

Use animations to support knowledge transfer built on the understanding of the non-experts' mental model

Wu Xiangyi

KTH Royal Institute of Technology

Stockholm, Sweden

xiangyi@kth.se

ABSTRACT

Kunskapsvisualisering som en ny filial av visualiseringsvetenskap grundades av Burkhard [1] år 2004. I hans teori nämndes animering som ett av de stora visuella formaten för kunskapsöverföring. Det saknas dock ytterligare forskning om dess inverkan på kunskapsöverföring. Syftet med denna studie är att förstå nyckelegenskaper som utgör den mentala modellen för icke-expert på domänkunskaper. Därefter undersöks hur animeringar stöder kunskapsöverföring till icke-expert. I denna studie används hemautomatiseringsplanering som ett fall för att utforska de egenskaper som bäst utgör en bra animation för kunskapsöverföring. Resultaten visade att icke-experters generella uppmärksamhet placerades på orsak och effekt relationer av en typisk automatisk belyningsstyrning och icke-expert hade missuppfattningar möjligen på grund av olika livserfarenheter, kunskapsbakgrund, informationsvaghet och övertygelse. Händelsesegmenteringen i icke-experters mentalmodell användes för att styra animationsdesign som resulterade i högre uppfattad klarhet, mindre missuppfattningar vid kunskapsöverföring till icke-expert. Dessutom visade våra resultat från förklarande observation att animeringar har potential att underlätta samverkande kunskapsöverföring och beslutsprocess.

ABSTRACT

Knowledge visualization as a recent branch of visualization science was established by Burkhard [1] at 2004. In his theory, animation was mentioned as one of major visual formats for knowledge transfer. However, there is a lack of further research about its impact on the transfer of knowledge. The aim of this study is to understand key characteristics that constitute to the mental model of non-experts on domain knowledge. Subsequent to this, it is investigated how animations support knowledge transfer to non-experts. In this study, home automation planning is used as a case to explore the characteristics that best constitute a good animation for knowledge transfer. The results showed that non-experts' general attention was placed on cause and effect relations of a typical automatic lighting control and non-experts had misconceptions possibly because of different life experience, knowledge

background, information vagueness, and overconfidence. The event segmentation in non-experts' mental model was used to guide animation design which resulted in higher perceived clarity, less misconceptions during knowledge transfer to non-experts. In addition, our results from exploratory observation indicated that animations have potential to facilitate collaborative knowledge transfer and decision making process.

Keywords

Animation; Knowledge Transfer; Knowledge Visualization; Mental Model

INTRODUCTION

Domain expert usually refers to a person who has professional knowledge or skills in particular area of endeavour. Communication between domain experts and non-experts to make decisions has been a common scenario in knowledge intensive industries and daily life. Boland and Tenkasi [2] pointed out that conflicting interpretations of given knowledge among different communities may result in communication obstacles. For instance, computer programs implemented by coders sometimes are not in line with project manager's expectation due to lack of preliminary shared understanding of technical constraints; the congress might hesitate funding a valuable scientific research if researchers cannot explain the value of their research clearly, just to name a few.

Seel [3] supported that the learner organizes information strategically in the process of constructing and applying domain-specific knowledge. Information overload caused by the increasing quantity and the decreasing quality of information is one major problem identified in knowledge transfer [4]. Tergan [5] defines knowledge visualization as a field of study which "investigates the power of visual formats to represent knowledge. It aims at supporting cognitive processes in generating, representing, structuring, retrieving, sharing and using knowledge". Tools often used by experts to transfer knowledge are text, images, and Microsoft PowerPoint, which sometimes lack of visualization competency for sufficient understanding [1]. Animations allow for representing complex and dynamic

changes over time and contains information which can be cognitively processed by multiple channels [6].

In this paper we report on a study that was designed to expand the knowledge about non-expert's mental model during knowledge transfer so that the implications could generally help design better knowledge visualizations. The purpose of this research is to understand comprehension process of non-experts on domain knowledge and to investigate the characteristics that animations supporting knowledge transfer should have. The results from an animation evaluation indicated there is great potential of animations to improve knowledge transfer. In addition, through diagrammatic-oral interviews, we found several features of non-experts' mental model when it comes to transferring automation controls knowledge. Furthermore, by presenting voiced animations explaining home automation controls for non-experts, we observed an increase of correct understanding on automation control knowledge.

BACKGROUND

Burkhard [1] states that while there are many different visual formats only a small part of them are actually used for transfer of knowledge, for example through clip arts or diagrams. Furthermore, he came up with the knowledge visualization (KV) model (Figure. 1) and framework to offer evaluated visualization tools and help choose the best visualization for different problem.

In our study, we applied key suggestions from KV model to diagrammatic-oral interview and animation evaluation. In Burkhard [1] knowledge visualization model, the key strategy in knowledge visualization suggested is the usage of complementary visualization for the different steps in the knowledge transfer process. In his KV model, he sketched a general guideline of designing KV following steps as 1) provoking image, 2) context of the knowledge to make the recipient aware of the importance of the knowledge for him, and that the 3) overview should show the big picture on the topic followed by some options to act.

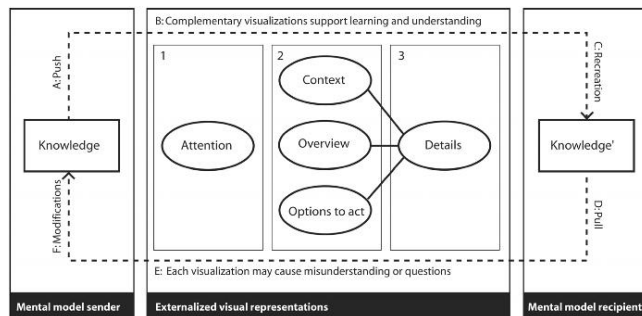


Figure.1 Knowledge Visualization Model

FUNCTION TYPE	KNOWLEDGE TYPE	RECIPIENT TYPE	VISUALIZATION TYPE
Coordination	Know-what	Individual	Sketch
Attention	Know-how	Group	Diagram
Recall	Know-why	Organization	Image
Motivation	Know-where	Network	Map
Elaboration	Know-who		Object
New Insight			Interactive Visualization
			Story

Figure. 2 Knowledge Visualization Framework

Burkhard [1] also raised four perspective types (Figure.2) that should be considered when creating visual representations aiming to transfer knowledge. A Function Type Perspective answers why a visualization should be used, a Knowledge Type Perspective clarifies the nature of the content, a Recipient Type Perspective points to the different backgrounds of the recipient/audience, and finally the Visualization Type Perspective structures the main visualization types according to their individual characteristics. Burkhard [1] defined an animation as “a depiction of changes through time that would not be evident if the frames were viewed separately”. He classified animation as one type of Interactive Visualization in this KV framework. However, the KV model does not give further implication or guidance on practical animation making purpose of knowledge transfer, and there is insufficient attention paid on integrating relevant visualization principles to support knowledge transfer and collaborative decision making sufficiently.

As regards the effectiveness of animation, Mayer [7] has stated that the effects of animation will be major when (1) the material is explanative (2) the animation is explanative and depicts the changes in a system, or (3) the subjects are inexperienced. There were controversial conclusions about effectiveness of animations on comprehension and learning. For example, Kim [8] asserted that “animations are not more effective than equivalent static graphics in learning” after reviewing many other studies and conducted their own experiments. However, Fleming [9] claimed that when it comes to demonstrating processes which are hard to be viewed naturally, animations are highly effective because a creation of mental representations of phenomena was supported to promote better understanding. Tversky [10] reviewed research on animation and they found most of the successes of animation seem due to advantages in extra information conveyed or additional procedures, rather than the animation of the information *per se*. They suggested two principles for successful animated graphics, which is congruence principle and the apprehension principle. The congruence principle is that the structure and content of the external representation should correspond to the desired structure and content of the internal representation. The apprehension principle is that the structure and content of

the external representation should be readily and accurately perceived and comprehended. The event segmentation theory (EST) [11] defined that “event segmentation is the perceptual and cognitive processes by which a continuous activity is segmented into meaningful events”. By segmenting dynamic process into a number of meaningful units people comprehend complex activities.

When it comes to the knowledge transfer, Rosen [12] designed an animation-based learning environment for knowledge transfer and tested it with 400 students. Their results indicated that animations significantly increased the ability to transfer scientific and technological knowledge. Olakumbi [13] examined the usage of visualization principles on supporting knowledge transfer in teaching and learning. They found some principles have better impact than others in improving high-school learner’s knowledge representation. Guidelines with noticeable influence on knowledge transfer include know your data, clarity, easy to understand, use of colors, clear boundaries, legend and relationship between concepts clearly shown. Martin J. Eppler [14] examined what is an effective knowledge visualization and they extended listed of requirements for KVs which are visual variety, visual unfreezing, visual discovery, visual playfulness and visual guidance. In a case study of Business knowledge visualization for Architects (BKV4A) [1], business diagrams were integrated into a method toolbox of architects to deal with the gap between decision makers and architects. The result of the case study is that the use of complementary visualization can improve communication, knowledge transfer and fosters the engagement of decision makers in presentations. Moreover, it reduces information overload, prevents misinterpretation, increases the information quality and improved the making of decisions. Cyril [15] indicated that animation was overall beneficial to retention, but only learners studying collaboratively benefited from animated over static graphics. Novak [16] examines the effects of collaborative knowledge visualization on cross-community learning and identifies that the knowledge exchange between heterogeneous communities of practice as the critical source of innovation and creation of new knowledge. Through interaction and social relationships between the members of the communities, new knowledge can be created with the help of visualization. Sabrina [17] introduced a collaborative knowledge work framework which contains five collaborative dimensions which are visual impact, clarity, perceived finishedness, directed focus, inference support, modifiability, and discourse management.

In summary, prior research identified problems in knowledge transfer and knowledge visualization theory was established as a tool to help knowledge transfer and

management. As one mean of knowledge visualization, animations have been proved to benefit people’s understanding while some researchers are skeptical about its overall effectiveness. Studies of animation’s effectiveness under individual and collaborating setting have been done. However, regards to in what way animations could be helpful to knowledge transfer is not fully understood or investigated. The relation between non-expert’s mental model and its support on animation design was not sufficiently studied either. This paper is interested to bridge these gaps by an user-centred design process.

RESEARCH QUESTIONS

1. What are the directed attention, misconception and event segmentation of non-experts when they comprehend domain knowledge information in text.
2. In what ways could animations help facilitate knowledge transfer to non-experts more accurately.

METHODS

Case study

Since investigating knowledge transfer in general is unrealistic, we focus on home automation planning, namely deciding automation control to be installed at home, as a hypothetical case study. There are numerous home automation possibilities, and often complex and abstract to be understood easily or accurately by non-experts. Still, a home owner needs to make decisions based on suggestions given by automation experts. Information overload and misinterpretation are common and usually cause time waste and sub-optimal decision making. The reason of choosing this case is that three conditions initiated by Mayer [7] were met thus effects of animation suppose to be major. First, animations are used for explaining automation control. Second, the target of knowledge transfer is inexperienced home owner. Third, automation controls involve many changes among system components. E.g. the status of sensors will trigger changes of corresponding actuators.

A typical home automation control selected to be examined in this study was daylight dependent lighting control (Figure 3). It is a stand-alone control of the lighting within a space which can save operating and energy cost by utilizing the natural light. The lighting control works when required electrical components were wired and communications among components were established according to industrial standards.

Daylight Dependent Lighting Control
Constant light switching switches on the lights whenever people are moving about in the detection range and the available daylight is insufficient to provide the desired level of brightness in the room. In doing so, the presence detector detects the lighting power of the installed lamps. As soon as there is enough daylight, the artificial light source is switched off.

Figure.3 Text description of the lighting control [18]

The research method contains four steps which are diagrammatic-oral interview, parallel design, animation evaluation, and exploratory observation. (Figure 4) The reasons for the four steps setting are as follows:

1. There are two research questions to be answered, and the answers for the question one help figure out the answers for the question two. Therefore methods are designed in step manner. At least two steps needed to answer two questions.
2. An intermediate step (step two) is designed to provide animations for evaluation purpose in following steps.
3. Step three and step four both aim to answer the question two, while the step three is the main evaluation stage and the step four is to explore animation's impact under collaborative scenes.

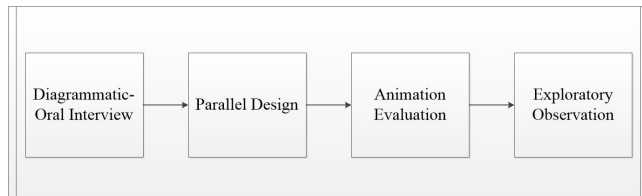


Figure. 4 Research Methodology

Step one: Diagrammatic-Oral Interview

Diagrammatic-oral interview has been proven to be an effective elicitation method of mental models. [19] Different from ordinary oral interview, it allows users to draw their thoughts in visual forms and combines the oral explanation and drawings to reveal user's mental pictures more completely. After receiving the instructions, users are provided with a piece of paper and varied color pens, they will draw out their minds in sequences of picture, diagram or text. Due the visualization nature of our study, it is a good method to complete visual information which is hard to be accessed through normal oral interviews. Also,

drawing itself may contains direct indications on animation design.

Nine participants (7 male, 2 female) between 21 to 33 years old were invited to diagrammatic-oral interviews. Four of them were mechanical engineering students, with three design students, one electrical engineering student, and one communication engineering student. All participants are not experts in home automation control. Regards knowledge level about selected lighting control, only one participant had experience of using similar control. Rest of them either never heard of it or never use it before. Except two designers, others have very limited experience in information visualization.

In the interview, participants were first asked to fill out a survey on gender, age, knowledge level about automation control, and experience in information visualization. After signing the informed consent, they were presented a scrap of paper with text description about daylight dependent lighting control. They were asked to depict their mental picture of this control in sequences of drawing and text. This was followed by a semi-structured interview including five questions asking them about drawing explanation, clarity of control description, details in mental picture, limits on drawing, and their degree of interest. The data collected in this step are nine drawings and recording of interviews, which were analyzed by thematic content analysis method to (1) recognize non-experts' directed attention, perceived clarity and misconceptions of presented lighting control, (2) to find possible explanations, and (3) to understand mental event segmentation of selected lighting control. Findings in this step were taken as input for making the animations in step two. Table.1 explained each focus explicitly.

Participants were encouraged to draw the selected control in the blank comic strip we provided, so that we can investigate their mental event segmentation partly by observing what did they draw in each grid of comic strip. For example, if there is one element changes in the first piece of drawing and second piece, then it is inferred the change of that element should be the event boundary in segmentation.

Table.1 Focus of diagrammatic-oral interview analysis

Directed Attention	What non-experts highlight in their drawings or talk about most
Perceived Clarity	How clear non-experts think the selected lighting control is after reading text
Misconception	False assumptions or wrong belief toward the selected lighting control
Possible Explanation	What might caused the misconceptions
Event Segmentation	How non-experts segment the selected lighting control cognitively

Step Two: Parallel Design

Nielson [20] proved in his case study that when various designs were made independently, measured usability from interface version 1 to version 2 was improved by 70%

compared to the 18% improvement when using iterative design. Parallel design has been widely used in user interface design, the idea behind it is adopted in our animation design process. In this study, this was done in order to achieve more diversity in animation design and therefore potentially gaining more and contrasting feedback in step three.

Based on findings from diagrammatic-oral interviews and animation design implications from previous research, three different voiced animations were made to visualize daylight dependent light control (Figure 5, 6, 7). Microsoft PowerPoint was used to make the animations due to its abundant animation effects and efficiency.

From related work done in animation's effectiveness of expression and influence on human's cognitive process [6, 10], the following deprived principles were applied into animations:

1. Animations should be slow and clear enough for observers [10]

Animation one, two and three were 26, 28, 18 seconds long respectively. Transformations occur in a long period of time. For example, in the animation one, a simple transformation that lamp turns to yellow from grey took almost 2.5 seconds. When animations were designed in Microsoft PowerPoint the default slowest animation effects were applied to element transformations. Animation three is the shortest because it involves less number of transformations than animation one and two.

2. Annotation, using arrows or highlighting or other devices to direct attention to the critical changes and relations. [10]

In each animation, effects like object flickering/color change/size change/object motions were designed to direct attention to critical changes and relations.

3. Narrated animations are a very effective form of a representation as they allow complex information to be presented in ways that take maximum advantage of the limited capacity cognitive system. [6]

Animations were narrated using computer synthesized female voice.

4. Knowing where people naturally perceive discrete events is important to decide where to segment long animations. [6]

All of animations were in line with participant's event segmentation pattern.

Three animations focused on visualizing essential cause-effects of control and only included visual elements

appeared in user's drawings. The differences among three animations were that the third animation is in pseudo 3D form while the first and second animation were totally 2D schematic. Because we assumed information of context will be conveyed to different extent when designing in higher/lower dimensions. For example, with 2D visualization, the relative spatial depth information is not revealed. The first animation was a bit richer in elements and context-oriented compared to second animation, but the context was not as realistic as third animation. Realistic visualization might convey a sense of reality while the abstracted visualization probably leads user focus on the essential relations between elements instead of get distracted from richer information contained in realistic context. Second animation used least colors, while the third one used most and the first was in between. The reason of designing so is that we think color of use could probably influence user's directed attention.

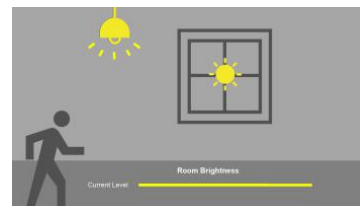


Figure. 5 Animation one

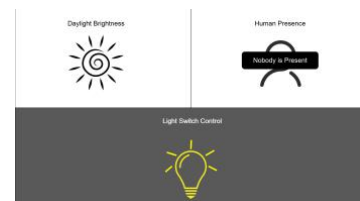


Figure. 6 Animation two



Figure. 7 Animation Three

Step Three: Animation Evaluation

In total, nine subjects were invited to the animation evaluation by hallway testing. All of them were non-experts on automation controls. Each animation was presented to three non-experts with different academic backgrounds. In order to "catch receiver's attention to make him open for knowledge" [1], a provoking image (Figure. 8) of artificial

light was presented on the screen at the beginning. The researcher started introducing the context to “make the recipient aware of the importance of the knowledge for him” [1]. This was then followed by a semi-structured interview to examine their comprehension level, perceived clarity, misconception, degree of interest, perceived experience with animations after video displaying. The interview data was qualitatively analyzed to draw conclusions on how could animation help facilitate knowledge transfer to non-experts more accurately.



Figure. 8 Provoking image of artificial light from the internet

Step Four: Exploratory Observation

The exploratory observation contains two role-playing sessions which were set up to simulate real communication scene between home owner and automation expert. Role-playing have been widely used in design ideation. Hosseini [21] evaluated the utility of role-playing methods and they found that details generated from role-playing sessions “provide designer in terms of actor’s actions, settings, events, evaluations and plans.” The purpose of the step four is to observe the influence of animations on user’s actions, opinions under real collaborative settings, thus role-playing is a suitable method to use.

By convenience sampling [22], two participants without technical knowledge on target control were invited as non-experts, and a designer previewed the technical information on target control played as automation expert. Text and animation were used in the first and second session respectively. In each session, one non-expert and the expert had conversations based on the material provided.

Each role-playing session ends when the non-expert signals the researcher he/she has made the decision or does not want to discuss further with the “expert”. The time duration of each role-playing session was counted. The “expert” was provided with an iPad and responsible for introducing selected lighting control by

the aid of text description (in first session) or animation (in second session) to two non-experts respectively. The animation used in this step (Figure 9) has been improved aesthetically based on participant’s suggestions from step three. The non-expert was asked to imagine to have a new house that should be equipped with the latest home automation controls and that he is consulting the expert. They needed to decide whether they want target control at home after consulting the “expert”. The whole process was recorded and all participants had semi-structured interviews about perceived clarity of the control (only for non-experts) and collaboration experience. The recording and interview data was qualitatively analyzed to explore animation’s impact under collaborative knowledge transfer settings.

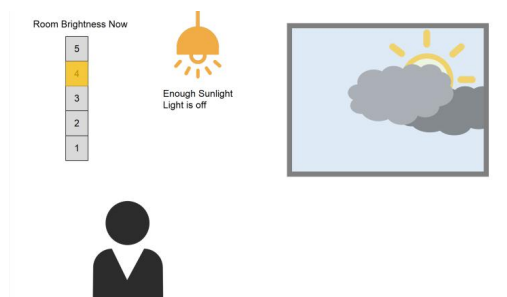


Figure. 9 Improved animation based on participant’s design suggestions from step three

RESULTS

In this section, evaluation results from step one, step three and step four are presented in succession. In the method step two, mainly animations were designed for evaluation purpose. Therefore it is not included in result section. Diagrammatic-oral interview results provide answers for how do non-experts comprehend domain knowledge information in their mental model. Animation evaluation results implied in what ways could animations help facilitate knowledge transfer to non-experts more accurately in individual setting, while the results from exploratory observation give hints on animation’s impact under collaborative setting.

Step one: Diagrammatic-Oral Interview

In semi-structured interviews, all participants explained their drawings sufficiently and the perceived clarity of text description were high in general. In the drawings collected, text with arrows were used often to explain how selected lighting control works as they perceived. One participant misunderstood researcher’s instruction, he thought he should focus on explaining the control clearly (so that he used a complicated graph) instead of just drawing out what was in his mental picture. Other two participants also used graphs to explain control patterns without misunderstanding

researcher's instructions. No one stated any difficulty in imagining the target control. Seven out of nine participants stated that due their drawing capability, they were not able to express all of aspects, for instance in the smooth transition between sun and moon. Results are presented in detail as follow from perspectives of directed attention, misconception, possible explanation, and event segmentation.

Directed Attention

From the drawings and verbal explanations, the participants' directed attention was revealed. Most drawings reflected the cases which leads to status change of artificial light. (Figure. 10 and Figure. 11). For example, participant of drawing one said "The second case is the light is insufficient, and the third case when there is a human...". Participant of drawing two said "Show different cases of the sense of the control working". During the interviews, they analyzed the cause and effects of selected lighting control.

Participants' directed attention also placed on the material needed (Figure. 12), the spatial location of components (Figure. 13), and control implementation (Figure. 14). The participant of drawing three said the window needs to contain some special chemical glass which allows to control the opaqueness according to real-time daylight. In drawing four, the participant explained that the lamp should be put besides the window because sunlight needs to be detected. The participant drew Figure 10 mainly talked about connections between electrical parts and he admitted that he focus more on how to optimize this control. As he said, "There must be some information exchanges between sensors, detectors, switches to realize this control. There must be a working connection between all stuff."

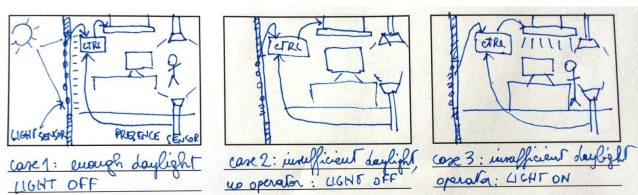


Figure. 10 Drawing one. Directed attention

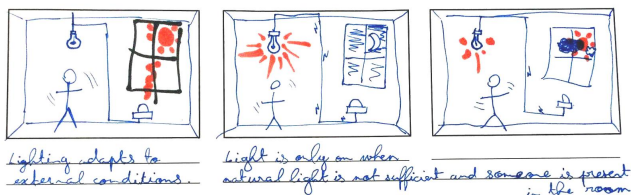


Figure. 11 Drawing two. Directed attention

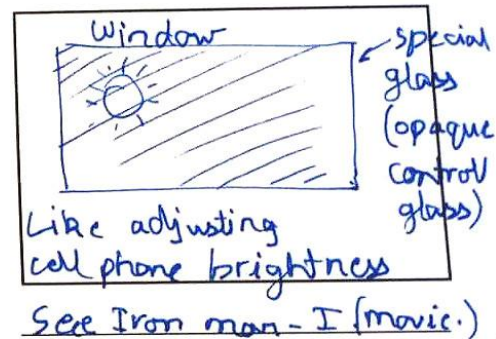


Figure. 12 Drawing three. Material needed

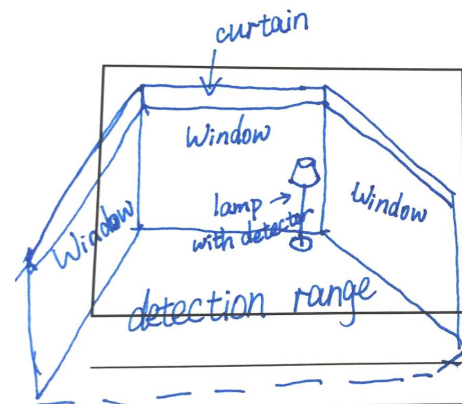


Figure. 13 Drawing five. Spatial location

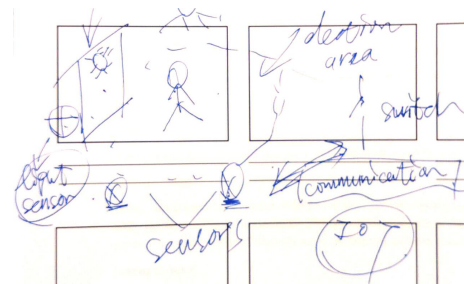


Figure. 14 Drawing four. Control implementation

Misconception

Three subjects assumed that the light would be dimmed or gradually changed even though it was only written as turned on/off in the instruction. One subject thought this control needs certain material such as special glass (Figure 12) in order to control opaqueness of windows and to adjust the amount of daylight coming inside. Another subject assumed three transparent walls needed for this control so that more sunlight could come in. (Figure. 13). Another participant explained how should the blind work automatically to allow maximum daylight with the assumptions that this control mainly relies on automatic blind and daylight coming inside could be adjusted (Figure. 15). When asked about how much were they interested in

installing selected control, one participant assumed the control can be expensive even though no price information was mentioned. As he said, "... but this is special glass, it can be quite expensive...depending on if I am rich. The normal room you just have the switch, room usually use sensors at home. Of course it can be expensive." One participant added an extra feature which did not exist in the text description. He thought the light would be turned on few seconds before people walks in. Table. 2 and Figure. 15 listed the misconceptions.

Table.2 Five typical misconceptions from text description

Number	Misconception	Actual information in text	Frequency
1	The artificial light will be dimmed or gradually adapted to natural light strength.	The light will be turned ON/OFF	3
2	Special material are needed (Special glasses/three glasses)	Not mentioned	2
3	The function will be expensive	No mentioned	2
4	Presence prediction feature	Not mentioned	1
5	An automatic blind will adjust the natural light coming in	Not mentioned	1

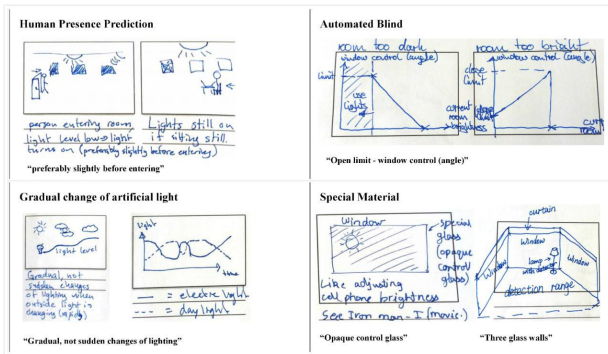


Figure. 15 Misconceptions reflected in drawings. Small images on Left-up, Left-bottom, Right-up, Right-bottom corner corresponds to misconception number 4,5,1,2 respectively.

Possible explanation

Life experience

Subject's life experience influenced their perception of the selected control. For example, the participant who initiated the presence prediction feature stated this feature existed in his previous project experience.

Knowledge background

One non-expert who had misconception of window control studied mechanical engineering, which might made him tend to quickly focus on possible mechanical control mechanism intuitively instead of examining the factual

control description. Another non-expert is an electrical engineering student, who focused on communication mechanism between electrical parts.

Vagueness of text

The text description itself was in lack of clarity in elements like how many person should be detected to trigger light, and what is the detection range etc. Vague information confused participants and drew their extra attention. Most participants tended to assume relevant cause and effects in vague situations.

Overconfidence

Overall the target control was perceived pretty straightforward to be understood, which caused subjects to feel assured that they understood when they actually did not. For instance, two participants had misconception of special material claimed the select control was "pretty straightforward, I understand what was there". When asked about is there anything unclear in select control, they both said no very confidently. It was observed that subjects who revisited the text more often to confirm facts had less misunderstandings on target control.

Event Segmentation

In most of drawings, subjects put all visual elements together (Light, Sun/Moon, Room, Window and/or Door, Sensors, human, graph). Then they focus on the abstracted key elements and key events. In this case, the key elements were artificial light and natural light representations (Sun/Moon). There is a lack of concrete images and details in their mental model according to the interview. Subjects identified which elements were changing and which were not, accordingly they imagined the changes of certain key elements and analyzed dynamic relations between these changes. They tried to synthesize cases and relations into graphs. As we observed, the event boundaries usually were different status of artificial light or the Sun. For example, when the artificial light is on or off. The order they mentally pictured continuous changes of sunlight slightly varies. For example, some participants pictured the sunlight is very weak in the beginning and gradually get brighter, while other participants started picturing it from bright at force to total darkness. (Figure. 16)

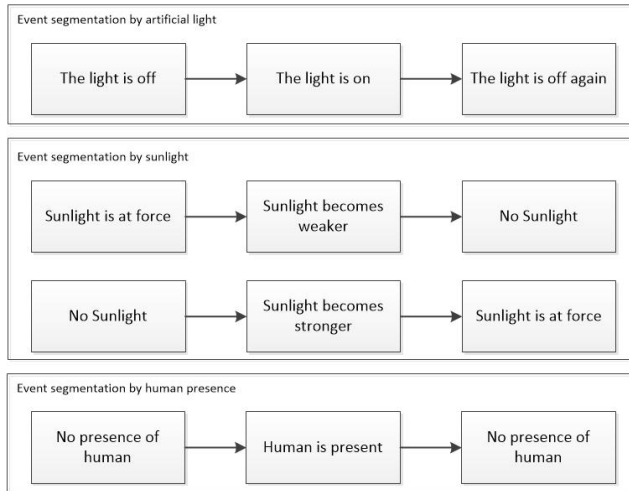


Figure. 16 Event segmentation patterns found in diagrammatic-oral interviews.

The commonality was that subjects selected key events, for example that people walks into the room. They pictured the control partly in the order 1) what is the status of each element before people come in, 2) the visual representation of people in the room, and 3) corresponding status changes of relevant elements when people stand in the room.

Step three: Animation Evaluation

comprehension level

Generally, all participants did not have problem in understanding the presented control, except one non-expert that needed to watch the animation three again. As showed in the Table 3, the animation two had best perceived clarity and did not cause any misconception from non-experts.

Table. 3 Perceived clarity of animations (5 is very clear)

	Participant one	Participant two	Participant three
Animation No.1	3	5	4
	Participant four	Participant five	Participant six
Animation No.2	5	5	4
	Participant seven	Participant eight	Participant nine
Animation No.3	2	3	5

In animation one, a participant misinterpreted on a line of text and assumed the light was turned on gradually or immediately while watching animation one. Later on in the interview he explained that it was because the lamp was filled with yellow color gradually in the video. Except for that, no other misconception occurs. In animation two, no misconception observed from the interview, non-experts understood it accurately. In animation three, the third participant thought the light should be switched on/off few seconds later after detecting human presence. Perhaps it was because when making the animation three, there was two seconds unintentional delay of light turning on after people showing up. Except for that, no other misconception were observed.

Two participants thought it was unclear how could they set up required brightness. However, this information was not mentioned in the control description itself.

“It is a little bit unclear Can I control this required brightness or not.” - Participant watched animation one

“So you set up the optimal quantity of light, how can you determine how much light do you want, is it something automatically?” - Participant watched animation two

degree of interest

Overall, non-experts with engineering background would like to see more details to be explained in the animations such as, where should the presented control be installed and how could it detect human movements etc. While non-experts with non-engineering background were more concerned about where the presented control could be used, and what benefits (in terms of energy and cost saving for example) the control offer them. Subjects interested in having presented control said they like it because it was automatic, saves energy and convenient. Two subjects decided not to install it. One of them thought it was not necessary for him and the other one said he already had an alternative control at home named *the telldus* [23], which he preferred more. Two subjects said they would like to experience it first before making decision. As they said, “Before I said yes I want to buy it, I want to experience it first. From the video I wouldn’t buy because I did not see the big value or how much better it will make my life.”, “I understand logically how it works but I cannot really feel or sense how much better it will make my day or my life. If i experienced it and found it is actually something really good... I would like to try it first. I wouldn’t pay money now.”

One non-expert with electrical engineering background watched animation three and explained why he cannot make decision immediately. As he said, “I think it is quite simple, It brings the concept but I think if you want to go deeper If you want to sell this product, to be more like detailed, matching with actual application, maybe have a video of how it is really working, if I would install it I would like to experience it first before I install it. I would like to see it in a room, to experience it.”

perceived experience with animations

During the study a few participant came up with small suggestions for improvements on animations. For instance, color use and how should figures move etc. For example, one participant claimed the animation two was too dark and he preferred some brighter colors. Another participant said the virtual character in animation one should not walk in and out the room with same gesture, he suggested to move the figure more naturally. Generally, the participants liked the narration pace and simplicity of all animations. Most of them thought the animations conveyed presented control very well.

“I like the pace, it was not too fast and not too slow for me, so I think I understood it.” - Participant watched animation one

“It is pretty good, I like it because it is simple, without lots of extra elements.” - Participant watched animation one

It was observed that non-experts with engineering background tend to think in terms of optimizing or implementing this control, so even though they think the animation is self evident *per se* but they believed more details needs to be explained. For non-experts with non engineering background, the amount of information is enough for them to understand the control, but when it comes to making decision, subjects wished to see its value in energy or cost saving.

“It is okay, maybe have a sensor so you can detect when people comes to room but now you don’t know happened in background. I should have a sensor to detect people coming to the room and maybe five minutes after it switched off.” - A Participant watched animation one.

Step four: Exploratory Observation

The first role-playing session (text used) lasted 10 minutes until the non-expert signaled the researcher to stop. The non-expert had a misconception in the beginning and assumed a dimming feature which did not exist in the text. The second role-playing session (animation used) only

lasted around 4 minutes, with the non-experts showed no misconception on presented control. Regards the perceived clarity, the animation was perceived explaining presented control clearer than the text.

When it comes to non-experts’ interested aspects of target control, they said they were interested in the cost, installation time, and how it would affect their life.

“I was most interested in how was it used as a user, how do I control it and how do I interact with it. The technical solution is interesting for me personally but what matters is how simple the control is.” - Non-expert in the first session

“I think I was interested in how will it be effecting me, how will I experiencing the difference of lights depending where the sensor is. Will it be different how light it is in the room. And If I don’t agreed what is automated, can I change that. Because I may in the mood I don’t want to have so much lighting one day, so the aspect I am interested in is how would I experience it.” - Non-expert in the second session

During the post-interview, the “expert ” compared her experiences between two sessions. She thought that the text description did not help her save time in explaining during first role-playing session because she still needed to explain the control description to clarify for the non-expert. It was quite interesting for her that non-expert in both sessions thought about the control in terms of various real-life scenarios which she never thought of before. For example, the second non-expert asked what if there was a curtain on the window, what would be the difference between installing light sensors inside or outside of the window. The expert thought that such communication would help technicians to think more about real life context instead of just simple installation according to product manuals.

DISCUSSION

In this section, possible explanations for partly results and potential flaw in methods which might biased our findings were discussed.

Possible explanations for effective animations

From the diagrammatic-oral interview results, there was an obvious conflict between subject’s perceived clarity and misconceptions on text description. Even though non-experts thought the control *per se* was simple and clear enough from plain text description, chances were very high they would have unexpected misconceptions. Potential explanations could be different life experiences, knowledge backgrounds, overconfidence, and vagueness of text. Animations designed to express the same control showed good performance in eliminating misconceptions while kept general high perceived clarity scores (in animation one and

two). This indicated that as a means of knowledge transfer tool, animations that are designed carefully indeed support knowledge transfer better than text, at least in the home automation control area. Our findings supported the effectiveness of animation in knowledge transfer, especially results in step four indicated similar results as Cyril [15] which proves that animation are more beneficial in collaborative settings. In addition, even though there were many research showed negative results about effectiveness of animations. Our study proved that animation can be effective for knowledge transfer when right information were added and when animation is well-designed. Incorporating results from step two, possible reasons of animation's effectiveness could be that:

1. Animations were designed exactly in terms of common directed attention and event segmentation pattern found in user research. Wang [24] initiated the rule of attention management which is "use perceptual techniques to focus the user's attention on the right view at the right time". The similar principle might apply to our results as well. When user's concerns were revealed through interviews, it enables animation maker to direct user's attention to elements he/she cares most therefore the user could monitor less irrelevant elements and do not have to remember key elements intentionally. We found non-expert's general directed attention was key cause-effect of the control, thus we highlighted that in all animations and avoid irrelevant explanation. That might decrease dramatic misconceptions by restricting non-experts' imagination of irrelevant elements (like the window). In addition, we segmented the animations according to key changes identified in non-experts' drawings, which are human showing up and daylight get darker or brighter. The representation of the control in line with non-expert's mentally event segmentation probably facilitated their understanding.

2. Animation used minimal elements appeared in non-expert's mental model which could help diminish information overload problem. It is especially proven in animation two. Since in animation two we only used three key visual elements (sun, light and human) appeared in non-experts' drawings in diagrammatic-oral interviews.

3. Animation naturally decreased the vagueness level of control description because it contains more information than plain text describing the same control. For example, we did not use a blind but only a square in animation one to represent the window, then the misconception that a window has an automatically controlled blind or other special material were avoided successfully.

When considering how animations could support knowledge transfer, our results indicated that it is critical to design animations in line with target audience's direct

attention and event segmentation, applying universal principles and above all, concretely visualize elements which are ambiguous. One thing noteworthy is that if the text description is long and detailed enough, misconceptions might not happen as well. But the problem in long text is that readability is worse and people tended to skim text (according to one participant) therefore they often forgot fragments of the information. Further research could be done to investigate whether longer text achieved the same effects as animations. In addition, what needed to be re-inspected is the potential bias brought by voice used in animations. It might be that the voice captured subject's attention more tensely than text thus subjects understood the control more accurately. One factor which might have resulted in poor knowledge transfer can be a recipient's lack of motivation, absorptive capacity, and a retentive capacity [25]. Within the study, these aspects of recipients did not get examined.

Event Segmentation Theory

Our results from diagrammatic-oral interview supported the claim from EST theory [26] that "Viewers tend to identify event boundaries at points of change in the stimulus, ranging from physical changes, such as changes in the movements of the actors, to conceptual changes, such as changes in goals or causes." Because non-experts identified such key changes like human presence, light turned on or off from the control descriptions. Hard [27] found the association between better performance of learned task and segmenting activities hierarchically in his study. In previous neuroimaging studies, Zack [28] let users segment a movie by pressing a button while watching movies. Their results implied that it is a normal part of ongoing perception for brain processes to correlate with event segmentation. In our study, instead of using buttons, we let users draw their mental pictures in comic strip which could partly reflect their automatic event segmentation pattern. The results from animation evaluation results indicated that when segmentation is in line with most participant's perception of event segmentation, the perceived clarity of information got improved. Zack [29] suggested that people use movement cues to identify event boundaries. This is supported by our results from diagrammatic-oral interviews.

Selected Lighting Control

The lighting control examined in this study was not very complicated to understand essentially, basically the domain knowledge information selected about this control was explicit and contain several cause-effects relations. The results indicated that animations have potential to help knowledge transfer in deeper level of details of automation control. Because when it comes to more complicated

controls, misconceptions presumably might happen more frequently than non-experts expected.

One finding that can inspire researcher in knowledge visualization was that a high level of perceived clarity of knowledge might still led to wrong decisions since there was underlying misconception when the participants thought they understood. This might be particularly problematic if it is the basis for a decision where this misconception get undiscovered by other stakeholders. It is noteworthy that our findings are currently only applicable for home automation planning. To validate the findings in larger scale, dedicated research on various fields need to be conducted to get general conclusions.

Different level of details in animations

Our results from animation evaluations indicated that different level of details on presented lighting control is needed for non-experts with different level of technical background. In order to make non-experts be clear about presented control, factual description of the control itself proved to be enough for non-experts without technical background, however it is not sufficient for non-experts who would like to know more technical details in terms of implementation and how it works more practically. This result proved Burkhard's claim that recipients have to integrate transferred knowledge into their own knowledge based on individual backgrounds and experience [1].

Method Critique

In the exploratory observation stage, while we were confident about the result that animation caused less misconceptions or false assumptions, facilitated decision making, and saved time for knowledge transfer during collaboration. The sample size was too small to be representative. That said, it needs to be examined further by large scale in the future.

In the step one, inferences from drawings presumably were biased due to different level of drawing capability, misunderstandings on researcher's instruction and constraint on explanation tools. For example, the subject who drew only graphs explained later that actually he had visual mental pictures first but he thought the purpose was to abstract the control instead of translating mental pictures directly. Most participants had very limited experience in information visualization and most expressed that they had limited drawing capabilities, which might have caused information loss during translation from internalization to externalization of thinking. However, it is impossible to investigate fully how non-expert mental model works since it is a black box essentially, our focus was to elicit part of their mental model and capture any beneficial finding. An ideal supplement in future research would be increasing

sample size to compensate information loss caused by personal differences, and recruiting subjects with advanced drawing capabilities.

Animation design implications

From the case study of home automation planning, there are several design implications which can be useful for future research in general animation design for knowledge transfer:

1. Understand non-experts' directed attention and event segmentation pattern. Make animations to highlight their attention and segmentation pattern.

Segment animations in user's perceived event boundaries and mainly visualize important elements that interest users most during knowledge transfer.

2. Consider designing the animation in different level of details according to non-expert's relevant knowledge level.

An understanding of non-expert's background or domain knowledge level would be helpful to deliver animations containing right amount of information in animations so that users are neither overwhelmed nor bored.

3. Keep animations slow and simple without including too many elements or transformations at a time.

Trying not to make too many transformations occur in short period of time in animation so that it is slow and clear. Avoiding irrelevant use of elements to decrease user's cognitive load and help them focus on the main message.

4. Design the content to in line with non-expert's interests.

Sometimes, information such as price, cost etc. seems not relevant to core technical knowledge transfer. But depending on non-expert's purposes, these extra information need to be highlighted in the knowledge visualization to support their behaviors. (e.g. decision making or problem solving)

CONCLUSION

When it comes to knowledge transfer between experts and non-experts in home automation planning field, we took a typical automatic lighting control as an example and we concluded that non-experts common directed attention lied on key cause and effect relations in presented control. There was a lack of detailed images in non-experts' mental picture. When the lighting control was presented in text, non-experts had several misconceptions which possibly caused by overconfidence, text vagueness, life experience, and knowledge background. It is helpful to design animations in line with non-experts' directed attention and event segmentation patterns to enhance their correct understanding towards automation controls. Practical means

include using minimal key visual elements, segmenting animations by key changes of automation control (For example, people coming in changed the status of the light). To clarify automation control knowledge for non-experts with engineering background, there is a need to transfer more information about working mechanism of automation controls. For non-experts with no engineering background, knowing how does the control behave literally would be clear enough for them. However, when it comes to decision making based on knowledge transfer, non-experts need more knowledge on the cost, value, and use cases of automation control instead just knowing how does the control behave. The result from exploratory observation hinted a well-designed animation has potential to facilitate knowledge transfer and decision making process in collaborative setting. In the end of the discussion section, four design implications were given to help future research investigating animation's impact in general knowledge transfer. The findings could be potentially beneficial to other application areas of knowledge visualization. For example, by utilizing user-centered animations to support student's learning progress of science and technology, or to bridge the communication gap between product manager and technical developers etc..

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my supervisors Anders Lundström and Goranka Zoric for their guidance, patience, useful comments, and engagement through the process of this master thesis. Furthermore I would like to deeply thank Gayathri Gopalakrishnan for great support on many aspects of my thesis. Also, I am very thankful to all participants and my thesis fellows in each step of my study, who have willingly shared their precious time and advice during the process. Without kind help from them, the thesis wouldn't have been done. Lastly I would like to thank my beloved parents, who have supported me throughout the entire process.

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