

Schemata, Gambits and Precedent: Some Factors in Design Expertise

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The paper begins by outlining some methodological problems, concluding that to understand design expertise we will need to recognise that such practice includes the roles of teams, communication and shared experiences and understandings. It explores the significance of experience in expertise focussing on the way precedent stored in the form of episodic schemata is used by experts to recognise design situations for which gambits are available. The paper combines evidence from new empirical data on the perception of drawings with interviews with expert designers and research on expertise from other cognitive fields. The paper concludes that design expertise cannot be understood by studying actions alone but that our research needs to concentrate on perception and recognition and that we will have to examine conversations and memories as much as drawings.

Much of our empirical research in design not only ignores expertise but has actually been carried out on students. Even Schön in his now seminal papers dwelt extensively on the comments made by students including the famous characters Harold (Schön 1984) and Petra (Schön and Wiggins 1992). Schön does however suggest that Petra's tutor Quist 'can work simultaneously in many domains', thus suggesting that experienced processes may differ from inexperienced ones.

Design seems to be an activity that requires a certain level of maturity to be practiced well. To qualify professionally in architecture throughout the EU now takes about 8 years on average. Most product designers will have studied for 4 years and many for 5 or 6 if they have done a master's. For a designer to be known individually by name in these two fields before the age of 40 is exceptional. By contrast mathematicians and scientists in research universities are expected to have made their major contribution well before this age. Many good musical performers and virtually all successful sportspeople are likely to be similarly youthful when achieving their reputations. This already hints at one characteristic of design expertise. It is to a significant extent dependent on gathering experience.

1. Some methodological issues

Experienced designers are frequently working in practices, groups or teams. Again relatively little of our research has so far focussed on this. The fascinating Delft workshop of 1994 did at least use protocols from design teams as well as individuals (Cross, Christiaans et al. 1996). The

interesting work of Rianne Valkenburg on how design teams work has explored the Schönian view of design in a team context with some significant results (Valkenburg 2000). However neither the Delft workshop nor Valkenburg used designers who were experienced in working together. Nor did they study them in real-world and real-time conditions.

For all the reasons above I am going to rely on a variety of data including interviews with outstanding designers and studies that compare novices at least with those further along the path of learning to design. I shall also explore a little of the data from studies of expertise in fields other than design but which share some of its cognitive characteristics. I am also going to argue that to get good data on this we need to study not just the actions, graphical outputs and finished designs of these designers but also the conversations they have with each other and their clients during their normal working practice. From this some common patterns emerge that we can at least use to map out the territory for further research.

2. Design conversations

Some time ago we started to explore design processes by trying to write computer programs that would conduct conversations that other designers would consider useful (Lawson and Loke 1997). This led us to understand the importance of narrative and memory in design thinking. Coming from a linguistic background Medway and Andrews have studied a real recorded conversation in an architect's office between three partners of the practice who are obviously highly experienced designers (Medway and Andrews 1992). Medway and Andrews note that the 'base mode of the conversation is narrative'. That is to say that although from time to time the conversational mode changes temporarily, it begins in and generally returns to a style similar to that of telling a story. This chimes with the Schönian view of design as a conversation in which characters are introduced, or 'named' and the story set up, or 'framed' around their characteristics.

Secondly this analysis shows that there is frequent reference to documents throughout the conversation. This is hardly astonishing in itself but what is of particular interest to these researchers is the way in which the designers treat drawn and written documents and 'regard them as equivalent'. This clearly surprises those steeped in linguistic research.

That architecture is such a textual business is not what we expected to emerge from our close analysis of the transcripts.

This research above all else shows that design conversations are extraordinarily compact since they are full of references which in turn point to huge chunks of information. It also draws our attention to the importance of words as well as pictures if we wish to understand the way knowledge is handled in the design process. If we listen to conversations within experienced teams of designers it is quickly evident that they have

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many common expectations and use a shared language. I am going to use some data here from a study I did of the architect Richard MacCormac (Lawson 1994). This senior and distinguished British architect is widely regarded as an outstanding designer, he is recently knighted, an ex-president of the RIBA and his clients include the BBC, London Transport, Cable and Wireless and several UK Universities.

In describing his own role in the practice MacCormac described an interesting variation in process that is particularly revealing about our exploration of experience.

I think that my role in the practice is to initiate the design processes in all the major jobs, not so much in building types like housing where I think we have established a kind of repertoire, a typological repertoire, which is to do with density and to do with the main problems like car parking and so on which are... it's sort of vernacular if you like, we do quite a lot of it for housing associations and so on..... vernacular in the sense that its a language that's the common language.

Clearly Richard is telling us here that he changes the process depending on the level of experience the practice has with the problem in hand. He is also telling us that this relates to the way the practice relies upon its known sub-solutions to the generic typological problem. In such cases he feels then that the job architects can be left to work without his personal intervention at the early conceptual stage. This proves to be a significant point as the argument unfolds.

3. Schemata

I spent some time in MacCormac's design office and in the space of one day I heard three members of the practice use the word 'belvedere'. Of course this is a perfectly acceptable architectural term but hardly common parlance even in a contemporary practice. This suggested that this word represented a complex set of ideas that were common ground within the practice. During an interview with MacCormac himself, he described the process leading to his design for the chapel at Fitzwilliam College Cambridge.

...at some stage the thing (the worship space) became sort of round but I can't remember how....early on we were playing with round shapes in square containers, you know the sort of thing...

Here Richard was obviously expecting that I would understand from this reference a whole series of architectural ideas, and that I would recognise the architectural game being played. I remember him looking at my eyes to see if this was the case. He must have inferred that it was or I guess the conversation would have halted or proceeded differently.

Listening to conversation in such practices reveals just how extraordinarily efficient communication becomes since enormously complex and sophisticated sets of ideas can be referred to using simple diagrams, catchphrases (for example 'round shapes in square containers') or even single words (for example 'belvedere'). Such a phenomenon is hardly new to us. It is precisely that of concept formation or the development of schemata. For experienced architects the concept or schema of 'round shapes in square containers' includes not just the simple idea of that geometry but the whole game of contrasting the curved and straight lines, and all the examples and variations have been developed by other architects. For MacCormac's practice members, the schema of 'belvedere' was not restricted to the commonly shared idea of a viewing tower. For them it was not a matter of a building typology at all but rather a whole series of devices for organising space vertically in order to afford dramatic views that helped building users to build mental maps of their surroundings. They collectively delight in these ideas and have studied them and exploited them in previous designs.

But how do expert designers actually come to use these schemata in the process of designing? In particular how do they know when an individual schema may be useful or not?

4. Recognising

These questions turn out to be more about perceiving than acting. To answer them I want to turn to some other data from my conversations with expert designers and to string together two other pieces of evidence. The first of these is the number of times that expert designers have described their drawing process as relying on surprisingly small drawings. Santiago Calatrava uses mainly A5 sketchbooks to draw in and A3 pads to paint on. Herman Hertzberger uses A3 pads to design on and communicate with his design team. Eva Jiricna draws on A4, and Ian Ritchie on A4 or A3. Michael Wilford talking of his practice with James Stirling said (Lawson 1994):-

I like to see things encapsulated in one small image. We have a rule never to draw at a size larger than necessary to convey the information intended...we always use the smallest possible image.

In the work of Stirling and Wilford I have examined this usually turned out to be A4. So what is the significance of all this? If we take the A4 drawing and hold it at arms length as if drawing on it, then the whole of the image remains within the foveal area of the retina. This means that the whole drawing is in view and in clear focus without moving the head. Herman Hertzberger gave a clue to the importance of this for him when he said (Lawson 1994):

It's a sort of imperative for me, you know. I insist upon having my concentration on quite a small area, like a chess player. I could not imagine playing chess in an open place with big chequers.

Within a hundred metres from Hertzberger's office in Amsterdam there exists such an outdoor chess board marked out by the paving in a square which might have been in his mind when making this remark. The reference to the chess board is interesting for two reasons here. Firstly surely he is right about the playing chess. Anyone who has tried this knows that it is frighteningly easy to 'lose sight' as it were of one of your own or an opponents pieces. In my experience the opposing Rook lurking on the flank more easily goes unnoticed in such a situation when the focus of attention may be on the area around the King. The second reason is that this links with the work of the psychologist De Groot, who studied not expert designers but expert chess players (De Groot 1965).

De Groot's work showed that a key distinguishing factor between the chess master and the less expert player was as much in perception as in action. Chess masters, he found, rarely analysed a board situation, rather they *recognised* it. He showed that chess masters could remember mid-game board situations much more reliably than novices. However their comparative expertise vanished when asked to remember randomly positioned pieces that did not relate to game situations. Taken together these results suggest something we are familiar with in design, the use of known precedents that have been studied and about which the expert has schemata. These precedents linked problem to solution and such chess masters could articulate this link. Thus the schema for the situation also includes one or more known gambits for solving it.

5. Gambits

This then enables chess masters to play demonstration matches where they take on many amateur players simultaneously moving from board to board. Relying upon analysis this would take too long, but using recognition they are able to use a standard gambit and pass on to the next game. There is a further interesting analogy for us here. Chess masters can easily defeat amateurs in such a way. However to beat another chess master who is also recognising and similarly has a vast pool of precedent and gambits to rely on, they need to create something new, original and surprising. This sounds remarkably like what we also expect from expert designers. We expect them not just to solve problems well but to surprise us and add something new to the pool of precedent other designers rely upon.

During interviews Richard MacCormac described his practice as 'having a repertoire of tricks'. These can be seen as design gambits or possible ways of solving recognisable problems. Here it seems important to distinguish between two sets of ideas that come into play frequently when interviewing experienced and expert designers. I have already proposed the notion of 'guiding principles', which are commonly expressed and identifiable in the work of expert designers (Lawson 1990). Such principles are really sets of values and priorities which on the one hand guide each project, and on the other hand are informed and refined by projects. In a study of several leading architects we found quite distinctive

sets of guiding principles (Lawson 1994). Ken Yeang is concerned to produce sustainable tropical architecture particularly of the high rise urban variety. Eva Jiricna is concerned to develop languages of materiality in her often high-tech interiors. Herman Hertzberger is by contrast rather less interested in materials and more concerned with how people possess and use space. In Richard MacCormac's case the clear guiding principles are ones of light and geometry. He often cites the work of John Soane and in particular the magnificent use of light in his work. Also Richard studied at the Martin Centre in Cambridge with Leslie Martin himself and Lionel March and was heavily influenced by the studies they did along with Phil Steadman of geometry in the environment (March and Steadman 1974).

We look for a clear geometric analogy for the content of the problem.

So for these expert designers then the guiding principles are well established and well developed. MacCormac is clearly telling us that they are sources for what my ex-research student Jane Darke neatly and memorably described as 'primary generators'. (Darke 1978) Further examination then reveals that MacCormac has many geometric precedents that he relies on. These 'tricks' or gambits are actually patterns known to have certain properties and to offer certain capabilities. These are applied as appropriate.

All of our schemes have a geometric basis whether it is the pinwheel arrangement of...the courtyard....the tartan grid....or the circle based geometry of....

Studying the design work then reveals quite openly the precedents that have inspired these designs. Some are recent buildings, and some are historical buildings. Some may be from other objects such the clinker built hulls of boats and so on. I largely agree with Gabi Goldschmidt when she calls for such precedents to be better described as references (Goldschmidt 1998). She is quite right in her argument and in pointing out that unlike the use of precedent in a legal argument there is no attempt here to demonstrate a close parallel with the original, but rather to use it as a point of departure. However I persist in using the term precedent because that is what most designers would call it. MacCormac explicitly refers to his process when on familiar typological territory as being based on the assembly of known 'tried and tested precedents'. In fact he goes so far as to use the word 'vernacular' when describing this process, and he clearly does not mean nor does he produce a vernacular style of architecture.

Vernacular in the sense that each time you come to the problem you already have large elements of the solution. It's vernacular in the sense of process rather than product....

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This then takes us from conversations to drawings, or at least to conversations about drawings. What happens when we compare the way expert or experienced designers look at design drawings with the way novice designers do? Alexandre Menezes has been studying this in the laboratory. Sadly we have so far been unable to persuade world expert designers to take part in these experiments and Alex has had to make do with comparing first year with sixth year students of architecture! This work will be published more extensively elsewhere in due course so the methodology will not be described in detail here. Suffice it say that the experiments ask designers to describe a drawing to another person who cannot see the drawing but must reproduce it from the verbal description. Some of the drawings are sketches done during design by expert designers (Mies van de Rohe) and in some cases they are pure art (Paul Klee). We based our protocol recording and analysis techniques on ideas first suggested by others for recording actual design protocols (Suwa, Purcell et al. 1998). These description protocols are amenable to similar sub-division into chunks or sequences that develop a description by what Goel referred to as lateral and vertical transformation (Goel 1995). That is to say a particular part or relationship of parts in the drawing is described in a variety of ways each related to the previous one (lateral), before a deliberate change to a different aspect of the drawing (vertical). This mirrors results of previous studies of what designers perceive in their design sketches (Suwa and Twersky 1997).

The more experienced designers described both art sketch and design drawing in a shorter time than the novices. They also described the design drawing more quickly than the art sketch and characterised it as 'easier' to describe. The novices on the other hand thought the art sketch was easier to describe. Preliminary detailed analysis shows that the more experienced design students tend to use symbolic references to design precedent whereas the novices use formal geometric descriptions more. It seems that symbolic descriptions such as 'it looks like a squashed sun' are more economic in time than formal geometric descriptions such as 'it is a long flat ellipse with some lines growing radially from it all round and extending out about as far as the vertical diameter'. Although the art sketch was capable of symbolic descriptions, these are entirely metaphorical. Clearly the experienced designers recognise precedents more readily in their home context. Put simply, designers are recognising architectural or design ideas for which they have schemata to which are attached symbolic descriptions. Provided the recipient of the information knows these schemata the symbolic descriptions are very compact compared with the formal or geometrical characteristics. To see how this works imagine saying 'tartan grid' compared with trying to describe such a formation through geometrical formal language. There is plenty of evidence from the psychology of perception for this tendency to prefer to use symbolic rather than formal material when storing information in long term memory. Such an idea dates back at least as far as Bartlett's famous experiment in which he asked subjects to recall a formalised Egyptian drawing of a local ornithological species, the Mulak. Subsequent

subjects were shown the previous subject's remembered drawing and so on. Bartlett ran the experiment for many sequences in England and on each occasion ended up with a drawing of a black cat hardly resembling the geometry of the original drawing but adequately and reliably communicating the feline schema.

It is now many years since we showed another difference between these two groups of subjects, who were just starting and just finishing their full-time architectural education (Lawson 1979). These earlier findings showed that the sixth year architectural students adopted a strongly solution-focussed strategy which was not detectable in the first year group. That research also showed that by comparison post-graduate science students showed a strongly problem-focussed strategy when completing similar design-like tasks. Taken together with this new finding it does indeed suggest very strongly that the educational period has developed a knowledge and understanding of design solutions, or what designers would normally call 'precedent'.

Alexandre Menezes' data also shows that designers who know they are describing to other designers seem to make much greater use of this domain specific knowledge of precedent showing very considerable reductions in description times. This last point suggests that designers are tacitly aware of this knowledge and the greater likelihood of being able to share it with another designer. Returning to the interview with Richard MacCormac we find similar evidence of this. This tends to confirm our view here that the more experienced a designer the more likely it is that perception of drawings will be by recognition of schemata that conceptually organise precedent.

6. Episodic and procedural memory

I have argued elsewhere that design knowledge and a 'designerly way of knowing', to use Nigel Cross's delightful phrase (Cross 1982) are heavily dependant on experiential rather than theoretic memory (Lawson 2001). To be more correct I should call these 'episodic' and 'semantic' since they are the terms more normally used in cognitive psychology (Tulving 1983). Whatever we call them the distinction is an important one here. We remember many events in our lives. We do not work hard to remember them; indeed we probably put no conscious effort at all into the process of storing this knowledge. We may however struggle to recall it sometimes. However once recalled it is quite likely that we recognise its correctness or otherwise. A way of demonstrating the distinction is to try to recall your own earliest experiential memory. You will find it hard to know what it was but you can be fairly sure that you have little recall from early childhood. However you were learning theoretical knowledge such as language and remembering it quite clearly even before your earliest experiential memory. Similarly people can suffer extreme forms of amnesia so that they are quite unable to recall periods of their life. However they may still remember and be able to use language and in many cases sophisticated professional theoretical knowledge.

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By contrast to this 'experiential' memory, you will also probably have had to study for some examinations. You will have been required to remember theories and related ideas perhaps even formulae and procedures. You may have found all this very difficult to remember and had to work very hard to store the knowledge. Your struggle was quite likely to have been an attempt to make this knowledge semantic and meaningful so that it could be stored in long-term theoretical memory. Here detail is vital and accuracy of recall the essence. The likelihood with the theoretical memory is that unless you recall and use the knowledge sufficient detail will fade for it to be unusable for its purpose.

Let us see this distinction at work on design knowledge. A long time ago when I was a student of architecture at Oxford our tutors expected us in our history exams to be able to draw from memory most of the famous buildings of history. We got up to all sorts of clever devices for remembering particular building plans and elevations. Unfortunately since I have not used this knowledge for many years I have largely forgotten the clever tricks themselves. However I can very clearly remember the pain of study and of devising them. I can even recall a particular day sat in Christchurch Meadow rehearsing with two other students how to draw the plan of Sancta Sophia. I know it involved a clever aggregation of circles and squares but that is the extent of my recall of the actual formula. Thus the formulae for generating plans, which were theoretical, have faded even though I studied them very hard at the time. However the experience of studying them I still recall even though I made no attempt whatever to remember it! I can even recall who was with me and what we ate for lunch, the kind of weather and where we sat in Christchurch Meadow.

The point here is that it seems that design knowledge is more heavily dependent on this experiential or episodic memory than the knowledge used in many other professions. Now there are some sound reasons why designers depend so heavily on this. One in particular seems important and that is the integrative nature of the design solution and its very messy mapping onto the design problem. In his famous study of why cartwheels were dish shaped George Sturt found one reason after another each seeming equally plausible (Sturt 1923). The dishing gave lateral strength to resist the sideways motion resulting from the gait of the horse. The form made it easier to shrink on a heated iron rim, which then cooled, compressed and effectively post-tensioned the structure to make it even stronger rather than buckling it. The necessary tilting of the wheel outwards towards the top gave a wider load space while keeping a more manoeuvrable narrower track. This in turn helped comply with legislation governing un-metalled roads. It is a classic and yet delightfully simple example of how a single feature of a design solution can relate to many aspects of a design problem.

Of course this was a vernacular process but the same essential characteristic remains true for the professional process. We simply do not

have theoretical structures that are capable of storing knowledge that leads us from each of these problems to this single solution. Designers it seems rely heavily on knowledge that is not so much theoretical or semantic but more on experiential or episodic knowledge. Visser has demonstrated the use of episodic data seems to be common and normal in an analysis protocols (Visser 1995). It seems that experts have not only gained more experience but they can also link problems to solutions. In fact they appear to have access to knowledge of what we might call 'Gambits'. These are what Richard MacCormac has called his 'repertoire of tricks'. It is clear that in a design practice such knowledge has to become common or shared for the team to operate effectively.

Other studies have shown that a characteristic of experts in general is their knowledge of information sources. (Berlin 1993) Such knowledge is often not explicit but held in minds rather than recorded in an organised manner and is accumulated through practice rather than through instruction. In a discussion of design education in schools Laxton suggested that children cannot expect to be truly creative unless they accumulate what he called a 'reservoir of knowledge'(Laxton 1969). In fact he proposed a rather elegant model of design learning based on the metaphor of a hydro-electric plant. He argued that design learning should pass through three stages. First the accumulation of experience and knowledge (reservoir). The ability to generate or initiate ideas (generator) he claims depends upon having the reservoir well filled. Then students need to develop the skills of critical evaluation and discrimination of these ideas and then to interpret (transformer) them in new contexts. Thus this whole model of education for creativity is actually based on past experience rather than directly on the generation of new ideas and perhaps runs counter to the late twentieth century design education world values of originality almost for its own sake.

The argument here is that recognising design situations is one of those key skills. Seeing some kind of underlying pattern or theme that enables a designer to recognise this and make a connection with some precedent in the episodic memory. Remarkably that episodic memory may relate to something from an entirely different context. Quite how we make such connections is surely a question that suggests much more research is needed. However it is entirely reasonable to suppose that such a skill is indeed highly dependent on experience for most people. Experienced designers have simply seen more and made more connections already than inexperienced designers. There are some clues as to how this might work from research into expertise in other areas. Maintaining the chess theme, more recent research has shown that expert players break the board down into segments or chunks such as attack and defence, and can remember larger chunks than can novice players (Chase and Simon 1973). Similarly expert computer programmers appear to recall larger chunks of code and to be more able to adapt them to their current situation (Adelson 1981). Chi compared experts and novices solving problems in physics and found that they used quite different methods of

classifying problems. Novices tended to group together problems that had similar superficial characteristics, whereas experts grouped together problems that were amenable to solution by the same principles (Chi, Feltovich et al. 1981).

As yet there is insufficient hard empirical evidence on expert designers to know if these characteristics are reflected in their behaviour. However it is probably commonly accepted in design that creativity involves making use of solution ideas from apparently superficially different situations.

7. Drawing and talking

Nigel Cross has shown the importance of the conjunction between drawing and talking in design groups. (Cross 1996). A design group were trying to design a device for carrying a hiker's backpack on a mountain bicycle. Cross points out that well over an hour into the design process one member of the group introduced a design concept with the words "maybe it's like a little vacuum-formed tray". Prior to this point the team had been using the word 'bag' as a way of describing to each other what they were trying to create. The word tray was sufficiently evocative without being too prescriptive, and this word then continued to be used by all the members of the team in turn as they drew alternative interpretations of how this might work.

Cross also points out that by studying both together we can see the development of design ideas not necessarily as creative 'leaps' but as 'bridges' between ideas as the words enable transitions between ideas which look abruptly different if we only look at the drawings. Data from the MacCormac interviews demonstrates a similar process at work. Later in the design process for the Fitzwilliam Chapel already referred to MacCormac describes how eventually the upper floor began to float free of the structure supporting it.

The congregational space became a sort of ship.

Interestingly the team cannot remember who first thought of this way of perceiving, or as Schön would put it 'framing' their scheme. However from then on in sketches, conversations and written documents the worship space is always referred to as a 'ship' or 'vessel'. The impact of this on the way it was eventually detailed is now clear for all to see in a beautiful building.

These two examples then show the application of a form 'tray' or 'ship' from apparently different areas into the current situation. This suggests that indeed expert designers can recognise the possibility of applying ideas from other domains, and makes a strong link to the work previously quoted on physics and computer programming.

8. Affordances

It was Gibson who first drew our attention to the idea of affordances in perception (Gibson 1986). Gibson argued that whatever the explicitly intended function of an object we also see that it affords the possibility of certain behaviour. Others have since shown how this can be applied to the architectural environment (Lang 1987) (Heft 1997). Thus a low window cill affords us the possibility of sitting on it. This delightful concept sums up very well what we have been discussing here so far. It seems that expert designers have accumulated a huge range of precedent which is stored as having affordances that might come in useful at some point in design projects. Somehow the possibility of exploiting these is recognised as a result of having studied them so assiduously in just the way chess masters study past games. This also supports the idea that expert designers acquire knowledge about solutions rather than necessarily about problems.

It is interesting to see how Alexander moved his stance from being problem focussed to solution focussed in his attempts to understand design knowledge. Originally in his Notes on the Synthesis of Form he wrote (Alexander 1964);

If the pattern of the problems could only be seen as it is and not as the bromide image of a previous solution conveniently at hand in the catalogue or magazine around the corner.

By contrast when later developing his 'Pattern Language' he wrote (Alexander 1977);

We have tried in each solution to capture the invariant property common to all places which succeed in solving the problem.

9. Conclusions

To some limited extent then this set of arguments proposes reasons for the need for considerable experience to accrue before designers become expert. They need to have studied a substantial body of precedent in order to have developed schemata that enable them to recognise underlying structures in design situations that allow them to employ and adapt gambits. Such high level thinking is likely to be far quicker than that based on pure analysis. For this to occur in design teams the schemata and gambits need to be shared to the extent that they can be named and communicated with simple references.

All this suggests some fruitful lines of research into design expertise. We should explore perception of design situations and in particular how they are recognised and classified. It seems likely that traditional and superficial classifications are misleading here. For example building typologies such as hospitals schools or offices may turn out to be superficial, whereas the kinds of situations implied by Pattern Language

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studies and the idea of Behavioural Settings may offer the deep structures that enable experts to exploit ideas from apparently superficially different contexts. Such research is probably best pursued not so much by studies of actions designers take but more from the way in which they classify and conceptualise the bank of precedent based on episodic memories upon which they rely. Such research almost certainly requires us not just to look at drawings but to listen to design conversations and explore long-term episodic memories.

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