Ambiguity is a double-edged sword: similarity references in communication

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AMBIGUITY IS A DOUBLE-EDGED SWORD: SIMILARITY REFERENCES IN COMMUNICATION

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Abstract

Designers often explain new concepts and new ideas by reference to existing designs. This is parsimonious, as it only requires a pointer to the referent and a description of the modifications. Such descriptions can be extremely powerful, expressing the entire context of a design or a process in a few words. However similarity assertions are inherently ambiguous, because they depend not only on the chosen description but also on the intention behind the similarity comparison. In this paper we attempt to analyse the effect that the ambiguity of similarity references has on communication and idea generation in design. The reinterpretation of a similarity assertion can be extremely creative, where ambiguity allows for new interpretations of a problem. At the same time, it can make accurate communication extremely difficult because every assertion can be interpreted differently unless the context is fully shared.

Keywords: Creativity, cooperative design, communication, ambiguity, similarity

1 Introduction

When designers talk to each other, they frequently make reference to other designs that they have been involved in or that all are familiar with. This is entirely normal for members of a group that shares context – awareness of a range of other designs. But the same conversation can be very bewildering for novices or outsiders like design researchers. The common references and objects of discussion give the group a sense of cohesion. At the same time talking in references is a very powerful way of communicating. Instead of describing something accurately it is sufficient to refer to an object and the intended modification [1]. Moreover some concepts can only be expressed by naming examples, because the range of object or feature categories exceeds the available names, and they cannot easily be described in terms of their structures [1, 17].

For example, designers discussing a diesel engine may say “we use the same arrangement of the cylinder head assembly as on the new 4 cylinder engine for the 6 cylinder engine”. This makes perfect sense to an insider explaining exactly the layout of the cylinder head assembly, fuel injection points and so on. For an outsider this is baffling. What did they mean by new engine? How is the cylinder head assembly arranged? What does this mean for the fuel injection? What does it mean for the pistons? However on closer inspection the implication of the statement might not be clear for an insider either. The new design will clearly inherit more than just the location of the cylinder head, but which of the design decisions that follow from this are kept? Maybe the speaker meant really just where they wanted to put the cylinder head assembly, whereas the listener concluded that naturally this must mean the fuel injection system as well. At the same time the listener is reminded of the reference object and thinks

about the 4-cylinder engine. This might remind him that this engine had a very elegant solution or the location of the high pressure fuel pipes and he proceeds to think about fuel pipes, missing half the conversation about engine heads but coming closer to the solution to his problem. So communicating by reference to objects is ambiguous.

The aim of this paper is to examine the ways in which the ambiguity in similarity assertions can lead to misunderstandings in communicating by reference. Our aim is to provide part of a conceptual toolkit for understanding design communication in a wide variety of situations as well as a wide variety of industries. This paper concentrates on the similarity references made in conversations between expert designers – between the people who share knowledge and understanding of the objects they refer to. Novices and outsiders apply the same cognitive processes to different knowledge, to interpret similarity references differently. The argument presented in the paper is based on our observations of design interactions and design meetings in several large engineering companies, where we studied change, planning and communication behaviour in complex organisations [2]. In a separate study [3, 5] we have looked at the nature of ambiguity and its effects on asynchronous communication through writing and sketching. In some situations ambiguity can have a very detrimental effect. We have observed ambiguous descriptions of designs having very harmful effects in the knitwear industry, which we have studied in great detail [4, 9]. The structure of similarity, its description, and implications for complexity in design are subject of ongoing research [6, 7, 8].

2 Design Discussions

In the complex engineering products, such as diesel engines, we have studied, the generation of solution concepts or details is often a solitary activity interspersed with meetings. Somebody defines a problem, it is discussed in a meeting, everybody goes away and thinks about it, and discussions are held as required. Then at a subsequent project meeting each designer presents one or more solutions to the problem allocated to them. Meetings are important for evaluating and making decisions about relatively well-developed proposals [12]. This is quite different to the relatively uncommon design situations that are frequently analysed by researchers [10, 11], where a group of designers is given a design task and kept together until the problem is solved or the time is up.

Some of the meetings we have observed were convened as change meetings, where a creative solution to a problem needed to be found quickly before an emergent change could upset the design schedule [2]. In these meetings designers reported on their progress and brought open issues to the discussion, that were sometimes resolved in the meeting or actioned for following meetings. The meetings fulfilled several functions at once: (a) inform other participants of the progress of the design and alert them to future issues; (b) negotiate the key parameters of the system and agree interfaces between different components; (c) specify tasks for other people; and (d) jointly design solutions for specific problems. Meetings slip fluidly between these different functions. When designers are specifying or negotiating for a mutually acceptable design decision, their utterances have quite different intentions to those they make when jointly developing design ideas. They are saying “my situation is X, what is yours?” or “I want X, make sure you have it ready by Monday” or “I need 4mm clearance, you only leave me 2mm. What shall we do?” In these situations they want to be understood clearly and express themselves unambiguously. While there will always be an element of negotiating for a shared understanding, with room for discussions arising from ambiguity, as Bucciarelli points out [12], ambiguity is not desired.

Communication is rather different when designers are developing designs together, especially for early conceptual design, where design ideas are typically vague, provisional, imprecise and incomplete. Such situations have been extensively studied from a variety of perspectives, primarily through experiments [see for instance 11]. In conversations for joint designing, sketches, gestures and words are used in combination to explicate and disambiguate each other [13, 14, 15, 16]. The participants in joint designing usually get rapid feedback on whether they have been understood (though clarification is a major activity within meetings). So they can interactively negotiate an understanding of each other's positions, as well as negotiate about decisions, before the (provisional or imprecise) decisions are represented in precise-seeming forms [10]. Designers use rhetorical techniques for argumentation, including subtleties of phrasing and tone, to modulate the degree of belief they express in ideas, and signal willingness to make trade-offs, as well as to express exactitude [10, 16]. However there is no guarantee that all the participants will always pick up these signals. Some people use them badly or in idiosyncratic ways. We have observed participants disagreeing about the purposes of meetings, and listeners being mistaken about the function of an utterance as intended by the speaker. In consequence they do not recognise information that they are given as uncertain or provisional. The opposite possibility is that they might interpret a specification wildly.

3 The Structure of Similarity

There are two problems in interpreting communications by reference, first determining the respects in which the new design suggestion is meant to be similar to the referent, and second determining *how* similar.

3.1 Understanding similarity statements

Psychological research has long been concerned with the roles of similarity and analogy in reasoning. The mechanisms involved in interpreting similarity statements and analogies remain an active topic of research. While similarity can be described in terms of the number of features shared between two items [18], similarity judgements depend crucially on which features are most salient when the comparisons are made [19]. What features people attend to, and how similar they judge two things to be, is influenced by the context – importantly what category both items are indicated to belong to, and what other contrasting items are also present for comparison. Similarity statements are interpreted to be informative [18]. There is evidence that the features of the items compared are aligned, and attention is directed to the features each shares with only some members of the category [19]. Comparisons like "a robin is like a question", where there are no category-universal features to provide a ground for identifying relevant features, seem peculiar. These features include not only simple or perceptible attributes, but also structural relationships between elements of the items, so that the recognition of shared patterns of relationships which drives analogical reasoning [20] is also important in the perception of similarity [21]. But even directly perceived features are learned from deep understanding of structure and function – for instance what a diesel engine expert *sees* when looking at a cylinder head assembly is very different from a non-engineer – and mental representations of objects include behavioural characteristics as well as structure.

For example a conceptual designer of diesel engines understands the trade-offs between heat and noise through the fan. The nature of this trade-off remains independent of the type of engine. Communication through metaphor and analogies depends on identifying correspondences between these abstract relational features when more concrete attributes are dissimilar. In design, inspiration is the unprompted recognition of such correspondences to the

needs of a current problem – though in some industries designers actively search for inspirations, looking for relatively concrete similarities across object categories[17].

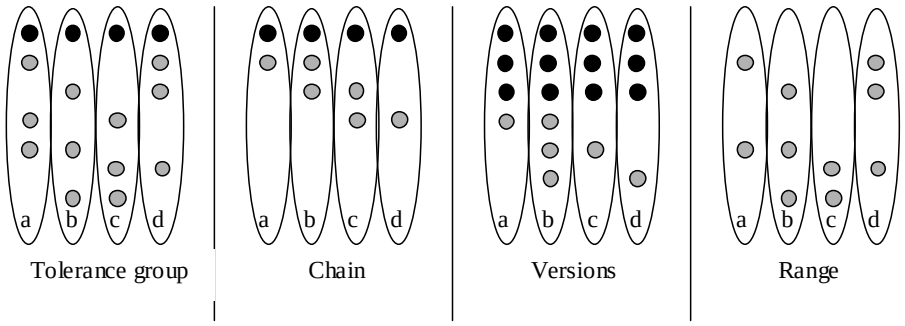

Figure 1 Different types of Similarity Groups

3.2 Types of similarity relationship

How similarity assertions are interpreted depends on how target and referent are classified into one category, so that the attributes shared by all category members serve to identify the significant attributes shared by only some category members. But the relationship between items and category can vary, influencing interpretation. It is possible to identify several distinct formal types of similarity relationship that designs can have to each other, linking them into subcategories of similar designs [7, 8]. Figure 1 shows some of these patterns. The black spots indicate common features among all designs in a population and are disregarded in a similarity analysis. The grey spots show the features shared by pairs of designs – the features that are the focus of attention in interpreting similarity assertions. Typical patterns of similarity based on shared features are:

- • *Tolerance classes* are groups of elements where each pair shares at least one common feature [23, 24, 25].
- • *Chains* are groups where each pair of elements is connected by a sequence of elements such that neighbouring elements share at least one feature. A chain is a weaker similarity grouping than a tolerance class. In chains perceived similarity may not be based on directly shared features. Thus removing an intermediate link can alter perceptions of similarity, or make a reference unintelligible. Chains are significant when designs are linked historically through a sequence of intermediate developments. Knowing this may influence the features one thinks are relevant to the similarity assertion; not knowing this may make a reference unintelligible, or lead to it being taken to indicate closer similarity than is intended. The recognition of pertinent features can also be influenced by recollection of a chain of comparisons in previous discussions, which other people might have missed.
- • *Versions* of the same product, or a family of closely related products, share many common features, while each one has additional features which do not necessarily have any specific relationship to each other.
- • *Ranges* – such as the ranges of complementary products produced by clothing manufacturers – span a variety of basic categories and so do not share any common basic attributes beyond being objects. What ties them into a common category is more abstract relational features such as having complementary functions within some larger scheme. Usually every design is linked to others in the range through several shared features, giving the range its coherence.

3.3 Instances, categories, and spaces for interpretation

Perceived similarity relationships can change as the context for comparison changes [18]. In particular perceptions can shift of how different a design is from what is typical for its category, when new members are added to the category (Figure 2). Our interests include situations where designers' mental representations of the spaces of possible designs are formed by remembering many different designs, recognising similarities, and creating category concepts [17]. The relationship between mental representations of instances and categories is difficult to unpick, but there is evidence that instances are represented at least partly in terms of how they vary from category-typical; deviations that are recognised as significant are remembered and can be exaggerated, while other deviations are ironed out [17, 26]. Smaller categories might be represented extensionally as aggregates of all their elements; so if a new element is added then it is included in the list of the elements (Figure 2(A). But for larger categories, representations of what is typical are primary (Figure 2(B)). A new element may influence this; however the representation of category-typical is not merely the average of all instances. For example when people are asked to draw a car, they often draw old-fashioned saloons. In some cases the representation of category-typical may be a particularly important or memorable canonical example – this may be unrepresentative of the range of instances within the category (Figure 2(C)). When similarity to reference point statements are interpreted, the features that are compared are their deviations from category-typical. This can give a skewed or asymmetric character to the similarity relationships between pairs of non-canonical designs.

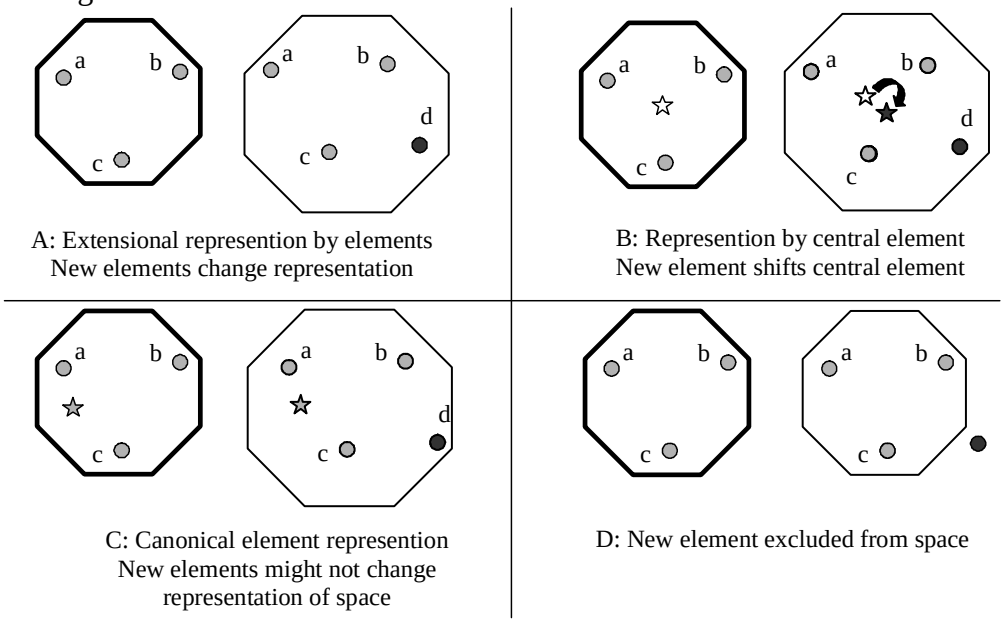

Figure 2 New elements in Similarity Spaces

When a reference is made to a unique design within a very general class, or one of a set of equally well-known designs, then the differences between the referent and what is general for the category gives some indication of how close to the referent the new design is intended to be – though there is plenty of scope for ambiguity. But the scope of references to canonical elements can be unclear: is the comparison exact, or is the referent a placeholder for a broader class, in which case the intended space of possibilities for the new design is wider. In design conversations this can be extremely confusing for the recipient, who does not know the extent of the space or the role of the representative object; if the canonical element is not recognised as such, the specification by reference might be interpreted too narrowly. Conversely, how far does a reference to a category include what is typical rather than just what is common to all

members. Total misunderstanding arises when one person includes an object into a space and others exclude it.

4 The Nature of Ambiguity

Ambiguity is created by the availability of alternative referents for words, symbols, and symbolic or deictic gestures [15]. What referents are available depends on the originator's understanding of languages and notational conventions, and their expectations of the recipient, as well as of the design situation [27]. But the role of prior context in design communication goes beyond the need for the recipient to recognise the graphic codes used in sketches and diagrams, and ascribe the intended referents to words and symbols. Representations of designs are abstractions in which aspects of the design are not fully specified. Understanding how much of what is *not* described is fixed, and what can be varied, is as essential as understanding the explicit content of a representation [3]. This applies even more so to verbal references to other designs, which are barely specified at all.

Research on ambiguity in design communication has largely concentrated on sketches. Understanding the ambiguity of sketches is relevant not only for their parallels to similarity references, but also because sketches are often used in conjunction with verbal references in an attempt to disambiguate each other. As is well known, people don't mean exactly what they draw. Roughness in sketches expresses lack of certainty, but the viewers often cannot distinguish between intended imprecision and poor drawing, or between a qualitative placeholder and a relatively exact depiction, or between a simple form drawn roughly and a more subtle form drawn more accurately [3, 28]. One sketch or drawing often stands for a whole space of possible designs, but the viewer and the creator cannot know whether they interpret this space in the same way. Idiosyncrasies and poor drawing in sketches and diagrams bias interpretation by others towards different central meanings, as well as towards different judgements of imprecision and provisionality.

This is also well recognised in engineering companies. The head of new product development at a large UK engineering company has completely excluded sketches from communications with external people, because he is concerned about them forming wrong expectations from their interpretations of sketches. Instead of sketches they use CAD drawings for early external communication, where they draw the newly designed features and use parts of the old design partially stripped of detail as placeholders for their other newly designed parts.

Some earlier discussions of imprecision, uncertainty and ambiguity in design communication [10, 16] lump all these together under 'ambiguity'. This is confusing, and promotes the currently influential view that ambiguity (more narrowly defined as the availability of more than one qualitatively distinct interpretation) is beneficial in design communication, and that aiming to use computer tools to create unambiguous descriptions of designs is a discredited enterprise; this we doubt [3]. However Minneman [10] argues that designers sometimes do exploit ambiguity. Nonetheless joint designing is very different from communication between activities; handing over ambiguous representations can cause severe problems [24, 4]. The view that ambiguity is beneficial in design communication is related to two doctrines. The first is that ambiguity facilitates creativity by enabling reinterpretation. Schön [29] views this as interacting with the sketches as in a conversation: the designers see more in their sketches than they put in when they draw them, and these insights drive further designing. The extensive body of research on how architects and other designers use sketches, has focused on how designers reinterpret elements of their sketches [30]. The other influential doctrine is that design is inherently social. One important contribution of sociologically oriented studies of

design practice [10, 12, 27] is highlighting the role of ambiguity in providing negotiating space, which allows individual and group creativity to flourish. Henderson [27] puts it as: "Ambiguous communications provide an opportunity for designers to project and reflect – breathing room from rational concerns. Designers project a story onto suggestive fragments to make a whole, creating the shared understanding". But the effect of ambiguous communication is rarely so clear cut in design – it can be very harmful [3]. It depends on the function of the design communication (see section 2) and the stage of the design process at which the ambiguous communication takes place.

5 The Ambiguity of Similarity References

Communicating by reference to other designs is a double edged sword. It is very quick, but the references can be harder to understand than people realise, and can bias creative thinking. But sometimes their imprecision and ambiguity can give designers space for flexibility. The spaces of possible new designs afforded by references to other designs have a similar structure to those of afforded by sketches. Usually "like" doesn't mean "exactly like", so some flexibility is allowed in mapping the old design into the new situation – some aspects will usually have to be different to meet the constraints of the current problem, and others will be free to vary to meet other needs. So how like is like? Similarity references are inherently ambiguous. What aspects of the referred to or sketched design are significant? How precisely are these aspects specified? Are some aspects intended as accurate detail while others are rough indicators? How committed is the speaker to the proposal? Some aspects of similarity utterances make them harder to interpret than sketches or written documentation. Like all utterances they are quick and fleeting. A quick reference in a sentence can carry a huge amount of information including the reference point, the modification to it, and the history of change that they referenced design has gone through. With a sketch we have time to reflect about its uncertain nature and pick up the degree of uncertainty from the way it is drawn – people often confuse polished drawings with final design decisions. While verbal cues can signal imprecision or provisionality in analogous ways, uncertainty in a speaker's expression can be uncertainty about what they want to say, rather than an indication of the looseness with which it should be interpreted. When designers create and look at sketches, they are aware that they are looking at an incomplete representation; but when they specify elements of designs or outline negotiation positions though verbal references to other designs, they can be unaware that they are actively constructing interpretations based on background knowledge and assumptions that the other parties might not fully share. The need to query assumptions and ask for clarification can be less obvious.

Another fundamental source of ambiguity is abstraction. Any form of abstract description, whether it is verbal, written or pictorial affords many more interpretations at a low level of detail. When somebody says the engines needs a fuel pump as an abstract statement, then this says very little about the fuel pump, what make, what size etc. The details are often filled in by he listener from experience. A fuel pump might imply a certain make because it always does, or it could be the one used last time, but it could also be a logical placeholder for a certain functionality. Again this is often not clear to the listener, who might then fill in some details but not others according to their own experience.

Similarity references can play a significant part in the generation of new ideas, because they allow a very fast exchange of imprecise or skeletal ideas. With the rich context of a similarity reference, people can very quickly pick up on a different feature of a design that they like. The influence of similarity references on creativity go deeper. Designers often get fixated on a certain type of solution and find it difficult to think of radically different solutions [31].

Designers encouraged to consider a source of inspiration for one aspect of the design can find it difficult to avoid thinking about it for another aspect of the design for which it is unhelpful. A reference to another design can help them to reframe the problem and think of a different type of solution. However problems can only be reframed this way within the range of existing designs. More radical solution either have to be introduced by analogy to other types of products, or derived from theoretical analysis. This is a potential problem in mature products, such as diesel engines, where there is little scope for improvement within established problem-solving approaches. The efficiency of similarity references depends a lot on how well the people know each other and how completely they share the concepts, techniques and examples with which they think about design – their object worlds [12]. On the other hand the more the members of a team share, the more they suffer from collective fixation. They are locked in their jointly created solution space and need outsiders to break it for them. Whether this is positive or negative overall depends on the nature of the product. We have observed very efficiently working knitwear design teams, who needed to bring in students or freelance designers to get new ideas; as well as engineering teams where designers communicate effortlessly and quickly through shared object references.

6 Applications

The general results in the body of this paper are the outcome of many individual observations in a variety of design contexts. These range from fashion to complex electromechanical engineering. The analysis of ambiguity and similarity in the design processes of these industries indicates some strengths and weaknesses of these processes as well as how they might be improved.

The fashion industry demonstrates a strong reliance on similarity, whether creating garments in a fashionable style or drawing on inspiration from non-design sources such as natural phenomena or design sources from different domains. This was observed in detail for the knitwear industry. Although similarity is used extensively, communication especially in the knitwear industry between designers and technicians (who realise prototype designs) is fraught with difficulties because of extensive ambiguity. The analysis based on the general results above indicates why communication between disparate teams of technicians and designers and even among collaborating designers is prone to break down. In some cases this failure is because several parties do not share common interpretations for similar objects – similarity is used inappropriately. Other cases of failure in communication come from problems in actually realising the similarity. Then alternative interpretations or rough approximations are created, many of which are far away from initial intentions. The key conclusions in this industry example are that (a) similarity (and ambiguity) is essential for inspiration; (b) ambiguity (and similarity) should be managed carefully if the whole design process is to deliver design intention to product.

Another case from a highly contrasting domain confirms the usefulness of the analysis of similarity. This is the design of diesel engines, a largely mature product. Product development is driven by regulatory requirements. The analysis applies to groups of design specialists in particular features and functions of the product. These specialists are both inside the immediate company, in other divisions of the same company or in suppliers. Similarity of descriptions is widely used both at the broad conceptual level and for functional parts. Similarity to existing and previous company designs as well as with competitors' engines is central to success of new designs in the market. Inspiration may be aided by ambiguity. However, ambiguity is generally avoided. In communication with third parties and suppliers only CAD representations are used in our collaborating company. Similarity although vital to

these designers is used in a tightly controlled and analytical way. Competitive advantage is gained by small customer oriented changes rather than new styles and major revamps of the product range as takes place in fashion.

In both examples the double edged sword is clear. Similarity is an effective mode of communication among designers but associated ambiguity needs to be managed closely. This is especially true when communicating parties operate at different stages of design (eg knitwear designers and technicians) or when designers work in different contexts (eg designers and suppliers). The analysis of the paper shows why communication interfaces, say between product designers and part suppliers, or between knitwear designers and technicians, are sensitive to misinterpretation through ambiguity whilst interfaces within a shared context can exploit similarities and common meanings.

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