ICT-based learning in home environments – flexibility for individuals?

A study of presentational formats for verbalizers and visualizers in educational multimedia

Submitted by Karin Engdahl to the University of Skövde as a dissertation towards the degree of M.Sc. by examination and dissertation in the Department of Computer Science.

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I hereby certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has already been conferred upon me.

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Abstract

The overall aim of the study is to get a better understanding for the relation between different forms of representation in ICT-interfaces and cognitive variation in individuals. Cognitive style is, according to Riding & Al-Hajji (2000) ”an individual’s preferred and habitual approach to both organizing and representing information”. Research of the relation between cognitive style and learning performance has shown, according to Riding & Al-Hajji (2000), that pupils learn best when the structure, the content and the mode of presentation of the material suits their style.

On the basis of an explorative pre-analysis of a multimedia program for learning mathematics, named Matador, a general hypothesis was formulated. The general hypothesis that was examined is: The Matador multimedia program can be improved as concerns the presentational formats both for pupils who are *helped by* and *attracted by* visual information and – in particular – for pupils who are *helped by* and *attracted by* verbal information. A minor user’s test with 10-15 year old pupils was carried out in order to complement the pre-analysis by testing some specific details of the program with users. The results of the study indicate that there are certain aspects that could be improved, especially for those who are helped by and attracted by verbal information.

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1 Introduction

Today technology is not far away from everyone's home. The new Information and Communication Technology (ICT) introduces new possibilities for learning in home environments.

Traditional education is carried out in a group of individuals, where the group is treated as homogeneous. This might lead to a situation in which not everyone gets information presented in a way suitable for her or his unique learning process. An alternative approach would be to offer individuals knowledge material in forms that suit their learning processes.

Modern technology offers new possibilities concerning learning. By bringing the computer and the Internet into learning environments the learning process changes. ICT makes it possible to take individual variation into account to a larger extent than the traditional education as the possibility to learn in home environment offers the individual more choice and flexibility. The focus of this study is on *cognitive variation*, that is variation in how individuals organise and process information.

The overall aim of the study is to get a better understanding for the relation between different forms of representation in ICT-interfaces and cognitive variation in individuals. The focus is on verbal and visual information styles.

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2 Background

Relevant concepts as well as some of the work that has been done in the area will be presented in this chapter.

2.1 Learning

The German philosopher Hermann Ebbinghaus began the scientific study of learning in the early 1880s. He found that learning was a simple function of amount of practice, although exceptions to this general rule occur. One exception is that learning a little and often leads to better results than learning a lot at one time (Baddeley, 1999).

Ebbinghaus was criticised by Bartlett who argued that learning was more than just forming habits on the basis of repetition and that learning had to be studied in a naturalistic learning situation. Bartlett carried out experiments on human memory and found that what is remembered is material that is seen as natural to the person and that, at the same time, fits into his or hers expectations. Factors as emotions and response are also affecting the learning situation (Baddeley, 1999). The essence of Bartlett's approach is its emphasis on our struggle to impose meaning on what we observe and what we recall of our experience. Bartlett developed the concept of the schema, an internal representation of the subject's knowledge (of the world) that is used to help encode and store new knowledge (Baddeley, 1999).

2.2 The computer's contribution to education

The computer can be used in many different ways and be looked at in different ways. For instance the computer may be seen as a tool, an aid for individuals in searching for information, a learning device, a communication channel or a device that enables

individuals to share some of their own knowledge through WebPages etc (Bjessmo, 1997).

ICT has its own contribution to make to education, enhancing the learning process in exciting ways and enabling students to (Cook & Finlayson, 1999, p. 4):

- Take more control of their own learning.
- Access up-to-date information from a wide range of real world sources.
- Communicate efficiently with other people on a worldwide scale.

ICT presents opportunities as well as challenges to find the ways, in which every student can be motivated to learn (Cook & Finlayson, 1999).

Now when the technology enters the schools questions like “what is knowledge” and “how shall it be presented and mediated” arises (Bjessmo, 1997). To be able to design applications that foster effective learning, knowledge about cognitive variation is required in order to choose appropriate methods of presentation.

Orhun (1995) writes about the difficulty to design effective computer-based tools, which aims to facilitate cognitive processing and learning. This is still a challenge for designers.

How the information is structured and presented influences its acquisition and understanding, which is reflected in performance (Orhun, 1995). By offering the users a possibility to choose learning style and learning context the motivation can increase. It

is well known that motivation is an important ingredient to the learning process, in other words learning may be more efficient.

2.3 External representation of knowledge material

Knowledge can externally be represented in different forms or codes. For instance in images or in more symbolic forms, such as words.

2.3.1 Visual-verbal representation

Some ideas and phenomena are better and more easily represented in pictures, i.e. visual representation, and others in symbols, i.e. verbal representation (Sternberg, 1996). For instance, the shape of an egg is more easily explained by drawing an oval figure. But to tell what justice is you find it harder to represent it as a picture. Instead justice will probably be explained better with words.

A word is a symbolic representation where the relationship between the word and what it represents is simply arbitrary. A picture is relatively analogous to the real-world object it represent; the picture shows concrete attributes, as shape and size, that are similar to the features and properties of the real-world object the picture represents (Sternberg, 1996).

Speech and text both represent verbal information. Text can be processed at the learner’s own rate, it is rehearsable, it is better for conveying spatial information and it is more efficiently stored and processed in a computer (Shih & Alessi, 1996). Voice has an advantage in that it is easier to understand for children and 'poor readers'. Auditive information does not compete over visual attention from stimuli such as diagrams and is usually experienced as more natural (compared to displayed text) (Shih & Alessi, 1996).

Pictorial representations convey all features simultaneously. Representations in words usually convey information sequentially, according to arbitrary rules that have little to do with what the word represent. Blueprints and identification photos serve different purposes than essays and memos do (Sternberg, 1996).

2.4 Cognitive variation

A definition is introduced at the beginning of this chapter. A section with related concepts will then follow together with a presentation of the verbal-visual dimension and of the dual-coding hypothesis.

2.4.1 Definition

Cognitive variation, or cognitive style, is defined by Marton & Booth (1997) as "the variation in ways in which people experience situations and phenomena in their worlds". Riding & Al-Hajji (2000) state that cognitive style is an individual characteristic variable which is seen as "an individual's preferred and habitual approach to both organizing and representing information".

To put it in other words; cognitive variation concerns differences in people's way of thinking, their preferred way of learning, their way of working on a problem, and their interests in different information codes, and so on.

2.4.2 Related concepts

Concepts related to cognitive style are *multiple intelligence, learning style* and *learning strategy*. Gardner (1998) points out individuals' different ways of viewing the world. He presents his theory of multiple intelligences that concerns individuals' different

ways of learning, remembering, performance and understanding (Gardner, 1998). The seven different intelligences that he discusses are the following: linguistic intelligence, musical intelligence, logical-mathematical intelligence, spatial intelligence, bodily-kinesthetic intelligence, interpersonal intelligence and intrapersonal intelligence (Gardner, 1985). Gardner (1998) criticizes the traditional educational system that does not consider individuals' variation. Today's system takes for granted that everybody can learn the same material in the same way and that one universal measurement is enough for measuring learned knowledge.

A person's learning style is "the intelligences put to work. In other words, learning styles are the pragmatic manifestations of intelligences operating in natural learning contexts" (Armstrong, 1994, p. 13).

The general tendency to adopt a particular learning strategy is, according to Entwistle (1988), referred to as a learning style. In other words, a learning style is the underlying way in which an individual thinks and tackle problems, and a learning strategy a reaction to a single task (Entwistle, 1988). However, in most literature learning style and learning strategy is referred to as the same thing.

Multiple intelligence, learning style and learning strategy are concepts that are closely related to cognitive variation. This paper will not deal with above mentioned concepts other than mentioning that there are differences in opinions among researchers concerning these concepts. Also there exists a confusion of ideas that complicate a survey of concepts.

2.4.3 Verbal – visual dimension

Riding et al. have identified two fundamental dimensions of cognitive style; the Wholist-Analytic dimension and the Verbal-Imagery dimension (Riding & Al-Hajji, 2000; Riding & Rayner, 1998). Each dimension can be seen as a group of styles or families. These groups contain labels and models of styles identified by a number of researchers (Riding & Rayner, 1998).

The Wholist-Analytic dimension presents style measures that determine whether an individual tends to organise information into wholes or parts. The Verbal-Imagery dimension, on the other hand, comprises measures that determine whether an individual is willing to represent information during thinking verbally or in mental pictures (Riding & Al-Hajji, 2000; Riding & Rayner, 1998).

The figure below (Figure 1) presents an overview of the dimensions together with a brief description.

The Wholist-Analytic dimension	
Field-dependency-independency	Individual dependency on a perceptual field when analysing a structure or form which is part of the field.
Levelling-sharpening	A tendency to assimilate detail rapidly and lose detail or emphasise detail and changes in new information.
Impulsivity-reflectiveness	Tendency for quick as against a deliberate response.
Converging-diverging thinking	Narrow, focused, logical, deductive thinking rather than broad, open-ended, associational thinking to solve problems.
Holist-serialist thinking	The tendency to work through learning tasks or problem solving incrementally or globally and assimilate detail.
Concrete sequential/ concrete random/abstract sequential/ abstract random	The learner through experience concrete and abstraction either randomly or sequentially.

Assimilator-explorer	Individual preferences for seeking familiarity or novelty in the process of problem solving and creativity.
Adaptors-innovators	Adaptors prefer conventional, established procedures and innovators restructuring or new perspectives in problem solving.
Reasoning- intuitive active-contemplative	Preference for developing understanding through reasoning and or by spontaneity or insight and learning activity which allows active participation or passive reflection.
The Verbal-Imagery dimension	
Abstract versus concrete thinker	Preferred level and capacity of abstraction.
Verbalizer-visualizer	The extent to which verbal or visual strategies are used to represent knowledge and in thinking.

Figure 1. Descriptions of style dimensions (after Riding & Rayner, 1998, p.20).

Early work on the Verbal-Imagery dimension started off with Galton's (1883) interest in individuals' way of thinking and knowing with 'imagery'. Paivio's (1971) dual-coding theory has provided the basis for further work investigating the nature of a Verbal-Imagery dimension (Riding & Rayner, 1998).

2.4.4 Dual-code hypothesis

In the late 1960s and early 1970s Allan Paivio presented a very influential theory, which is known as dual-code hypothesis or dual-code theory, about analogical images versus symbolic mental representation.

Humans' imaginal and verbal internal representations may be viewed as two different codes, which organize information into knowledge that can be acted on, stored somehow and even later retrieved for subsequent use. According to Paivio (Sternberg, 1996), mental images are analogue codes for the physical stimuli we observe in our environment. In contrast, our mental representations for words are, according to Paivio, represented in a symbolic code. A symbol may be anything that is arbitrarily designated to stand for something other than itself (Sternberg, 1996).

In Paivio's dual-code hypothesis it is suggested that some information is represented in nonverbal and analogue images and other information in verbal and symbolic forms (Sternberg, 1996).

The imaginal, analogue code and the verbal, symbolic code are two distinct codes for mentally representing information. Some information may also be encoded and stored in each of the two discrete forms. For instance the concrete word apple can relatively easy be formed into a mental image. However, for highly abstract words such as truth and justice is much harder to form mental images of. These words are instead stored in the symbolic, verbal code. Some images evoke a rich base of verbal information and may therefore be stored both as imaginal code and verbal code (Sternberg, 1996).

Further support for the dual-code hypothesis is based on individual differences in mental representation. Paivio found that the ability to form mental images does not seem to be linked to verbal ability. This finding suggests that the cognitive system is involved in the manipulation of imaginal representation of symbolic representations (e.g. words) (Sternberg, 1996).

Several findings suggest the use of two distinct codes for mental representation of knowledge: an imaginal (analogical) code and a verbal (symbolic) code (Sternberg, 1996).

2.5 Cognitive style and learning

Kolb (1984) writes about the importance of studying the learning process in order to get successful learning. Kolb presents examples of different educational techniques designed to assist the learning process. Some examples are computer-aided instruction, experienced-based learning material, multimedia curricula and open classrooms. The weakness of nearly all above mentioned techniques, according to Kolb, is the failure to recognize and explicitly provide for the differences in learning styles (Kolb, 1984).

One problem identified by Kolb (1984) is that there has been little attempt to specify which dimensions the individualization is supposed to support. Another problem is that little has been done to provide the learner with alternative learning methods based on the person's learning style. An example is that a wrong answer only gives the learner more information about the question instead of a different learning method that is in line with the persons' learning style, such as pictorial versus symbolic presentation (Kolb, 1984).

Since cognitive style affects the ways in which an individual thinks about and internally represents situations in the external world, it follows that it is also likely to affect pupils' behaviour in school (Riding & Al-Hajji, 2000). In Riding & Al-Hajji's study it was assumed that imagers would respond more quickly to statements that describe the appearance of items because the objects could easily be represented as mental pictures. Verbalizers would perform worse to the appearance statements but have a shorter response time on the statements that contain information about conceptual categories. This would happen because the semantic conceptual category membership is verbally abstract in nature and cannot be represented in visual form (Riding & Al-Hajji, 2000).

Research of the relation between cognitive style and learning performance has shown, according to Riding & Al-Hajji (2000), that pupils learn best when the structure, the content and the mode of presentation of the material suits their individual styles.

Riding & Al-Hajji (2000, pp. 40-41) write:

> "Matching presentation style to the cognitive style of the pupil is particularly important for pupils of lower ability, or when the task is complicated and the material is relatively difficult for the pupil. This is because, in these cases, there is more pressure on the pupil's learning system, and consequently danger of overloading them with information to be learned".

The quotation implies that the style in which the problems are presented influence the learning process. By matching presentation style to cognitive style pupils, especially those of lower ability, would learn more efficiently.

2.6 Verbal-imagery code performance

Evidence of the verbalizer-visualizer dimension has accumulated since Francis Galton in England and Jean Martin Charcot in France made their initial observations on imagery types in the 1880s. Contributions have been made from three different research traditions: experimental, physiological and behavioural (Richardson, 1977). Research in these fields has "provided some evidence for the belief that people differ in the extent to which they favour verbal or visual strategies when processing many different kinds of information. Though it is likely that most people can and do switch strategies according

to the nature of the task, there are some who appear to be heavily depend upon one or other of the two methods" (Richardson, 1977, p. 123).

According to Riding & Taylor (1976) visualizers tend to be poor at verbal coding and vice versa. The authors maintain that reading or listening to prose evokes images, which probably play an important part in understanding and retention of the material. Some people experience much more imagery than others while some do not have any images at all. These observations indicate a variation in the occurrence use of imagery by learners.

In terms of mode of presentation, verbalizers can cope with abstract (semantic) material that is verbally presented, while imagers perform best when the material is concrete and presented as pictures or diagrams (Riding & Al-Hajji, 2000).

Riding & Calvey (1981) carried out a study concerned with the assessment of verbal-imagery learning styles and their effect on recall. The study showed that individuals differ in the mode in which they represent information during learning. The results indicated that the representation form used during learning affects the efficiency of learning and recall, and that performance is best when the style and content of the material matches the mode of representation in which the individual performs best.

In Riding & Calvey's (1981) opinion the results do not imply that some subjects use only one mode while others use only the other. Instead a more reasonable conclusion would be that most subjects prefer one mode rather than the other and that all individuals use a dual representation in processing material.

To explain why subjects differ in their performance on prose material Riding & Calvey (1981, p. 63) state:

> "When the material does not match their characteristic mode, they either have to try to translate it into their preferred mode with a consequent use of processing time and perhaps some loss of information, or use the mode in which they perform less well. Either way, performance will be less good than when the favoured representation and the material are appropriate to one another".

To sum up:

Verbalizers
- Learn best if the information is presented as text or speech.
- Tend to be poor at visual coding.
- Can cope well with presentations of abstract material that is verbally presented.
- Learn most effectively when the style and the content of the material matches verbal presentation.

Visualizers
- Prefer information that is presented as images.
- Tend to be poor at verbal coding.
- Perform best when the material is concrete and presented as pictures or diagrams.
- Learn most effectively when the style and the content of the material matches visual presentation.

3 Problem definition

The problem is to survey if the needs of both verbalizers and visualizers are met when using educational multimedia. The study will be based on an analysis and a usability test of the multimedia program *Matador*, which is a program for learning mathematics, for the ages from 10. On the basis of an explorative pre-analysis of the program a general hypothesis was formulated as below.

Problem specification

The general hypothesis that will be examined is:

1. The Matador multimedia program can be improved as concerns the presentational formats both for pupils who are *helped by* and *attracted by* visual information and – in particular – for pupils who are *helped by* and *attracted by* verbal information.

Specific hypotheses:

2. Some pupils, but not others, want to add text to certain presentations in the program in order to get a better understanding of the problems presented.
3. Some pupils, but not others, want to add visual 'help' to certain presentations in the program in order to get a better understanding of the problems presented.
4. Some pupils, but not others, want to complement some presentations in the program with narrative text in order to make it more interesting.
5. Some pupils do not want to remove certain visual images because they find that those images make it more interesting. Other pupils would not mind removing those images; they even find them unnecessary or disturbing.

Hypotheses 2 and 3 concern the 'helped by' aspect and hypothesis 4 and 5 concern the 'attracted by' aspect, which are both contained in the general hypothesis.

Delimitation

This pilot study sets off with to investigate, in a chosen group of pupils, possible variation that gives support to the four, or some of the four, specific hypotheses and to the general hypothesis. With more resources for the study the *Cognitive Styles Analysis*[1] would have been used in order to ensure a selection of test subjects which are relatively clear verbalizers and visualizers respectively, and the same number of each. With such procedure roof effects would be avoided, and the risk of getting a majority of subjects in either group as well as getting most subject to be 'in the middle' could be minimized. An adjustment of a standardized test for the study would however take too much time, and will therefore be left for future studies[2].

Due to time bounds the problem definition has been delimited. With more time it would be desirable to analyse and evaluate several programs. The programs could then be compared in order to identify differences.

In this study a user's test of a qualitative character is carried out. With more resources it would be desirable to complement the test with some form of performance measures.

[1] For a description of Cognitive Styles Analysis' construction see Riding & Rayner, 1998.
[2] At an early stage, an informal method of selection was applied. The teachers/personnel were asked to choose subjects on the basis if they were clearly picture-interested or language-interested. Due to different reasons the personnel could not make such assessments and the method was abandoned.

Expected results

One expectation is that the general hypothesis as well as the specific hypotheses will be supported by the user's tests. Another possibility though is that the user's test will support some of the specific hypotheses but not others. Yet another possibility is that a quite different pattern of user's comments will emerge than the predicted, which shall then be analysed both from a content and from a methodological perspective. Whatever the results, it will not be possible however, due to the small number of participants in the study, to draw any definite conclusions as to the distributions of user opinions in a larger population.

4 Method

The following chapter describes the chosen methods and the plan of the study.

4.1 Chosen methods

Chosen methods for the study are evaluation, analysis and usability testing of the program.

4.1.1 General evaluation

A general evaluation of the interface will be carried out. The evaluation will be based on Jacob Nielsen's (Nielsen & Mack, 1994) ten usability heuristics used in Heuristic Evaluation. The purpose of the general evaluation is to give an overall view of the usability of the graphical user's interface. The reason why the general evaluation is carried out is because when it comes to the verbal-visual analysis it is important not to confound pure design faults with the result of the verbal-visual analysis.

4.1.2 Verbal – visual analysis

One multimedia program will be analysed with respect to its verbal and visual presentational aspects. The aim of the analysis is to estimate to what extent the presentation suits verbalizers and visualizers respectively.

4.1.3 Usability testing

A minor user's test with 10-15 year old pupils will be carried out in order to complement the verbal-visual analysis by testing some specific details of the program with users.

Usability testing is defined by Rubin (1994, p. 25) as: “a process that employs participants who are representative of the target population to evaluate the degree to which a product meets specific usability criteria”.

In order to perform a fruitful usability test the goals/objectives need to be stated. Preece (1993, p. 47) points out four key aspects of interest in usability testing;

- *Learnability* – the time and effort required to reach a specific level of user performance (also described as ‘ease of learning’).
- *Throughput* – the tasks accomplished by experienced users, the speed of task execution and the errors made (also described as ‘ease of use’).
- *Flexibility* – the extent to which users can adapt a system to new ways of interaction as they become more experienced.
- *Attitude* – the positive attitude engendered in users by the system.

Rubin (1994, p. 26) presents three criteria that usability testing intent to ensure that the product has. The criteria are:

- Easy to learn and to use.
- Satisfying to use.
- Provide utility and functionality that are highly valued by the target population.

Both Rubin (1994) and Preece (1993) point out the user’s attitude as one aspect. Preece talks about the positive attitude engendered in users by the system and Rubin about the aspect that the product should be satisfying to use. The goal with the test is to contribute to the survey of whether pupils along the verbal-visual dimension are satisfied with

respect to the verbal-visual presentation used in the program. The test will therefore focus on *the attitude aspect* and aim to investigate an aspect of *satisfaction of use*.

4.2 Planning the study

Below an account of the subjects, the material and the procedure are presented.

4.2.1 Subjects

Ten 10-15 year old pupils will participate in the study. All subjects are representative for the population which is expected to use the product. The test subjects are not randomly chosen and no balancing of age and gender is used.

4.2.2 Material

Matador is a CD-ROM with over 800 problems divided into three different levels of difficulty. The program is available only in Swedish and is designed for pupils from the age of 10 who are about to learn problem solving in mathematics. The user chooses what level of difficulty to work on as well as which problem solving method to use. Matador offers the user the methods: ‘let’s pretend’, ‘use a figure’, ‘guess and try’ and ‘look for patterns’. All points earned are gathered and will gradually give the user rewards. If it is too easy the program will suggest a higher level of difficulty, but the user decides whether to follow the suggestion. If the user performs badly the program will suggest a lower level.

The testleader used an interview manuscript (Appendix A) with questions and comments about the screens. The manuscript was used in order to ensure that all subjects were presented with the same information.

4.2.3 Procedure

General evaluation

The program's interface was evaluated in order to identify possible usability problems. Based on a positive outcome an assumption can be made that the program exhibits an acceptable level of usability. The evaluation was based on how well the interface agreed with the heuristics.

Verbal – visual analysis

The analysis of verbal and visual information style was conducted in order to estimate to what extent the presentation suits verbalizers and visualizers respectively. The program was analysed with respect to its verbal and visual presentational aspects. The analysis formed the base for the hypotheses.

Usability test

The test consisted of two main sections: a tour about the program and an interview session. The tour is offered by the program for new users in order to get an idea of how the product works and how to use it. During the interview session the subject and the testleader discussed certain presentations of different problems. The total time of each session was between 30-45 minutes, and each subject worked individually.

The testleader's manuscript (Appendix A) was the basis of the usability test. Since the test was investigating the users' attitude and satisfaction of use, the aim was to have a dialogue about each screen.

5 Process

Results from the general evaluation and from the verbal-visual analysis will be presented in this chapter as well as a description of the procedure of the usability test.

5.1 General evaluation

A general evaluation of the Matador's interface will be presented. The evaluation is based on how well the interface agrees with the heuristics.

1.	**Visibility of system status**
	The system keeps the user informed about what is going on through feedback within reasonable time. Feedback is presented through voice as well as an indication in the interface.
2.	**Match between system and the real world**
	The system speaks the user's language with words, phrases and concepts familiar to the user. Real-world conventions are followed and information appears in a natural and logical order. All texts and instructions are read out for the user.
3.	**User control and freedom**
	Undo and redo are supported in the program through pointing at the arrows that are presented in the interface.
4.	**Consistency and standards**
	The program is consistent in its design, in other words same words/phrases, actions and situations mean the same thing independent of where in the program the user work.
5.	**Error prevention**
	It is better to try to prevent errors from occurring in the first place with a careful design. The program fulfils the heuristic by applying a careful design.

6.	**Recognition rather than recall**
	All options are not visible to the user. The user also has to remember information from reading the tutorial to start working with the program. Some information is presented in the form of tool tips, which means that the user easily can retrieve information about a specific choice or icon.
7.	**Flexibility and efficiency of use**
	Both inexperienced and experienced users can efficiently use the program. The novice can get the information repeated if desirable and the more experienced user are not forced to process information.
8.	**Aesthetic and minimalist design**
	No dialogues contain irrelevant information or information that is rarely needed.
9.	**Help users recognize, diagnose and recover from errors**
	Since errors do happens it is necessary to offer the user an error message that presents the error, indicates the problem and suggests a solution. The program does not consist many error messages (which in a way is good) and those that are presented do fulfil the heuristic.
10.	**Help and documentation**
	Help for the user is offered through the tutorial, the offered roundtrip or the help for each task, which presents hints to help solve the problem. Any help is easy to reach, focus on the user's task, list concrete steps to be carried out and is not too large.

Figure 2. Results from the general evaluation.

The figure (Figure 2) presents each heuristic with comments about the specific interface. To sum up, the design of Matador's interface is very good since nine out of ten heuristics was reached in an exemplary way. The more negative aspect concerns recognition rather than recall (heuristic #6). The evaluation states that "all options are not visible to the user and that the interface demand the user to remember information from reading the tutorial to start working with the program".

5.2 Verbal – visual analysis

The analysis of information design with respect to verbal and visual information style is presented below.

Information with respect to verbal information style	
+	-
▪ Tooltips is presented when the mousepointer is placed over a clickable picture ▪ Both speech and text	▪ Lack of some sort of text at first glace (even though tooltips are available) ▪ Lack of narrative text to the problems ▪ At times too short instructions which makes the user forced to trust the illustrations ▪ The main menu consists of pictures only (should be combined with for instance the numbers 1, 2 or 3 on the bulls' stomachs as well as the letters A, B, C or D on the matadors' stomachs)

Information with respect to visual information style	
+	-
▪ Pictures to the problems ▪ Relevant pictures (most of the time) ▪ The possibility to solve specific problems by using pictures; e.g. be able to drag and drop cubes, matches etc. ▪ Colour changes on certain buttons depending on which level 1-3	▪ The images do not bring out the essential; for instance the main menu, method A-D ▪ Insufficient mapping between image/symbol and information; for instance clown - contributors ▪ 'Unnecessary' images; for instance flashing squares that does not provide any information

Figure 3. Results of the verbal-visual analysis.

To sum up, the analysis reveals that as the graphical interface looks today the program is not particularly well adapted neither for verbalizers nor for visualizers. The program can be improved concerning the presentational formats for both verbalizers and visualizers but for verbalizers *in particular*. Several problems presented by Matador ought to be complemented with more text, and some problems ought to be supplemented with some visual presentation in order to help the pupil to understand and solve the problem.

5.3 Usability test

The user's test was carried out on ten 10-15 year old pupils. The subjects were informed by the testleader of the nature of the test and about the program Matador. Furthermore, subjects were verbally instructed to view the tour given by the program. They were informed that there were no correct answers and that they could at any time ask the testleader for assistance.

The environment in which the test was conducted was not the same for every subject. This depends on that the subjects were at different locations. The fact that the context is not constant is assumed not to influence the result since the test is not measuring performance. An advantage with a familiar environment for the subjects is that they probably feel more relaxed and safe.

6 Results

The pre-analysis of the program suggests that as the design look like today the program is not adapted for the needs of verbalizers as well as visualizers.

Four specific hypotheses were tested in the user's test in order to complement the pre-analysis. The hypotheses were as follows:

- Some pupils, but not others, want to add text to certain presentations in the program in order to get a better understanding of the problems presented.
- Some pupils, but not others, want to add visual 'help' to certain presentations in the program in order to get a better understanding of the problems presented.
- Some pupils, but not others, want to complement some presentations in the program with narrative text in order to make it more interesting.
- Some pupils do not want to remove certain visual images because they find that those images make it more interesting. Other pupils would not mind removing those images; they even find them unnecessary or disturbing.

An analysis of the data from the user's test was carried out. Special attention was carried out on the first two specific hypotheses regarding the 'helped by'-aspect. Furthermore the results were analysed with respect to the general hypothesis, namely that:

- The Matador multimedia program can be improved as concerns the presentational formats both for pupils who are *helped by* and *attracted by* visual information and – in particular – for pupils who are *helped by* and *attracted by* verbal information.

Below is an account of the analysis.

6.1 Analysis

All subjects, except one, agreed on that text should be added in order to support problem solving.

Subject 5: “it is simpler with the text”

Subject 8: “easier with text”

Most subjects, independent of if they prefer verbal or visual information style, are of the opinion that the Matador’s interface should be complemented with more verbal presentations. This indicates that there is a huge lack of appropriate presentational format for the verbalizers.

Out of the ten subjects, six answered that they would prefer to add/redesign a visual presentation in order to better understand and solve the task.

Subject 7: “easier to understand with the picture”

Subject 10: “with the picture it gets easier”

The proposals were not about adding more pictures, but about improving the already existing pictures. This indicates that also the visual presentational format can be improved in order to better suit the visualizers.

One subject seemed strictly verbally oriented. The subject does not want to add any images in order to better understand and solve the problems, and the pictures are not seen as interesting but unnecessary.

Some subjects wanted to add both text and visual ‘help’ to the presentations. This might be due to their finding the tasks too difficult, and/or it might be due to them not being either verbally or visually oriented, but somewhere in the middle along the dimension.

All subjects, with two exceptions, answered to the test as if they were helped by more verbal presentation, and these subjects also seemed attracted by verbal presentation. Eight out of ten subjects answered to the test as if they were helped by more visual presentation, and these subjects also seemed attracted by visual presentation. A preliminary observation is that there is a relation between ‘helped by’ and ‘attracted by’.

6.2 Conclusions

Based on the results from the user’s test, the four specific hypotheses could be verified.

Regarding how well the result of the four specific hypotheses answer to the general hypothesis, it can be stated that the Matador multimedia program could be improved as concerns the presentational formats – both verbal and visual.

The results of the study also corroborates that individuals’ cognitive style differ and that they manipulate the material in different ways.

7 Discussion

The overall aim of the study is to get a better understanding for the relation between different forms of representation in ICT-interfaces and cognitive variation in individuals. The results of the case study indicate that there are certain aspects that can be improved, especially for those who are helped by and attracted by verbal information.

7.1 Reflections on the methods

Since the program is designed to be used by pupils from the age of 10 and the youngest subjects were 10 years of age this might have caused some methodological problems. First of all, the mathematics problems they were about to solve might have been slightly too difficult, which could have led to a more negative attitude towards the program. Secondly, younger children might have difficulty to express their opinion and understand the testleader's questions.

All subjects were exposed to the same level of difficulty. This might have been the reason to why some subjects did not want any kind of extra help, text or image. In other words, older subjects had no problem understanding the task that led to no desire of adding any kind of help. Also, subjects with knowledge of a particular problem might adopt a learning strategy connected to a different dimension than the preferred one. This can lead to a misleading result since this kind of a situation is treated as if the subject exhibits a flexible approach.

Given the small number of subjects included in the test, the external validity is low. Even though the sample is representative for the population for which the instruction multimedia program is designed for, a more extensive study is needed.

7.2 Limitations and directions for further work

The study cited here is an initial step to examine individual cognitive variation. The overall aim of the study is to get a better understanding for the relation between different forms of representation and cognitive variation in individuals. The next step would be to learn from the experiences of this pilot study and develop a more powerful design.

This paper has stressed the advantages of representing information in a style that suits specific cognitive variations. But there are also arguments that would talk against customised educational multimedia. Firstly, an interface designed for verbalizers does not imply that all verbalizers are helped by and attracted by the interface since verbalizers can be anywhere along the dimension. Secondly, if all educational programs are designed to suit a specific style there is a risk that individuals do not develop other sides. Another argument is the economical aspect. In order to be able to adjust educational programs, different relevant combinations must be identified as well as adapted to which is, of course, an economical issue.

It would be desirable to look at the presentational formats in *several* multimedia programs in order to broaden the study.

It would also be desirable to group the subjects into a few groups along the verbal-visual dimension. For this study the *Cognitive Styles Analysis* would have been of interest. But due to limited time bounds it was not possible.

Images can have varying purposes. Wright, Milroy & Lickorish (1999) stress the need for more studies dealing with different kinds of *illustrations* and animated as well as static displays. Such studies would be interesting in an educational context (Wright, Milroy & Lickorish, 1999). The results could help the designers how to design instruction multimedia in order to reach effective learning.

There are different types of information. Examples are: procedural information, descriptive information, spatial information, abstract information and contextual information. It may be better, or more efficient, to represent a certain type of information in a specific format. Studies on such issues would be important for the design of educational multimedia.

Also, problems can be of different character. The results might have been different if the multimedia program were about learning history or English. One aspect, which would be interesting to study, is the dimension's relation to the right and left hemispheres. Probably verbalizers have an advantage when it comes to mathematical problems and logical discussions, and visualizers when it comes to artistic knowledge and language learning. Such studies would be relevant for the design of different educational multimedia.

I would like to end this paper with a quote:

"media is a tool or a learning environment; we […] must have a better understanding of it before we can wisely use and design it" (Shih & Alessi, 1996).

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Interview manuscript

'Helped by'

Hypothesis: Some students, but not others, want to add text to certain presentations in the program in order to get a better understanding of the problem.

1. Cut shoelaces (method B, level 1)

Add text: The shoelace is 14 m long. Every piece shall be 1 m.
+ *question*

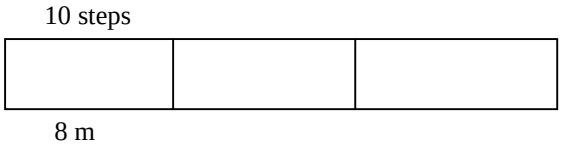
2. Count comics (method C, level 1)

Add text: Kalle and Pelle have 18 comics together. Kalle has 6 more than Pelle. + *question*

Hypothesis: Some students, but not others, want to add visual 'help' to certain presentations in the program in order to get a better understanding of the problem.

3. The pirate's treasure (method B, level 1)

Add picture:



4. Cat & dog chase (method B, level 1)

Add picture: see 4b

'Attracted by'

Hypothesis: Some students, but not others, want to complement some presentations in the program with narrative text in order to make it more interesting.

5. Candy-eater (method C, level 1)

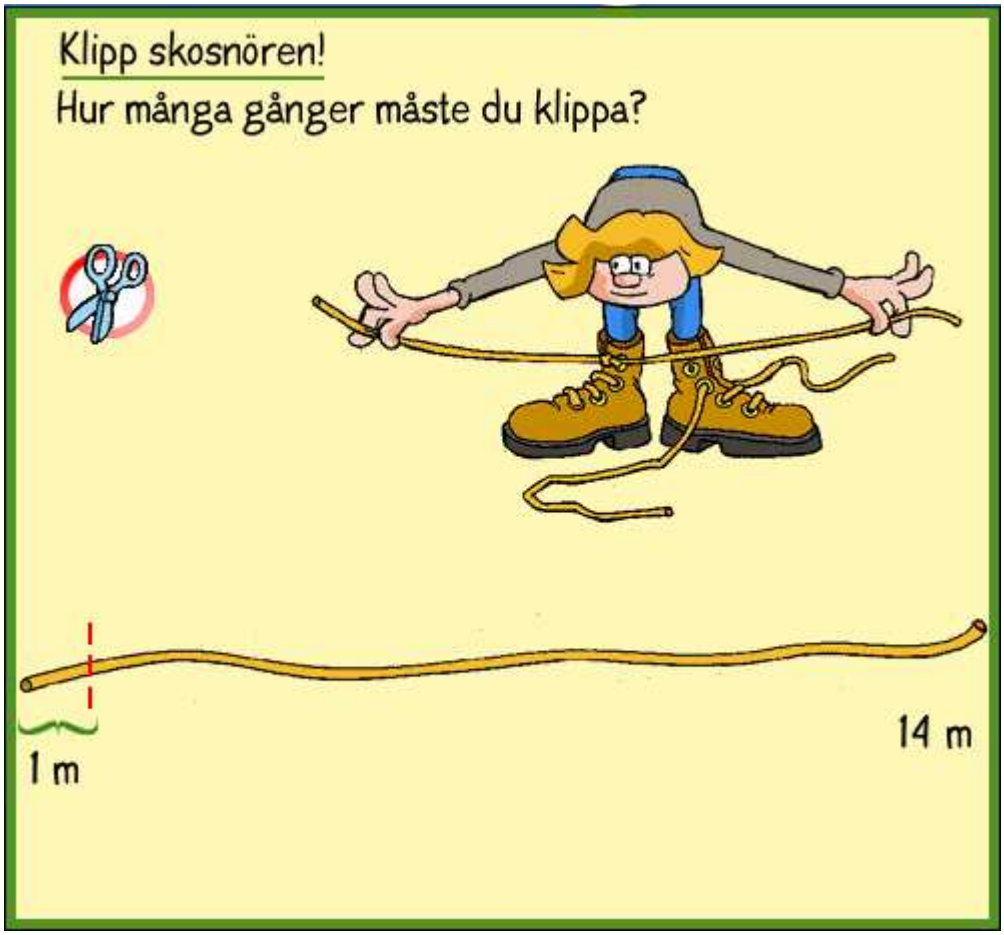
Add narrative text: Anna has just got herself a bag full of candy from her mum. The bag was full of licorice, toffees and mints. Anna ate first half the bag. Then she ate half of what was left. Now looking in the bag there was 11 pieces of candy left. + *question*

Hypothesis: Some students do not want to remove certain visual images because they find that those images make it more interesting. Other students would not mind removing those images; they even find them unnecessary or disturbing.

6. Main menu

Remove: all unnecessary items such as the clown, the parrot etc

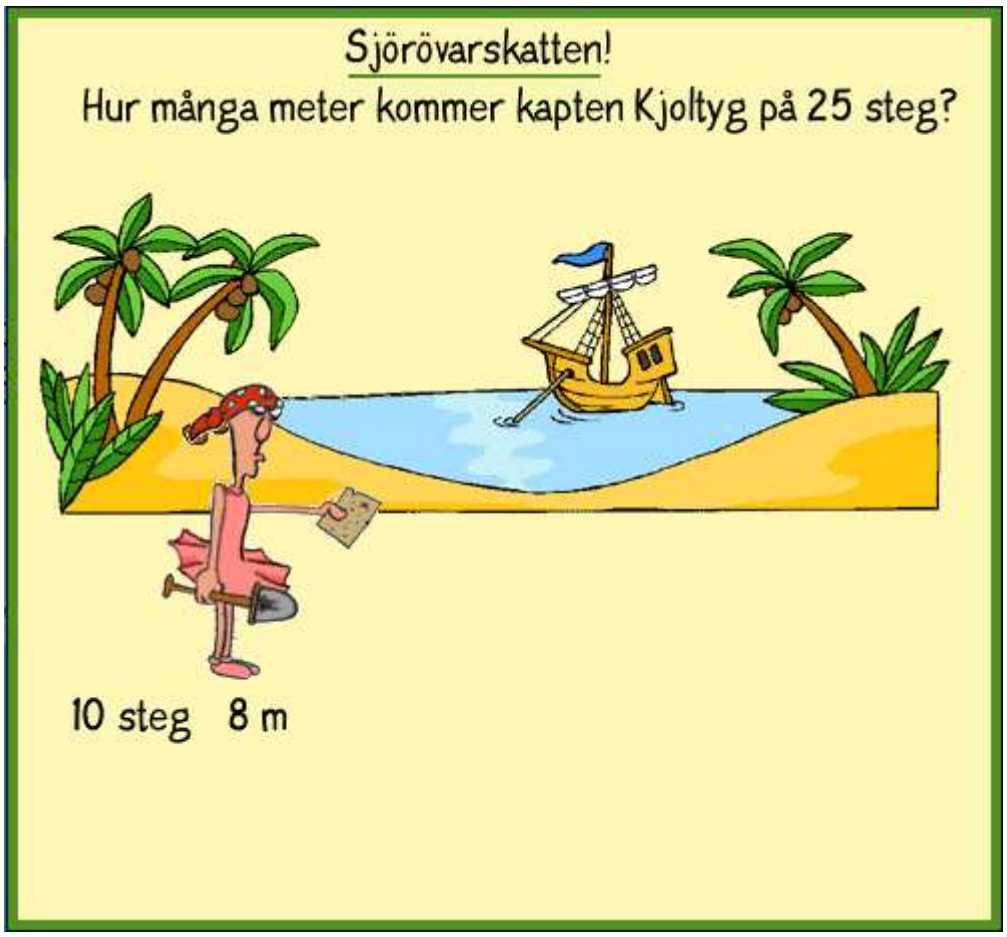
Question 1.



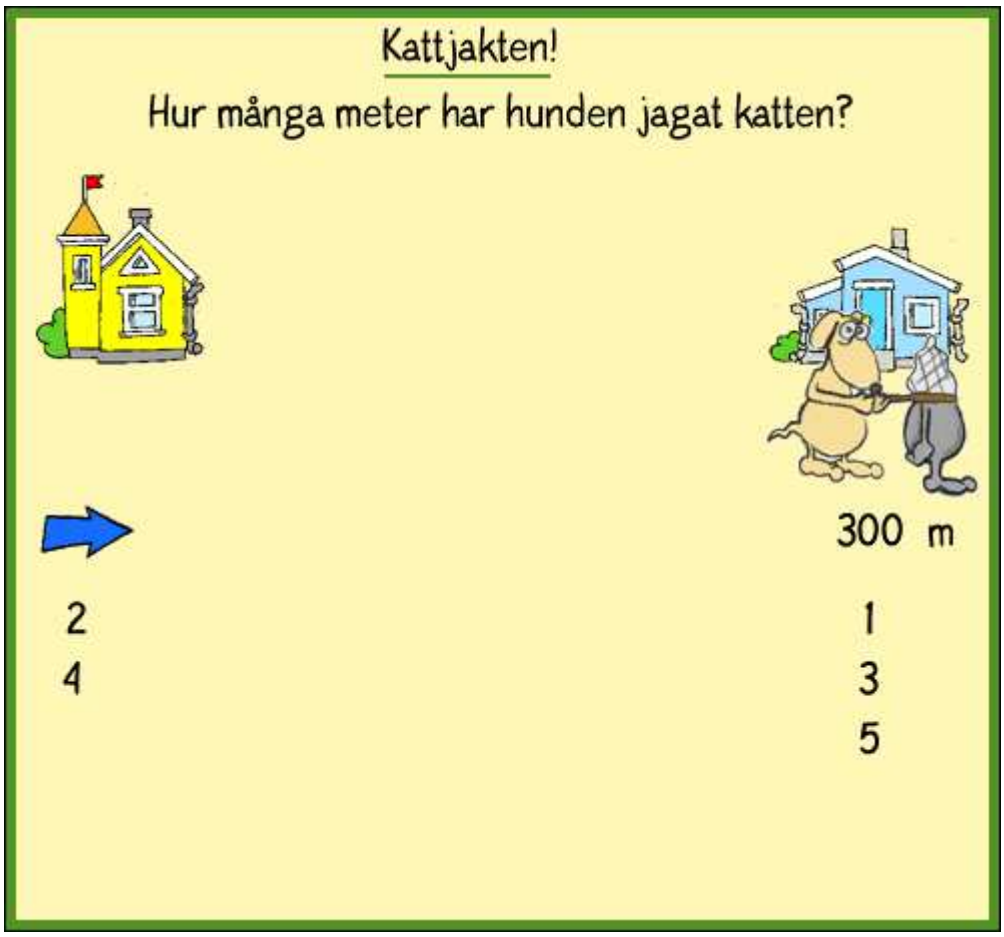
Question 2.


Hur många serietidningar har var och en?
6 fler
18 tidningar tillsammans

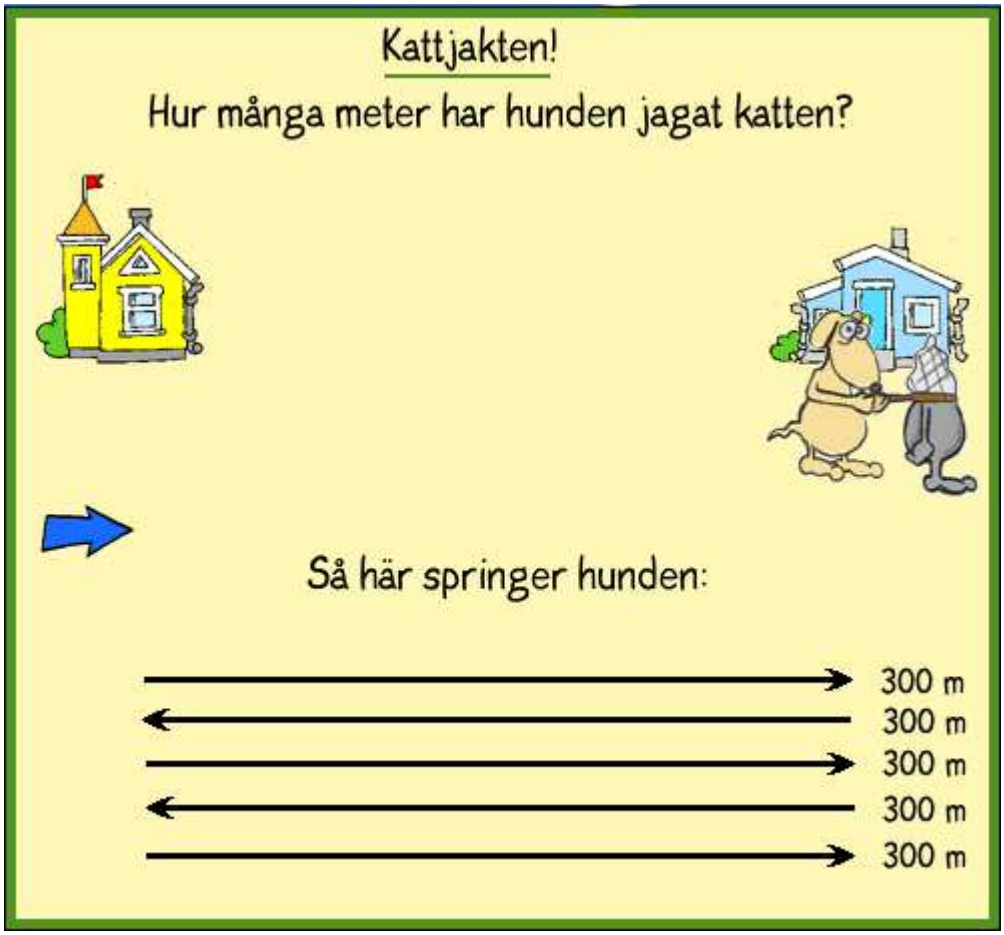
Question 3.


Sjörövarskatten!
Hur många meter kommer kapten Kjoltyg på 25 steg?
10 steg 8 m

Question 4.


Kattjakten!
Hur många meter har hunden jagat katten?
300 m
2
4
1
3
5

Question 4b.


Kattjakten!
Hur många meter har hunden jagat katten?
Så här springer hunden:
300 m
300 m
300 m
300 m
300 m

Question 5.


Äta godis!
Hur många godisbitar fanns det från början?
11 bitar kvar

Question 6.