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IT 15 016
Examensarbete 15 hp
March 2015

The Effect of Visualisation on a Cognitively Demanding Task

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Abstract

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Nowadays, it is more common to see simple interfaces rather than working with the interfaces which look complex. The problem that most students and experts face with when evaluating an interface is mixing up the meaning of usability and complexity. The point is that some of these complex interfaces fulfill the requirements for the definition of usability, ISO 9241 (Bevan, 2001) and usefulness (Nielsen, 2012). In the experiments in what follows, visualization might help the subjects to have a better understanding of a riddle. We did two experiments in two different times and in both of them a well-known riddle was given to the subjects. Since the subjects had to repeat the riddle by themselves to solve it, they had to use their working memory. The riddle was presented in two conditions (auditory and visual) in the first experiment and in three conditions (auditory, visual, visual informative) in the second experiment. In both the first and second experiment the subjects of visual condition did not perform much better than the auditory condition. In the second experiment the subjects did much better in the visual informative condition in comparison with the auditory and visual condition. My conclusion is that the vague visualization does not help much and sometimes bad visualization may misguide the user. But having good visualization with necessary information can help the subjects to have better performance.

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Human-Computer Interaction Degree Project, D-level, 15Credits
June 2014

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1.Introduction

When students taking basic courses and modules in Human-Computer Interaction (HCI) are asked to evaluate user interfaces with a lot of information, they often argue that the interface is not usable because it is too complex. This tendency to mix up usability with complexity is unfortunately not restricted to the student community – it is also a common misunderstanding among usability practitioners. This has led to a situation where it is more common to see interfaces characterized by simplicity rather complexity. The point is however that some of these seemingly complex interfaces fulfill the requirements for the definition of usability, ISO 9241 (Bevan, 2001) and usefulness (Nielsen, 2012). Although they are complex for a novice or lay person, they are serviceable for the professional users because the visualization contains all or most relevant information the users need. It is not efficient for professional users to have interfaces characterized by simplicity in front of them, whereas a complex interface can help them to carry out the task in an efficient way. Andersson, Jansson, Sandblad & Tschirner (2014, p.47) stated that “The solution to the visualization problem is therefore not to avoid or hide complexity, but to cope with it, to accept that the complexity must be there”. Another problem with simple interfaces is that they do not convey and give access to all information that is necessary for the completion of a task in one single interface. Often such interfaces are linked to other pages, so when the users want to carry out another task or search for additional information they need to browse different pages and go back to the main page to complete a certain work task. The problem is that when they do not have all the information in front of them, they need to recall them from what they have seen from other pages. As a consequence, information has to be stored in the working memory during these different tasks, and what users need to do is recalling the information over and over again. During this retrieval process the there is a possibility to forget or to loose the information if they do not rehearse it. So it takes more time in comparison with the situation when they have access to all the information in one and the same screen.

One way to have a usable visualization of information in an interface is to consider human capabilities and limitations. “The design of information and control systems, and the user interfaces, must match the complexity, the needs and the capabilities of the human operators” (Andersson et al., 2014, p.48). Two aspects are considered extra important when visualizing information for professional users: mental models and working memory limitations. In this paper, focus is on visualization in relation to theories on mental models and working memory. An exploration on how subjects might perform in different situations when they need to recall information from different parts of their working memory is conducted. Two experiments are carried out, and in both of them a cognitively demanding task is introduced to the subjects. The effect of visualization on the solution of the task is investigated by having conditions that are supposed to relieve some of the cognitive burden placed on the subjects. The idea was to investigate the relation between the visualization, mental models and working memory, more specifically how visualizations might help the subjects to perform the task. This is seen as an experimental operationalization of the kind of tasks users are confronted with when they meet user interfaces that are designed according to principles of simplicity, not respecting the complex information needed to solve a particular task. The visualization is seen as an operationalization of the situation where the users have all information they need to solve the task.

2. Background

2.1 Mental Models

The term "mental model" originated around 1943. According to Craik (1943/1967) in his book "*The nature of explanation*" the brain imitates what is happening in the real world. In the other words, the brain models the physical processes and predicts the events in the real world. So the power of a mental model is to predict the reality. However, the model that is formed in the brain can differ from the structure of the events in reality. "For Craik a model parallels or imitates reality, but its structure can differ from the structure of what it represents"(Johnson-Laird, 2004, p.183). In 1970 the new ideas initiated to define the mental model in three research areas: Vision, knowledge representation, and discourse. There are six types of mental models, which are explored by Payne (2003). The four types of mental models relevant for the purpose of this study are:

1) **Mental models as naïve theories**: The main idea here is that performance of experts and non-experts are different, but the difference is not in terms of problem solving skills or general information processing capacity, but in terms of domain knowledge. This idea of mental models focuses on the content of knowledge. See for example Gentner and Stevens (1983) for an introduction to this approach.

2) **Mental models as problem spaces:** When a non-expert person tries to solve a problem according to established theory in cognitive psychology (Newell & Simon, 1972), it involves using a mentally constructed problem space of possible states. Problem solving skills here depend on the person's expertise in terms of strategies for using the problem space. For example, Anderson (1987) stated that transitions from search to routine method-application are the major dynamic in most theories of skill acquisition. Card, Moran and Newell (1983) emphasized this view on mental models in cognitive science, and by that parallels the approach to plant operators by Rasmussen (1983).

3) **Mental models as representations in the form of homo-morphisms:** This is the special kind of representation sometimes called an analog representation. It is the idea that mental models share the structure of the world it represents. This is perhaps the most influential of all mental models theories since it deals with both the structure of the world to be represented and the mental processes needed to manipulate the content in order to come up with a judgment or decision. Johnson-Laird (1983) provided some compelling evidence on how humans use mental models in the form of analog representations in order to solve problems, and that humans normally use only one mental model at a time to do this. If it is necessary to use more than one mental model simultaneously, the performance is both slower and inaccurate.

4) **Mental representations of representational artifacts:** Mental models in terms of mental representations of representational artifacts mean that the subjects try to make a map between the meaning of the structure of the environment (for example a work task) and a device's representation of the same structure. In other words, the user needs to know in what way the device (and the designer) has tried to represent the structure of the environment in order to carry out certain tasks. One of the more well know hypotheses in this domain is the yoked state space (YSS) hypothesis (Payne, 2003; Payne, Squibb & Howes, 1990) which states that the any artifact, including computer systems, is conceived of in this way by the users.

2.2 Experiments on Mental Models

There have always been questions about people's perception of their environment. One of the questions is that, whereas we are living in an environment with physical objects and see motion around, why we have problem to understand mechanic physics. But our perception totally depends on how we interpret the question. Larkin (1983) in her work" *The Role of Problem Representation in Physics*" describes the motion and simple mechanical systems by using physical representation and naive representation. We see how it is sometimes complicated to describe a system with physical representations. When we focus on some features in mechanic physics we figure out that the difference between physical representations and naive representations is the cause of our wrong assumption and inaccurate interpretation. It is the difference between simple inference and expert inference. In an expert inference we should put the system in a physical condition.

One of the examples in Larkin's (1983) paper is how to interpret a ball movement when it slid on a smooth curved path. It is possible to look at the movement in different spots by showing the physical forces. For instance in Figure 1, you can see in a curved path in the spots like C1, C2, C3 the height is different so the resultants of physical forces are not the same. We can also calculate the speed in different points based on physical forces. But looking at the movement from the naive point of view is more like comparing it with the similar experiences in everyday life. It is important to know about the naive or student understanding of a system, in order to develop the idea to the expert understanding.

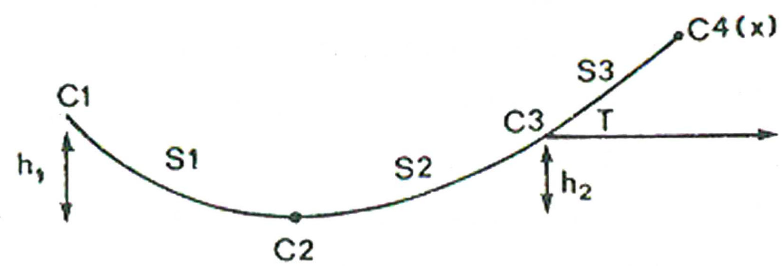

Figure 1. A ball sliding on a smooth curved path.

Beside the aforementioned representations, a good way to analyze physical phenomena is to focus on people's understanding. In the paper "*Phenomenology and the Evolution of Intuition*" by DiSessa (1983), the author looks for the roots and reasons behind physical phenomena around us. The causes are not visible but they are the main reason for the outcome. The terminology for the starting point or primitive layer is called "phenomenological primitives". DiSessa (1983) examines the idea by presenting some physical questions in the form of interviews from some freshman physics students. It is a way to see how naive student sees physical phenomena and compare it with a way that an expert interprets the physical phenomena. For instance asking question about kinetic energy in a ball movement. Here is the moderator statement about the question: "If a ball is dropped, it picks up speed and hence kinetic energy. When the ball hits the floor, however, it stops (before bouncing upward again) At that instant, there is no kinetic energy since there is no motion. Where did the energy go?" (DiSessa, 1983, p.17). She explores the development of the P-prim springiness. The idea is that it reaches from naive to the expert level. The primitive point for different systems is more related to cognitive rather than science theory. She also describes the subject problem with understanding bouncing when a ball hitting the floor. The subject did not believe in the compression of the ball, even after one week she did not mention springiness, but since experts look at their environment based on physical forces they see springiness. There is a difference between the expert and interviewee interpretation of the reason for ball stopping and the start point of the ball, in other words, there is a difference between the expert's priorities and the student's priorities. The priorities are depending on the context and circumstances of the action. Some of p-prims are not recognized by the students and some of them are unknown even by the experts.

Another example of naive perception is the false intuitions. One reason for false intuition is an old mental model in our mind, which makes us to interpret what we see, based on that. For instance the old image from yoyo movement is from our childhood. In this image the gravity force help us to play with yoyo. On one side there is the force of our hand and on the other side there is the force of gravity. Asking the subjects about a yoyo movement on a flat surface is a good example of false intuition. The question is that in what direction the yoyo goes if we put it on a flat surface and pull the string. From an expert point of view, we need to see the whole system as a box in order to calculate the resultant force. Figure 2 shows the direction of reluctant forces on a yoyo when it pulled to the right.

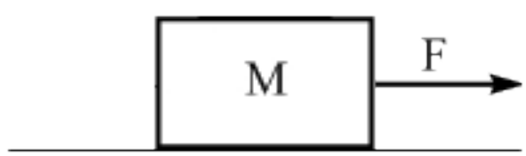

Figure 2. The resultant of physical forces on a yoyo when it is pulled to the right direction on a horizontal plane.

Since there is one physical force in the system to the right, the resultant force will be to the right. But, most people have an old image from yoyo movement. Playing with yoyo make an image in our mind that makes it hard to think about the yoyo in the new situation. In the new system there is no gravity and the image that we have from the yoyo would not help us to guess the right direction for the yoyo. "Even some physicists will make the wrong prediction and attempt to justify it by technical arguments about torque which we strongly suspect are cued by force as a spinner in expert thought" (DiSessa, 1983, p.32).

2.3 Working Memory

Working memory is defined as a system, which can hold the information for a short time. It is also described as the short-term memory, which is the ability to remember information for a short period. There are different ideas about the model of working memory. One of the most famous models is known as Baddeley's model of working memory which is proposed in 1974. According to Baddeley and Hitch (1974), there is the central executive, which has a phonological loop and a visuospatial as its main components. The central executive is a supervisory system and the phonological loop and the visuospatial sketchpad are the specialized temporary memory. " The two specialized temporary memory systems are used actively maintain memory traces that overlap with those involved in perception via rehearsal mechanisms involved in speech production for the phonological loop and, possibly, preparations for action or image generation for the visuospatial sketchpad"(Baddeley & Logie, 1999, p.28). The components has constrains according to their functions in different situations. The constraints caused by the limitation "from the capacity for rehearsal or from the capacity for complexity of material, or from the extent to which they supported by acquired strategies and prior knowledge"(Baddeley & Logie, 1999, p.30).

2.4 Limitations in Phonological Loop

Humans have different phonological loop capacity. One of the factors, which effect on the capacity, is the amount of available memory activation. For instance the patients with impaired verbal short-term memory have low activation of memory. Even though they have capacity to speech but lack of memory activation effect on their performance. They can understand and encode the words and sentences but "the trace of such perceptual processing does not persist, indicating a lack either of adequate activation or of maintenance"(Baddeley & Logie, 1999, p.33). Beside the degree of activation limitation, there is also different capacity for information rehearsal. Studying verbal rehearsal in word length effect can show the limitation in rehearsal. In the mentioned studies, subjects were writing the first three letter of each word. According to Baddeley "rehearsal operates in real time and that longer items will take longer to rehearse, allowing more forgetting to occur"(Baddeley & Logie, 1999, p.34).

2.5 Limitations in Visuospatial Sketchpad

The focus of visuospatial sketchpad measurement is on memory for spatial movement and for visual patterns. So there is a difference between the capacities for retaining visual pattern and for sequences of movement. About the spatial subcomponent, complexity such as dimensionality can effect on the memory for movement sequences. For instance in an experiment (Cornoldi, Cortesi & Preti, 1991) subjects who were asked to imagine paths through two different matrices found the three dimensional 3*3*3 matrix more difficult than two-dimensional matrix 5*5, however, the number of items were approximately the same. About the visual subcomponent, the visual similarity can cause visual confusion. For instance, Hitch, Halliday, Schaafstal and Schraagen (1988) found that the children had poorer recognition in a group of pictures which are visually similar in comparison with the group of pictures which are visually distinct.

2.6 Visualization

In the experiments in what follows, visualization might help the subjects to have a better understanding of a riddle. Ware (2000) defines visualization as a representation which is either an "internal construct of the mind " or an "external artifact supporting decision making". It is like a cognitive support, which assists, human with data by representing information visually. In the *Human Factors in Visualization Research* paper by Troy and Moller (2004) different methods are mentioned which show how visualization can support cognition. The methods are more about the interaction between human and computer in a system like: Increased Recourses, Reduced search, Enhanced Recognition, Perceptual Monitoring and Manipulated Medium. In our experiments, we have tried to improve Enhanced Recognition. Recognizing information presented visually can be easier than recalling information. Improving recognition also make selective omission and aggregation of data possible for the user so the subjects can recognize higher level patterns.

2.6.1 Hypotheses

We did two experiments in two different times and in both of them a well-known riddle was given to the subjects. Since the subjects have to repeat the riddle by themselves to solve it, they have to use their working memory. Using working memory and the construction of mental models helps the subjects to solve the riddle. Our assumption is that since the users need to use two mental models it would be very demanding to solve the riddle. And in fact, the riddle has often been used by social psychologists to investigate the impact of group-think, and one result coming out of these studies is that the expected frequency of correct answers when individuals try to solve the riddle is only 25%.

Hypothesis one: More than 50% of the subjects will fail in solving the task correctly when facing the task in its original version (verbal-auditory condition)

In all conditions of the experiments the riddle is read for the subjects. In the visual condition an image that describes the riddle is given to the subjects. We want to show that the effect of visualization might help the subjects to solve the riddle. In the second hypothesis we assume that the effect of visualization is positive.

Hypothesis two: Subjects in the verbal visual condition will perform better than the subjects in the verbal auditory condition.

In the second experiment we had visual informative condition. In this condition some more information for the subjects were in the image. We expect that the subjects in this condition perform better than the other conditions in the second experiment. There are some text and arrows in the image, which might help the subjects to guess the right answer.

Hypothesis three: the informative visual condition containing the two critical relations that is needed to solve the riddle will be easier to understand.

3. Method

A riddle was presented in two conditions in the first experiment and in three conditions in the second experiment.

The riddle:
A man walks into an art gallery and concentrates on one picture in particular. The museum curator notices this and asks the man why he is so interested in that one painting. The man replies, " I have no brothers and sisters, but that man's father is my father's son" Who is the man in the painting?

A. His son B. Himself C. His father

The right answer is A - His son.

3.1 Experiment One

3.1.1 Design

Two groups of subjects did the test in two different conditions. Table 1 shows the number of subjects in each condition. There were 20 subjects in the verbal auditory condition and 20 subjects in the visual condition.

Number of Groups	Auditory	Visual
1	20	0
1	0	20
Total	20	20

Table 1. The number of participants in each condition in the first experiment.

The Verbal Auditory Condition: In this condition the subjects had to listen to the experimenter reading the riddle. It was also possible for the subjects to read from the written text and choose the best choice.

The Verbal Visual Condition: In this condition the subjects had to listen to the experimenter reading the riddle. Then the subjects had a drawing in front of them to solve the riddle and choose the best answer. Figure 3 shows the drawing version of the riddle, which might help the subjects to choose the right answer.

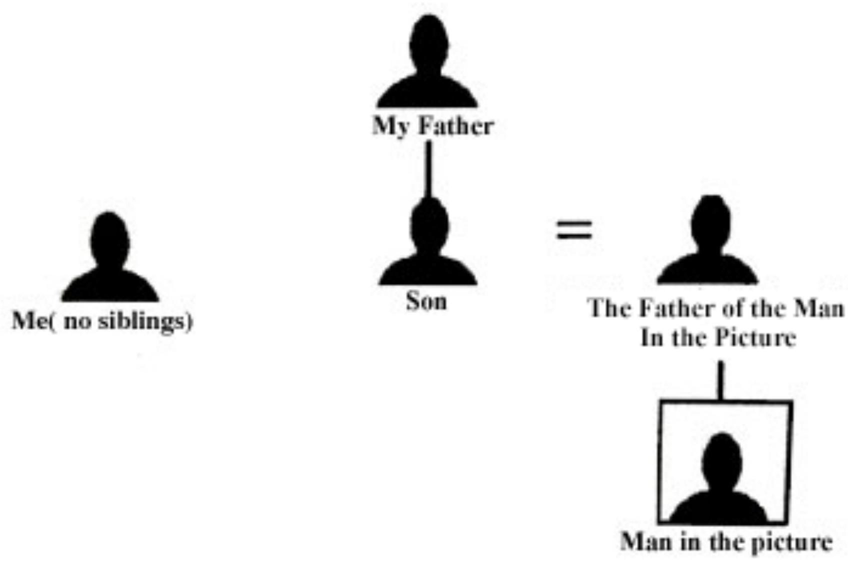

Figure 3. The image shows the drawing in the first experiment in visual condition. Based on Hypothesis two we expect that the image help the subjects to perform better than verbal auditory condition.

3.1.2 Material

In the verbal visual condition the subjects had the drawing on the paper and in verbal auditory condition they had the riddle text on the paper in front of them. They also had the multiple-choice question on the paper to guess the right answer and answer verbally.

3.1.3 Subjects

The experiment conducted by 40 participants from a random set of volunteers from Uppsala University students.

3.1.4 Procedure

The participants tested one by one. First they were briefed by the moderator about what they were supposed to do, then they were listening the text which was reading by the moderator. In the next step they had drawing in the verbal visual condition and the text in the verbal auditory condition in front of them. Finally they answered the question verbally to the moderator. There was no time limitation for answering the question in this experiment.

3.2 Experiment Two

3.2.1 Design

There were 15 groups who conducted the test. Thirteen groups had 18 subjects. One group had 21 subjects and one group did the test for 27 subjects. In the second experiment we had three conditions, Table 2 shows the number of participants for each condition. It shows that there were 94 participants in each condition so the total number of participants in the second experiment is 282.

Number of Groups	Auditory	Visual	Visual Informative
13	78 (6x13)	78 (6x13)	78 (6x13)
1	7	7	7
1	9	9	9
Total	94	94	94

Table 2. The number of participants in each condition in the second experiment.

The Verbal Auditory Condition: In this condition the subjects had to listen to the experimenter reading the riddle. They can ask the experimenter for having it read to them as many times as they wish.

The Verbal Visual Condition: In this condition the subjects had to listen to the experimenter reading the riddle. They can ask the experimenter for having it read to them as many times as they wish. They also have a simple visual drawing of the riddle. Figure 4 shows the drawing, which might help the subjects to choose the right choice.

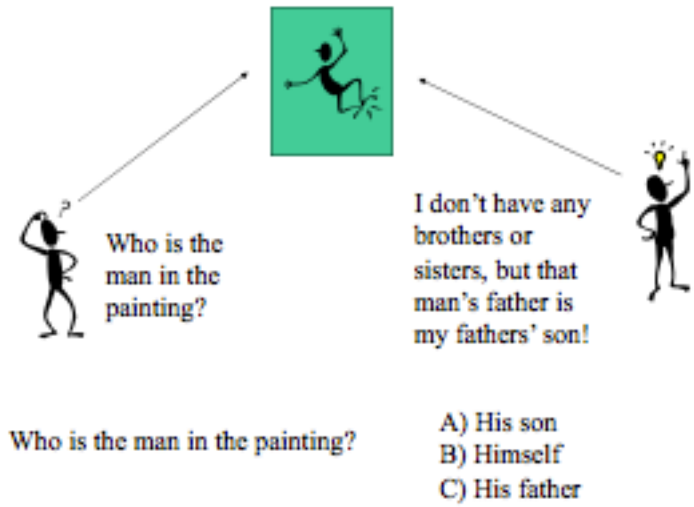

Figure 4. The image shows the drawing in the second experiment in the verbal visual condition. Based on the second hypothesis we expect that the image help the subjects to perform better than verbal auditory condition.

The Verbal Auditory Visual Informative Condition: In this condition the subjects had to listen to the experimenter reading the riddle. They can ask the experimenter for having it read to them as many times as they wish. They also have an informative drawing of the riddle that explains the riddle. Figure 5 shows the informative drawing, which might help the subjects to guess the right answer better than two other conditions.

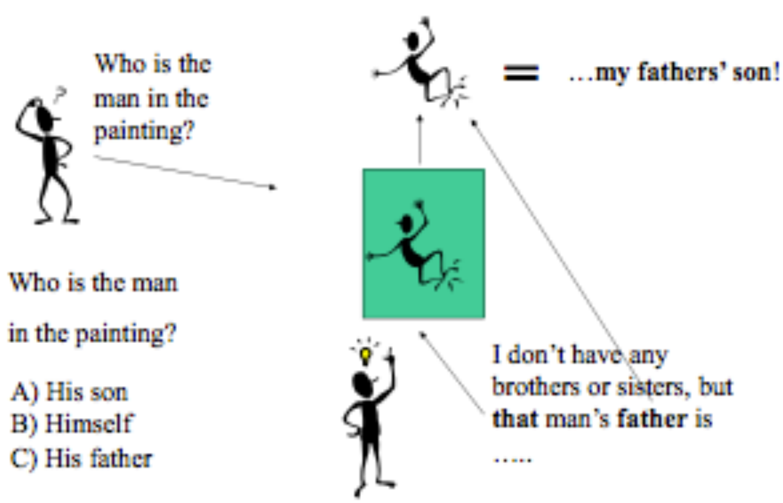

Figure 5. The drawing in the verbal auditory visual informative condition of the second experiment. Based on the third hypothesis we expect that the image help the subjects to perform better than the subjects of other conditions.

3.2.2 Subjects

The experiment conducted by 282 participants from a random set of volunteers from Uppsala University students.

3.2.3 Material

In the verbal visual condition the subject had the simple drawing (Figure 4) on a paper and in verbal auditory visual informative condition the subjects had informative drawing (Figure 5) on a paper in front of them. They also had the multiple-choice question on the paper to guess the right answer. At the end they had piece of paper to write the right answer on that.

3.2.4 Procedure

The participants tested in groups. First they were briefed by a moderator about what they were supposed to do and then they were listening to the text which was reading by the moderator. In the next step they had simple drawing in the verbal visual condition and the informative drawing in the verbal auditory visual informative condition in front of them. The subjects had to reply within 5 minutes by writing down their answers on a piece of paper (A, B or C). They were asked individually to answer the question not in the group.

4. Results

4.1 Tables

Table 3 shows the number of subjects who guessed the right answer in each condition in the first experiment. In the verbal auditory condition seven subjects and in the verbal visual condition three subjects could choose the right choice.

Auditory Condition	Visual Condition
7/20	3/20

Table 3. The table shows the number of correct answers in the first experiment. The result proves the first hypothesis, since more than 50% of the subjects in the verbal auditory condition did not choose the correct answer, but the result is not the same as what was expected in the second hypothesis. Visualization could not help the subjects to perform better than verbal auditory condition.

Table 4 shows the number of subjects who guessed the right answer in each condition in the second experiment. There were 94 participants in each condition. In the verbal auditory condition 29 subjects, in visual condition 31 subjects and in visual informative condition 38 subjects could choose the right choice.

Subjects in each Group	Auditory	Visual	Visual Informative
1 = 6x3 = 18	2/6	1/6	1 /6
2 = 6x3 = 18	3/6	2/6	0/6
3 = 6x3 = 18	1/6	2/6	3/6
4 = 6x3 = 18	2/6	4/6	5/6
5 = 7x3 = 21	2/7	2/7	2/7
6 = 6x3 = 18	0/6	2/6	2/6
7 = 6x3 = 18	4/6	2/6	5 /6
8 = 6x3 = 18	0/6	2/6	5/6
9 = 6x3 = 18	2/6	2/6	3/6
10 = 6x3 = 18	3/6	0/6	2/6
11 = 6x3 = 18	1/6	1/6	0/6
12 = 6x3 = 18	3/6	2/6	3/6
13 = 6x3 = 18	2/6	4/6	1/6
14 = 6x3 = 18	1/6	2/6	2/6
15 = 9x3 = 27	3/9	3/9	4/9
Total N = 282/3	**29/94 = 31 %**	**31/94 = 33 %**	**38/94 = 40%**

Table 4. The table shows the number of correct answers in the second experiment. More than 50% of the subjects could not choose the right answer so the first hypothesis for this experiment was proved. The result also proves the second and third hypothesis since the number of correct answers increasing by improving visualization.

Table 5 shows the duration of completing the task for the users in different conditions of the second experiment. The visual informative condition took more time for the users.

Subjects in each Group	Auditory	Visual	Visual Informative
1 = 18	2 min 6 sec	1 min 50 sec	3 min 19 sec
2 = 18	2 min 10 sec	1 min 43 sec	1 min 34 sec
3 = 18	I min 15 sec	1 min 8 sec	57 sec
4 = 18	46 sec	54 sec	29 sec
5 = 21	2 min 24 sec	2 min 16 sec	2 min 31 sec
6 = 18	1 min 8 sec	54 sec	2 min 47 sec
7 = 18	33 sec	36 sec	42 sec
8 = 18	50 sec	2 min 24 sec	3 min 22 sec
9 = 18	48 sec	1 min 25 sec	2 min 7 sec
10 = 18	3 min 57 sec	1 min 17 sec	2 min 3 sec
11 = 18	2 min 5 sec	2 min 12 sec	1 min 55 sec
12 = 18	1 min 44 sec	1 min 55 sec	1 min 51 sec
13 = 18	1 min 29 sec	1 min 5 sec	1 min 31 sec
14= 18	1 min 12 sec	1 min 24 sec	1 min 57 sec
15 = 27	2 min 1 sec	1 min 51 sec	1 min 30 sec
Total N = 282/3	**1 min 38 sec**	**1 min 32 sec**	**1 min 54 sec**

Table 5 The table shows response time in each condition in the second experiment. However it took longer time for the subjects to solve the riddle in the third condition, but they performed better than the two other conditions.

4.2 Charts

Figure 6-8 shows the number of correct answers in different conditions of experiment one and two.

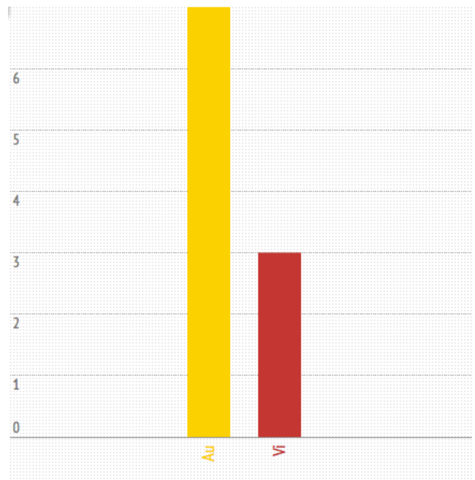

Figure 6 The chart shows the number of correct answers in each condition in the first experiment. The second hypothesis was not proved in this experiment. The visualization did not help the subjects to perform better than verbal auditory condition.

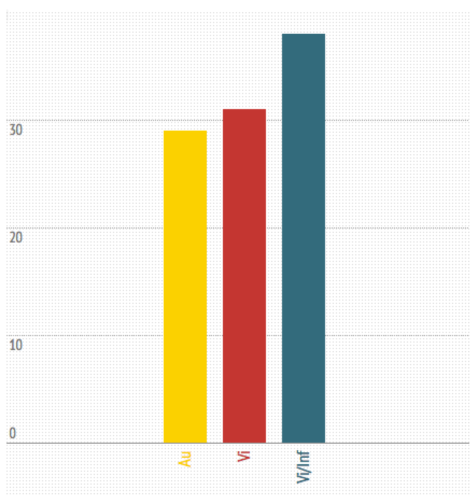

Figure 7 The chart shows the number of correct answers in each condition in the second experiment. It shows that the number of correct answers has increased by improving visualization. The second and third hypothesis for the second experiment was proved.

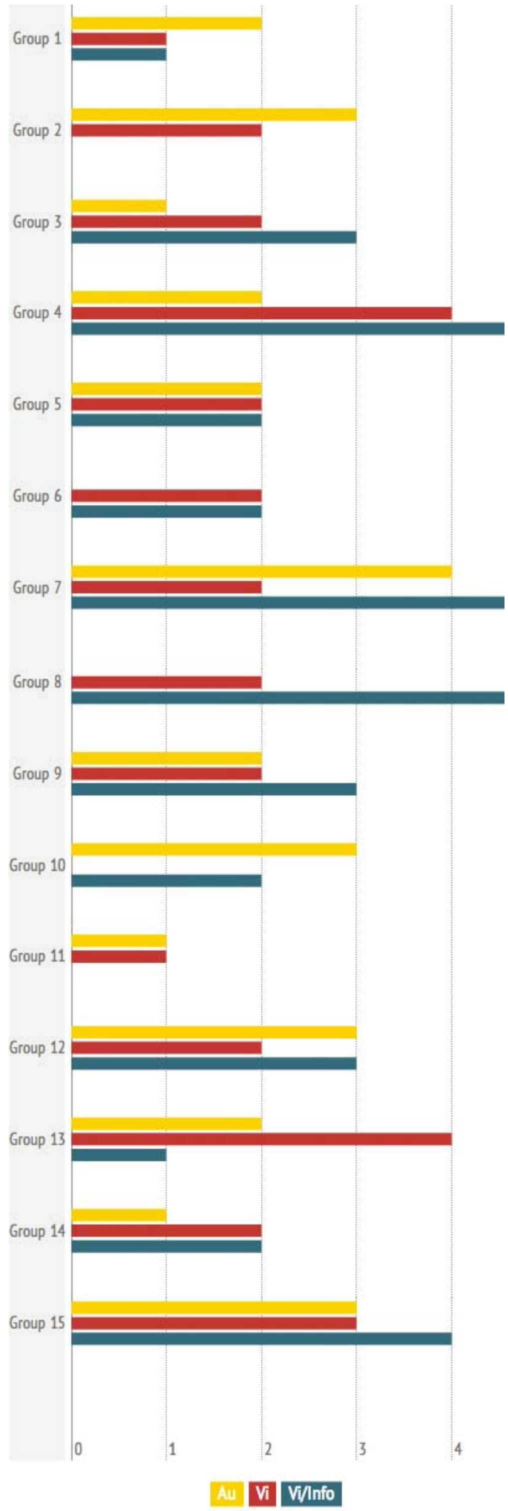

Figure 8 The chart shows the number of correct answers of each condition for each group in the second experiment. Although the results in each group is not the same as what was expected in the hypotheses, but the final result proved all three hypotheses for the second experiment.

5. Discussion

The first hypothesis was proved since more than half of the participants in the auditory condition in the both experiments could not choose the right answer for the riddle. The result is what we were expected. The subjects had to repeat the riddle by themselves. It was hard to use two mental models at the same time. But for the second hypothesis we did not get the result that we were expected, neither in the first experiment nor in the second one. In the first experiment the subjects performed worse than the auditory condition and in the second experiment they did not perform much better than the auditory condition. The third hypothesis, which was related to the second experiment, was proved and the subjects in the visual informative condition performed much better than other conditions in the second experiment.

Considering the visualization of the riddle, one of the reasons that may cause the unexpected result is that the subjects have problem with understanding the visualizing version of the riddle. After the first experiment when I was talking to some of the subjects I figured out that they found the image complicated. One of the subjects tried to draw a simple version of riddle by himself, which might have helped him to answer the question. On the other hand, in the second experiment the subjects performed much better in visual informative condition. I think having the text and image in one paper and connecting the words with arrows could help them to perform better than visual condition. Sometimes the visualization is vague and complicated at first, but reading from the text and mapping the words help the subjects to choose the correct answer. I think that the subjects could make connection between what they are hearing and the text. It is easier for them to connect what they read and what they hear. But in the visual condition in the first experiment when a subject finds the image vague, it is not possible to connect the riddle to the image. In the third condition in the second experiment the combination of the image, text and arrows helped the subjects to choose the right answer. In visual condition, there is no mapping between the images and text so it would be hard to choose the right answer. The other factor that can affect the user's performance is the language. The subjects were chosen from the international students at Uppsala University and most of them were not native, so sometimes they tried to translate the riddle in their language, which makes the riddle more complicated.

There were the subjects with different background but comparing the result of visualization condition in the first experiment and second experiment shows the effect of good visualization. In the first experiment 15% of the subjects could choose the correct answer but in the second experiment more than 40 % of the subjects could choose the right answer. In addition, in the first experiment the subjects in the visualization condition performed worse than auditory condition. Colors and arrows can play a prominent role for improving perception in visualization like highlighting some information by blurring other parts of an image. According to Chen (2005) there are also some unsolving problems for information visualization, which are mentioned in the paper under the name of "*10 unsolving problems for information visualization*". There are some problems, which could be related to our experiments. The first problem is the prior knowledge of the subjects. The image should communicate with the user so information visualization and its users must have a common ground. The domain knowledge of the users helps them to interpret the content. The second problem is education and training, researchers and participants should “learn and share various principles and skills of visual communication and semiotics” (Chen, 2005, p.13).

6. Conclusions

The mental model in both experiments is like what we see in the fourth mental model by Payne (2003) and Payne et al. (1990). The relation between the meaning and the structure of the text, which helps the subjects to solve the riddle, is the important part. If the subjects find the visualization vague they cannot connect the image with what they were hearing. In both the first and the second experiments the subjects of visual condition did not do much better than the auditory condition. The second hypothesis was not proved. In the second experiment the subjects performed much better in the third condition in comparison with the first and second condition. It took more time for them but they have more information and they managed to choose the correct choice. The vague visualization does not help much and sometimes bad visualization may misguide the user. But having good visualization with necessary information can help the subjects to perform better and choose the correct choice.

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