Chapter 9

Communication in design

Claudia Eckert and Anja Maier
University of Cambridge

Chris McMahon
University of Bath

Design is never a solitary activity. It is a social interactive process. Complex products are designed by teams of people, perhaps in single companies but more often distributed through a supply chain. An extreme example is the design of a new aircraft, where thousands of engineers may work together in collaborating companies. Hundreds of other engineers work on the design of a new aircraft engine in a first-tier supplier company. In addition, dozens of engineers work on the fuel pumps as second-tier suppliers, and this company will in turn have its own suppliers.

At the other extreme, a specialist engineer or a graphic designer might work alone on a design. Even in this example, communication takes place in many different forms, e.g. between the graphic designer and the customer. Communication is an essential part of any design process, and problems in design communication can lead to delays, mistakes and even the ultimate failure of this process.

Communication can happen between many different people or groups, such as different engineers, project teams, different departments within one company, or between the company, the supplier and the end customer. It has different directions, such as top-down from manager to design engineer, bottom-up or in-between. Communication can be formal or informal. It can happen at the same time – synchronously – or at different times – asynchronously. Transmitted information can take many different forms, e.g. verbal, written or pictorial.

Design is never a solitary process. It is a social interactive process.

For designers and design managers, it is important to understand how communication works in design, where it breaks down and how it can be managed and supported. This chapter will start off with a short theoretical background on the conceptualisation of communication. The central focus will then be on characterising communication in design and on the ways it can break down. Understanding how communication works and where it breaks down is an important step towards improving it. Finally, active management and support of communication through electronic media will be discussed.

Theoretical background

The following sections will set the scene by starting with a short discussion on data, information and knowledge and then introduce some general characteristics of communication.

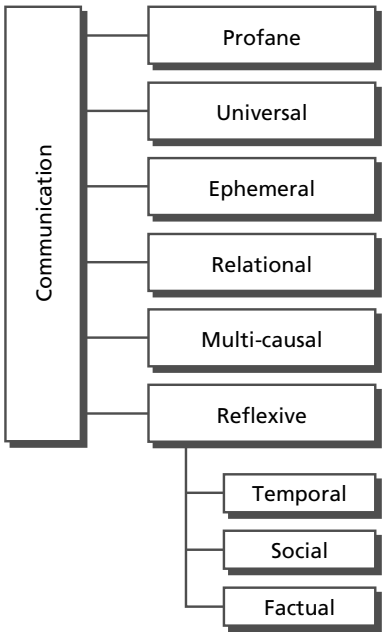
Communication is about exchanging data and information, as well as creating knowledge. These are broad, abstract, complex and multi-faceted

concepts and thus difficult to define. The question of their definition has occupied the minds of philosophers since the classical Greek era and has led to many epistemological debates. A commonly held view is that data consist of raw numbers and facts whereas information is defined as knowledge only once it has been understood and authenticated (Ahmed *et al.*, 1999).

In contrast, Alavi and Leidner (2001) suggest that the presumption of hierarchy from data to information to knowledge is inaccurate. Similarly, Dahlbom and Mathiassen (1995) argue that data, information and knowledge correspond to different forms of human activity. They contend that data are a formalised representation of information, and that information is essentially a charting of knowledge within a shared practice – where the reliance on shared practice and experience of situation is the key.

Tuomi (1999) provides an alternative view, arguing that the assumed hierarchy from data to knowledge is actually inverted. Knowledge must exist before information can be formulated and data can be measured to form information. Furthermore, 'raw data' does not exist *a priori*. Knowledge processes are always employed in identifying and collecting even the most basic data.

However, in the everyday language of design the terms data and information, as well as information and knowledge, are used fairly interchangeably for items of communication. This is because the same item can be data, information and knowledge at different times and to different people. This chapter will therefore refer to all items of communication as information.



9.1 General characteristics of communication

General characteristics of communication

Sociologists have long tried to define communication, but find it difficult to come up with simple models. Merten (1999) points out that communication is profane, universal, ephemeral, relational, multi-causal and reflexive. His characterisation of communication is summarised in Figure 9.1. Everybody communicates all the time in many different ways, so we can never measure the quality of communication in general terms. Most of what we express only has meaning for a very short time. Even if we analyse a particular aspect or time span, much of the relevant communication cannot be captured.

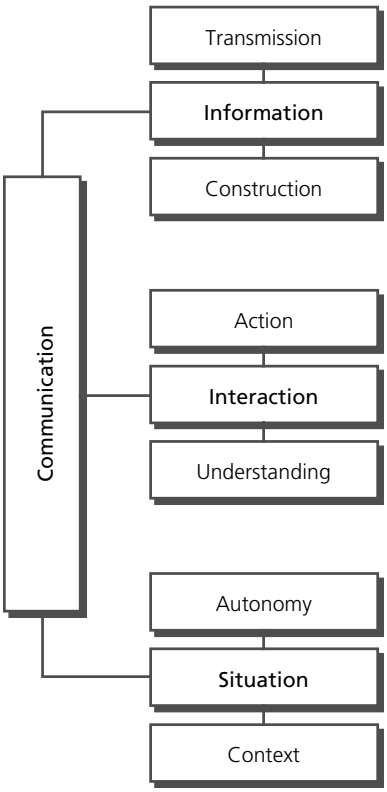
Furthermore, communication is relational. It is a process that can never be attributed solely to the communicators (sender and receiver), nor to the message, but occurs as the specific relation between these units. Communication, therefore, cannot fully be modelled as an object but only as a relational category. Communication is also never static ; it is dynamic. It is multi-causal

and inherently reflexive, *i.e.* influenced by other communication acts in three fundamental dimensions (Merten, 1976):

- *Temporal* – communication processes directly impact themselves.
- *Factual* – all communication processes require factual statements, but also require meta-statements to make communication understandable and targeted.
- *Social* – communication processes are orientated towards others.

Theoretical conceptualisations of communication

After having introduced general characteristics of communication, the following sections group existing theories according to their respective foci on information, on interaction or on the situation in which communication takes place, as illustrated in Figure 9.2. All these viewpoints are combined in a systemic view of communication.



9.2 Theories of communication

Information-centred theories

Information-centred theories focus on the transmission and processing of information. There are basically two ways of looking at a communication process from an information-centred viewpoint. One either focuses on transmission of information, adapting reductionist models from electronic data transfer in electronics to human communication, or one focuses on the creation of sense by the communicators, following social constructivist viewpoints.

Models of information transmission, which were originally developed for noise reduction in electric data transmission, are simple sender–receiver–models that assume that the sender sends a message through a channel that is received by the receiver like an object. The Shannon–Weaver model (Shannon and Weaver, 1949) proposes that a basic system of communication may be thought of as being composed of five elements: source, transmitter, channel, receiver and destination as schematically represented in Figure 9.3.

The information source produces a message, which is encoded into a signal, which is transmitted across a channel. The receiver decodes the signal and the message arrives at the destination (Shannon and Weaver, 1949). A similar model is the 'conduit metaphor' (Reddy, 1979), where the sender is seen as putting a message and its meaning in a tube and out it comes at the other end.

9.3 Shannon and Weaver's model of communication

Underlying both models is a mechanical, linear view of communication, which is seen as a one-way process. While these models are intuitive and shed light on many difficulties in communication, they ignore the individual cognitive processes of the communication partners and their interaction and do not consider the factors outlined in Figure 9.1.

Transmission theorists model communication as the passing on of information.

Whereas the transmission theories model communication in essence as the passing on of information, the constructivists model communication as the construction of new knowledge via the communication partners. What looks like a pure information flow on the surface is actually a process where the information flow is taken as a trigger to create social reality.

Delia (1977) contends that an essential determining factor of the communication process is the cognitive complexity of the communication partners, which becomes visible in interaction processes. The communicators interpret the received information. Underlying this interpretation – or the act of making sense – are cognitive schemes and categories, which develop as a result of interactions between the individuals and the challenges in their environment.

Interaction-centred theories

In addition to information-centred theories, which are mostly interested in internal processes within a communicator, interaction-centred theories focus on the relationship between communicators. For the latter theories, again, one can basically differentiate between two approaches. On the one hand, there is the view that interaction forms one unit insofar as the goals of the individual actions of the parties concerned will be reached. On the other hand, there is the view that communicative interactions represent an understanding between the partners on the basis of joint conventions.

Constructionists model communication as the construction of new knowledge via the communication partners.

In general, communication involves some kind of interrelation between several participants. Advocates of the speech–act theory (Austin, 1962; Searle, 1969) focus their analysis of the communicative interaction on the individual contribution of the participants. Communicative interaction is seen as a sequence of individual actions of the participating communication partners.

Goodwin (2000) sees the interrelation as co-operative, where the partners strive to pursue a common goal to reach consensus. This requires common understanding of conventions and the rules and obligations that can be inferred from them. Conventions form a specific basis for communication that is applicable to all members of one culture.

Habermas (1981) envisages a universal basis for communicative interaction by calling each participant of the interaction to agree on the validity of his or her respective expressions. However, the willingness to support a common understanding is just one among many other dispositions.

Psycholinguistic researchers, such as Herbert Clark, assume that speakers and listeners understand each other because of a common ground. This common ground is generated through cooperation between speakers and listeners (Clark and Carlson, 1982; Clark and Murphy, 1982; Clark *et al.*, 1983; Clark and Brennan, 1991) or, as later proposed, through coordination (Clark, 1992, 1996).

Situation-centred theories

The third basic dimension of communication is the communication situation, which influences the information transmission and the interaction. The situation does not just take the directly perceivable environment into account, but also the wider context, such as the nature of the team within which communication takes place, the organisation and the social background. There is as much debate as to how this happens as there is consensus over the fact the environmental factors influence the communication process. The classical linguistic tradition (Levelt, 1989) processing of speech is seen as relatively independent of the communicative situation. Contextual theories, such as ethnography (Hymes and Gumperz, 1972) assume that communication is dependent upon context variables and thus varies strongly.

Systemic view of communication

To capture the richness of communication fully it is necessary to take a systemic view, which concurrently incorporates the concepts of information, interaction and situation. Communication is seen as a process. For the purpose of human-to-human communication there are at least two participants, who can both be senders and receivers. The communicators are seen as interacting cognitive systems distinct from, but also influenced, by their emotions and their environment; see Figure 9.4. Interactions do not necessarily have to be visible from the outside, although they are often accompanied by gestures.

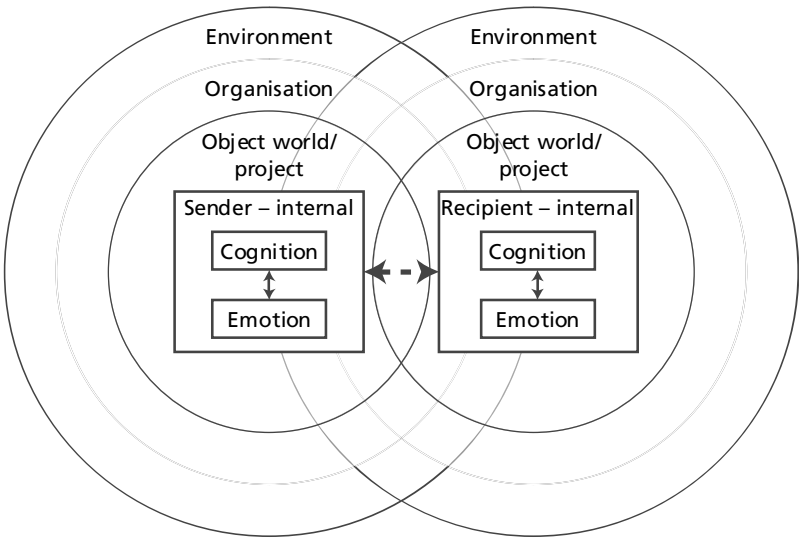
Communication is at the same time a social, a cognitive and an emotional act.

Communication is at the same time a social, a cognitive and an emotional act. It is social because different people are interacting with each other in a social and political context. Communication is cognitive because what people say and how people make sense of what they perceive depends on their mental models and prior realm of semantic, syntactic, and pragmatic know-

ledge. Communication also depends on how we feel about people we communicate with and about the content of the message we are trying to convey. As far as the emotional aspect is concerned, it is worth mentioning that trust and amicability, the willingness of someone to hear the thoughts of another person with good will, is often central to any communicative act (Cockburn, 2001).

As depicted in Figure 9.4, several factors influence each communication process. Because group cohesion needs to remain high, particularly if work is to be brought in on time and on budget, the choices the communicator makes will be influenced strongly by the norms and values of the project team (Maletzke, 1963). Furthermore, the individual members of the teams have different educational backgrounds and thus are entrenched in their own object world (Bucciarelli, 1994). The next layer is the organisation. Features such as the size, organisational set-up, policies and leadership style influence the communication process. A third layer is the environment, which includes society as a whole, the communicator's immediate community, the groups he or she belongs to and the individuals he or she interacts with. All these layers influence communicative behaviour.

After having outlined theoretical conceptualisations of communication and the way the concept of communication is used throughout the chapter, the following sections concentrate on those aspects of it that are specific to design, leaving aside universal factors, such as emotion.



9.4 A systemic view of communication

Characterising communication situations in design

Design in its broader cultural sense includes all activities involved in the generation of a complex product, which can entail many different communication situations.

At present there is no complete taxonomy of different design tasks. Frost (1994) provides a useful classification of products, which can be used to assess characteristics of their design processes. While there have been many attempts made to describe engineering design in general in taxonomic form (e.g. Ullman, 1992), detailed taxonomies address only specific issues. For instance, Ullman (1995) classifies decision problems in design; and Kaplan *et al*. (1992) are concerned with the information requirements of tasks requiring interaction between designers.

In contrast to Kaplan *et al*. (1992), we are looking at communication activities within large design processes, where the mode of collaboration is not necessarily predetermined by the task but rather by the organisational set-up.

How designers communicate, and how designers could communicate, has been studied from a variety of intellectual perspectives. But discussions of collaborative designing usually consider only a handful of activities; and support systems for cooperative design are developed for specific scenarios, whereas consideration of a wider range of uses could reveal a broader range of requirements and potential pitfalls. Product information is communicated differently according to the stage of the design development and the intended recipient of the communication.

Product information is communicated directly according to the stage of the design development and the intended recipient of the communication.

Pahl and Beitz (1996) distinguish between original, adaptive and variant design. Each of these modes of design involves different types of communication, and very often each mode can be found in the same company, even where the company is working in an established product domain. For example, routine design work in a company may involve the rapid development of a current standard design, perhaps using parametric design or knowledge-based engineering techniques. This would be an example of variant design, and the communication issues would involve the rapid population of design automation tools and rapid communication with customer and manufacturing organisation.

With a longer term focus, the same company may incrementally adapt its design approach to improve product performance and reduce product costs. The communication issue in this case concerns the application of design evaluation tools and design for X methodologies (where X is such issues as manufacturability, maintainability, *etc.*).

Concurrently, the company may explore radical approaches to its design challenges, and will seek to be aware of disruptive technologies that will impact on its markets. Communication, in this case, concerns awareness of leading-edge technological developments, and communication within a design team to allow novel concepts to be explored.

Studies of communication in collaborative designing

Research on design collaboration has largely focused on team meetings. Many studies have given a group a design brief and analysed the resulting design activities (see Cross *et al*. (1996) for 20 detailed analyses of the same episode of collaborative design by various different researchers). Design conversations almost always employ sketches, drawings, prototypes or other visual referents, either actual or imagined (Eckert and Stacey, 2000).

Communication in joint designing is multi-modal: speech, drawing and gestures are used in combination, with each channel used to explicate and clarify what is expressed in the others (Bly, 1988; Tang, 1989; Minneman, 1991). This multi-modal communication involves the use of argumentation strategies and rhetoric and subtle modulation of the degree of commitment with which a proposal is put forward (Brereton *et al*., 1996). Minneman (1991) points out that describing the design itself is just one aspect of design discourse. He classifies the content of design communication according to a 3-by-3 matrix (see Figure 9.5).

Communication can be about an artefact, a process, or a relation (between individuals or groups, or between people and tools, rules, representations, *etc*.). It can describe the state that something is now in, or how and why something got to be the way it is (making sense), or how something might or should develop (framing the future).

There has been extensive research on how using computer technology influences people's interactions in meetings. One important finding is that people will exploit ways to communicate that do not exist in conventional

Trajectories \ Facets	An artefact	A process	A relation
State of			
Making sense of			
Framing futures of			

9.5 Framework for considering design communication (Minneman, 1991)

face-to-face interactions – for instance, by drawing or gesturing in the same place at the same time in a virtual workspace (Bly and Minneman, 1990). Another is that using group support systems influences what happens in meetings, but how they change what happens depends on both the technology and the purpose of the meeting; for instance, decision-making is different from idea generation (Huang and Wei, 1997).

Minneman (1991), Bucciarelli (1994) and Henderson (1999), among others, have studied large-scale engineering processes as participant observers. They report that complex designs are developed largely through social processes of argumentation and negotiation. They view designs as arising through a process of negotiation between participants, where information is actively communicated and made sense of, rather than seeing it as passively transmitted through an organisation. However, this view also downplays the role of a designer working alone communicating with himself/herself – sketching, modelling, *etc.* and then needing to communicate externally to pass on the results of the work.

A significant aspect of many design processes is the handover of information, where one designer has generated a specification that another member of the team is supposed to implement. In these cases designers do not wish to enter a negotiation process. Henderson (1999) shows that graphic representations play a critical role in structuring the design process and conveying information between people with different knowledge and responsibilities.

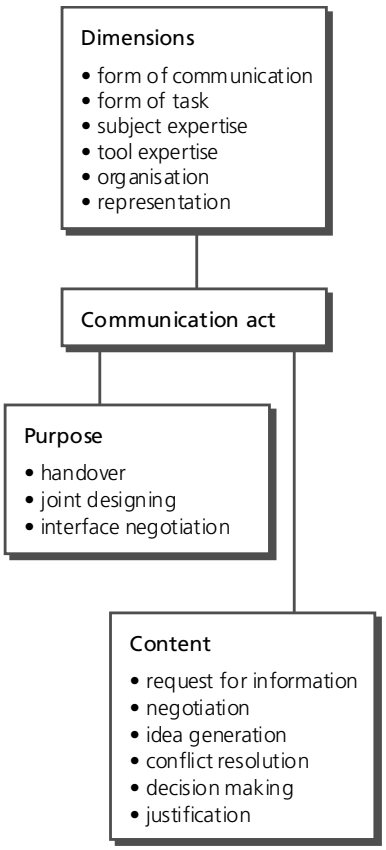
Eckert (2001) has analysed the communication breakdown during design handover and showed that remarkably little conversation takes place to resolve ambiguity in specifications when designers are not aware of multiple interpretations. In a handover situation, ambiguity in representations can seriously decrease the efficiency of a process (Stacey and Eckert, 2003), while ambiguity can be a driver for creativity in joined design situations, as argued in Minneman (1991). For example, creativity is enhanced by allowing designers to reinterpret sketches. Schön (1983) views this as interacting with the sketches as in a conversation: the designers see more in their sketches than they put in when they drew them, and these insights drive further designing.

Designers communicate through reference to objects.

A similar phenomenon occurs when designers communicate through reference to objects (Eckert *et al.*, 2003), when the listeners might pick up on a different aspect of a reference design than that intended by the speaker, or might break out of a mental fixation (Jansson and Smith, 1991) by being

provided with an alternative frame of reference. The effectiveness of communication through references to objects varies with the objects and intentions of the speaker and the knowledge of the recipient (Eckert and Stacey, 2000). This discussion of ambiguity shows how difficult it is to understand the characteristics of communication in general. It is necessary to differentiate between different communication scenarios, modes of interaction and intentions.

The following section provides a classification of different communication situations according to the dimensions of variability, the purpose and the content of the communication act (Figure 9.6).



9.6 Classification of communication acts

Interaction scenarios

The situations in which designers interact vary in a large number of ways. The dimensions of variation listed in Figure 9.7 are not orthogonal: common situations have related values along a number of the dimensions. This classification from Eckert *et al.* (2001) has been derived from industrial observations, and thus has more of a cognitive and social bias than those of others who are also considering the management of information. For example, Ostergaard and Summers (2003) started from communication between intelligent agents in a computer program.

These different situations can create different types of communication behaviour and, therefore, breakdown. For example, it is intuitively obvious that communication between people with the same expertise, who work jointly on a problem in the same room, is quite different from communication between people from different countries who have never met and come from very different lines of work.

Just a few of the dimensions of the communication scenarios listed in Figure 9.7 determine most of the characteristics of an interaction situation. They define common interaction scenarios, which turn up in many different industries. These scenarios reflect typical work situations, requiring their own support tools and methodologies. One way to classify scenarios is by the way that inputs to the tasks of the participants are related.

Handover

Handover situations are scenarios in which a person undertakes a design task and finishes it as far as possible, then passes on the design to another specialist, through a written or oral specification. The expectation is that the next person will do what is required within the specification rather

Form of communication

- ***Place***. Participants are face-to-face **<->** participants are geographically remote
- ***Time***. Communication is interactive in real time **<->** communication is asynchronous
- ***Size***. Interaction between pair **<->** interaction between many
- ***Identity***. Recipients are known (conversation, private notes) **<->** recipients are unknown (record keeping, subcontractors to be found, open audience)

Form of task

- ***Objective of task***. Generation of ideas or alternative solutions **<->** convergent problem solving ***vs*** decision making from alternatives ***vs*** acquisition or imparting of pre-existing information
- ***Division of decision-making***. Joint problem solving **<->** negotiated handover **<->** sequential problem solving
- ***Hierarchy of decisions***. Different participants' tasks are of equal importance **<->** some tasks are subordinate to others
- ***Duration***. Interactive or communicative activity is brief **<->** activity is extended.
- ***Information type***. Facts, proposals, specifications **<->** opinions or judgements or prognoses **<->** problem-solving strategy advice
- ***Time pressure***. Task is time critical **<->** task is not urgent

Subject expertise

- ***Equality of expertise***. Participants have equal levels of expertise **<->** Some participants are more knowledgeable than others (one important interaction type is apprentice consults more experienced colleague)
- ***Balance of Expertise***. Participants have shared expertise (and use the same concepts and can interpret each other's terms and representations) **<->** participants have complementary expertise
- ***Mental representations***. Participants conceptualise topic in similar terms **<->** participants conceptualise topic in different terms
- ***Familiarity***. Participants know each other **<->** participants cannot make assumptions about others' knowledge
- ***Context***. Participants share contextual information **<->** participants have different (or no) knowledge of the context

Tool expertise

- ***Competence with groupware***. Experienced frequent user (skilled at and comfortable with using the medium) **<->** novice or infrequent user of medium.

Organisation

- ***Hierarchy***. Participants at same level of hierarchy **<->** participants have different status
- ***Interest***. Participants from same company **<->** participants working for different companies
- ***Security***. All information can be shared **<->** some information must not be shared (for instance in dealings with suppliers, or with people without security clearance)

Representation of information

- ***Medium***. Speech, gestures, hand-drawn sketches, hardcopy printouts of text files or CAD models, Web pages, shared files, physical objects such as prototypes…
- ***Form of information***. Text, data plots, tables, diagrams, code, photographs…
- ***Notation***. Some fields have alternative notational conventions for the same information

9.7 Dimensions of communication scenarios

than advancing the design by changing the specification. The participants are often collocated but communication is asynchronous.

Later tasks are often seen as subordinate, so that two-way negotiations are excluded. For example, knitwear designers give their technicians specifications, without much discussion unless problems occur (Eckert, 2001). Such over-the-wall sequential design processes are still quite common in engineering, especially when designs are handed over to suppliers or contractors.

Joint designing

Joint designing refers to scenarios in which a group of people work on one problem together. Typically they work at the same time in the same room. Individuals might work on parts of the problems, but they have easy access to each other and discuss issues as they occur. Joint designing is typically done by groups of people with similar expertise, who are solving a problem that concerns all.

Over-the-wall sequential design processes are still quite common in engineering, especially when designs are handed over to suppliers or contractors.

The team members usually share a lot of background knowledge and awareness of context, and often get to know each other well. They can talk to each other spontaneously and get rapid feedback. For example, knitwear designers work out colour schemes as a group, because they all use the same scheme. In engineering, designers often work jointly during conceptual design, when even a complex problem is addressed by a small group.

Interface negotiation

In concurrent design, there are different scenarios in which people from different fields of expertise work on a design at the same time. Their tasks have mutually dependent inputs. To achieve full concurrency, they need to work with estimates of parameter values to achieve mutually consistent solutions to their individual problems. In reality, most processes give priority to some tasks and decisions, and stagger the beginning of the tasks. It is well recognised that concurrent design processes work best with collocated project teams. Communication occurs informally, through one-to-one conversations as well as in meetings.

Episodes of interaction can have a variety of purposes, even within a meeting with a different primary purpose. The types of discussion listed below can be about most of Minneman's nine classes of subject matter (Figure 9.5).

Request for information

Designers frequently find they need more information, and usually their main source is their colleagues. A pure information request is more likely to occur in design handover or concurrent situations than in joint design sessions.

Negotiation for clarity and negotiation of constraints

Participants in a discussion must make sure that they understand each others' positions – that is, achieve compatible interpretations of the situation. This often requires understanding the constraints that the others must meet in order to understand what the constraints on their own activities should be.

Thus, negotiation for clarity often leads to a negotiation over constraints. This is particularly important when designs are handed over (not necessarily in a linear process) from one specialist to another who is doing an equally important task independently.

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Idea generation

In many design processes that are essentially sequential, idea generation is undertaken as a joint activity in a meeting, because designers need each other's input before committing time and resources to any particular solution. Designers often reuse ideas from past designs or other sources; how much they refer to visual props depends on how much they need to explain ideas with reference to their sources.

Conflict resolution

Meetings are often set up to resolve conflicts between elements of a design, typically through real-time discussion. Conflict resolution situations vary according to whether there is an authority capable of arbitrating or imposing a decision on conflicting parties.

Decision making

Much design comprises an exploration of possibilities followed by a decision on which avenue to follow. Decisions need to be made about what trade-offs are necessary, and often about conflict resolution, as well as about concepts. If individuals make decisions on their own, then they have to justify them (see below). In meetings, decisions can be made jointly or by individuals higher up in the hierarchy.

Justification

Designers must often justify their solutions or decisions, either orally, in meetings, or in reports. The recipient cannot be assumed to have the same knowledge as the person who has to justify the solution. Justifications may be made to colleagues, bosses or outsiders; and the explanations must be pitched to the recipients' understanding. Specific justifications are often necessary in handover activities.

Each individual engages in most of these communication situations as part of their normal work. Designers use different channels on different occasions to convey different kinds of design information. For example, a designer might engage in joint problem solving with his boss in a face-to-face meeting involving conversation and sketches, when they are negotiating over the constraints on a particular problem. The designer then works on his own using a CAD system. When he has a question he sends an e-mail message or picks up the telephone. Later he has to return to the boss to justify in another face-to-face meeting the design that he has come up with.

Communication breakdown

Communication breakdown can have multiple causes.

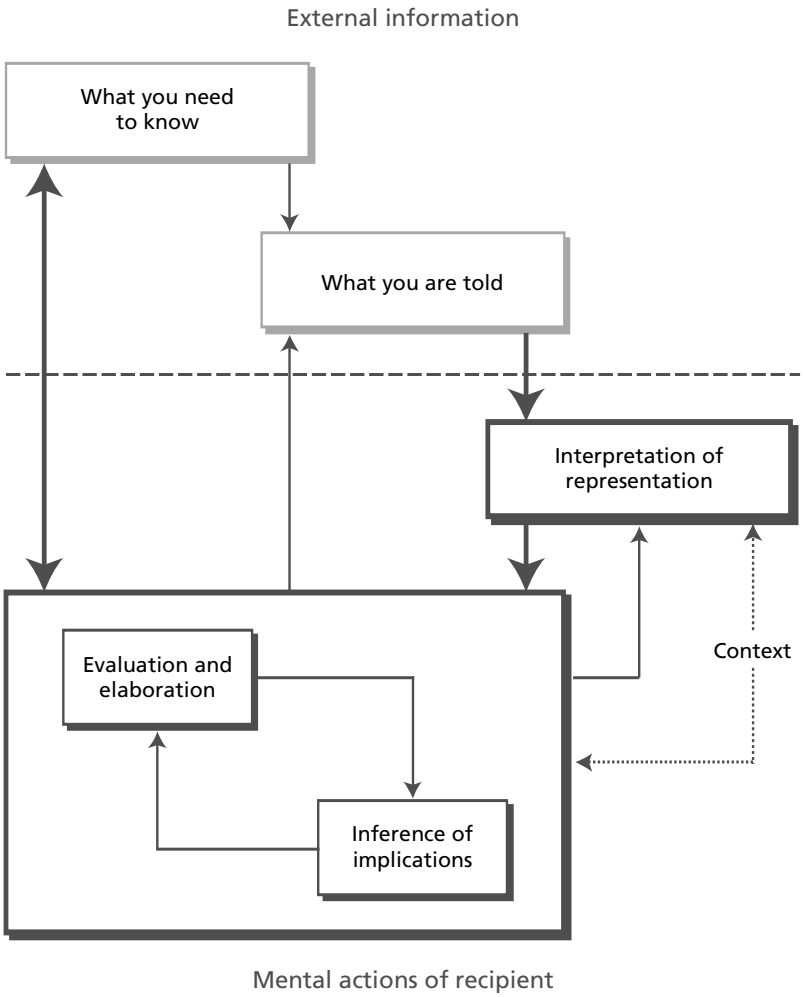
All the communication situations discussed in the previous section carry their own problems and difficulties. In many practical design situations it is difficult to identify communication problems as such or find their root causes, because they are so strongly interwoven with other process issues. Even if a communication problem is detected, companies often struggle to see where it comes from; sometimes it is the effect of factors such as management structures, at other times the problem is purely personal.

This section discusses causes for communication breakdown, which might be worth considering when a problem is encountered (Eckert and Stacey, 2001).

Constructing meaning

At the start of the chapter, a systemic view of communication was discussed in a theoretical manner. This section discusses in more practical terms the stages a designer goes through to make sense of design information. Successfully constructing an understanding of what to do in a new or changed situation, such as a modification to a design, comprises obtaining the information needed and making sense of it.

Making sense of what you see or are told has three aspects which are inseparable in practice, shown in Figure 9.8: interpreting this information



9.8 Recipient's perspective of information transmission (Eckert et al., 2001)
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from the form in which it is represented; integrating it into one's understanding of the situation by elaborating it and evaluating its quality with contextual knowledge; and inferring its implications for one's own tasks and responsibilities, and how to apply it.

This necessarily involves learned interpretation skills, background knowledge and awareness of context, which are different for each participant. A representation of design information might be incomplete, ambiguous or inconsistent, or might obscure aspects of the design. Missing information must be filled in from context, typically with conventional assumptions or

default values, which might or might not be right for the problem. If the recipient realises that the information is incomplete or inadequate, he or she will try to find the missing or correct information, either by going back to the person who has provided the information or by looking for other ways to find it.

Problems often arise simply because designers are not told what they need to know.

Causes of communication breakdown

Communication breakdown can have multiple causes. They are not independent, but they are listed separately here because their causal connection is not unique. For example, a lack of overview of the product can lead to designers not recognising that they are missing information, so that they do not follow it up. Alternatively, missing information leads to a lack of overview.

Not understanding the big picture

It is extremely difficult for an individual designer to fully understand a complex product or the process by which it is generated. Of course, complex products are decomposed as far as possible into modules with relatively simple interactions, to minimise the complexity of the design process. However, connectivity inevitably remains an important issue.

Designers and managers often have only localised knowledge of the processes they are involved with (*i.e.* processes of the teams they currently work with and processes they have worked with in the past). This lack of overview of the design process means that designers may not understand the context of the information that they are using. In particular, there is often a lack of awareness of:

- tasks that need to be done;
- information history;
- how information is applied;
- changes to processes.

Communication is profoundly influenced by what is communicated and how it is expressed.

Missing information provision

Problems often arise simply because designers are not told what they need to know. Others often do not know what information somebody else requires or do not have the time to talk to their colleagues. Designers often have:

- no feedback on information provided;
- no status information – people therefore often assume that values are exact and put great effort into meeting a seemingly exact target, even though the values could be just estimates or placeholders for other information;

- restricted viewpoint owing to power structure – contractors and suppliers are often excluded from decision-making processes, because they have no official standing in the company hierarchy;
- insufficient information due to confidentiality concerns – contractors or suppliers are often deliberately not given information that might be useful for their tasks, because it is considered confidential (Henderson, 1999).

Information distortion

In complex organisations information is often passed on via several other people before it reaches the recipient. The generator of the information may not know the ultimate recipients, or does not know the recipients' needs, tasks and background, and can thus do little to ensure accurate transmission. The following problems can occur:

- information is oversimplified or corrupted ('Chinese whispers');
- hierarchical communication paths leads to distortion and interpretation of information;
- expertise of intermediary puts a spin on the information.

Interpretation of representation

Communication is profoundly influenced by the subject of the communication act and the form chosen to express it. Any design descriptions only capture part of the object that they are describing, because of the complexity of the product and the richness of the context in which it is used and created. Any description is inevitably also selective, thus remaining ambiguous, leaving scope for interpretation. The representations that designers use to express design ideas and other information, and the representation-understanding skills they possess, have a powerful influence on design communication, because:

- interpretation of ambiguous information is based on context;
- recipients may be unable to extract the required information from the representation.

Communication is a two-way process whereby at least two parties interact with one another according to their own rules.

Managing communication

With a complex phenomenon like communication it is often impossible to fully understand what bears on it; however, in practice it is often useful to think about a situation in the following terms. It is easier to recognise that something is part of a pattern than to see the pattern itself in the first place.

Communication strategies should be clear, engaging and sustainable.

Looking for different causes of communication breakdown can help to see it in a less personal way, which might ease the tension involved in difficult communication situations.

Communication often fails because designers lack awareness of the design process, the tasks and competencies of other designers and the interfaces between them.

While it is hard to come up with universal ways to overcome a particular problem, it often sufficient to draw attention to a specific issue to work out a possible solution. The following sections give an overview of topics which need to be addressed in order to arrive at a necessary and satisfactory level of understanding in managing communication.

To recapitulate, communication is a two-way process whereby at least two cognitive systems interact with one another according to their own rules. The ultimate goal of research on design communication in academia and industry is to improve the design process. It is very difficult to direct and control communication in order to achieve intended results.

There is no definitive solution, partly because communication problems are often closely intertwined with process issues and partly because communication is a multifaceted concept. Yet, a setting can be provided to facilitate and encourage communication.

Improving internal communication

There are several techniques and devices available for improving internal communication which can be part of a communication strategy. The term communication strategy is used to denote a set of methods applied to realise short- and long-term objectives, and can be applied at several levels within the company and at several phases during the design of a product.

Management cannot dictate friendship, but it can create the necessary conditions.

A communication strategy for design does not solely refer to documentation and reporting at the end of phases in the design process, it should also encompass the points mentioned below. Communication strategies should be clear, simple, engaging and sustainable. A carefully thought-through communication strategy does not guarantee, but rather increases, the likelihood of successful communication. In this section, emphasis is put on necessary conditions for improving person-to-person contact.

General awareness

Major sources of information breakdowns have been discussed in the previous section. They need to be counteracted through positive measures. As was argued, communication often fails because designers lack awareness of the design process, the tasks and competencies of other designers and the inter-

faces between them. This understanding can be enhanced with computer tools showing product or process connectivity (Eckert and Clarkson, 2003; Flanagan *et al.*, 2003). Furthermore, it takes a certain mind set to be a good communicator. Designers must be educated to take responsibility for their general awareness of process, and also for the information needs of others.

Trusting atmosphere

Communication problems often arise from tensions between individuals or groups. While it is difficult to erase deep-rooted personal antagonisms, organisations can actively work on introducing a culture of open exchange of knowledge and ideas and can reward people actively for their willingness to communicate, both formally and informally. As Allen (1977) has shown, engineers keep abreast of their field and get a significant amount of design-related information by contacting their co-workers. He produced evidence that critical information leading to genuine innovation came from outside the immediate work group but from within the organisation.

Since proprietary information must be protected from competitors, bouncing of ideas with peers outside the company is rarely possible. Hence, management should make sure that each individual does not feel inhibited by status or other factors within the company. The design manager needs to ensure that there is an open 'no-blame' culture where team members can express their experience and knowledge freely. Management cannot dictate friendship, but it can create the necessary conditions. Social interactions serve the function of developing interpersonal understanding. The encouragement of social interactions outside the work environment is a mechanism to promote communication within the team.

Buildings and office layout can play an active role in facilitating interaction patterns, and thus communication within the work environment.

Team composition

This chapter has concentrated on the cognitive and social characteristics of communication and the root causes of communication behaviour. Some of these factors can be overcome or improved through suitable team size and team composition; indeed, overall team performance is itself quite dependent on these factors. For a detailed analysis, see e.g. Belbin (1991) and Hurley (1995). Even though the composition of a team is strongly influenced by the organisational structure and the nature of the product and the design process, product design managers should still pay attention to the way the individual team members interact and should use team communication as a factor in selecting team size and composition.

Interface management

The product architecture influences technical communication and interaction among design teams. To illustrate this, Sosa *et al.* (2003) conducted a study in an aerospace company in which they identified the impact of modular and integrative systems on design team interactions. Modular systems are those whose design interfaces with other systems are clustered among physically adjacent systems. Integrative systems are systems whose interfaces are physically distributed or functionally integrated across all or most other systems.

Many companies would benefit from a careful assessment of their communication processes.

The conclusion of the study was that team interactions between design teams that develop integrated systems are more likely to be predicted by design interfaces than are team interactions between design teams that develop modular systems. As was expected, system boundaries impose architectural knowledge barriers, which inhibit design experts' understanding of certain design interfaces. This results in some team interactions that are not predicted by design interfaces. This work highlights the importance of identifying design interfaces during the project planning stage so that corresponding design team communication is managed efficiently during project execution.

Design of office space

Buildings and office layout can play an active role in facilitating interaction patterns, and thus communication within the work environment (Allen, 1977). Penn *et al.* (1999) have found that patterns of space use and movement generated by spatial configuration have a direct impact on the frequency of contact between employees within office-based organisations. The underlying assumption of this study was that spatial patterns affect movement patterns and that movement patterns bring people past other people's workstations. Within existing buildings it is unlikely that one can change the overall structure and distribution of floors. One can, however, directly influence the layout of the office and strategically place interaction-promoting facilities, such as printers and water-coolers, so that they can be shared by several groups whose physical separation might otherwise hinder face-to-face communication. Team managers need to be alert and make the best use of the space available.

Organisational settings

Organisational settings are rarely changed solely to improve design communication and are usually beyond the control of individual design managers. However, an awareness of conflicts that might arise from the organisational settings is important in a project. For example, managers need to acknow-

ledge that designers in a matrix organisation are often required to communicate along both lines of report and in doing so may fail to satisfy both parties.

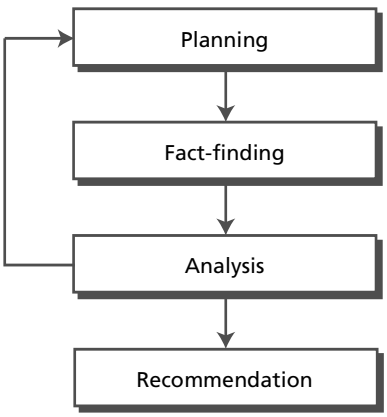
Another example is the trade-off between project and functional teams: a project-based organisation may have deficiencies in communication amongst functional groups and *vice versa*.

Communication audit

Many companies would benefit from a careful assessment of their communication processes. A communication audit will produce a clearer understanding of how communication really works and the degree to which it satisfies the needs of the organisation. From this, ideally, flow a number of possibilities, such as improved productivity, potential discovery of hidden sources of information, better context awareness, more efficient use of time, transparency of processes, connectivity of tasks and improved morale.

In addition to the analysis of communications media, patterns, flow, channels, and technologies, a communications audit examines content clarity and effectiveness; information needs of individuals, work groups, departments and divisions; non-verbal communications and corporate culture issues; and communication impacts on motivation and performance. A communication audit could range from an informal internal study to a formal process undertaken by internal or external experts. In a more or less structured form it would go through four stages (Figure 9.9):

1. At the planning and design stage, the audit's scope and goals, unit of analysis, types of communication to be audited, methods to be used and timeframe and budget are determined.
2. The fact-finding stage begins with informal exploratory research and often moves to formal, scientific methods of gathering information. The two informal, exploratory research methods used most often are in-depth interviews and focus groups. The formal, scientific measurement method used most often for primary source research is a survey. Another method would be to conduct observations.
3. The analysis and reporting stage establishes how well the communications satisfy the needs of the organisation and the stakeholder groups today and how well these communications will serve changing needs in the operational future (1–2 years).
4. Based on the findings, the recommendation stage suggests guidelines and recommendations on how to improve communication.



9.9 Stages of a communication audit

A communication audit is not always a linear and straightforward process. Iterative loops can occur between the stages, especially while analysing the acquired facts.

Conduct of a communications audit is usually performed by outside consultants because of their professional experience, expertise and objectivity. In addition, an independent third-party's guarantee of confidentiality often produces a higher level of trust from employees and other stakeholders in in-depth interviews, focus groups and surveys. This often produces more open, candid, real-world information than that which can be acquired by in-house research efforts.

Understanding specific communication situations

Technology plays a major role as an enabler of communication.

The same techniques are used in the academic community to understand how communication works as a social and cognitive process, so that tools and techniques can be developed to improve communication or aid the process it is part of. Many studies of communication involve a combination of methods. These fall essentially into three different categories (see Patton (1990) for a discussion on qualitative research and evaluation methods).

Observations

Observations allow for the study of the social basis of communication. Observers can see how groups and individuals act in their own context of work. Observations come in different guises. Ethnographic studies (Bucciarelli, 1994; Agar, 1996) try to look at cultures from outside, but at the same time try to understand the insider's view point. Action research, on the other hand, involves active participation in a process with reflection afterwards.

Experiments

Experiments allow a previously specified hypothesis to be tested. In the psychological tradition, context is made explicit and controlled as far as possible. Experiments can give insights into design cognition and those universal aspects of communication which are fairly independent of a specific context, such as the role of gestures. Design researchers often set up experiments, in which individuals or groups of designers are given a brief and recorded while they are designing, where the record is later analysed. These situations are, however, somewhat artificial, because design communication is very strongly influenced by the objects and terminology that designers have encountered during their previous working life.

Interviews

Interviews can be a short and efficient way to gain access to people's perception of communication behaviour. People are often happy to explain what goes on in an organisation, especially how and when communication breaks down. It is often difficult to get the real story from an individual's perception; however, a series of interviews can be one of the fastest and most efficient ways to find out what is going on in a company.

In addition to the suggestions made above, which focus on the human aspects of communication, technology plays a major role as an enabler of communication.

Supporting communication with technology

The generic term for many of the information and communications technologies that are used to support communications in design is computer supported cooperative work (CSCW – note that the term 'collaborative work' is also used). The term is frequently used synonymously with groupware, defined by Ellis *et al*. (1991) as "…computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment".

Figure 9.10 presents a variant of the space and time categorisation of CSCW originally presented by DeSanctis and Gallupe (1987) and refined by Johansen (1989). In design communication terms we can identify technologies that simply support the development of distributed communities

		Same time	Different but unpredictable time	Different and predictable time
		Synchronous	*Asynchronous*	
Same place		Face-to-face meetings and discussion aids	Physical bulletin and notice boards	Team meeting rooms and discussion areas
Different but predictable place	*Distributed*	Voice/video conferencing, virtual meeting rooms; shared applications	Messaging systems e.g. e-mail	Multi-user editors and collaborative writing tools
Different and unpredictable place	*Distributed*	Interactive multicast seminars	Virtual bulletin and notice boards	Workflow systems

9.10 Approaches to CSCW

and the sharing of encoded knowledge by the community, including electronic communications systems (mail systems, facsimile transfer, voice and video conferencing) and shared workspace systems (virtual meeting rooms, remote screen sharing and electronically aided intelligent whiteboards (shared applications). These are technologies that have already led to significant practical applications (e.g. Lotus Notes, 2003; Microsoft Exchange, 2003).

Mail systems, mail directories and workflow systems are now used routinely. Video conferencing is now employed in many companies, and low-cost hardware capable of transmitting highly compressed video images along telephone connections or packet-switching networks between PC computers is available. High-speed digital communication allows designers on different sites to work simultaneously on the same CAD model, and at the same time to have video and audio communication as well as the use of a shared whiteboard for drawing sketches and posting images. Research programmes demonstrated this capability in the mid 1990s (SMAC, 1995), and more recently there have been a number of programmes of shared distributed design work in academia and industry (Gomes *et al.*, 2001; Thomson *et al.*, 2001). The topic is likely to be of increasing importance as design is distributed between collaborating companies that are located throughout the world.

The design of any complex product is an inherently social process in which communication plays a vital role.

The key issue in the successful application of these CSCW technologies is the extent to which they provide a satisfactory alternative to direct, face-to-face communication, as studied for example by McGregor *et al.* (2001) and by Kunz *et al.* (1998). The emerging view appears to be that present-generation systems for handling text (e-mail, message boards) are becoming *de facto* mechanisms of working even for quite closely collocated teams. Voice and video communication is satisfactory for routine working, but for critical situations involving groups of people, and in particular where there are cultural differences, face-to-face communication is preferred.

E-mail and conferencing systems are entirely passive transmitters of information. There are, however, a number of CSCW techniques that themselves begin to incorporate encoded knowledge. Important amongst these are group activity support systems – including workflow systems that enable electronic documents to be sent on predefined routes through organisations (*i.e.* pushed), co-authoring tools for the joint writing of documents, decision-support tools to help group decision-making, and idea-generating and prioritising tools to help group creativity.

In the design context, workflow techniques are beginning to be applied in highly structured design tasks such as document sign-off (in particular associated with commercial product data management systems), and research programmes are addressing their application in less-structured parts of the design process, in particular where dynamic reconfiguration of processes is necessary (Clarkson and Hamilton, 2000).

Techniques of the World Wide Web are becoming increasingly important for the sharing of information within design organisations. Documents are routinely organised into company Intranet pages and engineering information portals. Such approaches tend, however, to require rather centralised creation and management of the content. Tools that support a more collaborative approach to content creation and management that may be more suitable for design team use include Web logs and Wikis – server software that allows users to freely create and edit Web page content and organisation using any Web browser and on the fly (Wiki, 2003).

Conclusions

The design of any complex product is an inherently social process in which communication plays a vital role. Communication is a multi-faceted phenomenon that can be characterised in many different ways. This chapter provides a characterisation and classification of communication, together with an overview of methods to improve it and to provide computational support for collaborative working. Its overall aim is to provide practitioners with a conceptual understanding of what happens in a communication process, so that they can draw their own conclusions and find a solution for problems in their context.

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