A Self-Paced Approach to Hypermedia Design for Patient Education

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ABSTRACT

Traditional theories on multimedia design have considered the importance of modality effect to a large extent. The stress on modality effect has often de-emphasized the importance of what information architecture can do to control modality effect if information presentation is self-paced instead of system paced. We have considered a patient education module as our case study. I propose a conversational interactive patient education module as a solution which responds to individual reader needs during hypermedia interaction. In this article, I take an initial step towards this approach, testing patient education modules with and without narration to support text and static graphics. Our results suggest that levels of reader comprehension and accuracy for modules with and without narration have similar performance. Readers have shown a preference towards using narration, online text and graphics based on individual task, if the system permits a self-paced interaction. Thus, we argue that modality effect may be influenced with a self-paced system.

Categories and Subject Descriptors

H.5.4 **[Information Interfaces and Presentation]**: Hypertext/Hypermedia- *architectures, navigation, theory, user issues*.

General Terms

Design, Human Factors, Documentation, Management

Keywords: Modality effect, design, self-paced system, activity theory, situated action, conversational design.

1. DESIGN OR MODALITY?

Hypermedia patient education modules are important tools used by the medical community to impart preoperative/postoperative general knowledge about specific medical conditions, treatments or surgical techniques. Hypermedia modules can go a long way in not only educating patients, but also engaging their attention and changing their emotional response. Patient education modules allow patients to understand the rationale behind each procedure before it is performed and thus they can encourage the patient to take ownership of their medical problem and care regimen [1]. Thus, as patient autonomy is a primary concern, self-paced multimedia systems have been proposed to keep the patient in control as much as possible.

To design a multimedia system which grants near complete control to the patient is not especially challenging. Designing a system that provides a higher level of user autonomy and ensures a high level of effectiveness, however, is a significant design problem. Many factors, including the basic cognitive capabilities of users, must be considered. While there are no comprehensive cognitive theories of multimedia learning, much is known about human cognition that can be applied to multimedia design. Research has concluded, for example, that working memory consists of independent auditory and visual working memory [2] but this working memory capacity is fundamentally limited [3]. Finally research has shown that meaningful learning occurs when a learner selects, organizes and connects corresponding verbal and non-verbal information (Paivio, 1990).

One of the questions raised traditionally for multimedia presentation is how best to present information on screen: as on screen text with graphics, as static or animated graphics, as on screen-text vs. speech? Determining the combination has always been an issue which bothered designers. So, is it a question of design or modality? Can design handle and explain modality?

A probable solution that we will discuss later in this article is to design a conversational framework that emulates an exchange a patient might have with a doctor. Towards this end, the text and graphic can be presented such that they do not convey the same message but support each other, much as they would if the patient were meeting with the doctor face to face. Earlier research has shown that patients can better comprehend an explanation when text is presented auditorily and visually rather then auditorily only, provided there was no other concurrent visual material. The overall pattern of results can be explained by a dual-processing model of working memory, which has implications for the design of multimedia instruction [4].

In Mayer & Moreno's (1998) study [5], the instructions in the animation were system paced. This allows for greater designer control over modality, but lessens patient autonomy and, perhaps, both the attention level and feelings of self-control of the patient. I ask: in order to preserve patient control, how might we go about designing a system that is self-paced, consisting of static graphics and narration modules similar to Mayer & Moreno's? We can

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anticipate a number of advantages from this approach, but several important design issues must be addressed. These issues deal, generally, with the way users must act to best coordinate the visual and auditory resources available to them when they have the freedom and ability to do so. The designer's task in this scenario is not to structure the experience for a user, but to permit users as much choice as possible, while still building in enough constraints to prevent them from becoming confused, lost, or frustrated with the system. To understand the importance of these constraints, consider the kinds of choices a user might make with a self- paced system. There would be no need to spend a fixed amount of time on any one graphic or section of text. The narration, if selected, might be muted or delayed to allow maximum concentration on the on-screen text. After how long an interval of time should the narration start? If we design the narration to be reinforcement, essentially the same information as the text, should the interval be shorter than if the narration adds, emphasizes, or qualifies something in the text?

As these few questions illustrate, the questions associated with information architecture for instructional multimedia modules are complex. But if patient control is an important goal, these types of decisions can no longer be made solely by designers. Some will be made by users as well.

A dialogic or conversational structure may be one way to introduce constraints on pacing and information presentation modes while still maintaining an acceptable amount of control for the user. Could this sort of structure influence the dual-coding effect? With this style of interaction, we might expect that the process of comprehension is similar for visual presentations with or without narration. The reason? Within a conversational structure, users may not need the dual-modality presentation of information. The self-paced timing and organization of the information may allow the patient to compensate for limitations to working memory on their own. In other words, readers can choose their own way of attending to different sets of modalities based on their own motivations and goals, and, at a more operational level, based on convenience and availability.

In this paper, I elaborate on the foundations for my speculation that user control may allow them to actively manage the need to switch between or even double-up on presentation modalities in order to compensate for limitations to memory, attention, etc. We must offer a theoretical rationale, drawing on Activity Theory and Situated Action theory. We also discuss a pilot study conducted to determine if users of pattern of information presentation in patient education modules might influence the modality effect discussed by Morano & Mayer. This is a preliminary step towards understanding whether a design hat uses self-paced timing of information might allow designers to hand over control of important information, architecture decisions to users in critical situations.

2. DEPENDENCE ON SENSORY PERCEPTIONS

According to dual-coding theory [6] when both verbal and visual information is presented, these two types of information are connected in working memory and this referential connectivity, in turn, contributes to the construction of a strong mental model. Dual–coding theory poses the argument that since on-screen text and visuals are part of the same processing system it should not be considered as cognitive load for the reader. However, other theories have argued differently about how the modality effect can be handled efficiently. According to Cognitive Load Theory [7] and Mayer's theory of multimedia learning [8], replacing visual text with audio will decrease working memory load and improve learning (modality effect). Knowledge acquisition in multimedia is facilitated through two effects.

The multimedia dual-coding effect which explains how learning is facilitated by the presence of visual and text based information simultaneously [8]. This theory considers the existence of two separate processing systems; one for visual information and one for auditory information and each have limited processing capacity [9]. The purpose in this article is not to question the research findings. What I am trying to get at here is how the information can be better handled to suit human modality.

So where would the focus be? Suppose the reader is presented with all the mediums of instruction for example, text, graphic and audio and has the choice to decide how these modalities would be used in the temporal order. Based on their ability to attend to different mediums of information presentation, can the modality effect be better handled? To try and answer this question, I need to discuss certain design issues here.

However, before moving into the design considerations, we need to discuss in brief certain social-behavioral theories which explain why a patient education module might serve the purpose better and how the objectives of the patient behind visiting these educational modules remain the primary consideration behind its design.

3. PATIENT EDUCATION AND DESIGN

Motivation is an important consideration if patient health has to be given due importance. Patients who perceive a degree of control and input in their own care and value the desired behaviors are more likely to perform the desired health promotion behaviors. This is the crux of the argument behind the theories of patient empowerment. The social-behavioral theories behind patient empowerment and patient value systems are Health-belief model, self-efficacy, cognitive dissonance theory, stages of readiness and adult learning theory [10]. Mas and colleagues has also discussed certain instructional theories like Edgar Dale's cone of experience, Gange's condition-based instruction, Merrill's component display/instructional transactions theory etc. All of these theories acknowledge the various levels of retention and cognitive understanding through perception, reasoning and intuition. Understanding the context based on these theories as to the possible way that a patient might think in specific circumstances opens up the scope for developing an user-centered patient education module, with focus on the task and patient state of mind. However, elaborate discussion of these theories is beyond the scope of this paper. The purpose behind initiating a discussion of these theories is to see how design of a conversational interface can consider and include elements of patient psychology.

3. 1. Designing Context

One of the things which have not been discussed explicitly is the context. For designing manuals for patient education, the animations or static graphics should be designed such that it might come close to substituting the patient need to talk with a doctor. The proposed educational module should be conversational in nature and not just an interface which imparts information without caring about the possible questions and potential scenarios which might crop up during the conversation. The patient might occasionally ask the doctor questions and about anything related to the impending medical conditions. My purpose is to design an interface which considers the above mentioned factors. In a text-graphic scenario, split attention effect is a serious load on the working memory, only when the graphic needs to be considered occasionally by interrupting the reading of the text [11]. However, if every issue and point is not graphically repeated or does not require graphical consideration in the sense of a complex procedural instruction, and the entire big picture is made to look like discussing a specific problem with the doctor, then the problem of split-attention effect and redundancy would not impede learning. Thus we aim to consider whether modality effect would still be an issue under the previously mentioned conditions.

Jameson [12] in her article *Patient education; the profession's greatest commission* has mentioned a five step approach towards a successful patient education system.

First, the designer should be clear about what he/she wants the patient to learn and what the ultimate goal of the lesson is. The second goal would be to change the patient's behavior as a result of learning so that the patient's recommendations are complied with. Third, Jameson [12] also mentions that using visual aids as teaching tools will have stronger impact than just telling them about what is wrong. Jameson also recommends getting the patient involved in an educational interchange. Simply telling the patient won't work. The fourth recommendation is to give the patients assignments so that they have the opportunity to learn better. Finally, she mentions that visual aid presentations are most beneficial when discussing or recommending a particular treatment to a patient.

Some of the major features of a multimedia animation design would incorporate major design issues [13]. A few interesting examples by Engvall in his article *Use of Computer-Assisted Instruction in Diabetes Education* would help understanding. "Sound and Color: In the section about, hyperglycemia, the sound of a flushing toilet is used as a link with the symptoms of increased urinary frequency that a child would experience if hyperglycemic. Sound serves as a positive reinforcer to enhance learning. Using different colors to mark various parts of the body and colored highlighting when clicked on a text label or when action needs to be shown might be effective measures. Animation: Animation can be used to teach pathophysiology of diabetes by demonstrating how insulin acts like a key unlocking the cell. This allows for a unique presentation of a difficult concept. Through animation, the key to the cell (insulin) is shown unlocking the door to the cell and allowing glucose to enter the cell. Paced Learning: The interactive nature of computer-assisted instruction allows learners to choose various paths through a program based upon individual needs. Learners can control the content, pace and instructional strategies. Patients can review content which is difficult for them to understand and can choose several learning options. Interactive nature: Patients respond to questions or follow instruction. Their actions initiate sound, animation, thus keeping the learner focused on tasks and making the learning process enjoyable. Knowledge Assessment: Using reinforcers such as flashing screens, sound and positive statements help increase self-confidence and self-esteem. Test questions and proper feedbacks help patients to apply knowledge in real life situations they would possibly encounter.

Thus, if we observe these previously discussed features of multimedia design, it should be clear that the whether it is text, static graphics /animation or the sound effect, patient learning is facilitated in a combination and with each of these features playing its individualized important role in the entire context. The major theories we need to discuss in this context are activity theory and the theory of situated action.

3.2 Activity Theory in the Framework of Current Design

The issue of sensory perception takes a back seat when activity theory explains a dialogic patient education module. Activity Theory is a set of basic principles that constitute a general conceptual system, rather than a highly predictive theory. The basic principles of Activity Theory include the hierarchical structure of activity, object-orientedness, internalization/ externalization, tool mediation, and development [14]. The basic unit of analysis of all human experience as is argued by this theory is activity, which is a broad definition as compared to individual goal-oriented action [15]. This activity involves artifacts motivated towards an object. Activities are differentiated based on motives/objects. Any activity involves a set of conscious goal-directed action and operation which are regularized unconscious dealings towards task orientation. This paper will discuss the patient education module with the purpose of capturing the context of HCI within the realm of activity theory as was discussed by [14].

The potential patient might have multiple goals to serve as part of its interaction with the education module, based on the objective. The patient might approach the problem from the perspective of a potential patient who has been advised by the doctor to undergo heart surgery and the patient needs detailed information as to what follows a heart attack and the process of rehabilitation. Also, a reader might just approach the module from the perspective of someone who is just gathering information. Thus, learning the module on heart attack and rehabilitation is kind of a subset of the larger goal. From the design standpoint, getting from one screen to another is kind of an operation, which might not otherwise need conscious attention of the reader. But, unless the narration is muted, it will appear a few seconds followed by the on-screen text. If it is so, that the user wants to hear the narration on a selective basis with a screen by screen consideration, and then it might not be very comfortable to mute the sound every now and then. Rather, it is easier to change to the next screen, before the narration and following the appearance of the on-screen text. If the user can pace the system accordingly, change from one screen to another would no more be an operation, but becomes an activity.

Also, there is question-answer sessions in the middle which throws questions and the screen cannot be linearly followed unless the correct answer is provided. However, the purpose of forcing the reader to consciously attend to each page might be successful or not depending on the intention of the reader. For example, if the reader is asked a question in the "symptom" section somewhere in the middle, the design is such that the reader has to attend to the questions and answer it correctly, to move on to the next page. But, since there are two options in each question only, the level of conscious attention might still be avoided and the reader might approach the correct answer with 50% probability in a trial and error format and progress to the next slide. However, these are still activities and seize to be called operations any further in the strictest sense, because of the way a trial and error format is generally followed. However, a trial and error level of consciousness does not guarantee that the material has been learnt. What we define here is consciousness in navigation and may not be in the sense of learning the materials. Thus, we still need to make difference between activity which demands consciousness in terms of navigation from one screen to another and some level of consciousness which leads to comprehension of the subject matter. Hence, one needs to focus on the structure of user's activities. This is the extent to which technology facilitates and constrains attaining the user's goals and the impact of technology on provoking and resolving conflicts between different goals [14].

Second, the focus is on the target environment to integrate technology with requirements, tools, resources and social norms of the environment. The modules under consideration are very dynamic in nature. It does not overload the screen with information. If explaining the module requires using words which the patient might know, the module does not do the explaining of the word as a compulsory feature but leaves it as a hyperlink which will pop up with an explanation when clicked, on the same screen. This might depend on patient's knowledge of the subject matter. Further, the module does not try to stand as a replacement for a doctor and that a doctor's advice is specific to the condition and that the modules cannot serve as replacement.

Third, the focus is on the structure and dynamics of interaction, which support the mutual transformation between the external and internal components of activity with target technology. The purpose behind designing the modules separately was precisely to match the internal and external components of activity. The potential patient might not have to undergo the surgery process. However, he/she needs to know the symptoms which leads to the problem and hence surgery recommendation. As an external component of activity, this module might actually be able to represent in a summary broadly what the doctor would say provided the specific patient related conditions do not alter the practicality of the situation and based on how the patient needs change over time and situation. The graphics used, the highlighting, the overall interactive nature allows for this. The ability of the patient to jump issues and travel within sub-sections and make referential connections support the mutual transformation from external to internal activity through technology. The questions asked within the module have to be answered by the user. Otherwise, the user can't move on to the next screen. If the answer in the first attempt gets incorrect, the same screen reappears and the patient has to answer it again before moving on to the next screen as we already discussed earlier. Thus, while mouse click for "next" could have been an "operation", is now a conscious action, by making the user read the screen consciously.

The fourth is the developmental transformation of the above components. The designers must keep track of the above features in the module and patient feedback might be used as part of an iterative design project.

For the above components, a possible limitation might be the use of static graphics when intricacies of the anatomical structure or surgery need to be shown. However animations have been shown on occasions involving functional intricacies. If user task has to be focused on, creating a logical model seems to be the need of the hour. A recommended patient education model for decision making would consider actively patient's level of understanding (novice vs. expert), IQ related to the problem in hand, wants and needs, attention span, age and interest level [1].

3.3 Theory of Situated Action in the Framework of Current Design

The second theory which needs to be considered in this context is the theory of situated action [16]. Nardi has criticized situated action model as indulging in too much moment-by moment analysis, thereby de-emphasizing the need for putting human behavior in a perspective of regularity. Situated action theory articulates the conversational design of the patient education module which is the primary recommendation in this article. The focus in this theory is the context which is very specific depending on the agents and artifacts involved in the process. Thus any minor change in any one factor might bring about a total rearrangement of the given situation which would need recalculation. In the patient education module under consideration, although interactivity provides scope for changing the generalized context in terms of patient needs, the content is still given in a customized sense and won't change as per patient needs which might be very specific.

For example, the module which discusses open heart surgery won't be able to incorporate unexpected conditions under which it has to be done. The designer has to consider that other medical conditions for the patient which has not been specifically mentioned in the conversation with the doctor before designing the module are normal and even if it is not, that won't play any adverse role in the surgery process. For example, the patient might be diabetic or has high blood pressure which would bring about a change in plan as to whether the surgery can be undertaken and when and how. These are very specific situations which the module won't be able to consider beyond a point. What I mean by "beyond a point" is that the patient might be made aware through on screen text and narrative about certain common problems which might hinder the normal circumstances under which the surgery could have been handled. This might cover the specific situation for many patients without replacing the need to see the doctor off course, but still the content is not customized.

However, since narration is another mode used as part of this module, wherever necessary, it might have been used to impart information which can be considered to be progressive steps towards customized information. What it means is that for example, the possible repercussions during an open heart surgery for a diabetic patient or one with high blood pressure might be narrated as a back up with on-screen text which provides only a general level information for open-heart surgery. On the flipside, if it is designed in the manner discussed above, it also calls for the user attention to be divided between on-screen text and narration. If the reader is not clear about the purpose of narration, he/she might want to mute the sound, thinking it to be a repetition of the on-screen text. There is no easy answer to the possible course of design decision which might facilitate an optimal strategy to accommodate various sets of information in different modalities.

However, the essence of situated action might be made part of the system through specific warnings, examples of specific medical conditions etc and off course interactivity which at least serves certain common sets of specific enquiries. A conversational design might actually help to travel beyond a generalized interface and thereby incorporate specificities.

4. A CONVERSATIONAL DESIGN

The Activity Theory and theory of Situated Action provides the groundwork for discussing the importance of a conversational design as part of a self-paced patient education module. Users go about their business in the internet with two levels of awareness; that of the interface and the social context behind the internet [17]. This section is based on the argument that a conversational design helps the cause of audience engagement which might actually better handle the modality effect. The better handling of modality effect should also be dependent on the manner in which the reader can be involved in the process of information presentation. If the reader feels like talking to an actual consultant or a professional, the level of engagement might actually overwhelm the modality effect which would always be partly inherent in any design chosen. Features of a conversational design in patient education module should incorporate:

- The potential to travel between modules and screen in his/her own pace. Make the system self-paced.
- A technical subject domain which is presented in a non-technical fashion resembling a doctor-patient dialogue. Situate the technicality in context of a simple conversation.
- The patient has to read the text and see the diagram but no time is really spent trying to relate every details of the text with parts of the picture. This is unlike a procedural design where the text and graphic shows the exact same process.
- The task should determine whether reading text and listening to the narration would be mutually exclusive or complementary. This should be dependent on information processing load, activity load and situated context.
- The module under consideration would also throw back the reader occasional questions within each module at positions where it thinks necessary for understanding the state of affairs. Here, narration stresses on the issue of right and wrong and what actually is the answer. Also, when the patient cannot answer the question correctly (choose the right option), it does not provide the cursor to approach to the next screen, thereby encouraging click on the right option, so that the on-screen text and subsequent narration appears to reiterate the explanation behind the chosen option.

5. A PILOT STUDY

It is better to refer to this as a pilot study. My purpose is to see if human navigation within the framework of a conversational design interface can be put into any structured perspective of regularity, even when confirming to any specific context. Thus, my idea is to find a balanced middle ground in interface design, which confirms to both activity theory and theory of situated action. Users were tested on two modules on heart attack and cardiac rehabilitation as part of this initial study. These two modules are considerably similar in terms of dealing with cardiac problems and recovery. Although the interface designs for the two modules are very similar in terms of how the modality has been addressed, there are very minor differences in the usage of animation, to show functional details of the body.

The participants were requested to go through the animated modules in details, as if the intention is goal directed pertaining to serious learning or attending to impending medical conditions. The modules are chosen in a way which addresses issues much talked about in the society. For the module on heart attack, the users listened to the narration while the text and graphic appears on screen. For the second module on cardiac rehabilitation, the users had to mute the sound and go through the module with on-screen text and graphic. Once the readers went through the modules, they were given a post-test questionnaire which asked design questions as to how and when they read the on-screen text and graphics and also how they attended to the narrative. The findings related to timing and choice of text they read, narration heard or a combination were interesting in this context.

My argument revolves around the fact that the load on working memory is not determined merely by the presence of modality, but how and when the reader chooses to use those, thereby making it a design issue rather than modality. Further as part of this test, I also had a comprehension and retention test for the users where questions from the modules would be asked, following their experience and learning from the modules.

I conducted this pilot testing with 5 participants, to make initial testing as to whether the results support our arguments. Our results showed no major difference when the participants used a module with sound versus when a module was used without sound. The average number of correct responses for both the modules with and without sound ranged from 60% to 80% for all the participants. A possible reason for no difference in the accuracy levels between these two modules might be that readers had the opportunity to attend to the narration, text or graphics based on their need and nothing was forced upon them.

A couple of participants mentioned that when there was the option of narration, they did not read the text at all. Overall, they mentioned that they needed either text or narration, depending on the question and the flexibility to choose from either might help to improve their accuracy and speed. Further, a few participants also mentioned that graphic might be an optional component, depending on the task. As an example, they mentioned, the necessity for a graphic which showed coronary artery with graphical indicators, thereby showing functionality versus when an example of saturated fat was shown for identification. The debriefing with the readers emphasized that the necessity for any particular medium of instruction is varied based on the task to be completed. What it might mean is that a question which asks structural or functional elements to be identified in the biological environment might necessitate graphic, but otherwise the need for a graphic depends on the complexity of the task. The shape of something, for e.g., egg is known and it might not necessitate the need for a graphic.

As part of their responses in the post-test questionnaire, majority of the participants mentioned that an easy to read text with graphic can replace the need for narration. Their responses were inclined towards the need for on-screen text. None of the participants preferred to have narration without on-screen text. However, participants mentioned the need for narration, but only when the narration appears followed by on-screen text and graphics. One of the possible reasons for such an approach might be to be able to use the narration, as a support when on-screen text and/or graphics are not entirely understandable or a confirmation is needed. This argument is partly supported as only 50% of the participants mentioned that the narration should provide with extra information beyond what the on-screen text suggests. However, as a support for our argument, the participants mentioned no clear consensus as to the order in which text, graphics and narration were attended during task completion. Further, readers decided to attend to the graphic, either with on-screen text, narration or both, depending on the task and individual preference. Readers, though, reasonably agreed that largely, the patient education modules were doable without the use of narration. Thus, overall, my results suggested that the readers opted for multiple ways of attending to various mediums of instruction as and when they needed it and there was no clear pattern to suggest a preference. These findings makes initial support of my theoretical argument that modality effect can be controlled largely when the design is such that readers can manipulate the use of different mediums based on their needs from the task. This reader preference suggests the importance of a regular pattern in navigation, but only when the context is emphasized.

6. CONCLUSION

This is only a preliminary study that I have conducted. However, the findings points towards specific theoretical conclusions. Information architecture generally works as a comprehensive package for the context. It considers the information content presented and how is it structurally organized in terms of the medium. Modality is definitely an issue which helps in the process of comprehension but it is the design of how the information is presented overall in the context which is the determining factor facilitating comprehension and how well the modality effect can be handled and put under check. This argument holds good even when only on-screen text and graphics are primarily the medium of instruction without narration. Thus, it is not the modality but design which determines reader comprehension and recall.

If the presentation is scenario-based and incorporates context in the design, both in terms of content and the choice of user interaction, the difference in the presentation modalities might not be the determining factor towards reader comprehension. The power of interaction should be given to patients considerably.

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