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Willemien VISSER
Projet de Psychologie Ergonomique
INRIA - Rocquencourt
78153 LE CHESNAY Cedex
France
tel: + (33) (1) 39 63 52 09
fax: + (33) (1) 39 63 53 30
email: visser@nuri.inria.fr

Abstract. In the study examined in this paper, intended at the start to analyse the reuse of problem-solving elements in design, what came to light is that the use of other types of "episodic" data, especially knowledge, also plays an important role in this activity. The paper presents various interesting results and raises different questions. Some of the results concern the contribution of different types and aspects of episodic knowledge to the construction of problem representations and to the development and evaluation of solutions; the types of information sources consulted and the modes employed; and the interest of data gathering from human informants rather than from non-human information sources. Some of the questions concern the distinction between the "reuse" of problem-solving elements and the "use" of other types of episodic data; and differences and distances between knowledge "domains". The paper closes with design-reuse assistance specification, a difficult question given the present state of knowledge on use of episodic data.

Keywords. Design. Protocol analysis. Episodic Knowledge. Episodic Data. Reuse. Problem solving. Cognition. Case-Based Reasoning

Problem solving based on "reuse" of problem-solving elements, i.e. particular solutions to particular problems, rather than on the use of general problem-solving knowledge ("problem-solving reuse", or "design reuse" in this text), is considered to play an important role in design[1,2,3] (cf. Case-Based Reasoning[4]). This affirmation which is often made, is generally based on introspection by authors who are design methodologists, A.I. researchers or designers themselves. The conclusion which may be drawn from their papers is that designers may have good reasons to proceed to design reuse. A question which may be asked however is: do designers indeed proceed to reuse, and, if they do, why, and how do they proceed? Only a few empirical studies have been conducted on this question, nearly exclusively in the domain of software design[5,6].

The study presented in this paper intended to examine the question of design reuse in order to identify requirements for reuse support tools through a characterisation of the actual reuse activities.

The analysis conducted and the first results obtained led to a change of perspective: we discovered that, in addition to the reuse of problem-solving elements, the use -or reuse- of other types of "episodic" data, particularly knowledge, also played an important role in the design problem solving examined.

This paper will present the questions and hypotheses formulated at the start of the study and the elements which led to modify the original perspective (first section), the results on actual problem-

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solving reuse (second section), and the results concerning the role played in design by episodic data not specifically linked to problem solving (third section). The Discussion will review and discuss these results and present some suggestions for design assistance.

1 Protocol analysis in search for problem-solving reuse: identification of episodic data

At the start of the study, we intended to analyse the protocol of an individual designer (Dan) with respect to problem-solving reuse.
The paper does not present the technique adopted for the protocol analysis. Its rather informal quality seems justified to us given its exploratory character and its aim, i.e. to examine if designers proceed to reuse, and if so, to identify possibly different reuse modes and/or types of knowledge reused.
The analysis was guided by several questions based on results obtained in three previous empirical design studies[7]. Although these previous studies on designers working in different domains (software[8], mechanical[9], and aerospace-structure[10] design) were not especially conducted in order to examine reuse, Visser[3,6] identified several characteristics of design reuse. Two of them are related to aspects of reuse identified in the present study and will be discussed in the final section of this paper.
• **Target-source relationships**. First, the association between the design problem under hand (the "target" problem) and a reusable problem-solution association (a "source") is often one of similarity (analogy or another kind of similarity), but also other relationships may be exploited by designers, especially opposition[7]. Second, the source can come from a more or less remote domain (even if the "distance" in question is difficult to measure).
• **Authors of the sources.** Designers refer to both sources developed by themselves and to solutions designed by colleagues or anonymous authors (e.g. designs presented in the literature, such as famous architectural projects).

1.1 When does one call use of problem-solving knowledge "reuse"?
Knowledge, i.e. data collected, processed and/or elaborated in the past, and integrated into memory, always plays an important role in problem solving.
The knowledge used in problem solving which has been studied most is abstract knowledge (problem-solving schemas or rules) referring to types, or categories, of problems and solutions.
Recently, researchers have started to discover the importance of problem solving reuse: the use of "episodic", i.e. particular, experience-linked sources which are at the same abstraction level as the target problem ("cases"), rather than general knowledge structures at a more abstract level. Notice that both can be applied in one and the same problem-solving situation[11].

1.2 Different types of episodic data
We use the term "episodic data" as an extension of Tulving's[12] notion of "episodic knowledge". Next to knowledge, i.e. data from an internal source, a problem solver may indeed use information on particular experiences coming from external sources.
In order to identify elements reused by the designer, we analysed the protocol in search for references to the use of episodic data exploited in order to solve the design problem. Looking for this kind of data, the analysis indeed led to the discovery of episodic problem-solving elements, but we also identified examples of episodic data not especially linked to a problem-solving context, but still very important for the resolution of the design problem. When referring to these data, often the designer verbalises a link relating them to a particular episode which was their "experiential" source.

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For example, the knowledge that, "in pack-to-bike attachments, the centre of gravity must be kept as low as possible" or "the pack should be attached in the centre" can be considered general rules applicable to designs involving bike and pack combinations. The way in which Dan, however, evokes this knowledge as related to -because based on- his personal biking experience, leads to qualify the knowledge he refers to as "episodic":

00:55 "That sorta looks classy, having a backpack in the centre; in fact when I biked around Hawaii as a kid, that's how I mounted my backpack. It was a framepack and I have to admit that, if there's any weight up here, this thing does a bit of wobbling and I remember that as an issue."

(Boxes contain quotations from Dan's protocol, where these can be found on the basis of the time indication, such as 00:55.)
In addition to the reuse of problem-solving elements, we therefore analysed the use of such other episodic elements. This "use" could have been called "reuse", and could have been not distinguished from the "pure" problem-solving reuse. We will come back to this point in the Discussion.

2 Reuse of problem-solving elements

We first present briefly a global analysis of the activity and the ideas Dan has about reuse. We then characterise the problem-solving sources reused and the different types of their use.

• **Global analysis of the activity.** In order to relate the use of data to the main components of the design activity, two "stages" were distinguished in the design process analysed, according to the activity which played the major role in the stage.
00:16 - 00:52 (36 minutes) Stage 1. Construction of a problem representation;
00:52 - 02:18 (86 minutes) Stage 2. Solution development and evaluation.
Two remarks should be made concerning this decomposition:
• We have many reservations concerning decompositions of cognitive activity into separate, independent, consecutive stages[13].
• The distinction between problem-representation construction and solution development and evaluation is particularly ambiguous in design where the progressive construction of a problem representation is a very important component of solution development.

• **Dan's ideas about reuse**. At several occasions, Dan's remarks on his activity, translating his metaknowledge -which we (try to) distinguish from the verbalisations of particular traces of his activity- may make us think that reuse is playing an important role in his activity.
Five minutes after he has begun the design session, Dan asserts:

00:21 "There's no sense in starting from scratch if you can start at square two instead of square one or square zero".

A few minutes later, he states:

00:21 "My general philosophy is: don't try to reinvent the state of the art if it already exists".

At 00:35, he reminds this philosophy:

00:35 "Don't redesign things".

2.1 Characteristics of the sources

Sources may be qualified with respect to many features. Five have been selected to be used here, because of their interest in the study.

• **Two families: Batavus and Blackburn**. Data on particular designs and devices play an important role in Dan's construction of his problem representation. These data mainly come from two families. One is the design of a carrying / fastening device and a corresponding prototype elaborated by the client, Batavus. The other comprises various carrying devices developed and commercialised by a concurrent company, Blackburn.

• **Two aspects: descriptive and evaluative.** Dan examines these sources from two angles: a descriptive one (technical-commercial presentations) and an evaluative one (users' evaluations, manufacturer's tests and judgements by an expert, a Blackburn employee).

• **Different status: from preliminary design to validated product.** The solutions have different status in the design - validation cycle: Batavus' solutions are a preliminary design and a prototype; Blackburn's devices are final products, i.e. validated solutions.

• **Different degrees of "satisfactoriness".** The Assignment mentions that "the user's test performed on [the] prototype … showed some serious shortcomings". Thus, the prototype design is an existing, unsatisfactory solution to the present design problem.
The Blackburn solutions are more or less satisfactory: the main object of the phone call is to identify the degree of "satisfactoriness" of different solutions and the underlying factors.

• **Availability**. The existence -and thus possible availability- of the Batavus solutions and evaluations has been referred to explicitly in the design assignment; that of the devices by Blackburn or other companies had not.

2.2 Use of the sources

The different ways in which Dan uses the sources are going to be detailed under two headings translating the two global objectives corresponding to the two "stages", construction of a problem representation, and solution development and evaluation.

2.2.1 Construction of a problem representation

Three examples of the way in which sources are clearly used to construct a problem representation are given in this sub-section, but a more equivocal example may be found in the next section ("Solution shift or problem-representation shift?").

• **Examine data: first descriptive, then evaluative**. In order to construct his problem representations, Dan analyses the sources, going from preliminary design to final product, and from descriptive to evaluative data. After he has read the Assignment, he asserts his general goal, translating one of his first problem representations:

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00:19 "OK, so I am going to make a concept design for the device and this is a … 'carrying / fastening' 'device' … and it is to attach to a … mountainbike".

• **Examine "what exists already": a "quick way of getting started"**. An examination of the Batavus prototype and its users' evaluation are considered a "quick way" of getting some ideas of "what exists already" (descriptive data) and "what's not acceptable" (evaluative data).

00:27 "OK. This is the part of the process where I'm sort of just getting some familiarity with the design and with the design issues and state of the art."

• **Examine similar, existing solutions.** After a quick analysis of the "home-made" solutions, Dan asks for information on "any other backpack, framepack / backpack or carrier devices [of which] the Company [has] done any market surveys". The experimenter presents him with "comparable products available in the US", from Blackburn and another company, Winchester. Dan examines the Blackburn documentation, then skips through the Winchester material, which he judges as not relevant for his present task.

After these descriptive data, Dan asks for "user evaluations of the different types of any of these products" (see above, "Examine data: first descriptive, then evaluative"). When the experimenter cannot provide these, Dan tries to obtain them from another source, i.e. a Blackburn employee, whom he is going to question by telephone, a usual information-collection mode to Dan.

2.2.2 Solution development and evaluation

The first three uses of the sources described below are presented as mainly contributing to solution development, but the second one, e.g., illustrates the arbitrary character of the distinction between problem-representation construction and solution development and evaluation.

• **Solution proposal.** Source analysis and evaluation, mediated by a more or less elaborated problem representation, lead to solution formulation.
As soon as he has looked through the three drawings of the prototype, Dan evaluates, negatively, the device:

00:23 "[It] doesn't directly take advantage of the frame."

One of the two key features of his own solution is exactly going to take advantage of the frame:

01:54 "That is going to be <u>the</u> feature: … [four] clips holding the backpack."

His quick examination of the prototype drawings also leads Dan to formulate his first solution idea:

00:22 "Put it on the front handlebars."

This solution proposal may be explained as the result of a particularly strong expectation-driven processing of the source: the Batavus carrier is a frame mounted <u>on the rear</u> of the bike.

• **Solution shift or problem-representation shift?** Mainly because of information gathered during the phone call with Blackburn, the "front-handlebars" idea (see above) is abandoned. Dan opens the solution-development stage asserting:

00:51 "My first thought is: 'Hey, the place to put it is back here'."

One might analyse the observed shift as leading to, either a "new" solution to "the" problem, or a solution to a "new" version, i.e. another representation, of the problem.

• **Solution-attribute assessment**. The importance attributed to the solution constraints "heel and thigh clearance" (as Dan reports during debriefing) is based on data gathered on the Blackburn solutions during the phone call. This importance leads Dan to calculate, approximately, the distance required between the pedal and the backpack.

The following three uses of the sources contribute to solution evaluation.

• **Anticipation of possible problems and solutions.** Dan questions the Blackburn employee, consecutively, on a great number of characteristics of the carriers and their evaluation (00:39 - 00:44), in order to anticipate the things "people can complain about" and to try to find out "what problems I am going to have and pick the right option". So he asks very precise questions about the possible positions of the carriers: front vs. rear; above the wheel (top-mounted) vs. alongside the wheel (side-mounted); if side-mounted: on one or on both sides; if high above the bike: front vs. rear.

• **Proposal of two solution options, but elaboration of only one.** The side-mounted location is considered by the Blackburn employee as one of two possible options; the other is the top-mounted location. Dan does not elaborate, however, both options. Mainly for reasons of making what -he thinks- "everybody likes", he privileges the central top position:

00:57 "There is that issue of it being off the side: you know, from the aesthetics standpoint, everybody likes things symmetric."

During debriefing, Dan notices that, due to bad scheduling, he did not have time enough to elaborate both options:

"I probably woulda wanted to make two designs or something like that, try the side-mounted one and the back, [but] scheduling my time on these things like this, that's the hardest part".

• **Confirmation of the possibility and/or validity of a solution proposal.** Based on the use of both problem-solving sources and personal experience, Dan develops a solution to the "parallelogram" problem in the form of a triangular structure.
In order to evaluate his idea, he examines if Blackburn had implemented such an option, i.e. he uses previous problem-solving elements to confirm the possibility and/or validity of his idea. When he discovers that Blackburn indeed did, Dan elaborates the idea, which is going to become one of the key features of his final solution, "a triangular rigid structure with no bends in it" "providing the lateral stability for the rear of the bike".

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3 Use of other episodic data

As noted above, not all episodic data used in order to solve a problem come in the form of problem-solving elements. The analysis of the protocol shows various interesting examples of other episodic data used in order to solve the design problem.

Episodic data can come from an internal source -a person's own memory- or from external, other sources. Both were exploited by the designer.

3.1 Exploiting one's own experience

Personal experience in cycling with or without a backpack, on a mountainbike or another bike, plays an important role in the construction of a problem representation, in addition to the previous problem-solving elements whose reuse has been presented above.
The personal episodic knowledge based on this experience can be used in different ways.

• **Solution proposal.** In order to determine a distance of the backpack to the frame that he wants to base on foot size, Dan takes his own body as the reference:

00:52-00:53 "I have about a 12 inch foot: I would assume that you probably don't wanna have a foot which is any more."

N.B. This "bodily" "objects-at-hand"-based knowledge might be considered as different from episodic knowledge (for the "objects-at-hand" and its pervasive use in Dan's design problem solving, see [24]).

• **Solution evaluation**. Dan also uses his biking experience to corroborate users' evaluations from the test report:

00:26 "I've read the Users' trials / evaluation. I have some agreements with that: the fact that the backpack is handled in a vertical position puts its centre of gravity very high: having used a backpack on a bike in the past and having ridden over many mountains …."

• **Solution-attribute assessment**. The importance attributed to a solution attribute may be based on episodic data. An example is the experience-based knowledge that the rigidity of the backpack-bike attachment is very important:

01:00 "The biggest thing that I remember in backpack mounting is that it's gotta be rigid, very rigid!"

The great importance of the rigidity attribute contributes to the choice of one of the design's key features, a "triangular rigid structure".

• **Attribute-value choice.** Personal experience may be a unique source for the adjustment of a theoretically developed value to reality. A possibility which "holds" "in theory" may be considered not "realistic" because of what may happen. Personal experience may have shown that what "might happen" indeed happens in real life -or that the risk that it happens is great. This may lead a designer to adapt the theoretical value:

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01:58 "OK now the reason I'm also gonna do that is because I'm sure that people are gonna try and misuse it; in fact kids are gonna sit on this thing so it's probably gonna have to be able to handle a little bit more than that."

• **Signal possible problems**. This function is more general than those presented above. The analysis shows that an important, possibly unique role played by episodic-data use is to point to possible problems (cf. the examples presented above, and especially the use of personal experience to adjust a theoretical value). Personal experience may make designers become sceptical concerning certain characteristics of a "theoretical" design, and not base their final design on it:

01:35 "[Being] in line is something that I never believe fully and not only that: if you got into your first little bike accident and you ever bent this frame, you might very well not have them in line, so …."

3.2 Exploiting the experience of other people

The experience of other people is as well an information source used in problem solving (cf. also the use of the phone call with the Blackburn employee whose expertise was exploited to gather design problem-solving elements). This experience can be accessed and exploited in several ways.
The interest of data gathering from human informants rather than from non-human information sources will also be discussed below.

3.2.1 Using other people's experience in problem solving

Other people's experience may be referred to explicitly as coming from them, or implicitly -or not at all- if the experience is considered a shared one.

• **Using friends and colleagues as informants.** Dan often uses -or under normal conditions would use- friends as informants.

00:33 "What I would do at this time if I was [at my office]: I would get on the phone, call up some friends …. I have a friend who happens to have worked in the bicycle business for many years and I would probably call him and pick his brain a bit."

Designers often use colleagues as informants -or colleagues present themselves as such without being requested explicitly[14, 15].

• **Using other people's experience as "shared" experience**. One can also use other people's experience without perceiving the need to refer to them as source. This may be due to the fact that one considers that one also possesses the knowledge in question on the basis of one's own experience. For example, without having asked, Dan knows how packing is done by "many people":

00:51 "Framepacks: many people don't carry their sleeping bags inside: they would carry it outside."

Thus, designers use other people's experience as "shared" experience when they attribute to these other people knowledge, beliefs, appreciations or other experiences that they (also) have had themselves. In these cases, there is no distinction between one's own personal episodic knowledge and that of other people.

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An example is Dan's decision that the weight "one" would carry on a mountainbike is going to constrain the weight one would put into one's backpack:

00:51 "You wouldn't carry that much on a mountain-bike. I would say probably in the order of 20 pounds …; I think that that's more like it of what a person might have."

(where "that much" refers to the "theoretically" possible weight, which is going to be adjusted, see above)

3.2.2 Interest of human compared to non-human information sources

Human informants may often provide information which could also be found in other, non-human sources (books and other technical documents or data-bases). There may be several reasons to prefer to refer to human rather than to other information sources.

• **Access is "direct"**. This point may be related to something Dan notes twice concerning calling up informants: it is "a way of getting up to speed quickly":

00:46 "In fact I might very well call up a few local bicycle stores and get some information too if I were doing this and I had to really get up to speed high."

• **Access to the underlying history and justifications**. Informants, if they have been involved personally in the experience on which the data they provide are based, may be able to provide, next to these "pure" data, the history and/or reasons concerning the adoption or rejection of certain choices underlying these data.

• **Access to other expertises**. If the informant is an expert in a domain in which oneself is not, she or he can present or combine information in an expert way. The telephone call with the Blackburn employee is a good example: this person knows the Blackburn devices, and the information that he can present Dan with is incomparable with the information which Dan alone could get from the technical-commercial presentations received. Dan exploits this possibility with great ability: he is also an expert in design, even if not of bike and/or backpack devices (see below Berlin's[14] remarks concerning knowledge on information sources as an aspect of expertise).

• **Access to other viewpoints.** Other people may have had the same information sources, and/or possess information on the same objects as I, but they probably have processed this information from another viewpoint -or they simply have processed it, whereas I did not (yet).

• **Trade off between the gain and the cost of using human informants**. The fact that referring to human informants has a particular interest does not mean that Dan decides to exploit all human informants available: the interest of referring to people is generally a trade off between the gain of the information which can be collected from them and the cost of what has to be given to them in return, e.g. personal attention, interest in the other, which, in addition, both also take time.

00:45 "I had considered calling another friend. I'm not gonna do that right now because in the interests of time here ….: I'm gonna have to ask about his wife and his kids and all these other things and also how the bicycle business is.… If I were normally designing this thing, rather than calling him during the day, I might call in the evening."

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4 Discussion

A discussion of the results will be followed by a reflection on their repercussions for design assistance.

4.1 Discussion of the results

After a paragraph on the frequency of the use of episodic data in the design process, the results will be related to two important aspects of reuse identified in previous design studies (presented in the first section of this text).

4.1.1 Is the use of episodic data frequent in design problem solving?

Explicit references in the protocol to problem-solving reuse and other use of episodic data not necessarily exhaust the effective use of these data, so these (re)use activities probably are more frequent than protocol analysis may suggest.
Secondly, we did not measure the proportion of the various design solutions elaborated by Dan based on episodic data compared to solutions based on general knowledge, often called "solutions developed 'from scratch'".
Given these restrictions, the only conclusion on this point can be that this study has presented evidence for a multifaceted contribution of episodic-data use to design. One may formulate the hypothesis that the use of other than strictly problem-solving linked episodic data has had such a great importance in the present design activity because Dan had never designed bike and/or backpack devices.

4.1.2 Target-source relationships: Reuse indeed, but what about analogical reasoning?

The relationships between the sources exploited and the target problem which they contribute to solve, can all be considered to be relationships of rather "close" similarity: the two families of previous designs reused were, the one the solution to a first version of the target problem (Batavus' prototype), and the other the solutions to a very close problem (Blackburn's devices designed for carrying packs, without a specific fastening device and not especially for mountainbikes). The other episodic knowledge exploited came from the domain of biking, with and without a backpack. One might thus conclude that no analogies from "completely different" or "remote" domains were evoked.
Two remarks, at least, may be formulated concerning this conclusion. First, as noticed already, "distances" between domains are difficult to measure. Second, and more importantly, what delimits a domain? The target problem, i.e. the design of a bike-backpack carrying / fastening device, may circumscribe as the relevant target domains, those of "bikes", "backpacks", and "carrying / fastening devices". Many questions might be raised concerning this circumscription. The only one we want to evoke briefly is the following. Is the domain of "biking", from which emanate several instances of episodic data evoked by Dan, this domain of "bikes" that we considered one of the three target domains? The knowledge concerning the everyday activity of biking, with or without a backpack, on a mountainbike or not ("general" or "common-sense" knowledge), can it be considered as pertaining to the same "domain" as the knowledge involved in designing devices for bikes ("technical" or "scientific" knowledge)? Does the knowledge on the everyday use of an object pertain to the domain containing the technical-scientific knowledge on this object? Does a designer of an artefact proceed to an inter-domain shift when he or she refers to his or her everyday knowledge on the use of this artefact, and does she or he thus use analogical reasoning?
This question is related to the following: which kind of knowledge is necessary, or even only

relevant, for design? Is it -only or especially- technical-scientific knowledge? As far as we know, the research literature on design does not seem to consider that the role of common-sense knowledge is important -even if it may mention this role[16]. Secondly, even if simulation in the "application domain" is often attributed an important role in design, the contribution of everyday knowledge in this simulation is never underlined. Still, in order to simulate mentally the use of a device, often the knowledge required is everyday knowledge. What about the present design if Dan had never ridden a bike?
Among the three other design projects we have analysed until now[8,9,10], the Visser[10] study was the only one showing a frequent exploitation of what we considered "analogies" from rather "remote" domains: for the design of an unfurling antenna, the designer studied in [10] referred to conceptual solutions such as "umbrella" and other "folding" objects. The project analysed in [10] was, of all three, the one requiring most innovation: "unfurling" was a new concept for antennas. This may perhaps explain the importance of the use of analogs: researchers have often suggested that there is a close link between analogical reasoning and creativity, and that creativity is crucial in innovative design[17].
The present design project may be qualified as rather innovative, so the question concerning the possible dependence of creativity on analogical reasoning remains open to further examination.

4.1.3 Authors of the sources
The previous problem-solving elements which Dan reuses come from various authors, different, from the designer himself. The episodic data Dan uses is both based on his own, and on other people's, experience.

4.2 Design assistance
Do the results of this study have repercussions for design tools -other than the ideas already often suggested in the literature on design, and on design reuse[3]? Which were the specific problems encountered by the observed designer in proceeding -or trying to proceed- to reuse?
After some remarks about repercussions of the results which are not specific to reuse, we will discuss the difficulty to assist reuse.

4.2.1 General design assistance
Three problematic aspects of Dan's design activity are discussed, all three having been discussed already in other design studies, but all three not (yet) having received a real "solution".

• **Visualisation aids**. When the experimenter asks Dan if there were any "things which were particularly difficult", Dan refers to two problems. The first one is visualisation, which he considers as "one of the biggest problems" he had, "at least in the preliminary design".
The problem is known from the design literature, but this does not necessarily mean that tools providing effective assistance on this point are available[18,19].

• **Scheduling aids.** The other problem Dan refers to is "scheduling my time on these things like this".
Visser[20] has discussed the problems involved in planning during design and in assisting the activity of organising one's design activity. Most existing design support tools are (still!) backed up by hierarchical-planning models of the design task which does not correspond at all to the actual activity of design organisation[7, 13,20]; and they do not support conceptual design.

• **Assisting alternative-solution development**. Dan says that he would have followed up longer

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than he did with two options, were it not his scheduling and other time problems.
Several design studies have shown that designers generally stick to their first solution idea[21,22], amending and patching it, and that they neither change it for another, nor develop it in parallel with other solution candidates.
Tools assisting working-memory management may be an aid on this point, but other factors than memory limitations certainly play a role and might require specific support modalities.

4.2.2 Design-reuse assistance: Providing access to the state of the art
As long as we has so few data on the activities implemented in reuse, it will be difficult to specify assistance tools. Given the results of the present study, what can be said about needs for assistance?
Dan considers that "there's no sense in starting from scratch if you can start at square two instead of square one or square zero": one should take advantage of "what exists already".
Traces of previous designs exist, on paper and in computerised data-bases; books, documentation and catalogues are manifold; colleagues possess information on "what exists already" -but they are not always there, especially in technical domains where there is a considerable turn-over.
However, providing designers with enormous bases, containing all possible information on "what exists already", is not a solution. The difficulty is indeed the access to the data (for the support of analogical reasoning, in particular in the form of access to analogs and other candidates for reuse, see[23]).
Berlin[14] points out that an aspect of expertise is knowledge about information sources: if these are human, experts know their areas of expertise and their "approachability"; concerning documentation, experts know "its reliability, location and tricks of use" (p. 14). As Berlin notices, "this type of information is rarely documented, yet is essential for proficiency" (ibid.).

4.2.3 Do designers need assistance in use of, and access to "other" episodic data?
This study has shown the use of other than problem-solving linked data, but -as noticed above- not its absolute contribution to the solution process. Concerning real design situations, we still know less about this contribution -only some anecdotal information that may be glimpsed through introspection.
And if the use of episodic data plays indeed an important role in design problem solving, do designers need support in this use? One may suppose that the difficulties involved are similar to those of problem-solving elements reuse, but they are perhaps greater, or more complex, because of the "private" character of episodic data.
Educators worry about the difficulty to provide students with "reference information": how can they manage to familiarise beginning designers with the enormous richness of experience in their field? Even if they possess (elements of) "libraries of past designs", these are not documented with respect to important questions for -not only- novices in a domain, such as solution procedures and alternatives which have been taken into consideration, and choices made and their underlying justifications. In addition, also here the question of access and exploitation is an enormous problem (see above).

These considerations lead us to conclude that, in the present state of knowledge on use of episodic data, design-reuse assistance specification remains a difficult question. As defended already, here and elsewhere[7], we judge that the main way to advance on this point is to analyse empirical data collected on actual reuse activities, in experimental contexts, but definitely also in real, professional work situations.

Preprint of
Visser, W. (1995). Use of episodic knowledge and information in design problem solving. *Design Studies, 16*(2), 171-187.
Also in N. Cross, H. Christiaans & K. Dorst (Eds.) (1996), *Analysing design activity* (Ch. 13, pp. 271-289). Chichester, England: Wiley.

Acknowledgements

The author wishes to thank Laurence Perron-Bouvier for several embarrassing comments on the first version of this paper: we did not manage to take all of them into account. Thanks also to Jean-Marie Burkhardt and Françoise Détienne.

References

[1] Pu, P. Introduction: Issues in case-based design systems. AI EDAM, 1993, 7 (2), 79-85, and the other papers in this special journal issue.
[2] Trousse, B., & Visser, W. Use of case-based reasoning techniques for intelligent computer-aided-design systems. Proceedings of the IEEE/SME'93 International Conference on Systems, Man and Cybernetics - Systems Engineering in the Service of Humans, Le Touquet, France, October 17-20, 1993.
[3] Visser, W., & Trousse, B. Reuse of designs: desperately seeking an interdisciplinary approach. In W. Visser (Ed.), Proceedings of the Workshop of the Thirteenth International Joint Conference on Artificial Intelligence "Reuse of designs: an interdisciplinary cognitive approach", Chambéry (France), August 29, 1993. Rocquencourt: INRIA, 1993.
[4] Kolodner, J. L. Case-based reasoning. San Mateo, Calif.: Morgan Kaufmann, 1993.
[5] Visser , W. (Ed.). Proceedings of the Workshop of the Thirteenth International Joint Conference on Artificial Intelligence "Reuse of designs: an interdisciplinary cognitive approach", Chambéry (France), August 29, 1993. Rocquencourt: INRIA, 1993.
[6] Visser, W. Raisonnement basé sur des cas: une thématique transversale en psychologie et ergonomie cognitives. In S. Rougegrez (Ed.), Séminaire "Raisonnement à partir de cas" (Rapport interne du LAFORIA n° 93/42). Paris: Institut Blaise Pascal, LAFORIA, 1993.
[7] Visser, W. Designers' activities examined at three levels: organization, strategies & problem-solving. Knowledge-Based Systems, 1992, 5 (1), 92-104.
[8] Visser, W. Strategies in programming programmable controllers: a field study on a professional programmer. In G. Olson, S. Sheppard & E. Soloway (Eds.), Empirical Studies of Programmers: Second Workshop. Norwood, N.J.: Ablex, 1987.
[9] Visser, W. More or less following a plan during design: opportunistic deviations in specification. International Journal of Man-Machine Studies. Special issue: What programmers know, 1990, 33, 247-278.
[10] Visser, W. Evocation and elaboration of solutions: Different types of problem-solving actions. An empirical study on the design of an aerospace artifact. In T. Kohonen & F. Fogelman-Soulié (Eds.), COGNITIVA 90. At the crossroads of Artificial Intelligence, Cognitive science, and Neuroscience. Proceedings of the third COGNITIVA symposium. Amsterdam: Elsevier, 1991.
[11] Détienne, F. Reasoning from a schema and from an analog in software code reuse. Fourth Workshop on Empirical studies of programmers, New Brunswick, N.J., December 6-8, 1991.
[12] Tulving, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of memory. New York: Academic Press, 1972.
[13] Visser, W. Giving up a hierarchical plan in a design activity (Research Report N° 814). Rocquencourt: INRIA, 1988.
[14] Berlin, L. M. Beyond program understanding: a look at programming expertise in industry. In C. R. Cook, J. C. Scholtz and J. C. Spohrer (Eds.), Empirical Studies of Programmers: Fifth Workshop.

Norwood, N.J.: Ablex, 1993.
[15] Visser, W. Collective design: A cognitive analysis of cooperation in practice. In N. F. M. Roozenburg (Ed.). Proceedings of ICED 93. 9th International Conference on Engineering Design (Volume 1), The Hague, August 17-19, 1993. Zürich: HEURISTA, 1993.
[16] Eder, W. Creativity demands knowledge -- Types for purposes. In W. Eder, V. Hubka, A. Melezinek & S. Hosnedl (Eds.), Engineering design education. Zürich: Heurista, 1992.
[17] Visser, W. Use of analogical relationships between design problem-solution representations: Exploitation at the action-execution and action-management levels of the activity. Studia Psychologica, 1992, 34 (4-5), 351-357.
[18] Candy, L., & Edmonds, E. Artefacts and the designer's process: implications for computer support to design. Revue Sciences et Techniques de la Conception, 1994, 3 (1), 11-32.
[19] Guindon, R. Requirements and design of DesignVision, an object-oriented graphical interface to an intelligent software design assistant. CHI'92, 499-506.
[20] Visser, W. The organisation of design activities: opportunistic, with hierarchical episodes. Interacting with Computers, 1994, 6 (3), 235-274.
[21] Kant, E. Understanding and automating algorithm design. IEEE Transactions on Software Engineering, 1985, SE-11, 1361-1374.
[22] Ullman, D., Dietterich, T. G., & Staufer, L. A. A model of the mechanical design process based on empirical data. AI EDAM, 1988, 2, 33-52.
[23] Falzon, P., & Visser, W. Variations in expertise: implications for the design of assistance systems. In G. Salvendy & M. Smith (Eds.), Designing and using human-computer interfaces and knowledge based systems. Amsterdam: Elsevier, 1989.
[24] Harrison, S., & Minneman, S. A bike in hand: a study of 3-D objects in design. Pre-prints of the Delft Protocols Workshop "Analysing Design Activity", Delft, The Netherlands, September 20-22, 1994.