insights of several linguists, logicians, computer scientists and philosophers that have studied the flow of information in language use and, specifically, dialogue. These insights are summarized in terms of three principles of information flow: (1) *Information flow = context change*, (2) *Information flow is context-dependent and* (3) *Effective information flow is a cooperative endeavour.* Each of these principles is discussed using examples from both naturally-occurring and scripted dialogues.

Introduction

(1) Tim and Gareth, two employees of a paper merchant, are having a conversation over lunch.

    a. TIM: I'm not thinking about it, I'm doing it. I'm leaving to go back to university to learn about more than the price of Opti-Bright Laser Copy paper.
    b. GARETH: Two ninety-eight a gramme.
    c. TIM: Two forty a gramme. Check the list.
    d. GARETH: Yeah. Thought you said something different. What are you gonna study?
    e. TIM: Psychology.
    f. GARETH: What you wanna be a psychiatrist for? They're all mad themselves, aren't they?

Dialogue from the script of the TV Series 'The Office'
(Gervais and Merchant, 2002, p.192).

(2) Conversation, over the phone, between an information provider at Schiphol airport (I) and a caller (C)

    a. I: Schiphol information
    b. C: uh good morning with L.A. uuhm I'd like to ask what time uuh the KLM 338 arrives
    c. I: where did it depart from madam
    d. C: Paris
    e. I: from Paris today … that one arrives at eleven twenty
    f. C: eleven twenty
    g. I: yes
    h. C: uuh ok thank you
    i. I: you're welcome
    j. C: bye
    k. I: bye

Translated from a Dutch spoken dialogue (Prüst et al., 1984, p.42).

As these two examples illustrate, dialogue comes in various flavours: from banter, as in the fictitious dialogue of example 1, to goal-oriented exchanges, as in 2. And yet, there are striking similarities, even between these two very different dialogues. Focussing on the flow of information, in both, questions are used to elicit answers, which result in the interlocutors sharing information, including that *Tim is going to study psychology* and *KLM 338 arrives from Paris at eleven twenty*. In short, despite clear differences between the dialogue fragments in 1 and 2, there are also common principles of information flow at work. The aim of this chapter is to examine three specific principles of information flow which we have distilled from the work by linguists, philosophers, logicians and computer scientists.

But why study information flow in dialogue? As pointed out by Fillmore (1981), dialogue is the primary means we have for the verbal exchange of information. Its primacy manifests itself in several ways. For instance, as opposed to reading and writing, the ability to engage in face-to-face dialogue does not depend on formal training. On the contrary, much of language learning by children presupposes the ability to engage in, admittedly limited, forms of dialogue. Importantly, dialogue as a means for exchanging information is not culture-specific; all known human cultures engage in dialogue.

Conversation, Thought and Games

The perspective this chapter adopts is rooted in formal and computational models of dialogue that have emerged over the last fifty years. The focus is, however, not on the technical details, but rather on a number of general principles that many of these models share. Each principle is illustrated with examples. Some examples will also highlight aspects of dialogue which, so far, have resisted formalization. The idea of understanding dialogue in computational terms and more specifically of building a computer that can engage in dialogue goes back to the very beginnings of the discipline of computing. A key figure is the British mathematician and logician Alan Turing (1912 - 1954).

Turing is well-known for the first rigorous definition of computation and for his work on one of the early general-purpose computers. Here, we are interested in a test which bears his name, the 'Turing-test'. Turing proposed this test as a practical way to address the question 'Can machines think?'. Rather than quibble about the precise meaning of the words 'machine' and 'think', he suggested we adapt a game, the 'imitation game', which is characterized as follows (Turing, 1950, p.433):

> It is played with three people, a man (A), a woman (B), and an interrogator who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. […] The interrogator is allowed to put questions to A and B […] The ideal arrangement is to have a teleprinter communicating between the two rooms […] The object of the game for the third player (B) is to help the interrogator.

Having defined the imitation game, Turing (1950, p.434) proposes a variant in which the interrogator has to determine which of the interlocutors is the machine and which is the human:

> We now ask the question, 'What will happen when a machine takes the part of A in this game?'. Will the interrogator decide wrongly as often when the game is played

like this as he does when the game is played between a man and a woman? These questions replace our original, 'Can machines think?'

Well over half a century after the Turing-test was proposed, computers still struggle. Since 1991, there have been annual runs of the Turing-test, sponsored by the philanthropist Hugh Loebner. The following transcript is from a dialogue with the best system of the 2009 competition, Do-Much-More. None of the systems that entered that year beat their human adversaries.

(3)   Judge-3:   I'm Jon
        Do-Much-More: Good to meet you Jon
        Judge-3:   What do you do when you're not doing the Loebner prize?
        Do-Much-More: Oh, I do much more than I intended to do at first. I got more
                        interested in the job as I went along.
        Judge-3:   Is that difficult?
        Do-Much-More: No, it isn't at all difficult. It is as peaceful as a platypus
                        playing with a potato pudding.
        Judge-3:   T~You have a fine line in metaphors
        Do-Much-More: I sometimes have a fine line, but that's not what I do best.
                        I'm better at growing antirrhinums and mimosas.
        Judge-3:   Ah a horticulturalist?
        Do-Much-More: Well I don't know how much a horticulturalist weighs, but I
                        reckon the average horticulturalist must be worth twice that
        much in gold.

        (WorldsBestChatbot.com, 2009)

At the same time, work on dialogue systems for restricted domains, such as train timetable information, has made great progress and such systems are now used in many countries to provide callers with up-to-date information through a dialogue. The focus of this chapter is, however, not on practical applications, but rather on how computational simulations of dialogue help our understanding of information flow. As observed by Artificial Intelligence pioneer and Nobel prize winner Herbert Simon, simulation or analysis through analogies is a time-honoured technique:

> Simulation, as a technique for achieving understanding and predicting the behaviour of systems, predates of course the digital computer. The model basin and the wind tunnel are valued means for studying the behaviour of large systems by modelling them in the small, and it is quite certain that Ohm's law was suggested to its discoverer by its analogy with simple hydraulic phenomena. (Simon, 1996, p.14)

In research on dialogue, the principal analogy that has emerged is that of a game. In particular, chess, or even better, correspondence chess, highlights certain salient properties of dialogue. Take a game of correspondence chess between Alice (A) and Bob (B). A and B each have their own chess board and communicate their moves through the postal system. At the start of a game, the boards of A and B are identical, with the pieces placed at the usual initial positions. Now, suppose A make the first move (e.g., pawn from e2 to e4). A writes the move in chess notation (e4) on a piece of paper, puts it in an envelope and sends it to Bob. On receiving the note, Bob changes the position of the pawn on his board and then decides on his own move, say, pawn from e7 to e5 which is communicated again in chess notation.

Such a game of correspondence chess has a number of interesting properties:

- Each of the participants has their own private *game board*, which ideally is synchronized with that of the other participant.
- Messages effect an *update*, i.e., *change* to the game board of the other participant.
- The *rules* of chess constrain which moves are possible at any point in time, and consequently also which messages are valid.

In summary, correspondence chess involves contexts (game boards), context change and rules. For each of these, there is an analogue in dialogue. Let us start with the context. As we have already seen, when two people have a conversation, they come to share certain information. Each of them keeps a mental record of this information, their personal representation of the context. We can liken this personal context to the private chess board of each of the two correspondence chess players. When an interlocutor produces an utterance, this leads to an update of the context. As a first approximation, let us assume that when a dialogue participant utters a statement, say 'KLM 338 arrives at eleven twenty' (compare example 2.e), this statement is added to the context of all dialogue participants. In other words, I and C share this information. Of course, interlocutors do not always immediately accept what the other party says; sometimes they even reject it or provide additional justifications for their statement (see examples 1.b and c). They may also misunderstand what has been said. For now, however, let us focus on the straightforward case where the speaker's statement is understood and accepted.

Context Change: the Elimination of Alternatives

**Principle 1**:   *Information flow = context change.*

An influential analysis of the precise effect of producing a new statement given a context involves the concept of possibility. According to this view, championed by the philosopher Robert Stalnaker (see Stalnaker, 1999), a context is viewed as a set of possible worlds. Each possible world represents an alternative way that the actual world could be. Prior to I uttering 2.e, I and C do not share information on when KLM 338 arrives. In terms of a context as a set of possibilities, this means that the context includes *KLM 338 arrives at 00:00*, *KLM 338 arrives at 00:01*, *KML 338 at 00:02*, etc.,[6] all of these are live alternatives in the context prior to 2.e. The effect of I uttering 2.e is that the alternatives in which *KLM 338 does not arrive at 11:20* are eliminated, resulting in a new context. In this new context, in each possibility that is still entertained, it holds that *KLM 338 arrives at 11:20*. In other words, the new context the information *KLM 338 arrives at 11:20* is shared. Of course, there may be many such worlds: e.g., in some worlds where *KLM 338 arrives at 11:20* it may also be true that *it rains at 11:20*, whereas in others it won't.

Let us look at the same idea, using a different, less complex, example. We assume that our interlocutors are only interested in three things: whether it rains in Paris, whether it rains in New York and whether it rain in London. Furthermore, let us agree that the letters P, Q and R

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[6] Assuming arrival times are expressed in hours and minutes, prior to I's utterance of e, the arrival could be on each minute of the day, resulting in a context with at least as many alternatives/possible worlds as there are minutes in a day. This, of course, assumes that it is already part of the context that the flight arrives on the day of the conversation.

stand for *It is raining in Paris*, *It is raining New York* and *It is raining London,* respectively. We can prefix such a letter with 'Not', as in 'Not Q', to represent the negation of Q (i.e., *It is not raining in New York*). Initially, both P and not P are possible and so are Q and not Q and, also, R and not R; we have $2 \times 2 \times 2 = 8$ possible worlds as depicted in the leftmost context (indicated by a box) in Figure 9.1. The statement P (i.e., It is raining in Paris) results in an update that eliminates all the worlds in which P is not true. In the new context, P is true in all worlds. Next, consider an update with Not Q. Now, all worlds in which Q is true are eliminated. We end up in a context where both P and not Q hold in all possible worlds. The only alternatives in this context are R and not R.
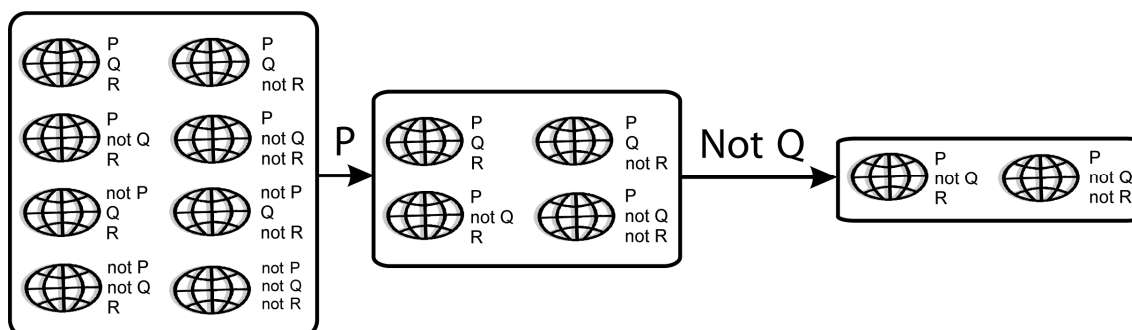
Figure 9.1: Two updates, *P* followed by *Not Q*, change an information state by eliminating alternatives

In summary, according to this view contexts are the containers of information. For this reason, the literature in this area often uses the terms *context* and *information state* interchangeably. Utterances are viewed as effecting a change from one context, i.e., information state, to another one, rather than carrying information per se.

So far, we have characterized contexts as containing the information that the interlocutors share as a result of the conversation. Inspired by the medieval Obligation Game of Walter Burley (ca. 1275–1344), the Australian philosopher and computer scientist Charles Leonard Hamblin (1922–1985) has suggested a particular perspective on the information in a dialogue context: as commitments, that is, information which the interlocutors have committed themselves to in the course of the dialogue (Hamblin, 1970). Often these commitments will be identical to what the interlocutors actually belief, but they need not be.[7]

Viewing context in terms of commitments allows us to complete the analogy with correspondence chess: commitments regulate the behaviour of the dialogue participants: they constrain what interlocutors should say next. Examples of two intuitively plausible rules which have been proposed independently by several researchers are:

CONSISTENCY RULE: Do not say something which is in contradiction
                    with the context.

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[7] For example, if someone makes a claim, but actually believes the opposite (in the vernacular, she or he is lying or perhaps just confused, depending on whether they intend to mislead the addressee), they will still incur a commitment. Hamblin has also pointed out that not only people can issue statements, but also, for instance, institutions. Our common sense notion of belief, as the mental state of a person, fails to do justice to such cases, in contrast to view of contexts as populated by commitments.

INFORMATIVITY RULE: Do not say something if it is already part
                        of the context.

At this point, let us hasten to point out an important limitation of the analogy between chess and conversation, which the reader may already have spotted. If a rule of chess is violated (e.g., a rook is moved diagonally), the chess game comes to a premature end or, at the very least, that move cannot be counted as part of the game. Now, violation of the rules of dialogue, such as CONSISTENCY and INFORMATIVITY does not seem to have quite the same effect. Rules in dialogue appear to be more flexible than the rules of chess. When we come to discuss Principle 3 in the penultimate section of this chapter, we will see that speakers often even exploit the flexibility of dialogue rules: they will violate a rule with the very purpose of communicating information.

Context-Dependence: Filling Informational Gaps

In chess, which moves can be played next depends on the current positions of the pieces on the board. In other words, the set of available moves is context-dependent. In this section, we explore how moves in dialogue depend on the context as well.

Principle 2:   *Information flow is context-dependent.*

Our account of information flow in dialogue has assumed that context change is a result of the exchange of complete statements. Statements are, however, often far from complete. Speakers economise by using short cuts, relying on the ability of the addressee to figure out what is meant. For instance, in example 1, many of the utterances consist of phrases (e.g., 'Two forty a gramme' and 'Psychology'), rather than full statements. The addressee has to work out, based on what has been said so far, which statement is being made. Take the question 'What are you gonna study?' followed by the answer 'Psychology'. Schematically, the question introduces a gap, here indicated using underscores: 'Tim is going to study __' (for the moment, we ignore the pronoun 'you'). The addressee is expected to provide a filler for that gap, a short answer such as 'Psychology'. The full statement that the short answer conveys can be pieced together by taking this filler and inserting it into the gap, yielding 'Tim is going to study psychology'. Thus question words such as 'What', 'Where', 'Who', etc. function as gaps that the questioner expects the addressee to fill by providing an answer.

For the efficient exchange of information in dialogue, 'gaps' play a central role. Question words are one among many types of expression that can introduce informational gaps. Other examples include pronouns ('it', 'he', 'she', 'you', etc.) and definite descriptions (e.g., 'the list' in example 1.c). Of course, the gaps these words introduce play a different role from question word gaps. Take the definite description 'the list' in 1.c. Here, Tim is talking about a list which he assumes Gareth to be already familiar with. Let's see how this expression introduces a gap.

Firstly note that the expression 'the list' is part of the instruction or suggestion 'Check the list'. For the addressee, such an instruction only makes sense if he knows which list is meant. In other words, the instruction 'Check the list' has two component parts:

- A gap __ which needs to be filled by a list from the context
- an instruction or suggestion to check the object the filler stands for

At first sight, there is a problem, since 1.a and 1.b make no mention of a list. Perhaps, the notion of a context as the shared information introduced during a conversation is too narrow. This context of the immediate dialogue, the *discourse context*, needs to be enriched with information that the interlocutors already shared before the current conversation got started. We will refer to this enriched context as the *common ground* of Gareth and Tim. The common ground includes:

- the discourse context
- information Gareth and Tim came to share in previous conversations or other activities
- background knowledge which they are presumed to share, e.g., by both living and working in Slough, England

For instance, in a previous conversation Tim and Gareth's manager, Brent, might have told them:

(4)   A list with all our products and prices is in the pricing folder
          of the shared drive.

The indefinite noun phrase 'a list with all our products and prices' provides the filler for the gap introduced by 'the list'. The interplay between indefinites and definites as providing fillers and invoking informational gaps has led to modifications and extensions of the view of a context as simply a set of possibilities. It is beyond the scope of this chapter to elaborate on the full technical details of such a revised view. Nevertheless, let us try to explain what such an extended notion of context looks like; here we base our explanation on the approach that has been worked out in detail in Piwek (1998) and Piwek & Krahmer (2000).

The idea is to think of contexts as structured representations of the world (or how it might be, could be, is imagined to be, etc.). This is in contrast with the eliminative view of context change that we have already come across and which views a context as an amorphous set of possible worlds. Contexts as structured representations first and foremost need to have counterparts for the things we individuate in everyday life – chairs, tables, houses, people, etc. We use the term *witness* for such a representational counterpart. An indefinite noun phrase, such as 'a list with all our products and prices', is seen as introducing a witness, a sign or proof of something. The descriptive content of the noun phrase ('list' and 'with all our products and prices') is taken as contributing a classification of the object that the witness stands for. This is achieved through labels that attach to the witness in the structured representation, see Figure 9.2. This figure also visualizes the import of the definite noun phrase 'the list', as a gap with a label that specifies the type of filler it requires.

Figure 9.2 is an example of a structured context that is inhabited by a witness (the small box in the context) and two labels that are attached to the witness. The witness, which has been introduced through the use of an indefinite noun phrase ('a …'), stands for an object in the world and the labels classify the object via the witness. This context provides a filler for a gap, introduced by a definite noun phrase ('the …'), that requires a witness that is labelled as being a list.
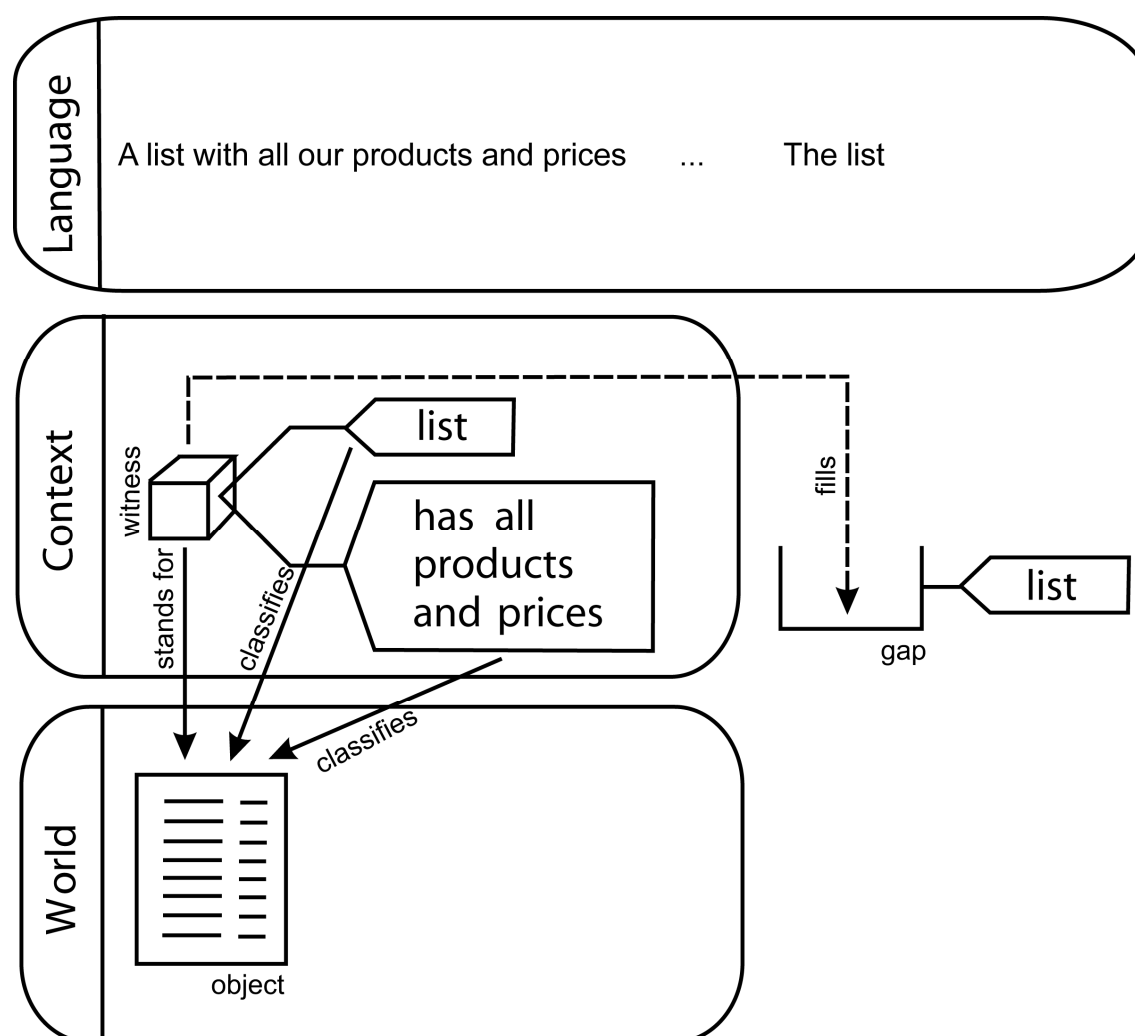
Figure 9.2: Example of a structured context that is inhabited by a witness and two labels attached to the witness

Thus, whereas indefinites introduce new witnesses, definites introduce gaps that require filling by witnesses that are already present in the context. The difference between the two types of expression is highlighted by their very different behaviour under negation:

(5) a. John buys a car.
    b. John buys the car.

(6) a. John didn't buy a car.
    b. John didn't buy the car.

When an indefinite is part of a negative sentence such as 6.a, the indefinite no longer introduces a witness: the sentence no longer commits the speaker to the existence of a car. In contrast, a definite, even when part of a negative sentence (6.b) still demands the existence of a car in the context. We can paraphrase 6.b as there is a car which John didn't buy. This property of definites, survival under negation, was first discussed by Gottlob Frege (one of the founders of Modern Symbolic Logic), who used the term presupposition ('Voraussetzung') for the type of information associated with definites.

So, we have now seen two different views of context: as a set of possible worlds and as a structured representation inhabited by witnesses and labels. We have seen that structured representations, in combination with the notion of an informational gap, provide a neat way to account for the effects of indefinite and definite noun phrases. Kamp (1988) takes this one step further by arguing that the view of contexts as sets of possible worlds is incapable of dealing properly with the interaction of indefinites and pronouns. The example he uses to make this point is:

(7) a. Exactly one of the ten balls is not in the bag.
    b. It is under the sofa.

(8) a. Exactly nine of the ten balls are in the bag.
    b. It is under the sofa.

Imagine that both 7.a and 8.a are uttered in a context in which the interlocutors do not share any information, in other words, everything is possible. So we start with the same context for both 7.a and 8.a. Both sentences lead to a new context in which there are ten balls of which nine are in the bag and one is not. In other words, both sentences result in the same set of possible worlds. But now suppose the speaker continues with 7.b or 8.b. For 7.b, 'It' picks up the ball that is not in the bag. In contrast, 'It' in 8.b can not be taken to refer to that ball. So it seems that the context for 'It' in 7.b is different from that in 8.b. But according to the possible worlds view of context change, there is no difference. In the words of Kamp (1988, p.158):

> We must conclude that no difference can be predicted if contexts are identified with sets of possible worlds. Therefore, a theory of meaning and context dependent interpretation of English must, if it is to handle such examples successfully, adopt a representation of contexts that goes beyond what sets of possible worlds are able to reveal.

Cooperation: Rules and Rule Breaking in Dialogue

Chess is primarily a competitive game. This can obscure the fact that playing chess requires a great deal of cooperation: both players need to obey the rules of chess and take turns in an orderly fashion, one after the other. Similarly, conversation, even though it can be adversarial, as in a dispute, requires the interlocutors to cooperate. Arguably, in conversation cooperation amounts to working towards the same end of effectively exchanging information.

Principle 3: *Effective information flow is a cooperative endeavour.*

In the field of linguistics, the view of conversation as a cooperative endeavour has taken hold ever since the philosopher Herbert Paul Grice (1913 – 1988) delivered his influential William James lectures at Harvard University in 1967. The first part of these lectures was published as Grice (1975). In those lectures Grice proposed four specific rules that cooperative dialogue participants should adhere to and which, if followed, result in effective information flow. Here let us provide short paraphrases of these four rules:

QUANTITY: Say no more and no less than is required.
QUALITY: Be truthful
RELATION: Be relevant.
MANNER: Express yourself clearly. Be brief, orderly and avoid
               obscure or ambiguous expressions.

Of course, participants do not always follow these rules. Firstly, they can explicitly opt out. A good example of a speaker opting out of QUANTITY can be found in an article that appeared in The Times on June 27 2008, some months before the troubled bank HBOS was taken over by Lloyds TSB plc, which in turn had to be rescued by the UK Treasury:

(9)   Lord Stevenson of Coddenham [chairman of HBOS] told about 400 retail
      investors at HBOS's general meeting, in Edinburgh, that for legal reasons he
      could not state his true feelings about the hedge fund managers thought to
      have forced down HBOS's share price through short-selling on the back of
        false rumours. (Seib, 2008)

Violation can also be intentional and covert, for instance, when someone breaks the QUALITY rule by intentionally telling a falsehood. Unintentional violations will often have a comical effect. Take the utterance 1.b in example 1: Gareth's guess at the price of Opti-Bright Laser Copy Paper is a blatant violation of RELEVANCE, following on Tim's utterance 1.a. The comical effect is enhanced further by Tim following up on Gareth's remark, without appearing to notice its irrelevance in the light of what he said in 1.a.

(10)   In this episode of the TV Series 'Father Ted', the whistle of Benson,
      a groundskeeper, has gone missing.

a.	BENSON:	Anyway father, come on. Have you heard anything?
b.	TED:	About what?
c.	BENSON:	About my whistle. […] I've had that whistle for fifty years. It saved my grandfather's life.
d.	TED:	Did it really?
e.	BENSON:	Yes. He was being executed by the British. They had him up against the wall and they shot him. And the bullets all hit the whistle in his coat pocket and bounced off him.
f.	TED:	Really? The bullets bounced off him.
g.	BENSON:	Yes.
h.	TED:	God almighty! So he survived?
i.	BENSON:	No, no. They just reloaded and shot him again.

     From 'The old grey whistle theft', episode 4 of the 2nd series of the
     TV Series 'Father Ted' (Linehan and Mathews, 2000:145).

This example is a further illustration of an apparently unintentional violation, this time of QUANTITY. When Benson says that 'It [the whistle] saved my grandfather's life', his dialogue partner Ted assumes that Benson says no more and, importantly, no less than is required. If one says that 'X saved Y's life', the implicit assumption is that Y went on to live for a significant amount of time. This is, in particular, the case if one refers to this event in order to justify the importance of X for the speaker. In contrast, if a speaker uses the phrase 'X saved Y's life' and Y actually died shortly after the event, the speaker should provide this additional information. The information that Y died shortly after the event affects the evaluation of the importance of X to the speaker. Not providing the information that is required to correctly evaluate the justification violates the injunction to say no less than is required for the effective exchange of information. After all, with Benson's Grandfather not surviving, the importance

of the whistle is greatly diminished, only having bought Benson's grandfather a few extra moments.

A third type of violation Grice labels 'flouting'. In these cases, the speaker intentionally and publicly violates a maxim. This violation usually serves a clear purpose: for instance, to communicate information which the speaker doesn't want to commit to explicitly. For these cases, it is essential that the addressee recognizes that violation has occurred and can work out what the speaker really meant.

The report on HBOS Chairman Lord Stevenson's speech to HBOS's general meeting (see example 9), continues with Lord Stevenson referring to the hedge fund managers which were instrumental in forcing down HBOS's share price through short-selling as:

(11)   "Very nice people", he said with a grimace. (Seib, 2008)

a blatant flouting of QUALITY (Be truthful).

Grice (1975, p.53) explains instances of this kind as follows:

> It is perfectly obvious to A [the speaker] and his audience that what A has said or has made as if to say is something he does not believe, and the audience knows that A knows that this is obvious to the audience. So, unless A's utterance is entirely pointless, A must be trying to get across some other proposition than the one he purports to be putting forward. This must be some obviously related proposition; the most obviously related proposition is the contradictory of the one he purports to be putting forward.

In other words, sometimes speakers choose to break the rules of conversation to communicate with their audience in a way which allows them to convey something and yet be less committed than would be the case if they had said it explicitly.

Concluding Remarks

At the heart of this chapter is the analogy between conversations and games of correspondence chess. This analogy led us to three principles of information flow which can be summarized as the three Cs of information flow in a dialogue game: Context change, Context dependence and Cooperation. We examined the influential model of context change as elimination of possibilities, and then moved on to the role of informational gaps and context change. We identified a limitation of the view of contexts as sets of possible worlds, and considered the alternative of contexts as structured representations. Finally, we turned to the insight that effective information exchange requires cooperation. We discussed Grice's four rules of cooperation in dialogue and examined the, at first sight, paradoxical fact that violating these rules can in itself be a form of cooperative information flow. At this point, we also seemed to have arrived at the limits of the analogy between correspondence chess and dialogue.

Further Reading

This chapter provides a rough outline of the mechanisms underlying information flow in dialogue. Wherever possible, I have included references to the detailed, often technical, studies that underpin this chapter. Even so, there are many issues and problems that were beyond the scope of this chapter. I conclude by highlighting a few of these.

When discussing context change, the concern has been primarily with the effect that statements have on the context. Conversations have an abundance of other types of utterances, including instructions, clarifications and questions. For example, Ginzburg (1996) argues that to deal with the effect of question asking on the context, an even more elaborate structural account of context than the one discussed here is called for. Traum (1994) presents one of the first computational accounts of how interlocutors come to ground, i.e., agree on information that has been introduced in conversation (recall the simplifying assumption about grounding that we made in the second section of this chapter). Recently, there have been efforts to arrive at an ISO standard for characterizing the rich tapestry of dialogue acts that occur in dialogue (Bunt et al., 2010). Other issues that we have had to skim over include the interaction between verbal utterances and gesture in information exchange (e.g., Lascarides and Stone, 2009), intonation (see the collection of papers in Bosch and Van der Sandt, 1999), vagueness (a complex topic which is dealt with in the accessible monograph of Van Deemter, 2010) and ambiguity (specifically the nocuous variety that arises when addressees interpret the same utterance differently, see Willis et al., 2008).

Acknowledgements

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