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POWER-BROWSING – A METHOD TO ACCELERATE DESIGNERS' FAMILIARITY WITH VIDEO INFORMATION IN DIGITAL LIBRARIES

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ABSTRACT
Video as a tool for information capture and reuse is being increasingly used in the field of engineering design. The capability of video to capture contextual information and tacit information makes it especially attractive to designers in the user testing and field validation phases of the design process. The ability to easily capture an event without spending added time on text documentation has enabled designers to record design activities in great detail. However, browsing through hours of real-time video is still a tedious process that discourages video information reuse.
This paper presents and defines power-browsing as the browsing of video at high speed with the use of sub-titles. This will lead to greater information reuse by allowing the designers to rapidly develop familiarity with the video content and thus accelerate design learning. Video content is segmented into two categories, video-centric and audio-centric. The videos that are audio-centric are first processed to convert relevant audio information to sub-titles in order to browse at high speeds without significant loss of information.
The power-browsing method was tested in a laboratory setting and the subjects' learning of the video content was examined with a test based on Bloom's Taxonomy. A key finding from the exploratory study was that there was no significant difference between learning at 2X speed and at 4X speed of video playback. The results of the laboratory study demonstrate the potential of power-browsing as a method to accelerate designers' familiarity with video information by browsing at speeds as high as 4X. This might address the problem of information overload from large video repositories and lead to greater information reuse by the designers.

Keywords: Video, information reuse, browsing, familiarity, design learning

1 INTRODUCTION
Engineering design is an information intensive activity. Designers capture, store and reuse information relevant to the design task [1]. It is therefore impossible to determine a priori what information is going to be relevant to a design activity at any given moment. It is hypothesized that a comprehensive capture of design information and its archival in the form of digital libraries that can be searched and browsed provides a way to facilitate information availability for innovative design teams [2].

1.1 Video - A Design Information Medium
We have been exploring the case for video as a medium for capturing, storing and reusing design information. The advantages of using video as a capture medium include its passive capture capability and its ability to capture tacit knowledge. Video is especially suitable in the conceptual phase of the design process to capture concepts expressed through gestures, sketches, dialogue, and hardware demonstration and manipulation. Eris et al. [3] explored the use of video as a design information capture and reuse medium and found that the concepts migrating from the video information source had a greater impact on the concepts that were developed by the designers later in the design process. Despite these advantages that video presents as design information capture and reuse medium, it suffers from a disadvantage that it is not easy to search or browse. Searching or browsing through long hours of video content is a tedious task that discourages video information reuse.

1.2 Browsing Vs Searching

The problem of information overload in video can be addressed by implementing better search and browse methodologies, and thus accelerating design learning, where learning can be defined as the acquisition of new information [4] through searching or browsing. Here search implies that a designer is going through the information resources with the intention of finding pre-determined relevant information, for example searching for the ultimate strength of steel. On the other hand, browsing implies that a designer is going through the information resources with the intention of exploring a particular area for information whose relevance is not know a priori but will be determined later, for example browsing through a catalogue of materials to use. In this case the designer is not looking for a particular material but she may find a material whose relevance is determined after it is found. Thus, searching can be considered as a pursuit of facts, while browsing can be considered as a pursuit of ideas. We hypothesize that, for an innovative design task, browsing a video resource and being familiar with the information content in the initial stages of the design process is beneficial to generate new concepts and also to facilitate more accurate searches later in the process. This will accelerate design learning and might contribute to more innovative outcomes.

1.3 Browsing Methods for Video Resources

A lot of work has been done in the field of video content management systems to develop better browse methodologies. The use of video surrogates which are substitutes for segments of video is especially common. Key frames [5], [6] and video skims [7] are some of the surrogates that have been used to shorten the time to browse through video. For example Wildemuth et al. [8] recommended a fast forward speed of 1:64 for browsing by playing every 64th frame of a video as a key frame. Though these methods are successful at speeding video browsing, they might not be suitable in the context of innovative design as they filter the information shown to the designers. As it is not known a priori which information is relevant to designers, the use of video surrogates might block the designers from accessing relevant information. Other methods to browse video include the use of hierarchical tree structures [9], [10] of frames as a visual map of the video content. These methods are good at giving an overview of the video, but lack the visual quality of motion that might be instructive to designers in understanding gestures and working mechanisms.

This paper defines and presents power-browsing as a method to rapidly browse through video without the implementation of video surrogates. In addition, an exploratory study of the effect of the power-browsing method on designers' learning performance is also described and the results are presented. The intention behind conducting this study was to prototype power-browsing as an intervention to tackle video information overload and facilitate reuse of information in order to accelerate design learning.

2 POWER-BROWSING METHOD IMPLEMENTATION

The working definition of power-browsing is the browsing of video at high speeds with the use of sub-titles.

Using the power-browsing method for video viewing requires a preparation stage. Any given segment of video has information content along two dimensions – aural and visual. These dimensions can be used to classify video into two categories.

1. Audio-centric: If a video segment has human speech for 50 percent or more of the duration of the video clip, that video could be classified as audio-centric. For example, a video of a Shakespeare play.

2. Video-centric: If a video segment has human speech for less than 50 percent of the duration of the video clip, the video could be classified as video-centric. For example, an action movie.

A video can classified as audio-centric or video-centric by measuring the time during which a language is spoken on screen as a percentage of the total time duration of the video clip. If the audio-centric video is played back at more than 2X times the normal speed, the information along the aural dimension is lost. In order to preserve this information, videos need to be processed to convert the information content from aural to visual dimension. This can be achieved by extracting noun phrases from the transcript of the video and then subtitling the frames where these noun phrases occur. The

noun phrases were chosen to be extracted as text surrogates based on studies by Mabogunje [11] that have implicated noun phrases as an index to learning objects.
By converting the aural information to visual information, the video can be speeded to more than 2x times. However, at high browse speeds the aural channel is still available for transmitting information. In order to take advantage of this channel, a musical piece appropriate to the visual content can be played at normal speeds while the video is being power-browsed.

3 EXPERIMENTAL DESIGN
The effect of power-browsing videos on designers' learning was tested in an exploratory experiment under quasi-controlled laboratory conditions.

3.1 Guiding Question
The guiding question for our experiment was as follows.

In what ways is design learning from video resources affected by the playback speed of video?

Specifically we wanted to test the speeds 2X vs 4X for power-browsing. The experiment was designed to explore the effect of power-browsing on various cognitive activities that required the use of information learned through power-browsing.

3.2 Video Content
The videos selected for the experiment were from a two week design exercise conducted in 1998 in a Master's level graduate design course, ME310 in Stanford University. The student teams of three to five students each were given a design challenge to construct a bicycle out of paper products. The design required the students to construct a bicycle that was light in weight and could support a human rider. The teams raced their bikes at the end on the exercise to evaluate the performance of their prototypes.
The salient features of the video were as follows.

1. The video spanned the prototyping, construction and design review for a single team in the 1998 class of ME310 as well as footage of the final race.
2. Since, the video was to be played at much faster speeds than normal, the audio channel was removed and key sentences were transcribed as sub-titles on the video. The key sentences were those that contained a noun phrases related to the design activity being undertaken.
3. Background music was added separately through another computer. This music was mapped to the kind of activity displayed in the video. For example, during periods when designers are having a discussion, a classical composition was played, while at times when they are building or constructing a piece, a lively piece of instrumental music was played.
4. The total duration of the video at normal playback speed was about 150 minutes. At 2X speed it was 75 minutes and at 4X speed it was around 38 minutes.

Figure 1. Sample frame from the power-browsed video. Here you can see the students working on attaching the wheels to the paper frame of their bike.

The video clips of the different design activities were arranged in a storyboard format in a video-triggering software called Grid 2.0 software on a computer. The subjects were shown two side-by-side projected displays of the video and the Grid 2.0 screen containing the video clips storyboard.

3.3 Subjects

Five subjects were selected for the experiment pre-trials. The salient features about the human subject selection were as follows.

1. All subjects were engineers.
2. Three out of the five subjects had prior knowledge of paper bike design.
3. Three subjects watched the video at 4X speed while two watched the video at 2X speed. One of the subjects for 2X viewing could not watch the entire video due to scheduling conflict and was not tested on all evaluation tests.
4. One of the subjects who watched the videos at 4X speed was involved with the preparation of the experiment and the evaluation tests.

3.4 Method

The experiment took place in the Design Observatory [12] at the Center for Design Research at Stanford University. The experimentation procedure was as follows.

1. The subjects were seated in front of the projection screen showing two projections – one projection was of the video being power-browsed and the other was of the video clips arranged in a grid. Snacks were served during the experiment.
2. The subjects were given a Flicker test to determine their relative ability to detect changes across scene changes. The Flicker test consists of a video which alternates between two images that are similar except for a single change. The time taken by the subject to notice the change is recorded as an outcome of the test (see details in section 3.2).
3. They were then shown the videos from the design exercise. These video clips were arranged in a progressive sequence from prototyping, construction, and design review to the final race footage. The videos were played at the normal rate of 30 frames per second at the start and were gradually speeded up to 2 times the normal speed (2X) for two subjects and up to 4 times the normal speed (4X) for the remaining three subjects. The subjects were randomly assigned to either 2X or 4X group.
4. After watching the videos, the subjects were given a series of performance tasks that were based on the Bloom's taxonomy (see figure 2).
5. The subjects gave their verbal qualitative feedback on the experience of power-browsing and answering the tests.

3.5 Evaluation Tests

The evaluation tests administered to the subjects consisted of a pre-test called the flicker test designed to detect change blindness and a post-test based along the six cognitive dimensions of the Bloom's Taxonomy.

3.2.1 Flicker test

Change detection blindness in video is the inability to detect large and otherwise obvious changes in a video. Visual cognition studies by Simons and Levin [13] have determined that although people can recall the meaning and contents of the videos in some detail, their memory is far from perfect. Since power-browsing involves watching video at playback speed much higher than normal, change detection blindness was an area of concern. Since no standard test existed for detecting change blindness, the flicker paradigm test [14], devised by Rensink et al, was used. The Flicker test consisted of a video which alternated between two images that were similar except for a single change. These images were separated by a gray screen lasting for 70 - 110 milliseconds. The time taken by the subject to notice the change was recorded. Two different flicker videos were shown as a part of the Flicker test. Prior to the test a flicker video was shown to the subjects to introduce them to the test concept.

3.2.2 Test based on Bloom's Taxonomy

The six learning objectives according to the Bloom's Taxonomy [15] are as follows.

1. Knowledge and facts
2. Comprehension
3. Application
4. Analysis
5. Synthesis
6. Evaluation

These objectives vary from simple to complex as we go from recognition of knowledge and facts to evaluation. The test that was based on these objectives contained the following sections.

1. **Object recognition**: The subjects were given a list of key words and they had to recognize whether any of the keywords were taken from the video. A visual form of the test was also administered. It contained a sequence of pictures and the subjects had to recognize if any of the pictures were taken from the video.
2. **Summary**: The subjects were told to write down a summary of the video that they power-browsed.
3. **Event-listing**: The subjects were asked to rank in chronological order, the events that they observed happening in the video.
4. **Brainstorming**: The subjects were given a brainstorming task in which they had to think of alternatives for connecting a wheel to an axle.
5. **Faultfinding**: The subjects were asked to describe if they perceived any mistakes that the design team had made as shown in the video.
6. **Critique**: The subjects were told to critique the decision of the design team to choose a bigger front wheel and a smaller rear wheel for their paper bicycle.

The correspondence between the objectives mentioned in the Bloom's Taxonomy and the test sections is given below in Figure 2.

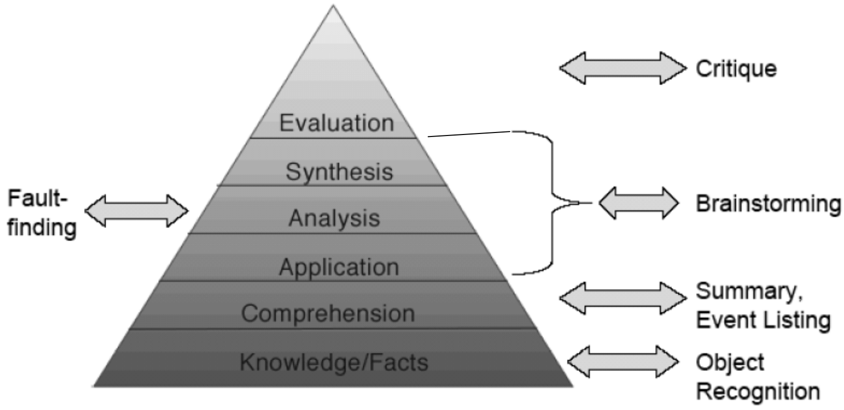

Figure 2. Correspondence between the Bloom's Taxonomy and the test sections

The evaluation test was based on the learning objectives of the Bloom's Taxonomy in order to explore the effect of power-browsing on the different cognitive activities performed by the designer on the information learned through power-browsing.

4 RESULTS

4.1 Flicker test

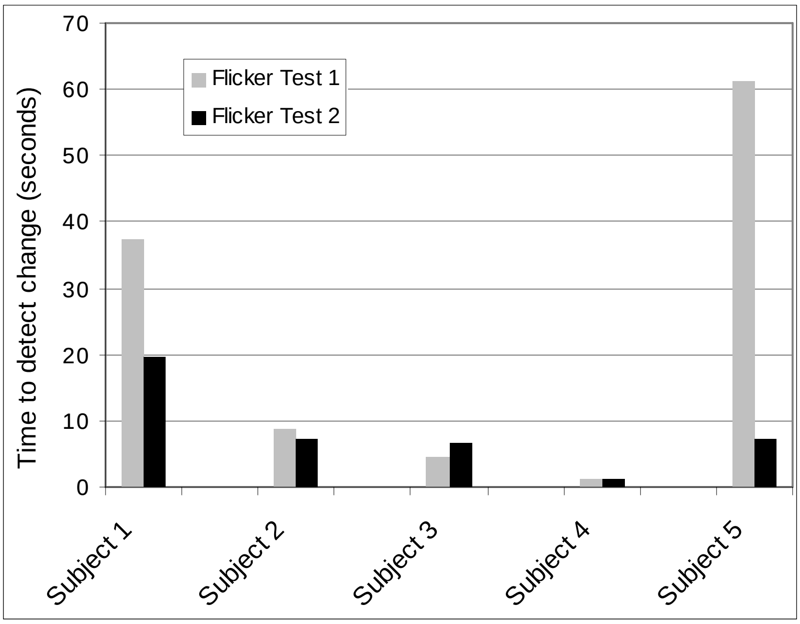

Figure 3. Results of the flicker test.

The Flicker test results varied widely from subject to subject and even within subject from test to test. From Figure 3, we can observe that responses for test 1 were longer than those for test 2 except for subjects 3 and 4. This might indicate that the subjects, especially subjects 1 and 5, formed a strategy to detect change in the flicker videos after the first test that enabled them to complete the second test faster. Subjects 3 who took a longer time for the second trial might not have formed such a strategy.

4.2 Event Listing

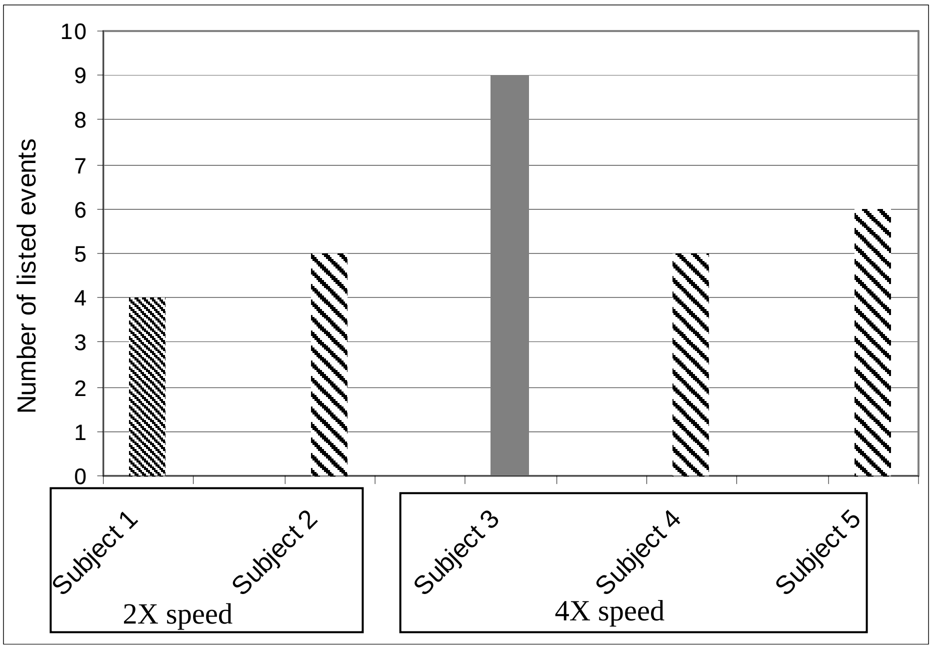

Figure 4. Results of the event listing test. The boxes on the X-axis indicate the two groups of subjects– one who viewed the video at 2X speed and the others who viewed at 4X speed. There is no significant difference in recall at 4X vs 2X speed.

The results of the event listing test are shown in Figure 4. From this figure we can see that the graph does not show significant increase or decrease in the number of events listed by subjects (1& 2) who had viewed the videos at 2X and those (subjects 3, 4 & 5) who had viewed the videos at 4X. Subjects 2, 3 and 4 were familiar with the paper bicycle exercise, while subject 3 was also involved with the design of the experiment.
The results also indicated that there were three granularities for the degree of detail in recall. Subjects 2, 4 and 5 had a coarse recall of detail, subject 1 had a medium recall and subject 3 had a fine recall where he was able to list events in greater detail. This could be explained by the fact that subject 3 was involved in setting up the experiment.

4.3. Object recognition

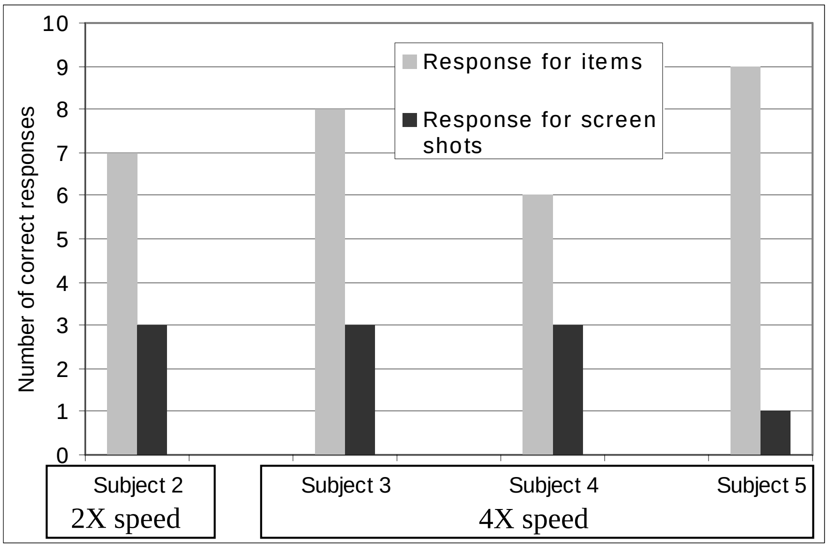

Figure 5. Results of the object recognition test. Recognition at 4X speed especially for images does not differ from that at 2X speed.

The results of the object recognition test as shown in Figure 5 show no significant difference between the responses of subject 2 who had watched the video at 2X speed and subjects 3, 4, and 5 who had watched at 4X speed. Subject 1 wasn't given this test as he did not watch the complete video.
From Figure 5, it can be observed that the responses of subjects 2, 3 and 4 for object recognition in case of the image test were 100 percent correct, while the response of subject 5 for the image test was only 33 percent correct. This might be because subjects 2, 3 and 4 were familiar with the paper bicycle design and hence had a notion of the images that are associated with paper bicycle design. Subject 5 was not familiar with paper bicycle design exercise and hence had difficulty in image recognition.

4.4. Brainstorming

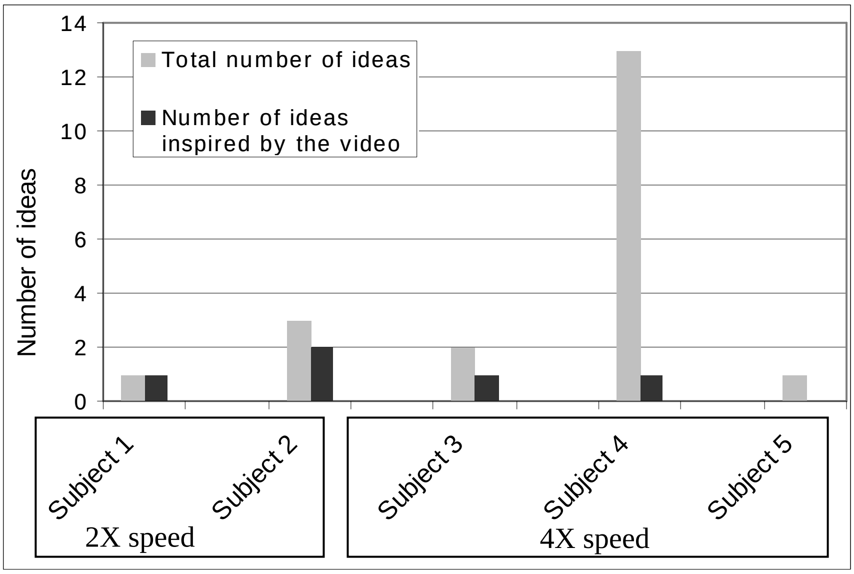

Figure 6. Results of the brainstorming test. The ideas inspired by video do not differ greatly in number between subjects viewing at 4X and 2X speed of playback.

The brainstorming results shown in Figure 6 don't indicate any significant differences between 2X and 4X speed. Except for subject 4 who came up with 13 ideas, the rest came up with 1, 2 or 3 ideas. The number of ideas inspired by the video does not go beyond 2. The less number of ideas inspired by the video might be due to the fact that there were not many design options discussed in the video.

4.5. Fault-finding

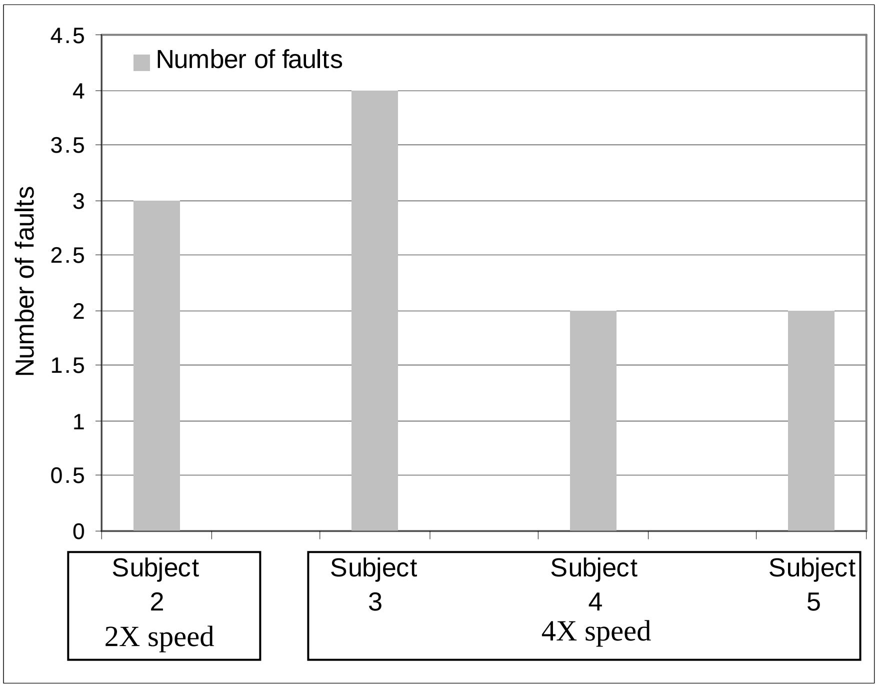

Figure 7. Results of the fault-finding test. There is no significant difference in the number of faults found at 4X vs 2X speed of video playback.

As shown in Figure 7, the number of faults found varies between a maximum of 4 to a minimum of 2. Once again, the results do not indicate any deterioration or appreciation in the number of faults found when going from 2X to 4X speed.

4.6. Summarization task

The results of the summarization task are similar to those of the event listing. It was observed that the subjects generated the event list first and then based their summary on that. The summary too had varied granularity of detail with most summaries being coarse in detail. It was also observed that subjects made errors in summarizing. The qualitative feedback received from the subjects indicated that though an action was understood from the power-browsed video, the purpose of the action was sometimes unclear. This might have lead to the errors in summarizing.

4.7. Critique

The subjects' responses to the critique task were brief, two to three sentences. This was perceived to be the most difficult of all the tests. It was observed that the responses depended as much upon prior technical knowledge as upon what was shown in the video.

5 CONCLUSION

5.1. 4X speed is more suitable than 2X speed for power-browsing

The results of the event-listing, object recognition, brainstorming and fault-finding sections of the test indicate that there were no significant differences between designers' browsing at 2X and 4X speed of power-browsing. However, according to the subjects' comments, there was greater perceived boredom while watching video at 2X rather than 4X. Also, this feeling of boredom was perceived more during a specific segment of video where there weren't many screen changes and which lacked subtitles. It might be possible to alleviate boredom to some extent by frequent screen changes, and by giving the viewer an opportunity to get involved in controlling the video speed. Frequent changes of background music might also help. Some subjects commented that the snacks provided to them helped in relaxation and reduced boredom. Thus food and, more generally, the ambience might also have an effect on the way a designer reacts to lengthy durations of video stimuli.

Overall, power-browsing video at 4X was considered to be a better experience than that power-browsing at 2X without significant difference in designer learning. However, the experiment did not explore power-browsing at other speeds higher than 4X due to equipment limitations and it is conceivable that the optimum power-browsing speed might be higher than 4X for some people.

5.2. Power-browsing is suitable for developing familiarity with video content

The following observations could be made from the use of the test based on the Bloom's Taxonomy to explore the effect of power-browsing on the different cognitive activities performed by the designer.

1. The results of the test and the qualitative feedback received from the subjects indicated that synthesis and evaluation were dependent on the subjects' prior knowledge as well as on the power-browsed video. It was difficult to isolate the contribution of power-browsing towards synthesis or evaluation.
2. The contribution of power-browsing towards recognition of knowledge and comprehension was easier to evaluate. However, between recognition and comprehension, there was no clear indication whether power-browsing was more suitable for recognition or comprehension.

The object recognition test was oriented towards testing recognition memory. Recognition memory could be categorized into familiarity memory and recollection memory, where familiarity implies the notion of having seen an object before, and recollection implies remembering where the object was seen or in what context [16]. The object recognition test thus tested for familiarity and recollection, but as the test was administered explicitly in the context of power-browsing, it did not isolate the familiarity component from the recollection component. However, we can hypothesize that as the speed of power-browsing increases, the designers will be more biased towards giving a familiarity response than a recollection response, as they will have shorter time to assimilate information in their conscious long term memory. Thus, one of the outcomes of the exploratory study was to focus our attention on the suitability of power-browsing for developing familiarity with video content rather than on more complex cognitive activities like synthesis or evaluation.

5.2. Implications for Design Practice

Designers can employ power-browsing as a technique to browse large video databases at the beginning of design projects. By browsing at playback speeds as high as 4X, designers can gain familiarity with the video information content in a shorter time and if they need greater detail they can go back to a slower speed of video playback. The familiarity of video content could lead designers to generate new concepts, and to conduct detailed searches further during the design process, thus accelerating design learning. Power-browsing is especially suitable for innovative design projects where the relevance of information is not known in advance.

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