Cognitive Dimensions Profiles: A Cautionary Tale

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Abstract

The cognitive dimensions framework is a useful tool with which the usability of information artefacts may be evaluated. The framework allows a cognitive dimensions *analysis* of an artefact to be created to evaluate the artefact in a particular setting. In order to assess the usability of the artefact it is necessary to consider the analysis in the light of a cognitive dimensions *profile* which shows the desiability of each dimension for a specific activity, such as incrementation or modification. Profiles may use a subset of the thirteen dimensions. We present the results of two studies in which the cognitive dimensions framework was used to evaluate intelligibility of specification notations. In the first of these a profile was created which used only a subset of the dimensions. In the second study, two cognitive dimensions analyses were compared, which had examined the notations under consideration with respect to all of the dimensions. The results of the second study indicate that if only a subset of the dimensions is used in the creation of a profile important aspects may be overlooked.

Introduction

Cognitive dimensions (Green, 1989, 1991) are a valuable tool for assessing information structures. Individual dimensions can directly support evaluation of such structures in terms of many important questions, such as 'how easy is it to make changes?' and 'how easy is it to distinguish the different components of an information structure from each other?' There are, however, other 'big' questions that are important and interesting, but where consideration of a single cognitive dimension cannot in itself supply an answer. Such questions include 'how easy is it to understand this information structure?', 'how easy is it to produce it?' and 'what are the affordances that two different versions of an information structure provide to the human user?' In attempting to answer questions such as these, no single cognitive dimension is adequate to address the whole question; we need, instead, to construct a cognitive dimensions *analysis* of the information structure or structures that we are interested in.

A cognitive dimensions analysis examines the extent to which certain properties (measured in terms of the dimensions), are held by an information structure. The desirability of any given property is dependent upon the activity to be carried out. Cognitive dimensions *profiles* show the extent to which these properties are desirable for a specific activity. This enables a cognitive dimensions analysis of an information structure to focus on those dimensions which are of most relevance for a particular activity.

In this paper we present the results of two studies in which cognitive dimensions were used. In the first of these a cognitive dimensions profile was created for a specific activity, requirements validation by untrained users. In the second study, different cognitive dimensions analyses were compared to establish the effect of making changes to a notation. The results of the second study suggested that using the full set of dimensions may be important to gain a full understanding of the artefact under consideration.

Definition of Terms:

- "**Cognitive Dimensions Profile**": In this paper we use the term 'profile' to refer to a definition of the extent to which the dimensions are considered to be desirable for a particular activity. A cognitive dimensions profile may use only a subset of the thirteen dimensions.

- "**Cognitive Dimensions Analysis**": In this paper we use the term 'analysis' to describe the extent to which the dimensions are considered to hold for a specific 'system' which has been analysed using the cognitive dimensions framework.

Cognitive Dimensions Profiles

The cognitive dimensions framework provides a vocabulary which may be used to derive a usability analysis of any information artefact. It may be applied to such diverse artefacts as programming languages, mobile telephones and central heating control systems. The dimensions articulate cognitively relevant concepts which influence the usability of such artefacts. The framework is intended to cover different types of user activity, a factor which may be seen to extend the utility of the framework in comparison to other usability evaluation techniques which evaluate all acitivities in an identical manner.

In order to enable the cognitive dimensions framework to be used to evaluate the usability of an information artefact for a specific activity, a *cognitive dimensions profile* is required. The profile shows the extent to which the dimensions are considered to be desirable for that activity. For example, the dimension of viscosity refers to the resistance to change of an artefact. Clearly, the desirability of viscosity will be dependent upon the activity in which a user is engaged: it is quite acceptable if that acitivity is transcription, but will be harmful if the user is attempting to modify the artefact.

Table 1 below (extracted from (Green and Blackwell 1998)) shows the extent to which a subset of the dimensions are considered to be desirable for the activities of transcription and modification, illustrating the differences in desirability of each property when different user activities are considered.

Dimension	Transcription	Modification
Viscosity	Acceptable	Harmful
Hidden dependencies	Acceptable	Harmful
Premature commitment	Harmful	Harmful
Abstraction barrier	Harmful	Harmful
Abstraction hunger	Useful	Useful
Secondary notation	Useful	V. Useful
Visibility/Juxtaposability	Not vital	important

Table 1: Profiles for transcription and modification

A number of different user activities have been identified. Green and Blackwell (1998) give profiles for *transcription, incrementation, modification and exploration.* It is recognised that this is not a complete set, and the additional activity of '*searching'* has been identified (Green 2000).

It is not uncommon for cognitive dimensions profiles to refer to a subset of the thirteen dimensions. Indeed it has been noted that *"…it is becoming crucial to identify a useful subset for new users … so that people only have to deal with the dimensions that they need."* (Blackwell 2000). However, we argue that our experience of using the cognitive dimensions framework in two different studies indicates that the use of a subset of the dimensions be potentially harmful, as important properties may be overlooked.

Study One: Creating a Profile

In the first study our context of interest was the validation of a requirements specification, and our ultimate aim was to evaluate different specification languages in terms of how easy it would be for readers who are not computer professionals to understand a specification written in the language (Britton and Jones, 1999). To address the question of intelligibility of specification languages, we planned to create a cognitive dimensions profile. Our choice of dimensions for the profile would be based on an analysis of the concept of intelligibility in our particular context of interest, the validation of requirements specifications.

We began the work by defining the concept of intelligibility of specifications in terms of the activities that we would expect a reader of the specification to be able to perform. Intelligibility was characterised in terms of two activities:

- extracting information from the representation;
- checking the correspondence of information in the representation with existing knowledge.

We considered that the importance of these activities, which are not externally observable themselves, lay in their role as the basis for three further activities that are essential for effective validation and that can be observed:

- developing and extending ideas about the intended system and possible changes in the work environment;
- suggesting changes and additions to the representation;
- making annotations to the representation.

For the purposes of the research, we assumed that, if clients and users are able to perform these activities effectively, the languages used to produce the representations are intelligible to them.

The next stage in the work was to determine which of the cognitive dimensions relate to intelligibility as we defined it. The dimensions that were found to be particularly useful in this context were *closeness of mapping, role expressiveness, visibility, secondary notation, hard mental operations, hidden dependencies, consistency and abstraction gradient*. These dimensions helped us to elaborate on the activities that a reader of a specification has to carry out: extracting information from the representation, and checking the correspondence of information in the representation with existing knowledge (see above). As an example, the cognitive dimension of abstraction gradient helped to pinpoint the activity of decomposing a representation into manageable chunks.

The dimensions of visibility and secondary notation highlighted the need to help readers to pick out the important parts of a specification. Both of these are part of extracting information from a representation. A further example relates to the dimensions of closeness of mapping and role expressiveness, which highlighted two secondary activities that the reader of a specification has to perform: relating elements of the representation to elements in the domain and inferring the purpose of individual components in a representation. These two activities are part of checking the correspondence of information in the representation with existing knowledge.

One of the dimensions that we did not include in our profile was viscosity. This was because of the way in which we had defined the activities relating to intelligibility; we assumed that readers who were not computer professionals would suggest changes and make annotations to the specification, but that the actual changes would be carried out by developers or requirements engineers. The final cognitive dimensions profile used in this research consisted of only eight dimensions, but we felt satisfied that we would not have gained anything from including the other five dimensions. Our early work on defining the concept of intelligibility in our context of interest resulted in a more streamlined profile and allowed us to concentrate on those dimensions that were of particular interest to us.

Study Two: Comparison of Analyses

Our second piece of research concerned two specification notations used in the specification of the temporal aspects of an interactive system. The main case study used was MOPyfish, an interactive pet fish, the behaviour of which is dependent on the way in which it is treated over time. The first specification of the temporal aspects of MOPyfish was produced using the real-time temporal logic $TRIO_{\neq}$ (Kutar, Britton and Nehaniv, 2000). The second specification was produced using NGT, an extended version of $TRIO_{\neq}$ which had been developed with the aim of making the temporal aspects of the specification easier to understand. We produced cognitive dimensions analyses of the two notations as part of the evaluation of whether the extended notation did in fact enhance understandibility. The question that we addressed was what effect did the addition of our framework to $TRIO_{\neq}$ have on the intelligibility of the specification.

In this study, we took a different approach to using the cognitive dimensions profile. Instead of first defining intelligibility in this context and using only the dimensions that related to this, we examined both specifications in the light of all the cognitive dimensions, and then compared the resulting analyses. A summary of the two profiles can be seen in table 2 below.

Cognitive Dimension	Trio ≠	NGT
Abstraction	Ability to use different time granularities, BUT there are cases where the notation forces us to use a time granularity that we would not choose to use.	NGT introduces additional abstraction mechanisms to the notation, and also allows the user to define further abstraction mechanisms according to need.
Secondary notation	There is no formal mechanism for the use of secondary notation in TRIO$_{\neq}$ but the specifier may incorporate it	No change *Cont.*
Diffuseness	Representation of regularity may cause specifications to become verbose. The nature of regularity is likely to increase the diffuseness of any representation regardless of the notation used.	NGT may increase the verbosity of the notation, where definitions of the temporal terms are included as part of the specification. A single formula may be used in certain circumstances where in TRIO ≠in its original form, many formulae would need to be created.
Hidden dependencies	These may occur. Careful annotation of specification needed.	No change
Visibility	Visibility is largely dependent on the specifier's structuring of a specification.	No change
Consistency	TRIO ≠ is a consisent notation	No change
Closeness of mapping	TRIO ≠ generally allows use of a natural time granularity, but there are circumstances where this is not possible.	NGT allows time to be represented in a manner which is reflective of natural language, e.g. in calendar definitions
Role Expressivenes	Generally dependent on the way in which the specifier uses the notation rather than any feature of the notation itself.	No change
Premature Commitment, Provisionality	Notation has no discernable influence	No change
Viscosity	Changing a TRIO ≠ specification is largely	Defining temporal terms in the initial part of the

Cont.

	dependent on the way in which it has been produced, rather than on inherent properties of the notation.	specification reduces the viscosity of the notation
Progressive evaluation	TRIO ≠ is similar to other logic-based notations. May be checked for consistency at any time, but validation of the whole specification can only be undertaken once it is complete.	No change
Error Proneness	Forced use of an unnatural time granularity may induce error.	NGT alleviates the need to specify time at an unnatural granularity and so the notation should invite fewer mistakes.
Hard mental Operations	Unnatural time granularity increases demand on cognitive resources	NGT allows natural time granularities to be used and consequently the demand on cognitive resources is reduced .

Table 2: Comparison of Cognitive Dimensions analyses

It may be seen from the table that NGT has an effect on only six of the cognitive dimensions in the profile: *abstraction, diffuseness, closeness of mapping, viscosity, error proneness and hard mental operations*. With regard to the other seven dimensions use of NGT has no effect. It could be argued that we should have spent some time, as in the first study, analysing and defining the precise question that we were addressing and selecting only the dimensions that related specifically to this (i.e. creating a new profile). However, as both pieces of research concerned the question of intelligibility of specifications, it is likely that our restricted list of dimensions for this study would have been very similar, if not identical, to the one we used in the first study.

If we had used our original restricted list of dimensions (closeness of mapping, role expressiveness, visibility, secondary notation, hard mental operations, hidden dependencies, consistency and abstraction gradient) we would have missed the effect of using NGT on the dimensions of viscosity, diffuseness and error proneness. Since our concern in this study was intelligibility of the specifications, we might feel that any changes in terms of viscosity are not particularly relevant. However, in the cases of the dimensions of diffuseness and error proneness it is clear that use of NGT does have a positive impact on the intelligibility of the specification. As regards diffuseness, NGT is less verbose, allowing a single formula to be used in certain circumstances where in $TRIO_{\neq}$ in its original form, many formulae would have had to be created. The effect of NGT on the dimension of error proneness highlights the fact that specifying time at a more natural granularity is likely to invite fewer mistakes both in writers and in readers of the specification. The comparison of the complete cognitive dimensions analyses indicates that using a subset of the dimensions may cause important aspects to be overlooked.

Discussion

We have presented the results of two different studies in which cognitive dimensions were used to analyse intelligibility of specification notations. In the first study we created a cognitive dimensions profile, aimed at analysing the intelligibility of specification notations. The profile created used only a subset of the thirteen cognitive dimensions, the remainder appearing not to be of importance for this activity. In the second study, two cognitive dimensions analyses were created, which were used to compare the intelligibilty of two specification notations. In the second study a full set of the dimensions was used. Comparison of the analyses show that changes in the notation had a notable effect on some of the dimensions which had been excluded from the profile created in the first study.

We believe that the results of the second study indicate that it is detrimental to use only a subset of the dimensions in the creation of profiles for different activities. Whilst it may be argued that use of the full set of dimensions is not essential in all cases, and even that it may be offputting for new users of the cognitive dimensions framework, it is apparent that using a subset may cause important aspects of the usability of an artefact to be overlooked. Users of a profile may choose to focus on a particular subset of the dimensions when creating a cognitive dimensions analysis. However, the profile itself should address the full set of the dimensions.

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