A Cognitive Dimensional Analysis of Idea Sketches

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ABSTRACT

In this paper Green's (1989) notion of "cognitive dimensions" is used to consider the properties of notations and media for sketching. First, a cultural-cognitive approach to HCI research is briefly outlined which draws on some ideas from "distributed cognition" and Russian psychology. Rather than focussing on the cognitive aspects of an activity or the social aspects (as do cognitive psychology and ethnography, respectively) this approach attempts to describe the artifacts used in an activity in a cognitively and socially relevant way. It is argued that such an approach requires a framework within which to analyse external representations, and that Green's "cognitive dimensions" provide such a framework. The cognitive dimensions framework is described and then used to interpret a study of collaborative idea sketching which used interviewing, observational methods and a questionnaire survey of 128 academics. This analysis resulted in a cohesive and comprehensive characterisation of the pertinent properties of idea sketches. Other studies of sketching in different fields (writing, typography, architecture, engineering design and fine art) are shown to support this characterisation.

1. A Cultural-Cognitive Approach to HCI and Creative Activity

Designers of complex systems to support human activity naturally have little influence over the internal cognitive aspects of an individual's activity (though it is possible to modify individual cognition within limits through training). Similarly, it is hard for designers to re-engineer the organisation of the workplace. Designers do need some contextual understanding of both the individual human mind and of how human activity is organised (as these are constraints within which they must design). However, it is the external artifacts and representations used in a task over which the designer can exert direct control. It would therefore seem natural for an approach to the study of human activity which aims to inform the design of systems for human-computer interaction (HCI) and computer supported collaborative work (CSCW) to focus primarily on those existing external artifacts and representations. But this must be done in a way which explores the relevance of those structures both for the individual mind, and for the social organisation of the activity around the artifacts.

Traditionally, research to inform HCI has been dominated by classical cognitive science and cognitive psychology. The cognitive focus is on the internal mental processes of individuals unaided by external artifacts, usually isolating "subjects" in a "white room" where there is minimal uncontrolled stimulation. Where observational methods and verbal protocols are used to study open-ended creative tasks the models that result still, like the model of writing of Hayes and Flower (1980), often have almost nothing to say about the importance of external artifacts and representations in the cognitive task. To read such work one could almost think that writing would be no different if writers were required not to use a pencil and paper to help themselves think. At the other extreme, ethnographic methods of enquiry have recently come to be explored for use in HCI and CSCW. Such sociological methods typically rely on painstaking and time consuming observation of group activity *in situ* in an effort to understand the socially organised nature of work. For example, Luff, Heath and Greatbach (1992) have performed ethnographic studies exploring the role of documents and screen in the activities of an architectural practice, a medical centre and the control rooms of the London Underground, which are of particular relevance to this report. Though these researchers make some very astute observations about the role of paper in supporting collaborative activity, their focus is primarily on the interactions between its users, there seems not to be a clear framework which might structure an analysis of the media involved, and the relevance of the analysis for cognitive activity is unclear.

Though primarily cognitive and social approaches are valuable, I have proposed (Wood, 1992b) that one approach to inform HCI and CSCW design might usefully focus primarily on external artifacts and

representations. There are two reasons for this: First, almost all intellectual human activity involves the use of external media. In idea sketching, the domain with which my current work is concerned (Wood, 1992a, 1992b), and in more or less any creative design activity, authors, designers and artists use sketches of their ideas, and it is clear that the sketches produced are not an accidental byproduct of thought that performs no useful function in the activity. Second, as argued above, it is over external media and representations that the system designer has most direct influence.

Over the last decade approaches which emphasise the importance of context have been gaining currency in Cognitive Science. Situated action approaches, like Suchman's (1987) "situated action", and Lave's (1988) "cognition in practice" consider that action arises more through a subtle moment by moment dialectical interaction between person and situation than the models of cognitive science and psychology which place the locus of unilateral control firmly on the person. The approach which I am developing to explore how creative cognitive tasks get done by people working together with one another and with their attendant artifacts draws heavily on Hutchins' (1991) "distributed cognition" and on the concepts of "mediation" and "activity" from the Russian psychology and activity theory of Vygotsky (1978) and Leont'ev. Distributed cognition essentially holds that one can consider collaborating people together with the artifacts that play a role in their activity as a single "complex cognitive system". Like Russian "activity theory", distributed cognition therefore focusses on any persons and artifacts that play a part in a cognitive activity. Particularly, distributed cognition focusses on the observeable external representations and communications which comprise the "mental state" of the complex system. The vygotskiian notion of "mediation" holds that human's relationship with the world, with one another, and with themselves is altered through the use of "mediating artifacts" (products of culture, or "tools" in the widest sense). Things as simple as hammers, as complex as slide-rules, computers and encyclopaedias, and even shared cultural schemas and language itself, condense cultural knowledge and allow us to control our own and other's attention and memory.

Concurrently with this research a number of researchers have begun to suggest that either Russian psychology or distributed cognition might inform system design (e.g. Kuutti, 1991; Kaptelinin, 1992; Rogers, 1992; Nardi, 1992). I have argued (Wood, 1992b) that concepts from these two approaches might usefully be combined: A rather "Russian" reading of distributed cognition might provide the "cultural-cognitive approach" which HCI and CSCW require. Distributed cognition, being an approach phrased in modern cognitive language devised by Californians in the late twentieth century rather than by Russians in the early twentieth century, might provide a framework within which some (often obscure) Russian insights might be made more accessible to contemporary system designers, without bringing with them the ideological baggage of Hegel, Marx and Engels. The Russian notion of "activity" allows one to define what constitutes a "complex cognitive system" in a rather more principled way than has been possible in distributed cognition, where the choice of what is included (A team? A dyad doing a sub-task within the team?) often seems arbitrary. Russian psychology also has a richer notion of "history", which in turn affords a better understanding of how our activity comes to be structured through previously designed artifacts (Pea, 1992). It is especially important to this cultural-cognitive approach that when cognitive activity is supported by external artifacts, be they sophisticated CAD systems or simply pencil and paper, cognition is never simply "amplified" or "externalised", but rather cognition is "mediated" through the external artifacts and collaborators such that the new cognitive system which is formed has a radically different character, structure and functionality than the cognition of the unsupported individual (Wood, 1992a). Among those artifacts which are involved in cognitive activity, a Russian emphasis causes us to focus especially on those which involve representations of knowledge in some notation or other, which I term "mediating representations" (Wood, 1992a). An important part of such an approach, the part to which this paper addresses itself, must therefore be an analysis of the cognitively relevant aspects of the external representations used for communication both with others and with the self.

Recent work in distributed cognition (e.g. Flor and Hutchins, 1991) uses an essentially observational approach to identify and describe the external representations used in a cognitive activity. My own previous research has similarly attempted to identify and describe the cognitively relevant aspects of "mediating representations" (Wood, 1992b) used in sketching activity using broadly ethnographic techniques. However, cultural-cognitive approaches currently lack a clear framework within which to consider the cognitively relevant aspects of external representations. It is the thesis of this paper that Green's "cognitive dimensions" provide such a framework.

2. Green's cognitive dimensions

Fitter and Green (1979) originally proposed that computer language notations should code information perceptually (using graphics, indentation, etc) in order that they be more readable. They proposed five principles which advised that perceptually coded information should be that which the user most needs to

access (relevance), that graphical notations should be restricted in their vocabulary (restriction), that particularly important information might be encoded symbolically and also redundantly encoded perceptually (redundant recoding), that a representation should ideally make the underlying structure of its data or process evident (revelation) and that the representation should also be easily revisable (revisability). Essentially, the first four principles here conspire to make computer programs as discriminable as possible, but this in turn means that a program has to have more changes made to it if it is revised to become a different program.

Green (1989) proposed cognitive dimensions (which were in part a development of the principles described above) as a vocabulary, or a set of concepts, which could be used to characterise how suitable different computer programming languages were for the creative task of designing a program. Cognitive dimensions ideally aspire to be like the physicist's dimensions in that a few easy to understand dimensions can be used to characterise any notation. (Though Green frankly admits that in reality there will be a growing list of sometimes poorly defined qualities rather than an exhaustive closed set of orthogonal fundamental dimensions.) Cognitive dimensions are intended to be more useable generalisations than the Fitter and Green analysis because they improve on it in two ways: First, the dimensions are "cognitive" because they are the features of notations which determine which cognitive strategies can be used to perform a task. Second, they do not consider the notation in isolation, but rather consider the system which consists of the notation together with its supporting environment, which in the case of a computer language may be a sophisticated computer text editing environment or simply pen and paper.

Important dimensions in the framework which seem relevant to a characterisation of notations for sketching include the following (Green, 1989; Green, 1990; Green, 1991; Green, Petre and Blumenthal, unpublished manuscript): "Delayed gratification" refers to how much effort is required to create the appropriate representation. "Premature commitment" occurs where users are forced to make choices early in the design process and are later unable easily to change these choices. "Viscosity" is a measure of how resistant representations in the system are to change. Sometimes high viscosity results in premature commitment. "Accessibility" is concerned with how easy it is to find information in the system, and may be improved through "perceptual cueing", for example by the use of typography to provide an access structure. Accessibility and perceptul cueing are also closely related to "role-expressiveness" (the property whereby a representation's meaning or a structure's function is easily recognised) and "distinction" (where different symbols mean different things, and vice versa). "Hidden dependencies" occur when there are conceptual links between entities in the notation which are not visible when the representation is viewed. "Diffuseness/terseness" is a measure of the number of symbols required to express an idea.

Though these dimensions were originally proposed for characterising computer programming languages Green (1991) is clear that it should be possible to analyse any information artifact with such dimensions. Since the early work with computer programming languages cognitive dimensions have been used to consider formal notations as diverse as musical staff notation and the "Sinclair SpecDrum" information structure (Green, 1991). Though the dimensions have not been applied to informal notations for sketching this paper shows that some dimensions which were developed originally for analysing the most formal languages can usefully be applied to even the messiest informal notations. Two cognitive dimensional studies (Shum, 1991a, 1991b; Petre and Green, 1990, 1992, detailed below) are of particular relevance to this report.

2.1. Electronics computer aided drafting

Petre and Green (1990, 1992) interviewed five electronic engineers who used computer aided design systems to draft circuit diagrams about their use of the system in order to determine the cognitively relevant issues of electronics computer aided drafting (E-CAD). Though this was a study of drafting, rather than sketching, it relates interestingly to the study reported here. (Indeed several of the issues which arise in this study are at least mentioned in Petre and Green's study of drafting - see table at end of section six.) The users interviewed were all expert users of a mature established formalism while the writers interviewed in my study, though experienced, were using informal sketching notations which are, by nature, "immature". One important finding of Petre and Green's was that the engineers used "secondary perceptual notations" to augment and clarify the "official" formal notation. For example one of two topologically (and therefore functionally) identical circuit diagrams might be much more readable due to the proximity of related components, etc. In the study of sketching below, where there is *no* formal notation, the distinction between secondary and official notations breaks down. Other issues arising in Petre and Green's study included the importance of overviews (which were facilitated by zooming and the use of adjacency and locality), the necessity to augment the graphical notation with text for some uses, and the problem of viscosity.

2.2. Design rationale

Shum's (1991a, 1991b) cognitive dimensional analysis of design rationale notations is relevant to the study reported here as, though it is not a study of sketches, it essentially argues that design rationale should be more "sketchlike". Design rationale notations are used to represent the reasoning behind the design of a system, either during a design meeting or after the meeting as a summary of decisions made. They are basically graphical node-link notations where typed nodes may contain (for example) "questions", "options", "alternatives" or "criteria", and typed links may mean "questions", "supports", "objects to", etc. Shum describes such notations as "semi-formal" because though links and nodes are typed and are built into structures according to formal rules, the content of nodes is free text (though Shum does not suggest that formality should itself be a dimension). Shum applies four cognitive dimensions to design rationale (premature commitment, viscosity, hidden dependencies and role expressiveness). Two types of premature commitment are distinguished: *Temporal* premature commitment occurs where a system determines the order in which things must be entered into the representation, for example stipulating that one should enter an "issue" before one can enter "arguments" which refer to it. *Structural* premature commitment occurs when the representation must always be formal and complete, even early in design when designers have only ill-formed tentative ideas. Temporal premature commitment cannot occur with pen and paper or wordprocessors, though it may occur with some authoring support tools such as the Writer's Assistant or the Writing Environment (Sharples, et al, 1989; Smith, et al, 1986). However, Shum points out that structural premature commitment can occur even with pen and paper due to its viscosity. Shum suggests that hidden dependencies in design rationale are less likely with graphical notations which convey "connectedness", and that semi-formal representations are likely to be more role expressive than free text and sketches. As a result of his analysis Shum argues for "rough design rationale", which, though semi-formal, achieves low viscosity and low premature commitment through allowing nascent unclassified ideas to be set down and spatially arranged, while maintaining high role expressiveness through a concise semi-formal design rationale notation.

3. An outline of the study and mediating representations

3.1. The idea-sketching exercise and the mediating representations produced

Six pairs of doctoral students took part in an idea sketching exercise in which they were asked to generate and organise ideas for a paper. (They were not asked to write the paper in well formed grammatical prose, but rather to reach a point where they had a clear structure for the paper and an order for the ideas they wished to express.) The participants sat side by side at a large desk, and were videoed from above (to show their drawing, writing and pointing) and from the front (to show their gaze, bodily orientation and gestures). The participants used no wordprocessors, but were provided with a variety of conventional media (a horizontal whiteboard, different sized pens and paper, post-it notes, etc) and were allowed to bring their own media and literature to refer to. Though the situation was not fully natural the authors generally chose topics of genuine interest to them and were drawn into the task. They reported that they felt they were behaving naturally. The experimental paradigm is therefore similar to studies of use of shared drawing surfaces by designers (e.g. Tang, 1991; Scrivener and Palmen, 1991) though here the participants were concerned with concepts rather than physical artifacts so that they used graphical and spatial notations only in metaphorical ways. The participants generally worked closely together over shared sheets of paper or the whiteboard, discussing ideas and representing these ideas and their structure in the shared workspace. In some pairs one participant would take the role of "recorder" for long periods, but more usually both participants would take turns at drawing marks[1], and these turns were closely synchronised with turns in the spoken dialogue. Each session ran for approximately one hour. Over the six sessions examples of all Brinck and Gomez' (1992) classes of conversational graphical objects observed on people's whiteboards (text, geometric objects, equations, block diagrams, tables, lists, sketches and graphs) were produced, though they are categorised differently here.

3.1.1. Labels

The mediating representations produced in the workspace mainly consisted of single words and short phrases which chunked and labelled complex ideas discussed at, or just prior to, the time they were produced. I will refer to these words and short phrases as "labels". Englebart has argued that such labels might be cognitively

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[1] In this paper I use the word "draw" generically to refer to the production of any mark in the shared workspace. The word "mark" is similarly used to mean any textual, typographical or non-textual mark.

powerful as they may allow the individual to do heavy thinking by "manipulating *symbols* instead of the more unwieldy concepts that they represent" (Englebart, 1963: 47), especially when this manipulation can be externalised with graphic representations which supplement the individual's memory and ability to visualise. It seems likely that the brevity of the labels means that they can be created and edited speedily, and their economy of space means that many labels can be placed on a single small page.

3.1.2. Typographical cues

These textual labels were invariably augmented with the different typographical marks which are well established in our culture (see e.g. Waller, 1988). Case, size, and underlining, were often used to indicate something like importance or stress. (Brinck and Gomez (1992) classify such emphasis and highlighting as sketches.) Bulleting and numbering were sometimes used to enumerate a list of ideas. Indentation was used to make the hierarchical chunking and organisation of ideas perceptually evident. The weight and neatness of writing was used to indicate the certainty or finishedness of ideas. It can be argued that such typographical cues add a perceptible access structure and also make the representations more visual and memorable.

3.1.3. Graphical notations

Some informal non-textual graphical and spatial notations were also used. As with typographical marks, these were also generally informal versions of graphical languages with which most educated people would be familiar (see e.g. Bertin, 1983; Tufte, 1990; Martin, 1987 for examples). Throughout all six sessions only one highly graphical representation combining nodes and links in the style of "spider diagrams", "pattern notes" (Fields, 1982) or "mind maps" (Buzan, 1982) was produced. Rather, labels and lists were augmented with graphical signs such as adjacency and spatial arrangement in an ad hoc way.

Related ideas were often placed in proximity to one another in a similar way to that in which several researchers have remarked that people can organise documents on their desk or computer workspace (e.g. Malone, 1983; Francik, et al, 1991; Mander, et al, 1992). Sometimes ideas were grouped by being clustered or enclosed together in a rectangle or circle. (Indeed much of the informal notations used were consistent with basic gestalt principles such as proximity, similarity and closure.) Where there was a relatively clear relationship between labels they were occasionally linked with a line. Lines were also used to divide space up into separate areas. The spatial positioning of a label in the two dimensions of the paper relative to other labels often showed in what phase of the work it had been produced, its place in an argumentative structure, or its projected place in the final text.

3.1.4. Other graphical signs

In addition to these notation-like informal graphical languages some graphical marks were more pictorial. For example, one author drew a large funnel shape to represent the structure of a paper (a general introduction followed by increasingly tighter focus on a particular topic). Later both authors pointed to places in this shape when talking about parts of the paper.

3.2. Interviewing participants about their graphical mediating representations

The videotapes of the participants' activity during the production of idea sketches were analysed using a very intensive and fine grained analysis methodology and transcription scheme (Wood, 1992b). This analysis, together with the above consideration of the mediating representations produced, and in combination with the cognitive dimensions framework, generated issues and questions surrounding the mediating representations the participants produced. The participants were individually interviewed[2] about their experiences of the exercise and were asked to comment on parts of the videos produced in the study. They were asked about their use of representations in the exercise, and also about their use of such representations in their everyday work as individuals. In order to allow the participants space to express themselves, and so that the interviewer's questions were not intrusive, the interviews took the form of unstructured discussions in which the interviewer tried to say as little as possible except to encourage the participant to speak and ensure that the agenda of issues was eventually covered. Some participants were not asked about issues which arose for the first time in later interviews, but most participants commented on most of the issues discussed below. This paper draws heavily on the informants' comments, and many particularly revealing or illustrative comments are included in this paper. These comments have been edited to exclude repeats of phrases,

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[2] Unfortunately, one particularly productive interview (of participant T) was lost due to faulty recording equipment.

meaningless phrases (e.g. "I mean", "you know") and the interviewer's encouragements to continue, but they are a faithful portrayal of the participant's meaning. The participants are designated "J", "P", "D", "M", "R", "O", "S", "A", "W", "B" and "C".

It is worth being a little cautious about participants reports, as they may be "telling more than [they] can know" (Nisbett and Wilson, 1977). It is well known that people are sometimes unaware of the stimuli which in fact affect their responses, and may give answers that are plausible rather than accurate when asked about their mental processes. However, the idea-sketching activity under investigation is one which occurs when (indeed, probably because) the sketcher is involved in particularly taxing and painstaking mental activity and needs to mediate her cognitive activity with external artifacts and representations due to the limitations of the internal cognitive system. Flavel (1979) has argued that metacognitive experiences are "especially likely to occur in situations that stimulate a lot of careful, highly conscious thinking" (Flavel, 1979: 908). There is therefore good reason to think that the participants may have good insights into why and how they use mediating representations.

The participants generally reported that they resorted to graphical mediating representations for the creative idea organising and structuring activities in writing, in order to help themselves think. It was found that though the informants universally had access to sophisticated workstations they all used paper based media for idea sketching in their own work.

> J: I do stuff on paper a lot. It's important for me to have a whiteboard or a blackboard where I'm working because it's important to be able to jot things down and use them like that and... I do get through a lot of paper. So its not true that my editor has usurped my paper. It doesn't. I do actually get through a lot of paper sketching stuff.
>
> S: I find there's some things about writing on paper that are good. It's more natural. It's something you grow up doing. It's easy to look at and so it's quite a nice way to do it.
>
> R: No I tend to do most of my, virtually all of my thesis, when I do most creative work, in writing. I don't do it at a workstation or computer. I find it too constraining I think in some ways, in a number of ways. I'm not quite sure why. I've not really thought about analysing it, but part of it is because I like doing things like this and I just I still find the interface too clumsy.

Much of the discussion in interviews aimed to ascertain why the particiapants used such representations, and how the representations helped them (see next section). When asked about *when* they were more likely to use mediating representations the participants generally reported that, while they might simply start writing a short essay on a computer, where they were (1) writing a *large* document with many cross-referencing parts, or (2) a very technical or difficult *complex* document, they very rarely used a computer for the very earliest planning activities. This is consistent with the hypothesis that mediating representations are used to overcome limitations of the internal cognitive system.

> A: The longer the thing I'm writing then the more there's likely to be on it and the more accumulated bits there are going to be that I want to remember to put in and not to just forget.
>
> B: I think its got a lot to do with what you're studying, its got to do with structure, and if you're only dealing with, I don't know, four or five concepts or something in an essay you can see how they relate together in your head without having to have them in front of you. But you know if you have 97 different things like "bigotry" there's no way that you can keep all the connections together.

3.3. Questionnaire study

Even from the very limited number of participants studied it was apparent that there were great differences between individuals in the extent to which they engage in such activity. There was some suggestion that typographical and non-textual signs might be used more by those who have a tendency to think visually and spatially or by those with a background in fields which use graphical representations widely (e.g. engineering, cognitive psychology, design, economics, etc). In order to get a broader view of how and why writers use graphical mediating representations, how pervasive such activity is, and in order to generate more quantitative data than the twelve interviews described above, a questionnaire survey was performed.

Questionnaires were sent to the first 500 academics listed in the Sussex University phone book as "Dr." or "Prof." (about 80% of people so listed). The 128 valid responses returned within two weeks were used in the analysis reported here. A few late returns were not included in the analysis. (The questionnaire is appended to this report.) Note that the order of the questions in the questionnaire (except for the first five "demographic" questions, and questions 6, 7 and 8 on preference) is not the same in which they are presented in this report. Note also that the "polarity" of questions 9 to 38 on the questionnaire is randomised, whereas in this paper all "A" statements are those which I expect preferrers of conventional media are more likely to choose.

In the questionnaire 65 people identified themselves as working in the "sciences" while 39 identified themselves as working in the "social sciences". Only 7 worked in "Arts". 17 did not answer to one of these

categories (either circling two, none, or writing another word such as "administration"). The first five questions of the questionnaire were essentially "demographic" questions. The responses to seven point Likert scales are recoded here such that those showing a tendency towards statement A (in all cases the most frequently chosen) are classed "A", and all others (including those showing no tendency) are classed "B". The percentages given (rightmost two columns) exclude those who did not answer the question. (The construct "preference" is explained later in this report.)

		Sample	A (1-3)	missing	B (4-7)	%A	%B
1	A: I have easy access to a computer terminal with text editing facilities B: It is inconvenient for me to get access to a computer	ALL	121	1	6	95	5
2	A: I use a computer in the process of writing a text B: I do not use a computer in the process of writing a text	ALL	116	0	12	91	9
	Spearman correllation with "preference"	N = 124		ρ = 0.393		p < 0.0005	
3	A: I use very sophisticated wordprocessing software B: I use a simple editor or basic wordprocessor	ALL	83	2	43	66	34
	Spearman correllation with "preference"	N = 122		ρ = 0.233		p < 0.01	
4	A: The computer I generally use has a large sophisticated display B: The computer I generally use has a small display	ALL	65	4	59	52	48
	Spearman correllation with "preference"	N = 120		ρ = 0.22		p < 0.01	
5	A: In my field, much use is made of charts, graphs, diagrams, etc B: In my field, little use is made of charts, graphs, diagrams, etc	ALL	80	1	47	63	37

Almost all respondents had good access to computers and used them when writing texts. Most respondents also used sophisticated software and computer displays, though many did not. Unsurprisingly, χ^2 tests between respondent's disciplines (Arts, sciences and social sciences) and their answers to questions 3, 4 and 5 (as recoded in the table above) showed that respondents of different disciplines had differential access to computer equipment and used graphics in their work to different extents. Scientists tended to have more access to sophisticated wordprocessors while social scientists had less access ($\chi^2 = 10.324$, df = 2, $p < 0.01$), and more access to large sophisticated displays while social scientists had less ($\chi^2 = 9.287$, df = 2, $p < 0.01$). Artists were evenly split on these questions. Scientists were also very much more likely to use charts, graphs and diagrams in their work than social scientists ($\chi^2 = 30.301$, df = 2, $p = 0.0001$).

Questions 6, 7 and 8 aimed to ascertain whether respondents had some general preference for conventional media over computers or word processors. Note that, like several questions in this survey, question 8 has a deliberate heightened sensitivity to a preference for conventional media (it opposes "...sometimes... use conventional media" with "...always use a computer..."). This is because even if people only occasionally find their computers inadequate the system designer should still consider how that need might be catered for. In this and all following tables the 7 point Likert scale responses are recoded for concise presentation by designating respondents who agree more with statement A as "A", those who agree more with statement B, as "B", and those who showed no preference (ticked the central box in the scale) as "No Pref". The percentages given for A and B (rightmost two columns) are exclusive of those who showed no preference. Any missing responses are ignored.

		Sample	A	No Pref.	B	%A	%B
6	A: Except where I am reworking existing text, in the early stages of planning a long and complex text I prefer to use pen/pencil B: Even when not reworking existing text I prefer to use a word processor in the earliest stages of planning a long and complex text	ALL	51	19	58	47	53
7	A: I find it easier to think with conventional media B: I find it easier to think when using a computer	ALL	47	36	42	53	47
8	A: Even in situations where I have a computer to hand I sometimes choose to use conventional media B: Wherever possible, I always use a computer in preference to conventional media	ALL	66	17	44	60	40
	Spearman corr. of questions 6 and 7	N = 125		ρ = 0.752		p << 0.0005	
	Spearman corr. of questions 6 and 8	N = 127		ρ = 0.554		p << 0,0005	
	Spearman corr. of questions 7 and 8	N = 124		ρ = 0.674		p << 0.0005	

On each of these questions approximately half of respondents who expressed a preference had some tendency towards using conventional media. As expected, there were very high correllations between all these three questions. (Note that throughout this report all "A" statements are those which preferrers of conventional media are expected to choose. As all significant correllations were in the direction expected ρ is always positive, and p is calculated from ρ and N for a one tailed test of significance.) These high correllations suggested it was legitimate to derive two constructs, "preference" (continuous) and "preferred medium" (category), from the responses to these questions. As one question for this research is "Why do some people sometimes prefer conventional media to computers?" the responses to these three questions were combined to give a "preference" score. Preference scores ranged from 3 (corresponding to ticks in the three boxes on the questionnaire closest to the A statements) to 21 (corresponding to ticks in the three boxes closest to the B statements). Scores were spread very evenly between these extremes, making the preference construct a very useful one for correllation against responses on Likert scales. Further, respondents with a preference score of 11 or less (corresponding to at least one of their responses to questions 6, 7 and 8 being closer to the A statement than the B statement) were designated "conventional media preferrers" (CMPs), while the remainder were designated "computer preferrers" (CPs). Fortuitously, when divided according to this rationale respondents were split exactly equally on preferred medium, with 62 conventional medium preferrers and 62 computer preferrers (with 4 respondents not included due to not answering one or more of the questions concerned). Elsewhere (Wood, 1992a: 82) I have hypothesised that people's preference for looser, more graphical media might be related to their discipline. However, surprisingly the preferred medium categories cut almost exactly evenly across the disciplines: Of 63 scientists 33 were CMPs and 30 were CPs; of 38 social scientists 19 were CMPs and 19 were CPs (5 of 7 artists were CPs, but there were too few artists for this to be meaningful). This even split across the whole sample and across disciplines is ideal to allow preferred medium to be compared with other category data with χ^2. Also, in the remainder of this study the responses of conventional media preferrers to questions are given in tables as well as those of the sample as a whole.

Unsurprisingly, respondents with a high preference for conventional media showed a strong tendency not to use a computer in the writing process (see Spearman correllation for preference against question 2). They also tended not to have sophisticated software (question 3) or large sophisticated screens (question 4). Elsewhere (Wood, 1992a: 82) I have hypothesised that people who are constantly exposed to many graphs, diagrams, etc, in their discipline might be more disposed to use graphical notations in planning text. However, no significant correllation was found between respondents' preference score and their estimate of how much graphical representations were used in their discipline (question 5).

4. Cognitive dimensions of idea sketches

The bulk of the interviews and questionnaire questions explored issues arising from a consideration of the videos of participants' activity during the study, and the graphical mediating representations produced, from the point of view of the cognitive dimensions framework described above. A number of cognitive dimensions proved to be useful for characterising aspects of the idea-sketches. Also, a number of factors were found to be important which, though not actually cognitive dimensions themselves, were closely related to one or more dimensions. These "subdimensional factors" were generally either an aspect of a particular dimension

(e.g. semantic potential is one aspect of formalness), an immediate effect of a particular dimension (e.g. overview is a result of terseness), a factor which affects a dimension (e.g. "finished character" causes premature commitment) or the effect of one dimension on another (e.g. "faciltation through terseness" is the effect of terseness on accessibility). In this section, the important findings of the interviews and questionnaire survey are organised under Green's dimensions of delayed gratification, terseness, perceptual cues, accessibility, premature commitment, and viscosity. An additional dimension of formalness (alternatively "completeness") is also proposed.

4.1. Delayed (and demanding) gratification

Delayed gratification, though its name emphasises the temporal aspect, is intended to cover the general amount of effort involved in creating a representation, rather than simply the time taken to perform an operation (e.g. Green *et al* unpublished manuscript). Participants generally felt that computer word processors and drawing tools required too much effort to achieve the required result:

> W: Why didn't I do it on a computer? I was actually sitting by my workstation so there must have been a good reason. I think in the early stages... I find it quicker and easier to scribble things down when it's very tentative rather than faffing around erasing things on the computer...
>
> M: Its to do with how much the media absorbs from me while I'm using it. How much brain power absorbs or is needed while I'm using it.

		Sample	A	No Pref.	B	%A	%B
9	A: When brainstorming ideas, I can get ideas down more quickly with conventional media	ALL	88	15	24	79	21
	B: When brainstorming ideas, I can get ideas down more quickly using a computer	CMP	57	2	2	96	3
	Spearman correllation with "preference"	N = 123		ρ = 0.704		p << 0.0005	

One important factor (mentioned by W above) within delayed gratification was speed. The majority of questionnaire respondents found it quicker to brainstorm ideas with conventional media, and respondents' preference for conventional media showed a very strong highly significant correlation with tendency to find conventional media quicker to use. However, M's comment above suggests that a medium can itself *demand* cognitive resources, as well as simply slowing thought down. Hence, a discriminable sub-dimensional factor within delayed gratification was labelled "transparency".

4.1.1. Transparency

Transparency is the property of a system of notation and environment whereby a user can be unconscious of it and concentrate on what she is using the system for. (Of course, a system's transparency depends on the familiarity of the user with the system, as well as on the system itself.) This is essentially the same as Heidegger's notion of "readiness-to-hand" where "to the person doing the hammering, the hammer as such does not exist. It is part of a background of *readiness-to-hand* that is taken for granted without explicit recognition or identification as an object" (Winograd and Flores, 1986: 36).

Several participants complained that the computer demanded attention and distracted from the task in hand, especially if one was not skilled with its input devices (e.g. O's and R's comments below). W's comment below suggests that when engaged in highly demanding creative thought such distraction can actually result in the loss of ideas:

> O: [the computer] jumps out at you a bit more... It forces you to think about it and you really just want to think about what you're writing about.
>
> R: Maybe perhaps if I was a touch typist that would make a difference. Maybe, I keep thinking, I should learn to type because maybe it will free my mind more to think while I was actually typing.
>
> W: I mean by the time I had drawn the arrow I'd have forgotten what I was going to put on the end of it... I mean this is all very much sort of what came into my head quickly so I mean I just wanted to get it down very quickly.
>
> J: Almost anything that wasn't stupefyingly simple would be too much trouble because you're doing this quickly, you know, you're thinking on the fly. You don't want to muck about looking for the button that makes the arrow or something. You don't want to muck about with anything really, anything that interferes with the process of communicating information.

With the computer one had to click on tool bars and pull down menus in order to select the correct font and size of text, the correct weight of line or style of arrowhead. Pen and paper, on the other hand, are transparent

in that one can choose font, size, place, etc, without wasting cognitive resources on interacting with the interface.

> J: Some things are in capitals and circled and they've got this brace here. And they were easy to do - you didn't have to think about it.

		Sample	A	No Pref.	B	%A	%B
10	A: When trying to think I do not want to be concerned with the practicalities of using a computer	ALL	43	18	62	41	59
	B: When thinking on the computer, I do not find using menus and toolbars, etc, intrudes on my thoughts	CMP	24	13	21	53	47
	Spearman correllation with "preference"	N = 119		ρ = 0.35		p < 0.0005	

Though the majority of questionnaire respondents did *not* find the computer interface "opaque" to an extent which interfered significantly with their thought, repondents' preference for conventional media showed a very strong, highly significant correllation with unwillingness to be concerned with the practicalities of computer use, suggesting that opaqueness is one reason that some find the computer unsuitable for idea sketching. If, as I have suggested, people use idea sketches as a way of mediating their cognition and thereby overcoming the cognitive limitations of the internal cognitive system, this benefit may be offset if an opaque system itself demands additional cognitive resources.

A consideration of J's comments above also suggests another significant factor related to delayed gratification, which I have here called "richness".

4.1.2. Richness

"Richness" is the very general property of a representation whereby there is a maximum of information, redundant encodings, typographical and graphical marks, etc. *as a result of the environment allowing such marks easily to be produced.* A "rich" representation is to be compared with a "minimal" representation which lacks such cues and encodings as a result of high delayed gratification. Richness (as I define the term here) should not be confused with, for example, perceptual cueing or accessibility (below), though it is clearly related to them, as it is concerned specifically with the presence of such properties *as a result of low delayed gratification.*

There was some suggestion in the interviews that because of the difficulty of producing typographical and graphical marks they tended to be left out of representations, whereas with paper such marks would have been present.

> J: If you were doing this with a piece of technology you'd think "ahh. stuff it! I'll just put another word there rather than trying to put a brace on it or put a circle round it or whatever". Unless it were very easy to do those things you wouldn't do it.
>
> J: With pen and paper without thinking about it these were written as capitals and circled and in that position and with that brace and it was very easy to draw the arrow. Otherwise I guess those things wouldn't be there, that emphasis wouldn't be in the diagram...
>
> B: It's extremely complicated to get a box of things here and a box of things there because the "return" takes you up to there and you've got to play around with cursor keys and God knows what to try and get things arranged in anything other than the linear order.

		Sample	A	No Pref.	B	%A	%B
11	A: I can more easily use case, size, underlining, indentation and other typographical marks if I sketch my ideas with conventional media	ALL	22	38	61	27	73
	B: I can more easily use case, size, underlining, indentation and other typographical marks if I sketch my ideas on the computer	CMP	12	31	15	44	56
	Spearman correllation with "preference"	N = 117		ρ = 0.393		p < 0.0005	

Only a small minority of questionnaire respondents believed that it was more easy to produce typographical marks with conventional media. Though, unsurprisingly, those with a stronger preference for conventional media showed a very strong, highly significant, tendency to find conventional media more easily allowed production of typographical marks than the population as a whole, more than half of conventional media

preferers believed the *computer* to make production of typographical marks easier. This is surprising, and may partly result from the respondents failing to recognise that when they use conventional media they unconciously produce the typographical marks with which the idea sketches produced in the idea sketching study were replete.

4.2. Terseness

A "terse" representation is one in which there are a low number of symbols per idea. It is to be contrasted with a "diffuse" representation which, in the domain of writing, might be fully formed grammatical prose as opposed to single word idea labels. Clearly, a terse representation is likely to allow low delayed gratification, and in turn higher richness. As remarked above, complex ideas generated in the idea sketching study were mainly encoded with single words or short phrases, and participants appreciated that this was an important property of idea sketches:

> M: I tend to write things into corners and cram everything up in one page and have a really funny layout. It doesn't have any overall structure, like a spider diagram or anything, it's just cram things in... The least amount of paper I use the better I feel, I don't know why.

		Sample	A	No Pref.	B	%A	%B
12	A: I sometimes use terse notes, lists or idea sketches in the early stages of planning a text B: I generally write in fully formed grammatical prose, and do not use notes or idea sketches	ALL	94	9	25	79	21
		CMP	48	4	10	83	17
	Spearman correllation with "preference"	N = 124		ρ = 0.223		p < 0.01	

The vast majority of questionnaire survey respondents claimed to use terse representations at some stage of planning a text. Further, respondents' preference for conventional media correlated significantly with their tendency to use terse representations, showing that there is some connection between use of terse representations and use of conventional media. Possible reasons for this include (1) that computers make it somehow difficult to produce terse representations (e.g. see "downsliding" below), (2) that conventional media allow terser representations (perhaps by substituting perceptual cues and accessibility for diffuseness), and (3) that conventional media do not allow diffuse representations (perhaps because of higher delayed gratification caused by the speed of handwriting).

Three sub-dimensional factors related to terseness which emerged as of probable importance in the idea sketching domain were "overview", "structurability" and "visible area".

4.2.1. Overview

Overview is the property whereby a user can see the whole (or much) of a representational structure at once, partly as a result of the terseness of the notation. (Overview is also a function of "visible area" - see below.) Overview is clearly related to accessibility, though parts of a representational structure can be accessible without actually being visible. Idea sketches were reported to provide an overview of the ideas and their relationships in a way that grammatical prose could not and this allowed the participants to achieve a wholistic conception of the content they were considering:

> J: Sometimes I have a piece of paper that accumulates over a number of days and I purposely make it so that everything about that article or whatever it was that I was doing is on that one sheet of A4. And it's important that everything be on that sheet. It doesn't matter how messy it gets... I use that sort of stuff quite a lot.
>
> R: I'm really into using just using A4, like the photocopying paper, blank... I really don't like lines because I actually tend to write extremely small at times. I mean if you go through these notes for notes that I kept for several years writing my thesis, I wrote them all in pencil... another reason for doing it is because then on one page I can actually get a lot. I think one thing is I tend to be quite a linear person, I think I mean text oriented, and I do things quite linearly but because I need to retain some kind of global structure I write very small. I've got all the global structure there.
>
> B: All this stuff came out of my head as I sat down at the table. It wasn't that I was ploughing through notes to find it. It was all in my head. It wasn't a memory thing - I mean I knew all the junk - but it's seeing how its going to cohere into a structured sort of essay.
>
> J: There's a composer, I don't know which one it was, but he said he could hear an entire piece of work that he was going to write in its entirety at one moment in time... Writing everything down on one sheet of A4 or whatever is my meagre attempt to try to capture all the components of an article or an idea in one place.

		Sample	A	No Pref.	B	%A	%B
13	A: It is sometimes important to see all my ideas on one paper sheet or screen, or on several sheets spread out in front of me	ALL	97	15	15	87	13
	B: It is not important to be able to arrange all the ideas pertaining to a text so that they can all be seen at once	CMP	47	8	6	89	11
	Spearman correllation with "preference"	N = 123		ρ = 0.184		p < 0.05	
14	A: I find that terse notes or sketches allow me to get an overview of my ideas which is not afforded by grammatical prose	ALL	104	15	7	94	6
	B: When planning a text, using terse notes or idea sketches does not help me get an overview of text structure	CMP	53	6	1	98	2
	Spearman correllation with "preference"	N = 122		ρ = 0.281		p < 0.005	
15	A: I find it more necessary to use conventional media when planning a long text	ALL	56	56	12	82	18
	B: I find it more necessary to use conventional media when planning a short text	CMP	42	17	3	93	7
	Spearman correllation with "preference"	N = 120		ρ = 0.556		p << 0.0005	

The vast majority of questionnaire respondents felt that it was sometimes important to see all their ideas together on one screen or sheet of paper (question 13), and felt that terse notes afforded an overview not so easily afforded by grammatical prose (question 14). Those who expressed a greater preference for conventional media also showed a significantly increased tendency to wish to see all their ideas at once (suggesting that conventional media may afford a better overview), and a very significantly increased tendency to find that terse notes or sketches afforded a better overview than grammatical prose. Many respondents thought it more necessary to use conventional media when planning a long text than a short one (question 15), and those with a strong preference for conventional media were very much more likely to think this. Taken together with the findings of questions 13 and 14 this suggests that overview may be especially necessary when there are many ideas involved, presumably in order that the writer can better organise and structure the ideas. Thus overview may support "structurability".

4.2.2. Structurability

Structurability is the ease of perceiving global structure, and thereby being better able to reorganise a representational structure, afforded by terseness. It is therefore the increase in accessibility, and the lowering of viscosity, which results from terseness. In the idea sketches produced in this study, many terse labels (which sometimes stood for many paragraphs of text) were placed in relation to one another. Participants' comments suggested that this allowed a gestalt perception of structure not afforded by grammatical prose.

> J: It's important to be able to retain more than one idea at a time. I quite often find... that I thought of one thing... and I think of another thing... and a third thing, and by the time I get to the third thing I've forgotten what the first thing was. But actually they are related and it's important to be able to relate them, and writing them down in definate spatial relations to one another not only means that I can actually get a grasp on what the various components were but also their relationships with each other on the paper.
>
> D: It's just a way of structuring for myself. I could structure it in my mind but my memory probably isn't good enough to do that... So it's a way of structuring it. It's a way of dividing it into the small areas. So say I divided it into four main areas... then divide each of those areas into four sub-areas... If I was just doing that in my head I couldn't remember those sixteen things and the way they're supposed to be going...
>
> R: I haven't used an outlining tool I think I've used something like it but I think I'd be happy to use it for certain sorts of writing like... project reports so I tend to sit down and type in headings and just proceed as if I was using an outliner and then writing fairly noddy prose but thats only for things like... or if I'm doing documentation of software I tend to go that way because it would follow maybe the structure of the code, which itself is kind of highly structured, so you just type in the general structure and you know write a paragraph for each piece... so that works quite well but when I'm doing kind of creative writing I rarely find that...

		Sample	A	No Pref.	B	%A	%B
16	A: It is easier to organise and structure ideas when they are represented as terse notes or idea sketches	ALL	101	14	10	91	9
	B: It is easier to organise and structure ideas when they are represented as grammatical prose	CMP	52	4	3	95	5
	Spearman correllation with "preference"	N = 121		ρ = 0.316		p < 0.0005	
17	A: When the structure of a text is clear from the beginning I am less likely to use terse planning notes	ALL	66	36	22	75	25
	B: When the structure of a text is clear from the beginning I am more likely to use terse planning notes	CMP	29	22	9	76	24

The vast majority of questionnaire respondents felt that it was easier to organise ideas when they were represented as terse notes. Further, respondents with a higher preference for conventional media showed a very strong highly significant tendency to feel this, again suggesting that computers may provide poor support for terse representations which allow an overview. Most respondents also felt that they were less likely to use terse notes when structure was clear from the start, implying that one function of terse notes is in determining structure.

4.2.3. Visible area

An obvious possible limitation of computers is the physical size of the screen which, though it is a window onto a virtual space of almost limitless size, may allow simultaneous perception of fewer notes than paper. Several participants reported using small writing, or large sheets of paper, in order to see far more information at once than they could with a computer screen. Similarly, several participants reported needing to spread work around them.

> S: If I had a big table I could spread out how many pages I'd read so far and I could look at everything I'd read and I'd have all the books as well... It helps for greater reflection on what you're writing I think.
>
> O: I find it difficult to work on a small desk... I'm particularly far from the sort of style of planning you might do on computer because I'm used to being able to spread stuff around like that... if you've just got the flat screen, and even if you have windows, it isn't really quite the same.
>
> A: I don't try and do it at the terminal which is disastrous because you don't get the overview and you can't refer forward and backwards to see what you're saying and you've said already.
>
> B: A bigger screen, a screen with more on it rather than bigger. I mean, it doesn't need to be bigger, but more on it and possibly with the capacity to put arrows and things...

		Sample	A	No Pref.	B	%A	%B
18	A: I sometimes find the size of the computer screen restrictive	ALL	87	18	21	81	19
	B: I do not find the size of the computer screen restrictive	CMP	43	11	6	88	12
	Spearman correllation with question 13	N = 123		ρ = 0.444		p << 0.0005	

Latour (1986: 21) writes "In politics, as in science, when someone is said to "master" a question or to "dominate" a subject, you should look for the flat surface that enables mastery". Most questionnaire respondents reported finding size of the computer screen restrictive. Those who tended to find this were also very much more likely to tend to find it important to see all their ideas on one sheet or screen (question 13), suggesting that small screens do not afford the required overview for the "domination" of which Latour writes. However, very surprisingly, there was no significant correllation between a respondent's tendency to find the computer screen restrictive and the size of the display of their usual computer, as they perceived it (question 4). Perhaps even more importantly, Those who tended to express a preference for conventional media had no significant tendency also to find the size of the computer screen more restrictive, suggesting that, though screen size is clearly an issue, it is not the factor which causes some to prefer conventional media while others are happy with the computer.

4.3. Perceptual cues

In existing cognitive dimensional work on formal notations "perceptual cues" are usually either "redundant recodings" of some particularly important variable, or "secondary notations" which add non-essential

information to improve readability (e.g. the layout of topologically identical circuit diagrams, above). In informal idea sketches, however, typographical and graphical cues were used to uniquely encode information such as "importance" and "relatedness".

4.3.1. Typographical cues

As noted above, the mediating representations produced in the study were replete with typographical cues. It is well established that typographical layout, case, size, etc, can carry important semantic information, even if the actual letters are all replaced with the letter "x" (Nygren et al, 1992). For example, in the study reported here there was some evidence that the degree of an idea's well-formedness was indicated by the amount of text, the clearness of the writing, the messyness of the marks, etc. When the participants were questioned about the representations they had produced several remarked that such cues were more likely to be produced with paper than on computer.

> C: [Typography is] based on what is important in a way isn't it? I mean "bigotry" and "liberalism" are in huge great drawn letters because they're the two main things and then boxes and fairly large writing for "definition" and "forms of" and "consequences" because they're sort of headings
>
> O: you can make more distinctive marks... different types of lettering sometimes, large headings... I can embolden and underline them easily. On screen it's hard to make anything look that different really. You certainly can't draw, not on the computers I use anyway.
>
> W: It's quite strange that in fact when I write things I indent but if I'd been writing it on the screen I wouldn't have indented it... because I don't indent paragraphs on the screen, I just use block style so I miss a line but when I write I do it like this
>
> A: Certainly paper is much better for [typographical cues] than computer, or the computers that I've come across, because it just gives you more visual freedom to vary the size, to vary the location, to vary the capitals among other things are to adapt it and put lines and other things... and also its just quicker to do all those things.
>
> S: I guess it draws your attention or something. If in writing you could easily embolden what you wrote I suppose you might do that, but underlines and capitalisation are quite um adequate... to draw your attention to kind of where the top of the section, where the start of something is.

Given the preponderance of typographical marks observed in idea sketches remarkably few questionnaire respondents believed that such marks played an important role. It may be that such marks are really incidental, though an alternative hypothesis might be that respondents did not realise how much use they unconsciously made of typographical cues.

		Sample	A	No Pref.	B	%A	%B
19	A: It is important to be able to use typographical marks like case and underlining when jotting down ideas	ALL	26	19	80	25	75
	B: It is not important to be able to use typographical marks like case and underlining when jotting down ideas	CMP	9	9	43	17	83

4.3.2. Graphical cues

Participants suggested that graphical marks could be desirable even though they resulted in a messy but visual representation. These cues were used to help participants relocate ideas, and helped prevent them from forgetting to instantiate an idea label into fully formed prose at a later stage. Such perceptual cues were less likely to be produced on computer because of the high delayed gratification involved (see "richness").

> O: If I had to use a system I'd want... ways to make things look more graphical I suppose, without necessarily being drawings.
>
> O: Sometimes I do little doodles in the margin or something, and I think of the page "well that's the page which has got that in the corner". I mean I certainly wouldn't demand of a system that it let you do that, but... it's just the appearance of the page. ... I'm aided when I'm revising in using colours and layout and things so that I can visualise the page, not photographically. I'm sort of helped out by that sort of thing, which I think some people aren't, so it's not that I necessarily rely on graphical things, but it does help me.
>
> D: If I didn't have any markings on that paper, and everything was just pushed in to the side... I could very easily miss things. For instance, if "traditional view" was pushed in here and there was no gap and there was no number one then I think I would quite easily miss it. So in a way its a way of saying to myself "look when you're going back and writing this essay remember the important things are these three people and in this person its these two things... "

The vast majority of questionnaire respondents sometimes clustered idea labels spatially, and respondents' preference for conventional media correllated with their tendency to use clustering. Most who expressed some preference felt that it was sometimes useful to draw diagrams of ideas, and that they used more "graphical" representations than linear prose when planning, though many felt that diagrams and graphical

representations were not useful. However, those with a tendency to prefer conventional media showed a corresponding very strong highly significant tendency to favour diagrams and graphical representations. This strongly suggests that the need to include graphical cues in their representations is one reason that some find computers inappropriate for idea sketching.

		Sample	A	No Pref.	B	%A	%B
20	A: I sometimes cluster related idea labels spatially on a page	ALL	80	22	22	78	22
	B: It is not significantly helpful to arrange related notes spatially on a page	CMP	42	11	6	88	12
	Spearman correllation with "preference"	N = 121		ρ = 0.194		p < 0.05	
21	A: When planning a text it is sometimes useful to draw diagrams of ideas (like informal "mind maps" or "spider diagrams")	ALL	62	19	47	57	43
	B: When planning a text it is not useful to draw diagrams of ideas (like informal "mind maps" or "spider diagrams")	CMP	35	13	14	71	29
	Spearman correllation with "preference"	N = 124		ρ = 0.312		p < 0.0005	
22	A: I find it useful to use more "graphical" representations than linear prose when planning a text	ALL	55	29	42	57	43
	B: I do not find it useful to use more "graphical" representations than linear prose when planning a text	CMP	30	14	16	65	35
	Spearman correllation with "preference"	N = 122		ρ = 0.283		p < 0.005	

4.4. Accessibility

Accessibility is the property of a notation/environment system which allows the user to access information with ease. Accessibility is a very important quality of more diagram- or chart-like representations. (For example, much of Larkin and Simon (1987) and Lohse (1991), two studies which aim to define what makes a good diagram or graph, can be seen to be concerned with how easily attention can be directed to the relevant part of the representation.) It is obvious that lists of idea labels (like shopping lists) serve to save the user having to remember ideas and retrieve them from long term memory. Neuwirth and Kaufer (1989) have also argued that in writing directly perceived external representations are used to maintain elements in working memory, group relevant elements together, group elements such that they are more likely to become internally encoded in a chunk, and store intermediate results of operations. External representations can also be used to maintain the activation of current goals or store future goals.

> D: I would always write things down because otherwise you work through your ideas... and if you haven't written them down you come to the end and you've forgotten things at the beginning. So basically it's just like a memory, I suppose. You can remember what you've thought and in what order you thought it.
>
> A: I always work a bit with lists of things that I don't want to forget... Don't think that we actually crossed things off but that's often what I do. Then when you've got nothing else, when everything has been crossed off, you know you haven't missed anything off.

		Sample	A	No Pref.	B	%A	%B
23	A: It is important to jot down ideas as notes when they occur to me	ALL	92	7	26	78	22
	B: I rarely lose an idea because it was not recorded earlier	CMP	45	3	11	80	20

The majority of questionnaire respondents reported that it was important to record ideas when they occurred, and there was no significant tendency for respondents with a high preference for conventional media to report this more than those with a preference for the computer. This suggests that both computer and conventional media are used as an alternative repository of information than internal memory. However, this study discriminated three finer level aspects of accessibility for the domain of idea sketching. The location of marks can be facilitated by (1) perceptual cues and by (2) terseness, and (3) perceptual cues can also facilitate the access of meaning.

4.4.1. Location through perceptual cues

Under the heading "perceptual cues" this report has shown that many idea sketchers use graphical and typographical cues and find them useful. Evidence from this study suggests that these cues were useful in maintaining high accessibility. Informants commonly reported that it was more easy to see the structure of a paper and find ideas when using an idea sketch than when using a text editor where one might have ideas in 12 point helvetica listed down the left hand margin. Though a representation on the computer might be "informationally equivalent" with a more graphical one on conventional media (though graphical signs can carry information) it is unlikely to be "computationally equivalent" with it (Bibby, 1992). Participants' comments suggested that computers did not provide the cues and space necessary to build an access structure.

> D: If you do have a bad memory, or disorganised memory, then plans can really save you there because if something is marked and underlined you're not going to forget it.
>
> W: I think if you know exactly what you're going to say and you've got a definate structure to it then VED [a text editor] is fine. You just type it in and you're away, but if you want to go back and look for things or change things around then its not very easy at all.
>
> O: I do prefer to do writing... by hand or sit on my bed and spread out... write things like that [pointing at idea sketch] and have things spread out around me. With the computer the computer is too kind of, I don't know, I find I can't sort of think around things as much. It's almost like a sort of spatial thing.

		Sample	A	No Pref.	B	%A	%B
24	A: It is more easy to locate ideas in a page of notes where they are underlined, emboldened or otherwise made more visual	ALL	87	17	22	80	20
	B: It is not significantly more easy to locate ideas in a page of notes where they are underlined, emboldened, etc	CMP	42	10	9	82	18
25	A: Because text on the computer is characterless and homogeneous it is more hard to find one's way around it	ALL	52	29	43	55	45
	B: I have no trouble navigating my notes when they are displayed on computer	CMP	33	17	8	80	20
	Spearman correllation with "preference"	N = 120		ρ = 0.388		p << 0.0005	
26	A: It is more easy to remember the structure of a more graphical idea sketch and locate ideas in it	ALL	49	51	25	67	34
	B: It is more easy to remember where ideas are when they are arranged in linear lists	CMP	27	22	11	71	29
	Spearman correllation with "preference"	N = 121		ρ = 0.168		p < 0.05	

The vast majority of questionnaire respondents believed that typographical or visual cues significantly assisted the location of ideas in a representational structure. More than half of all respondents showing a preference also believed that the homogeneity and characterlessness of computer text made it hard to navigate, and those with higher preference for conventional media also had a strong highly significant tendency to experience this. There was also support for Neuwirth and Kaufer's (1989) hypothesis that grouping of ideas is valuable for encoding as well as for direct use: Most respondents expressing a preference found it easier to remember the structure of idea sketches and find ideas in it (like students who use spider diagrams to help them memorise content for exams). Interestingly, respondents' preference for conventional media correlated significantly with this belief, suggesting that they may dislike computers because of the lack of cues for accessibility.

4.4.2. Facilitation through terseness

Participants' comments suggested that accessibility was also facilitated by terseness, as a good overview allowed marks which were immediately visible to be located easily.

> J: Mainly its important for me to have everything on one piece of paper so that the simultaneity of the whole enterprise is apparent to me. So I can look at that piece of paper and scan over the whole thing and and all of what is going to result from that piece of paper is in front of me. It's instantly accessible to me because I wrote it, and so it's like a huge knotted handkerchief... instant reminders of everything that's going to be needed.
>
> O: I wouldn't need all the paragraphs all the time but its like you want to be able to choose the ones you do see without ten minutes of clicking and pulling and you know trying to get things back off the edge of the screen and losing icons under other windows and lots of things.

W: It's easy to go back and get to this point and think "oh no I forgot something here" and, instead of having to scan all the way back up and find it on the screen, its very easy to say "Oh look I forgot that bit" and write it in here

		Sample	A	No Pref.	B	%A	%B
27	A: Using terse notes helps me to maintain several ideas in mind at once	ALL	89	27	7	93	7
	B: I do not find terse notes help me maintain ideas in mind	CMP	45	13	2	96	4
	Spearman correllation with "preference"	N = 119		ρ = 0.172		p < 0.05	
28	A: If I can get all my ideas laid out in front of me at once this helps me to access ideas quickly	ALL	93	19	13	88	12
	B: It is not a problem that when notes are on the computer one has to open files or scroll to find them	CMP	3	11	46	94	6
	Spearman correllation with "preference"	N = 121		ρ = 0.188		p < 0.005	

The vast majority of questionnaire respondents felt that using terse notes helped to maintain ideas in mind (supporting Neuwirth and Kaufer's (1989) hypothesis that directly perceived external representations are used to maintain elements in working memory), and that idea labels spread out before them allowed them easily to access ideas. Further, respondents' preference for conventional media correllated very significantly with their feeling this, suggesting that users of conventional media may be more concerned to overcome the limitations of working memory and recall from long term memory.

4.4.3. Meaning through perceptual cues

As well as facilitating the location of marks, perceptual cues (including the use of space which is facilitated by terseness, overview and visible area) can carry information itself. For example, Winn and Holliday (1982) write about how "semantic distance" (the metaphorical "distance" between concepts) can be represented in literal spatial terms on paper. Implicit relations can be expressed with spatial layout which cannot easily be expressed with links which demand more formality (Marshall and Rogers, 1992). There was also evidence that the increased context provided by such cues facilitates encoding such that when an obscure label is read the idea sketcher remembers more about what they meant by it.

D: Take the word "social". If I'd just written down "social" and then I came back to it say a week later or something I'd think "OK, 'Social effects'", but the fact that I've written down these questions [question marks] and arrows will just remind me of the particular angle that I'd taken on it.

Most questionnaire respondents felt that perceptual cues facilitated recall, and their preference for conventional media correllated significantly with this.

		Sample	A	No Pref.	B	%A	%B
29	A: It is more easy to remember what you meant by terse notes if they are, say, underlined or spatially arranged	ALL	62	30	29	68	32
	B: It is as easy to remember what terse notes mean if they are simply typed in linear lists as if they involve typographical or graphical aspects	CMP	30	18	9	77	23
	Spearman correllation with "preference"	N = 117		ρ = 0.161		p < 0.05	

4.5. Premature commitment

In the idea sketching domain premature commitment is the property of a notation/environment system whereby a user is encouraged to make choices too early on in the task. In any design task it is important that different options are fully explored. Apart from simply being a waste of energy to become concerned with producing polished formal sentences in writing (Neuwirth and Kaufer, 1989) there is a danger that the writer will become fixated on one option too early in the process. An advantage of spatial layout (Marshall and Rogers, 1992, Malone, 1983) is that rough clusters or piles of idea labels can be left un-named, arranged in a space which is interpreted by the user, without being interconnected with links which imply some more concrete relationship. Participants were generally aware that it might not be a good thing to be too specific early on in idea sketching.

J: It was only as rich as it needed to be for what we were doing... It might actually close off various options of you made it more complete very early on

		Sample	A	No Pref.	B	%A	%B
30	A: Sometimes it is a good thing to jot down ill-formed ambiguous notes rather than become committed to particular options too early on	ALL	89	15	22	80	20
	B: Notes should be as complete and specific as possible, even in the earliest stages of planning	CMP	41	8	11	79	21

Most questionnaire respondents felt that it was useful to jot down ambiguous notes, though a sizeable minority felt that notes should always be as complete as possible. Two subdimensional factors, "downsliding" and "finished character", were identifiable as significant within premature commitment in the domain of idea sketching.

4.5.1. Downsliding

"Downsliding" occurs when people who are trying to operate at a more global, exploratory level are forced, or encouraged, to concern themselves with more local and formal issues. Several participants commented that when using the computer they too easily became drawn into fine grained production and editing of grammatical sentences and could not "see the wood for the trees". On the other hand, conventional media, perhaps partly because they allow better overview and accessibility, were more suited to exploring nascent options.

O: I've always been reluctant to write straight onto the computer. I think part of the reason is you've got too much freedom with it. You write a line and you know you think well I could change that. You're spending far too much time on one line.

P: Once it's on the computer you have to know roughly... have some definate ideas to write down in some sort of an order first whereas this you can sort of play about and change the whole form quite quickly... quickly put arrows to do this and that and the other

Most questionnaire respondents who expressed an opinion reported that they found themselves focussing on writing well formed prose when they used the computer, though many did not experience this.

		Sample	A	No Pref.	B	%A	%B
31	A: When writing with the computer I am sometimes drawn into fine grained editing when I really want to focus on more global problems	ALL	58	19	45	56	44
	B: When I want to plan global aspects of a text on computer I do not find myself focussing on writing well formed prose	CMP	31	10	15	67	33

4.5.2. Finished character

Several participants suggested that the finished looking nature of text on the computer inhibited them from sketching provisional ideas. The finished character of computer text could lead to downsliding because ideas which were sketched on computer required more finishing. Also, it seems possible that ideas which were intended to be tentative when they were recorded might be mistaken for more definate ideas because of the illusion of finishedness created by the computer type.

O: [The wordprocessor] feels more like preparing something because... I mean you've made a page of notes it just looks like a page of notes, it doesn't look like a piece of desktop publishing...

R: I had a book... and I wanted to make a few notes... Somehow I wanted to record the fact that I'd read this book and I had a few thoughts from it. It just wasn't really clear what I wanted to do was try to write my own kind of mini book review of the book, or whether I just wanted to write a core dump of a bunch of loose scattered thoughts that I had... so I sat down and before I knew it, I think partly because I was typing, I started writing stuff that sounded like a Times Higher Educational Supplement or Observer book review. I think it was because I was actually seeing type and generally when I see type about books its book reviews. I was actually emulating that style whereas in fact what I really wanted was just a bunch of aides memoires that if I came back and looked at this spot later it would just trigger off ideas...

P: I think to some extent even just doing some little squiggle helps a little bit. Helps to keep the momentum. When you think of a computer its very hard to just muck about in a way. I mean you can write nonsense but it all comes out sort of printed nonsense and it sort of feels easier just to sort of sketch. Sketch a bit of rubbish here and then... you get a bit of feedback from what you can see and what you think and it sort of forms like that Whereas the computer is a bit cold and sort of hard. It's hard just to draw little squiggles and doodle.

Only a minority of questionnaire respondents found that the finished character of computer text was a problem for jotting down ideas, but a sizeable minority did find this. Further, respondents with higher preference for conventional media were very significantly more likely also to find the finished character of computer text a problem.

		Sample	A	No Pref.	B	%A	%B
32	A: The "neatness", "hardness" and "coldness" of computer text inhibits the sketching of half-formed ideas	ALL	27	20	77	26	74
	B: The "finished print" look of computer text does not make it more difficult to jot down ideas	CMP	20	14	24	45	54
	Spearman correllation with "preference"	N = 120		ρ = 0.515		p << 0.0005	

4.6. Viscosity

Viscosity is the property of a notation/environment system which resists change by editing. Conventional media seem to have a relatively high viscosity. Unless one uses a pencil one cannot even delete marks, while with a computer it is possible to cut and paste text and drawings and restructure an idea sketch. Common sense suggests that high viscosity may encourage premature commitment, as if it is hard to change a representation it seems likely that idea sketchers may continue with the ideas or organisation originally recorded. There was some evidence of viscosity problems with conventional media in the participants' comments in interviews, though there was also a positive aspect to viscosity, as it meant that the participant did not waste time editing and fine tuning an idea sketch.

> S: But the problems of writing on paper are that when you've several things and you want to change a word you have to rub it all out and everything so there's that disadvantage and that's the kind of thing thats led me to writing on line.
>
> O: I mainly write in pencil as well so that even when I'm making a plan I can rub things out it will look, you know the plan will look right and I can use it to do a piece of writing from.
>
> O: I think when I write on paper, even when you write in pencil, it's harder to change what you've written. You can't just wipe it out and delete it so I'm not a great one for crossing things out... It makes me give what I've written more of a go before I go back and change it.

There was also some suggestion from one participant that the "cut and paste" tools which allow easy editing on computer might be a distraction as well as a help. However, only a very small minority of questionnaire respondents found this. (Unsurprisingly, those with higher preference for conventional media were more likely also to find "cut and paste" a distraction.)

> R: Cutting and pasting and moving stuff around interferes too much with my thinking process... I think I do change my mind, I mean maybe several times quickly. If you've written a paragraph I think "I should put that before that, and then that,.. hang on I should put this one before that one" so you know several arrows moving things around, and then you don't want to rewrite it... because maybe you're in full flight of developing ideas.

		Sample	A	No Pref.	B	%A	%B
33	A: "Cut and paste" is usually more a distraction than a help when planning	ALL	10	12	102	9	91
	B: When planning the ability to cut and paste text is a great asset	CMP	6	10	43	12	88
	Spearman correllation with "preference"	N = 120		ρ = 0.333		p < 0.0005	

Though "cut and paste" was seen as an asset by most questionnaire respondents, high viscosity did not seem to be a fatal problem for conventional media. This might be partly because the single words and phrases produced were very quick to produce, and so there was little investment in them (see "temporariness", below). Also, they were terse, abstracted and idiosyncratic so that participants may have been able to change what they meant by them while still using the same physical marks to cue memory for new ideas (see "semantic potential", below).

4.6.1. Exhibits evolution

The analysis of the representations produced showed that they recorded aspects of their history which might not have been recorded had the users been able easily to delete, cut and paste. For example, where ideas were reordered in a list using arrows it was possible to see the original order in which the ideas had been generated, and some different possible orders that had been considered. However, it is not clear how much

this effect is purely incidental and how much it may have some useful function in the activity. Comments from participants, and responses to the questionnaire, suggested that where ideas were reordered with arrows the representation became too messy and confused. On the other hand, where a representation exhibits its evolution there is clearly more context to assist encoding and recall.

> D: I would always write things down because otherwise you work through your ideas... and if you haven't written them down you come to the end and you've forgotten things at the beginning. So basically it's just like a memory, I suppose. You can remember what you've thought and in what order you thought it.
>
> J: A blackboard would be better in that the thing can be manipulated whereas here we wanted to show things but other things couldn't be moved out of the way, they had to be sliced in there and that made it quite confused, or made it confused to me.

		Sample	A	No Pref.	B	%A	%B
34	A: It is fine to reorder ideas on paper by drawing an arrow from an idea to its new location	ALL	45	21	60	43	57
	B: If you reorder ideas with arrows the notes quickly become messy and confused	CMP	24	8	28	46	54

4.6.2. Temporariness

It seems likely that the main reason that viscosity was not a major problem for idea sketches was that, though they were hard to edit, idea sketchers were not prematurely committed to their representations because of their temporariness. There was little investment of time in idea sketches, so participants viewed idea sketches as temporary representations which were thrown away once a structure had been drawn from them or once the ideas they contained had been instantiated in a text. Temporariness may also discourage downsliding as when a representation is temporary there is no point in devoting time to getting it "just right" as the text will only have to be typed into the computer later. The vast majority of questionnaire respondents reported using rough idea sketches which were used only in the moment.

> P: If you've got a blank page its quite intimidating because you start to feel the new idea has to be good and maybe there's more feeling of that when its on a computer whereas if it was just a piece of scrap paper its easy just to play about with anything that doesn't have to be good at all but it can be just a line and then start mucking about and maybe write a word, maybe it gets into more of your sort of subconscious then than typing

		Sample	A	No Pref.	B	%A	%B
35	A: I sometimes sketch ideas to help me think in the moment, and these notes need not be kept for later use	ALL	90	14	22	80	20
	B: I do not produce planning notes except where I intend to keep them for later use	CMP	41	8	11	79	21

4.7. Formalness/completeness

The main difference between the formal notations that have previously been investigated with cognitive dimensions, and the idea sketches that I consider here, might be characterised with a new dimension of "formalness" or "completeness". Formalness (or completeness) is the property of a notation which allows it unambiguously to carry meaning without the reader requiring knowledge of context for interpretation. A formal representation, like an academic paper, is intended to be unambiguously read by anyone with the correct background and language. An informal representation, on the other hand, may depend greatly on the reader's interpretation in the light of "local" knowledge. (Note that formalness is not here used to refer to the difference in "styles" between, say, a business letter and a personal letter, though a business letter may often also tend to be more formal in the sense of the cognitive dimension, "formalness".)Formalness should not be confused with terseness, as representations can be extremely terse, but nevertheless complete. For example, Heath (1982) describes the medical record cards which follow a patient from doctor to doctor throughout her life. These appear extremely sketchy and crude, often leaving much to be inferred (e.g. a diagnosis from a prescription), and trainee general practitioners are often criticised by their colleagues for failing to produce terse enough records. However, the records are nonetheless perfectly formal and complete as they unambiguously describe the patient's history to any experienced general practitioner.

Several participants reported using words or graphical signs which did not (yet) have a clear meaning. The vast majority of questionnaire respondents also believed that ambiguous notes were useful for getting an ill-formed idea down. (Comparing this response with that to question 30, above, it seems that ambiguity may be more useful for recording ideas which are ill formed than for deliberately leaving options open). It has been

suggested that computers may force the user to formalise too much, such that the user rejects the system for intellectual work (e.g. Shipman and Marshall, 1993), but there was not evidence of a difference between people preferring conventional media more, and people preferring computer, on this question.

> O: We used a lot of these arrows that are a lot like implication arrows. We seem to sort of understand what we mean by those. I use that lots when I do this sort of thing and it can mean all sorts of things. It's kind of "led to", "developed into", "related to", sorts of things.

		Sample	A	No Pref.	B	%A	%B
36	A: Ambiguous notes are useful as you can jot down an idea without yet being quite sure what it is	ALL	98	16	13	88	12
	B: I do not write down an idea until it is concrete enough to be written down unambiguously	CMP	49	9	4	92	8

Two discriminable subdimensional factors were found which relate to formalness: "faithful conveying" and "semantic potential".

4.7.1. Faithful conveying

Faithful conveying is the aspect of formalness which allows knowledge to be represented accurately either over time to the person who produced the representation, or to another person. As idea sketches are informal and incomplete they are often poor at storing information faithfully. Several participants reported that if they return to sketches after some time they often find them unintelligible. A large minority of questionnaire respondents also reported this.

> O: If I was making a plan on my own would I understand it any better later? Um... I do have problems sometimes with my own things, as I say with things sort of using arrows... because you don't intend them to be come back to again...
>
> W: I looked at this today before I brought it in to you and a lot of it I couldn't make sense of anymore. I thought why have I said this at this point? This doesn't fit in here at all...
>
> J: I don't remember, I mean, I don't remember. That's P's. P drew this diagram and I think this is one of the early diagrams because at this point we were negotiating what we were going to do with the content of the article. And this was P saying "talk about general AI here and then make it more specific with IMAX here". But I can only guess now what this means.
>
> O: The range of meanings that are put onto [arrows and brackets] are actually fuzzy so I will come back to things and I'll think "well what does that mean?".

		Sample	A	No Pref.	B	%A	%B
37	A: After a period of time, when I return to planning notes I have previously made I sometimes cannot fully understand them	ALL	45	9	74	38	62
	B: The notes I use when planning a text are unambiguous for me and I have no trouble remembering their meaning if I later return to them	CMP	22	7	33	40	60

Participants and the vast majority of questionnaire respondents were aware that such representations were not good for communicating information. Participants appreciated that there was a context at the time the representations were produced which the reader needed to have knowledge of to interpret them. It has also been noted in collaborative design that "... marks often do not make much sense when viewed by themselves afterwards. It is through the process in time of creating and referring to those marks that the group comes to understand what the marks mean" (Tang and Minneman, 1990: 314).

> O: If you'd told us to write it so that somebody else could go and write it up, possibly even somebody who knew about the field, we'd have done it differently.
>
> J: P drew these things here. Can't remember what they're about which is probably because I didn't draw them.
>
> S: I'm obviously having to interpret it now and I was more writing it so I guess [the representations] don't have some of these mechanisms that you use, don't have any meaning themselves, but they do at the time because we did discuss what we meant... I guess there must be some knowledge that you have at the time that you have to rely on for interpretation...
>
> M: Sometimes I do drawings when I'm brainstorming, just in the corners, kind of doodling or on top of the drawings I've done already. And it's hard for me to go back and see what I've done. I mean if you give me this now and ask me what what is, I'd say I have no idea - I can't remember. But now [seeing the video-tape] I see it as a three dimensional representation with one dimension of time. You know, where it progressively gets drawn...

		Sample	A	No Pref.	B	%A	%B
38	A: Some notes which I produce when planning a text would be unintelligible to someone else B: Anyone who can read my notes, and has the right background, would understand them	ALL	104	8	16	87	13
		CMP	52	4	6	90	10

The negative side of low formalness then is poor faithful conveyance. However, there are also positive aspects which suggest that sketches are informal for good reason. As informal notations simply leave out a lot of information they can be even more quick to produce than the tersest formal representations, and this means that sketches have little work invested in them so that the sketcher is not prematurely committed to her representations, and the viscosity of conventional media is overcome. The "super-terseness" which informality allows also means that there is better structurability, overview and accessibility. Finally, informality is necessary for "semantic potential".

4.7.2. Semantic potential

"Semantic potential" (Wood, 1992a) is the possibility for a representation to mean different things. A formal representation, which carries unambiguous meaning for someone with the right background and language, has low semantic potential. (One could say it has a potential of "1".) At the other extreme, a representation whose physical aspect is a knot in a handkerchief has virtually infinite semantic potential, as almost all its meaning is carried through its context. Semantic potential should not be confused with Robinson and Bannon's (1991) notion of "ontological drift". Ontological drift is the sociological phenomenon which occurs where objects of work (documents, designs, systems) pass between "semantic communities" (professional groups with their own specialised languages) which interpret those objects differently. For ontological drift to occur there must be representations with some semantic potential, but representations with high semantic potential can be interpreted differently by people within the *same* semantic community, and even by the *same person* at different times.

I have remarked above under "premature commitment" (question 30) and "formalness" (question 36) that idea sketches tend to include a good deal of ambiguity and idea sketchers see this as necessary. This preservation of ambiguity has also been noted in collaborative design work (e.g. Minneman, 1991). Semantically potent representations seem to be useful in idea sketching for a number of reasons. They have the capacity to stand for the space of possible meanings of an as yet undefined idea, and place it in relation to other partially formed ideas, thus preventing premature commitment. As well as being ambiguous as to precisely what content they stand for, Flower and Hayes (1984: 135) point out that such abstract representations as large white spaces between ideas, arrows and asterisks, etc, "are good tools for thinking with because they do not commit the writer at that point to any particular linguistic means (e.g. the circled note could become a modifying word or phrase, an entire sentence with logical links to the text, or even a heading)." As ideas are generated and organised, and as structure develops, the meanings of representations change or become more precise, but the marks themselves may not be edited. Semantically potent representations can therefore have a low viscosity even though physical ink marks may be difficult to alter or delete.

> R: All of your concepts are changing or evolving slowly. You really have to think yourself back into the conceptual framework that you were in on the particular day. You rarely record things in a fashion which allow you to backtrack into that very easily because I look now, for instance, my definitions of keyterms that I was using were evolving slowly. If you look at any given day the term the same actual piece of syntax that I may have used three months later in a rather different sense will be occurring, and it won't be clearly marked as to which sense that I had particularly in mind when I was writing that, and so its very difficult to decode what is going on.
>
> O: It's kind of acknowledged when I write [plans] that if I look at them again I may get something different and possibly equally valid out of what I've written down.

4.8. Summary of the cognitive dimensions of idea sketches

Viewed as a whole, the above characterisation of idea sketches in cognitive dimensional terms provides a fairly cohesive and comprehensive understanding of the cognitively relevant properties of such representations. These cognitive dimensions and subdimensional factors are summarised in chart 1.

Delayed Gratification	How much effort and delay is involved in creating a representation. It is sometimes important to get ideas down quickly and conventional media is often better for this.
transparency	Can the user be unconscious of the system and concentrate on the task? It is important that the interface does not demand cognitive resources. Computers are more opaque than paper!
richness	Does the representation include many graphical marks, redundant encodings, etc, because it is quick and easy to make it so? Richness facilitates perceptual cueing.
Terseness	Are there few symbols per idea? Terseness allows overview, structurability, lower delayed gratification and in turn higher richness. Conventional media seem to favour terseness.
overview	Can the user perceive much of the representational structure at once? Overview favours accessibility and structurability. Conventional media afford better overview.
structurability	Is the user's ability to reorganise the structure facilitated by and increase in accessibility and lowering of viscosity which results from terseness?
visible area	Is there a large display area for the representation? A large visible area, combined with terseness, supports overview and structurability.
Perceptual cues (typographical)	Can the user produce many typographical marks easily? Typographical cues are facilitated by low delayed gratification and help accessibility by providing an access structure.
Perceptual cues (graphical)	Can the user easily produce graphical marks like clustering, linkng, etc? Graphical cues may not be produced on computer due to low richness.
Accessibility	Can the user access information with ease? Where idea labels are continuously perceived they help maintain elements in working memory and assist long term memory retrieval.
location through perceptual cues	Do perceptual cues help the user direct attention to the relevant parts of the representational structure? Computers do not generally allow such rich perceptual access structures.
facilitation through terseness	Does terseness assist the user in directing attention to the required parts of the representational structure? Conventional media seem to allow this more.
meaning through perceptual cues	Can perceptual cues be used to carry meaning, or provide context which facilitates the recall of meaning? Conventional media may facilitate recall with perceptual cues more than computer.
Premature commitment	Is the user forced to make choices too early in the task, or can she explore different options fully with the representation? Many idea sketchers use ambiguous notes.
downsliding	Is the user drawn into fine grained production of grammatical sentences, when they are trying to operate at a more global, exploratory level? Downsliding leads to premature commitment.
finished character	Does the typographical character of a representation fairly reflect its provisionality, or does its finished looking character mislead the user? Computer text can lead to downsliding.
Viscosity	Does the representation offer high resistance to editing? Computer "cut and paste" should reduce viscosity, but it is not a great problem for conventional media.
exhibits evolution	Does the representation display its history, as well as its current state? History is likely to be diaplayed if deletion is difficult, and may provide context which assists encoding and recall.
temporariness	Is there much investment in the representation, or is it intended to be thrown away shortly after production? Temporariness overcomes viscosity, and discourages premature commitment.
Formalness	Does the representation unambiguously carry meaning for someone with the right background and language, or does it rely heavily on context for interpretation? Idea sketches are informal.
faithful conveying	Can the representation be used for asynchronous communication with others or the self? Informal idea sketches are often unintelligible outside the context of their production.
semantic potential	Can the representation mean different things? Semantically potent representations are quicker to produce, terser, avoid premature commitment, and lower viscosity.

Chart 1: Summary of cognitive dimensions and subdimensions of idea sketches

It is also possible to see how these properties relate to one another. High terseness is necessary to allow a good overview and low delayed gratification. High overview and visible area together allow the space for spatial perceptual cueing. They also combine to allow high structurability. Overview, visible area and structurability all combine to lower viscosity and heighten accessibility. Together with high terseness, high transparency acts to reduce delayed gratification, which in turn allows higher richness. Higher richness facilitates perceptual cueing which in turn allows high accessibility. The semantic potential allowed by informality acts to increase delayed gratification and low viscosity. Finally, semantic potential, low delayed gratification, low viscosity, temporariness and high accessibility all act to discourage premature commitment and downsliding.

Diagram 1: Relationships and dependencies of cognitive dimensions of sketches

Together, these interelated dimensions form a model of the desirable aspects of systems for idea sketching. With such a model it is possible to analyse different media to ascertain their suitability for idea sketching. Sharples and Pemberton (1988) have attempted to characterise the properties of paper, word processor, file cards, post-it notes, whiteboard, back-of-hand, and dictaphone in terms of eight rather arbitrarily chosen properties such as "full text readable", "portable" etc. In chart 2, Sharples and Pemberton's seven media are characterised in terms of the cognitive dimensional analysis developed here, which has a very considerable empirical basis. It is also possible to characterise writing processes (such as those of the Hayes and Flower, 1980, model) in terms of the cognitive dimensions which they require. In the terms of Hayes and Flower, idea sketching is a form of "planning", which consists of the processes "generating", "organising" and "goal-setting". When both processes and media are characterised in cognitive dimensional terms it is possible to see how suitable different media might be for supporting different processes. In order to show how this approach might be applied to the whole of the writing process I have also characterised Hayes and Flower's other processes ("translating", "reading" and "editing") but it should be noted that (1) the cognitive dimensional framework developed here is really specific to idea sketching and other cognitive dimensions may be important in other phases of the writing process, (2) there is no empirical basis for the characterisation of translating, reading and editing given here. Many of the entries in the chart 2 are therefore merely informed guesses which I have made in order to roughly show how different writing media and processes might be characterised. (In the chart, "+" is used to mean "the medium/process has or requires a property", "-" to mean "does not have or require a property", and "=" to mean "does not matter". Boldness is used to emphasise a property or requirement for a property.)

	medium							process					
	paper	word processor	file cards	post-it notes	whiteboard	back-of-hand	dictaphone	generating	organising	goal setting	translating	reading	editing
Easy, fast Gratification	+	-	+	+	+	+	+	+	+	+	+	=	+
transparency	+	-	+	+	+	+	+	+	+	+	+	=	+
richness	+	-	+	+	+	+	-	=	+	+	=	+	=
Terseness	+	-	+	+	+	+	+	+	+	+	=	=	=
overview	+	-	+	+	+	-	-	+	+	+	=	+	=
structurability	+	-	+	+	+	+	-	=	+	+	=	=	=
visible area	+	-	+	+	+	-	-	+	+	+	=	+	+
Perceptual cues (typographical)	+	-	+	+	+	+	-	+	+	+	+	+	+
Perceptual cues (graphical)	+	-	+	+	+	=	-	+	+	+	=	=	=
Accessibility	+	-	+	+	+	+	-	+	+	+	=	=	=
location through perceptual cues	+	-	+	+	+	-	-	+	+	+	=	=	=
facilitation through terseness	+	-	+	+	+	+	-	+	+	+	=	=	=
meaning through perceptual cues	+	-	+	+	+	-	-	+	+	+	=	=	=
No Premature commitment	+	-	+	+	+	-	+	+	+	+	+	=	=
downsliding	-	+	-	-	-	-	-	-	-	-	-	=	=
finished character	-	+	-	-	-	-	-	-	-	-	-	=	=
Low Viscosity	=	+	=	=	+	-	-	=	+	+	=	=	+
exhibits evolution	+	-	+	+	-	+	-	+	=	=	=	=	=
temporariness	+	=	=	+	+	+	=	+	=	+	-	=	-
Informalness	+	-	+	+	+	+	+	+	+	=	-	-	-
faithful conveying	-	-	-	-	-	-	=	-	-	=	+	+	+
semantic potential	+	+	+	+	+	+	=	+	+	=	-	-	-

Chart 2: Using cognitive dimensions to match media and process

5. Studies of sketching in other domains

The cognitive dimensional analysis of writer's idea sketches detailed above is consistent with the findings of recent work on planning in writing, when that work is reinterpreted in cognitive dimensional terms. Also, as writing is essentially a species of design activity, and idea-sketching a particular case of sketching, we can expect that the findings of this study might be consonant with studies of sketching in other domains. In this section a representative (but by no means complete) sample of research on sketching in different domains is

reconstrued within the terms of the analysis developed above. Much of this research does not focus on the issues with which I am concerned (indeed some researchers make only passing mention of some issues) but it is enough that the issues I have identified here are of concern in other areas of design. Petre and Green (1993) argue that it is important to establish that cognitive dimensional generalisations which take into account the toolset or environment as well as the notation, can be contextualised and interpreted in different domains, and suggest that a body of "case law" showing how generalisations apply in specific cases, would fulfil this function. This section demonstrates that the findings from this study are robust across very different sorts of sketching and that the analysis above is the basis of a general framework for the required properties of sketches. (Findings of this literature survey are summarised in chart 3).

5.1. Studies of idea-sketching in writing

Haas (1990) reports findings from an experimental study of author's idea sketching using both computers and conventional media. Chandler (1992) reports a very comprehensive literature survey of established writer's own writings about their own experiences of writing. Chandler (1992b, 1993) followed up the issues arising in this literature survey with a questionnaire survey of academic writers. Both these researchers find, like the study reported above, that writers choose to use pen and paper rather than a word processor for idea generating and planning, especially where the tasks are more long and/or difficult. Both also suggest that part of the reason for this is the low effort and speed of gratification afforded by conventional media. Haas recognises that the terseness of "tags" (idea labels) for whole chunks of content is significant, and both researchers find, through very different means, some evidence that an overview of one's ideas is useful in organising and structuring those ideas, and that the size of the visible area of the workspace is therefore an important factor in useability. Though Haas compares computer notes with notes made with conventional media, and finds conventional media replete with graphical and typographical markings, she fails to focus on the possible functionality of such marks. Haas and Chandler both find that writers may be drawn into being very concerned with fine level details of writing when they intend to plan more. Several of Chandler's writer's emphasise the character of handwriting, and the use of a fountain pen or pencil, as having some effect on the way they think. Chandler also finds that viscosity and the way that conventional media can show their own evolution (through messy scratchings out, etc) may be important issues. Though, in the light of these studies and my own, these issues may seem self evident it is worth noting that in a recent (not empirically based) paper which aimed to "...catalogue some of the difficulties technology brings to writers..." Williams (1992: 1) touched superficially on only a very few of these issues.

5.2. Typographical and graphical design

Black (1990), performed questionnaire studies of novice typographic designers who planned texts using paper or screen or a combination of both. Hewson (1990), herself a typographic designer, describes the tools of the typographer, their place in sketching, and the role of sketching in typographic design, in a non-empirical position paper. Both Hewson and Black find that typographers often use paper in preference to computer, Hewson stressing the speed of gratification, readiness-to-hand and physical attributes of conventional media. Though terseness of marks does not seem to be especially important, Black finds that it is important to be able to get an overview of many different sketches at once in order to organise them, and states that designers often pin their sketches around their workplace. The visible area of the workspace is therefore important in typography. Both Black and Hewson find that typographers use typographical cues in their sketches, for example marks can be marked as more tentative or more certain by the weight of the pencil line (Hewson, 1990). The tentative character of pencil marks helps to prevent premature commitment, while the finished look of text in a desktop publishing system causes downsliding. Hewson suggests that low investment of effort in sketches prevents premature commitment and Black emphasises the fact that in a computer system where deletion, cut and paste is easy "... no concrete record is made of the progress of an idea" (Black, 1990: 288). Hewson also suggests that though they allow cut and paste, etc, CAD systems are too viscous for typographers easily to change their minds. Both Black and Hewson mention the ambiguity and completeness of marks as being a central functional attribute of sketches.

5.3. Fine art

Most of Fish and Scrivener's (1990) paper is devoted to theorising concerning how mental representations might be "amplified" if a sketchy image is allowed to facilitate, augment and influence a percept, and such mechanisms are outside of the remit of this research because (1) they are specific to *visual* sketches (the same mental faculties are not used when we sketch *ideas*), and (2) the metatheoretical orientation of my research resists becoming overly concerned with internal causal processes and rather focusses on the external aspects

of activity and the tools involved therein. However, as artists themselves, Fish and Scrivener touch at an abstract level on several issues which arose in this research. They show that artists' sketches are incomplete and ambiguous and point out that Leonardo Da Vinci believed that untidy indeterminacies in the sketch allow the artist to imagine different options. Artists who produce work with CAD systems tend not to use such technology in the early stages of design and Fish and Scrivener suggest that this is mainly due to the high effort and low speed of sketching in CAD systems, the lack of room such systems have for indeterminacies and tolerances (analogous to formalness), and "degree of abstraction or generality" (Fish and Scrivener, 1990: 117) (something similar to terseness). Some artists work more like oilpainters who manipulate oil on canvas without sketching and would argue that the lack of viscosity afforded by deletion, cutting and pasting, etc means sketching is not necessary with CAD systems, but the impression is that this is a minority view (Fish and Scrivener, 1990: 125).

5.4. Industrial and engineering design

Ballay (1987) reports insights into the process of sketching in industrial design which arose from a protocol analytic study of fifty designers individually performing a simple design task with both conventional media and a CAD system. Ullman *et al* (1990) demonstrate the importance of drawing through all the stages of mechanical design activity with protocol analyses of five mechanical design engineers performing a design task using pen and paper. Lakin *et al* (1989) discusses some issues that they consider important in the design of a system to replace the engineer's design notebook. Lakin *et al* and Ullman *et al* both find that engineering designers prefer paper for early stages of design and Lakin *et al* "take it as an indication of the superiority of paper as a performing medium that most conceptual design in engineering is still done using paper-based Engineer's Notebooks" (1989: 215). Both Lakin *et al* and Ullman *et al* also find that speed of use is the central reason for this (Lakin likens a designer's need for agility of the medium to a musician's requirements of her instrument). CAD systems are too slow to keep up with a designer's thoughts ("loss of a minute can mean loss of an idea" - Lakin *et al*, 1989: 217) and engineers often do not use instruments when drawing for the same reasons (Ullman *et al*, 1990). A related factor which all three research groups mention is described by Ballay as the need for the user to "feel like they are working on the representation, not on the computer" (Ballay, 1987: 81). Ullman *et al* similarly write that "the additional cognitive load to implement current systems is detrimental to the design process. Icon and menu selecting add an unneeded step to creating an image" (1990: 273). Ballay (1987) finds that designers need to consider a great deal of information at once and organise it, and they do this by constantly managing their workplace (which is partitioned into (1) the desktop where information currently in use is arranged, (2) the surrounding wall area where information can be easily accessed, and (3) out-of-the-way storage) such that information can be easily accessed. All three research groups find that formalness is an important characteristic of sketches in design. Ballay (1987) discriminates three dimensions which characterise how design sketches differ from "finished work". These are as follows: (1) "Inclusion" is the level of detail at which a form is represented. (2) "Coherence" is the level of agreement or conflict between different represented partial solutions. (3) "Precision" is the "refinement" with which a design is represented. In the terms of this research "inclusion" is roughly comparable with "terseness", while "coherence" and "precision" are aspects of formalness. Though Ullman *et al* suggest that definition and refinement is simply not necessary in conceptual design Ballay emphasises that the looseness of the sketch is a conscious choice which allows "enough ambiguity so that [designers] can take advantage of inventive opportunities right up to the end of the design process" (Ballay, 1987: 80) and Lakin *et al* similarly criticises CAD tools which "seem to require that the user know in advance what the design will be" (Lakin *et al,* 1989, 215).

5.5. Architecture

Goldschmidt (1991) performed informal protocol analytic studies of expert and student architects solving an architectural problem, focussing on the way in which they use sketches to help them see the implications of their ideas for the problem solution. Carter (1993) performed an informal observational study of architects sketching at drawing boards in two architectural practices, with a view to designing a development of Wellner's Digital Desk (Wellner, 1991) to support design in the domain of architecture by combining paper and electronic representations, similar to the system I have proposed to support design in the domain of writing (Wood, 1992a). As in other design domains, architects make much use of pencil and paper, and produce messy marks quickly. Carter notes that the drawing instruments an architect uses can be placed within reach in a particular location, so that without thinking about it the architect can, say, reach for a set square, make a mark, and replace the square. The working environment of the drawing board is therefore relatively transparent. Similarly, Carter notes that architects tape drawings within easy reach so that they can easily glance at them. Goldschmidt notes that architects sketches are often "so idiosyncratic that they are only

comprehensible to their maker" (Goldschmidt, 1991: 123), but also that architects see in sketches "things which are not explicitly there" (Goldschmidt, 1991: 127).

	E-CAD		DR		Writing			Typography		Fine Art	Design			Architecture	
	Petre +	Shum	Haas	Chandler	Williams	Hewson	Black	Fish +	Lakin +	Ullman +	Ballay	Goldschmidt	Carter
Preference for paper			•	•		•	•	•	•	•			•
Delayed Gratification		•	•	•		•		•	•	•		•	•
transparency					•	•			•	•	•		•
richness													
Terseness	•		•					•			•		
overview	•		•	•			•				•		•
structurability			•	•			•				•		
visible area	•		•	•	•		•						
Perceptual cues (typographical)			•			•	•						
Perceptual cues (graphical)	•	•	•										
Accessibility	•		•							•	•	•	•
location through perceptual cues	•									•			
facilitation through terseness													
meaning through perceptual cues	•												
Premature commitment		•	•	•		•	•	•	•		•		
downsliding			•	•			•						
finished character		•		•		•	•						
Viscosity	•	•		•	•		•	•					
exhibits evolution				•			•						
temporariness						•							
Formalness	•	•				•	•	•	•	•	•	•	
faithful conveying		•									•	•	
semantic potential						•		•			•	•	

Chart 3: Dimensions identified as important in different design domains

6. Conclusion: the cultural-cognitive approach and the dialectics of sketching

I have argued above that a cultural-cognitive approach can inform the design of systems by focussing on the external aspects of cognitive activity. Such an approach should (following from "distributed cognition") consider that people and their supporting artifacts constitute complex cognitive systems. In the study described above, if we consider that the idea-sketcher and the external notations and media together form a complex cognitive system it is important to ascertain what cognitively relevant characteristics the external notations and media should have, such that they complement the classical internal cognitive system. Cognitive dimensions can provide a cultural-cognitive approach with a framework with which to describe and characterise external notations in cognitively relevant terms.

Idea sketching is a paradigm example of an activity in which the functionality of the internal complex cognitive system is profoundly mediated in moment to moment interaction with external mediating representations. Several participants in the study reported here suggested that they had some dialectical relationship with their idea sketches.

> D: It is definately a two way thing. The thoughts in your head produce the plan and the plan acts to restructure the thoughts in your head... In the act of writing [an idea] down you have to make it clearer so the idea is slightly changed in your head... I always find I can sit around thinking about things for days and never actually get anywhere with them but once I write things down... I have to face all the little problems within them, the nitty gritty bits, that when you're just thinking about it you have to just gloss over.

Several of the researchers whose work is briefly reviewed in the previous section take this close relationship between the mind and the paper as the most important characteristic of sketching activity. Chandler (1992a: 69) cites O'Neill as saying that in writing "the writer's fingers and the page are a working ensemble, an alternation of intelligible space and spatialised intelligence". Ballay (1987) characterises design as a series of information transactions between the designer and the environment in which the designer starts sketching without knowing much about what she will sketch, thus changing the task environment such that new ideas and inferences are stimulated. Hewson makes a similar point, drawing on Heidegger's notion of readiness-to-hand, arguing that "the mark-making device is an extension of the designer's mind, which provides the direct means to make the marks the designer needs to see in order to respond to the ideas they embody" (Hewson, 1990: 1). Krauss and Myer (1968) find that architects also constantly create forms and then react to them, and Schon and Wiggins (1992) explore the different sorts of "seeing" that architects do ("seeing as", "seeing in" and "seeing that"). Fish and Scrivener (1990) suggest that in fine art sketches interact with mental imagery to facilitate and refresh mental images and provoke new streams of imagery. Goldschmidt (1991) (who coined the phrase "the dialectics of sketching") similarly emphasises the close interaction whereby marks are drawn until the designer can "read in" what has been drawn something useful. She writes "The old Italian name "pensieri" that was given to sketches when sketching first became a common practice in the art and design world of the Renaissance, means "thoughts"... The name most appropriately described sketches, which are indeed thoughts. Accordingly, sketching is thinking." (Goldschmidt, 1991: 130).

Considering that sketching is actually part of thinking it is possible to see why idea sketches have the cognitive dimensions identified in this research. It is important that idea sketches do not exhibit high delayed gratification in order that external representations can be created without slowing down thought, and similarly it is necessary to have high accessibility and perceptual cueing in order not to disrupt the creative flow while the sketcher searches for representations. Both speed of writing and reading, and the number of chunks of information that can be simultaneously accessed externally, are increased by using terse, incomplete and informal representations. When far many more chunks can be simultaneously accessed than could be considered at once using only internal working memory the sketcher is better able to have an overview and consider different global options without becoming prematurely committed. Though pen and paper are essentially viscous media the use of terse, throw-away representations which cost little effort to produce means this does not lead to premature commitment.

We have seen that sketchers in all design domains use paper as the preferred medium of choice for early conceptual work. Conventional media support very fluent externalisation of ideas in mediating representations in a way that authoring support systems currently do not. The participants in the study reported here were able instantly to choose their "font" (e.g. level of finishedness, style of handwriting), size, the angle and place at which a label should be drawn, the weight of the line, the shape of arrowhead, whether they would produce text or graphical marks, etc, without having to pull down menus or select tools. This ease of drawing was accompanied by an ease of reading which allowed a close interaction between the author and the mediating representations through a feedback loop. The visual structure of mediating representations made them more memorable and provided cues for access and navigation (e.g. lines between ideas, typographical cues, spatial layout) so that authors could locate ideas and their relations with ease. These

efficiencies allowed the participant a speed of thought and communication both with an interlocutor and with the self.

It is clear that conventional media may often complement the individual mind better than authoring support systems or CAD systems in the early conceptual stages of writing or designing. Such systems may generally not support conceptual design well: They exhibit delayed gratification, and generally require cognitive effort to be devoted to dealing with the interface which distracts from the creative task. Representations are generally more homogeneous and provide fewer perceptual cues and lower accessibility. Accessibility is also diminished by the small workspace provided by a conventional screen which encourages the author or designer to be concerned with small details, thus becoming prematurely committed to particular solutions.

Bearing this characterisation of the desirable cognitive dimensions of notations and media for sketching in mind, it may be possible to combine the desirable properties of conventional media with the lower viscosity provided by a computer's editing capabilities. For example, Wellner's (1991) "DigitalDesk" could be used to provide a desk sized workspace on which paper and pencil could be used with projected computer windows and an electronic stylus for idea sketching (Wood, 1992b) or for the design of two- and three-dimensional artifacts (Carter, 1993).

7. Postscript - further work: the socio-cognitive dimensions of idea sketches

I have argued that system design might be informed by a cognitively and socially relevant analysis of the artifacts in an activity, rather than focussing primarily on the cognitive or social aspects of an activity (as do cognitive psychology and ethnography, respectively). This paper has used cognitive dimensions, within the proposed cultural-cognitive approach, to consider how creative cognition might be mediated through external representations. But creative activity is often collaborative activity (e.g. Minneman, 1991) and in the study described above the pairs of participants supported one another's cognition in their moment by moment interactions using the external representations and media. Further work will develop a set of "socio-cognitive dimensions" which can characterise those aspects of external representations and media which determine their suitability for communication in different activities where "collaborative mediation" (Sibun and Shrager, 1992) takes place. It is anticipated that these socio-cognitive dimensions will draw on the approach of Green (1989) and combine it with a development of Clark and Brennan's (1991) "constraints on grounding".

It may be that cognitive dimensions required of notations and media for communication in creative activity are similar to those required for individual creative activity. For example, just as low delayed gratification and high accessibility are necessary in order not to slow down an individual's thought, they are probably also necessary in order that communication is not slowed down when two people are engaged in creative discourse. Similarly, as the overview allowed by terse representations allows individuals to help themselves structure their own thoughts it may help a pair to co-ordinate their thinking. However, one cannot communicate with another with sketches which are idiosyncratic and informal without augmenting them with contextual information, so an analysis of collaborative idea sketching must include a characterisation of the other channels of communication, such as speech and gesture, which surround the sketches.

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A COGNITIVE DIMENSIONAL ANALYSIS OF IDEA SKETCHES

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