Does Animation in User Interfaces Improve Decision Making?

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ABSTRACT

This paper reports a laboratory experiment that investigated the relative effects of images, transitions, and interactivity styles used in animated interfaces in two decision making domains. Interfaces used either realistic or abstract images, smooth or abrupt transitions, and parallel or sequential interactivity. Results suggest that decision making performance is influenced by the task domain, the user experience, the image, transition, and interactivity styles used in animated interfaces. Subjects performed better with animated interfaces based on realistic rather than abstract images. Subjects were more accurate with smooth rather than abrupt animation. Subjects were more accurate and enjoyed more the animation with parallel rather than sequential interactivity. Implications on the design of animated interfaces for decision making are provided.

Keywords: Animation, Decision Making.

INTRODUCTION

The conventional wisdom is that animation makes interfaces easier to use, more enjoyable, and understandable [15], [2]. However, inconsistent empirical results indicate that there is not enough theoretically-based evidence to guide the design of animated interfaces to improve human performance. Very little is known about the design and effective use of animation in user interfaces [17], [2], [13]. Managers have traditionally relied on static displays and textual or tabular data representations to make decisions. How should animated interfaces be designed to improve decision making performance? This is the main question this research addresses.

The uncertainty surrounding the use and effectiveness of animation starts with its definition. A definition of animation in HCI seems unclear [17]. Most definitions found in the literature are based on the classical notion that movement is the essence of animation, involving a change in the positioning of the objects on a screen [2]. However, computer animation seems to be quite different from classical animation [5]. Specifically, appropriateness of the user's/decision-maker's mental model and interactivity must be explicitly considered if computer-based animation is going to be an effective decision-support tool [7].

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To account for appropriateness and interactivity, animation in HCI can be defined as: *a series of varying images presented dynamically according to user actions in ways that help the user to perceive a continuous change over time and develop a more appropriate mental model of the task [7].* A task is generally considered a meaningful unit of work performance, and interactivity is usually defined by the visible or motor actions the user performs on the interface.

This paper summarizes previous empirical research on animation and reports a laboratory study conducted to evaluate the decision making effectiveness of different types of images, transitions, and interactivity styles used in animated interfaces. The paper concludes with implications and recommendations concerning the design of animated interfaces for supporting decision making.

LITERATURE REVIEW OF EMPIRICAL RESEARCH OF ANIMATION INTERFACE DESIGN

Empirical research on interfaces for decision making has largely focused on comparisons of textual information, table-based information, and static 2D charts [8] [9]. Relatively little empirical research has investigated the effectiveness and appropriateness of animation in HCI [13], [17]. Computer-Based Instruction (CBI) is probably the area that provides more information about animation effectiveness, but yet in this area there is a small number of studies concerning the empirical evaluation of animation [13]. The few serious attempts to empirically investigate animation in instructional studies have reported inconsistent results [14]. Reviews of selected empirical investigations from the literature in Education, Psychology, and HCI suggest that animation may make interfaces easier, more enjoyable, and understandable [7]. However, there is limited theoretically-based empirical evidence to design, use, and evaluate animation for improving human performance.

The inconsistency in the results of empirical studies of animation may be due to several factors. First, most studies involve the comparison of static textual information versus graphical dynamic presentations. Since it has been found that textual versus graphical symbols in static form have different effects on performance [4], differences in performance may be due to the use of different representations, not to the dynamic nature of the presentation of graphics. Second, most studies use animation to show obvious movements of graphical objects in demonstrating a computer task. When animation is used to demonstrate tasks that the user already knows or when the user does not feel mentally engaged in processing the task, animation will probably show no positive effects. Therefore, inconsistent results in animation may be caused by an inadequate selection of the tasks to be animated. Third, most studies use animation as a presentation technique rather than as an interactive technique. Passive environments and inconsistent allowance of user's interactivity may cause conflicting conclusions of animation effectiveness.

In summary, little or no work has been done to study the effect of animation on decision making. Most current studies suggest the need for theory and theory-based data to support animation design.

EMPIRICAL APPROACH

The empirical approach investigates the theoretical propositions developed in an Animation User Interface Design (AUID) Framework [7]. The AUID framework predicts that the task domain and structure, individual differences such as visual abilities and experience, and characteristics of the animated interface such as image realism, continuity of the transitions, and correspondence between the interactivity style and the form of presentation affect decision making performance. To investigate these propositions, a 2 (Image) X 2 (Transition) X 2 (Interactivity) X (2 (Task) X S(89)) mixed four-factor within-subjects design was used. Eight animation user interface prototypes were constructed to provide all combinations of two types of images, transitions, and interactivity styles in two task domains. The eight animated interfaces for each task varied by the type of image (Realistic, Abstract), the type of transitions (Gradual, Abrupt), and the type of interactivity (Parallel, Sequential). These prototypes created eight treatment conditions (Table 1) that were administered to eighty nine undergraduate students that participated voluntarily in the experiment. All subjects received course credit for their participation and an extra incentive of $5 cash based on both, accuracy and time performance. Subjects performed one task in each of two different domains. To reduce the possible practice effects, the tasks were presented randomly in a balanced order across the subjects.

Treatment	Image	Transition	Interactivity	Code
1	Realistic	Gradual	Parallel	1RGP
2	Realistic	Gradual	Sequential	2RGS
3	Realistic	Abrupt	Parallel	3RAP
4	Realistic	Abrupt	Sequential	4RAS
5	Abstract	Gradual	Parallel	5AGP
6	Abstract	Gradual	Sequential	6AGS
7	Abstract	Abrupt	Parallel	7AAP
8	Abstract	Abrupt	Sequential	8AAS

Table 1. Eight treatment conditions

Decision making performance was determined by objective and subjective measures. Objective measures of performance (time and accuracy) were determined during the execution of the tasks with the animated interfaces. Decision time constituted the minutes spent to make a choice. Decision accuracy was the closeness between the user's response and the objective. Only one correct answer existed for a given task. Subjective measures of performance (ease of use and enjoyability) were gathered by an instrument consisting of questions from previous satisfaction MIS questionnaires [7].

Task Environment

Each subject performed one decision making task in each of two domains: a real estate problem called "Home Directory" (HomeD) and a Physics problem called "Bolt in the Boat" (BinB). Finding a home has been considered a laborious task, usually performed by manual search on paper directories and used as an example in the development of dynamic queries systems [1]. Physics problems of classical mechanics such as the comparison of sunken and floating objects have been considered extremely difficult in perception and cognition experiments [10]. These two domains involved choice tasks with multiple alternatives corresponding to two common decision strategies: linear (based on alternative processing) and majority of confirming dimensions (based on attribute processing) [9]. In the selection and design of the tasks issues such as appropriateness and attractiveness of the tasks, facility to represent and implement the tasks graphically, minimization of differences among subjects, and possibility to evaluate and measure performance were considered.

The HomeD graphically described hypothetical places (houses and apartments) available to rent in a small southwestern city. The HomeD required the subjects to evaluate and select a place to rent from a set of twenty alternatives, based on the value of eleven fixed non-prioritized attributes. The alternatives and their attributes were obtained from real estate guides of the city. The user's objective was to select a place to rent among the alternatives that most closely met the attributes of a predefined ideal place. The attributes of the ideal place were explicitly given to the subjects in a pre-experimental description of the task.

The BinB graphically described alternative scenarios of fluid displacement levels caused by sunken and floating objects. The BinB required the subjects to compare, evaluate, and select a water level from a set of five scenarios. The base for the comparison was a realistic scenario: a heavy metal bolt placed into a boat floating on water within a container caused the water level to rise from level zero to a new level. Five different scenarios in which the same bolt was sunk into the water producing different changes in the water level were the predefined alternatives for this task [10]. The user's objective was to select the water displacement level that appeared less artificial and better predicted what would happen in real life.

Animation User Interface Prototypes

Sixteen animation user interface prototypes were constructed, eight different prototypes for each task domain according to the manipulation of the variables: image, transition, and interactivity. The prototypes were prepared in a PowerMac computer for a 13-inch color monitor using Macromedia Director version 4.0. The prototypes were embedded into an application to control the execution of the tasks and to store the information about the users' performance. The screen layout was divided into three

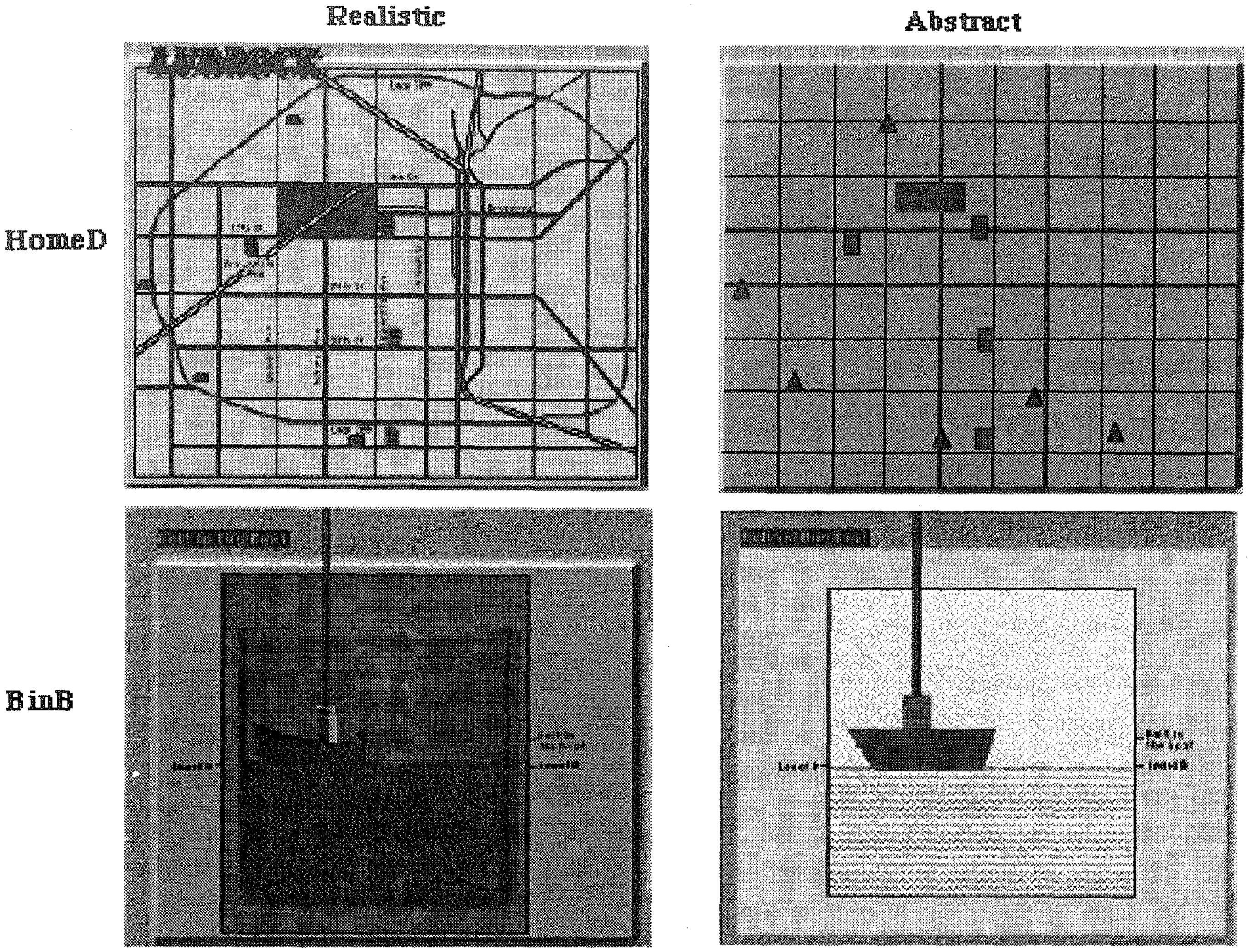

Figure 1. The Manipulation of Images as Realistic and Abstract in Two task Domains

functional areas: the images area, the interactivity area, and the messages area. Because it has been suggested that the addition of sound to animation improves the operation and understanding of interfaces [6], sound effects (i.e., mouse clicks) and music were added. These characteristics were constant for all prototypes. The eight prototypes for each task were designed to last the same time without any user interactivity.

Design of Images

Figure 1 summarizes the manipulation of images. In the HomeD, realistic images were based on the image of a city map. A map of the city was scanned and edited to provide shadows and colors with realistic effects. Graphical icons represented houses or apartments, and variations in the size of icons represented the number of bedrooms (small = 1 bedroom, medium = 2 bedrooms, large = 3 bedrooms). Abstract images in the HomeD were based on a starfield display (two-dimensional scatterplot) [1]. Geometric shapes were used to represent houses (triangles) and apartments (squares). As with realistic images, different sizes were used to represent the number of bedrooms.

In the BinB, realistic images were digital pictures taken from a real model constructed for this purpose. The model was constructed using a transparent glass container and a small toy boat. Pictures of the realistic model were taken with a digital camera and imported to Macromedia Director. A 3D representation of a metallic colored bolt was constructed using Macromedia MacroModel. Abstract images in the BinB were 2D geometric representations constructed using Director's drawing tools. A square represented a container, a trapezoid represented a boat, and a rectangle represented a bolt. The graphical elements in the abstract images were designed in the same sizes and colors as those in the realistic images, but no shadows or depth cues were included.

Design of Transitions

Gradual transitions were implemented by providing transition effects between the display of two consecutive alternatives and by assuring the minimum change between two consecutive frames. The dissolve "bits fast" effect provoked the fade-out of an image superimposed on the fade-in of the next. Besides transition effects, gradual transitions involved the change of only one element in each display frame of the animation. In the HomeD, icons representing

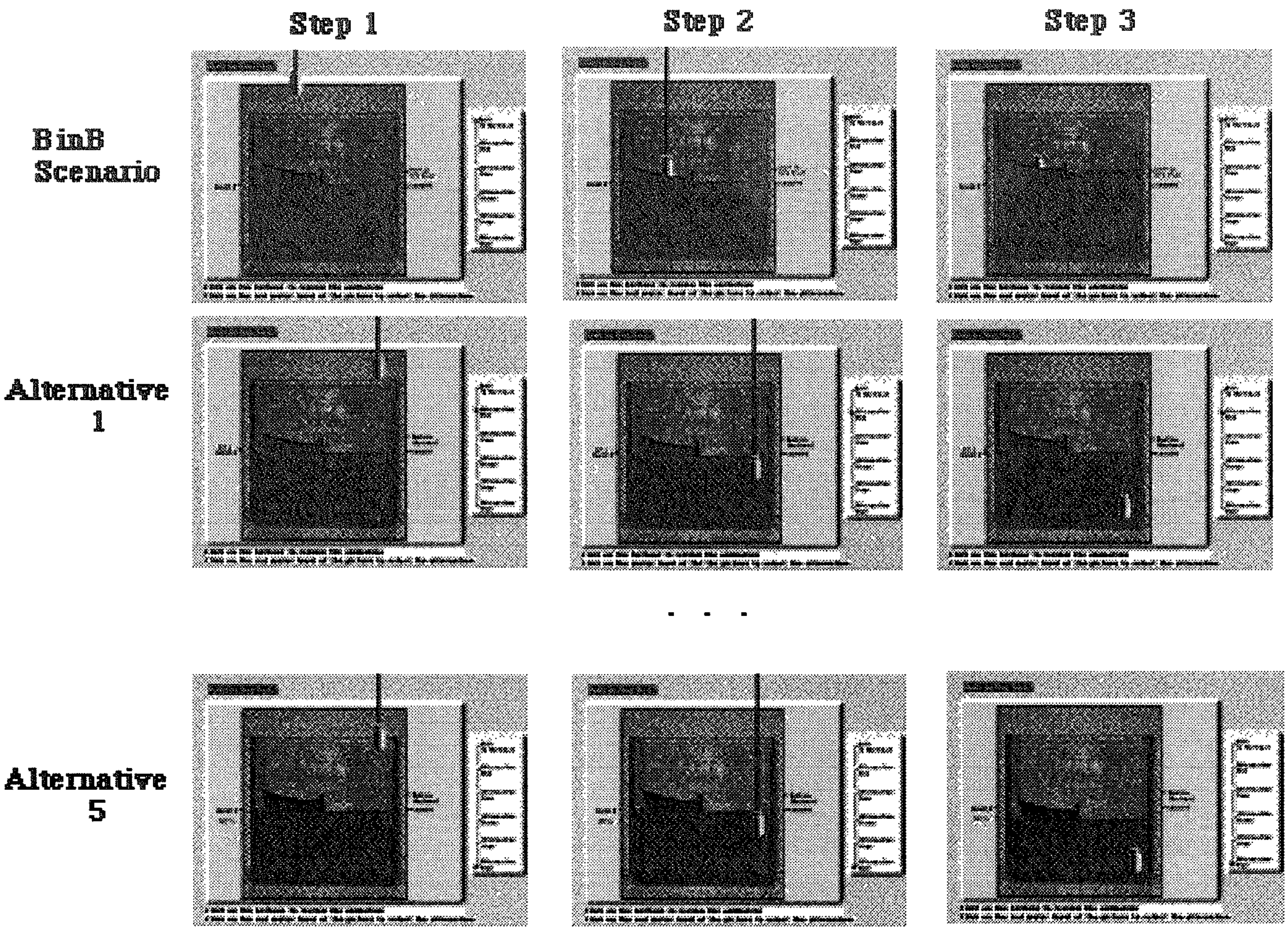

Figure 2. Example of Frames Used in the Animation of the BinB Problem

the alternative places appeared one at a time, instead of all together in one display frame. In the BinB, gradual transitions involved a small change of position in the objects between two consecutive frames. The movement of the bolt placed into the boat or the water and the movement of water and the boat to reach the new water level, were implemented by small changes on the positions of the elements between two display frames.

The treatments involving abrupt transitions used no transition effects, providing a relatively instantaneous change between animation frames. Also, the change provoked between one display frame and the next was considerably large compared to the gradual transitions. In the HomeD, abrupt transitions showed all the icons representing the alternatives that met one attribute in one display frame. In the BinB, abrupt transitions showed the change in position of the graphical elements in three screens. In one screen the bolt is shown out of the water, in the next one, the bolt is shown right above the water, and in the last screen the bolt is shown into the water. Figure 2 shows an example of some of the frames used in the BinB animation. The first three frames show the realistic scenario used for comparison; the next three frames show the first alternative continuing until the fifth alternative is presented.

Design of Interactivity

Icons representing buttons for direct manipulation were the interactivity style used for all prototypes. Figure 3 summarizes the manipulation of interactivity. Parallel interactivity provided the user with buttons to illustrate a segment of the task in any order. In the HomeD, parallel interactivity allowed the user to choose attributes to observe the alternatives. The user was allowed to click on any button of the interactivity panel at any time, and the system responded by showing the alternatives that met the attribute selected. In the BinB, parallel interactivity allowed the user to choose any alternative scenario in any order. The user was allowed to click on any button of the interactivity panel at any time, and the system responded by showing the animation of the scenario selected.

Sequential interactivity provided the user with buttons to navigate through the animation in the same order. The buttons included those normally found in any device for sequential manipulation: play, step forward, stop, step backward, and play backward. The user was allowed to click on any of these buttons at any time, and the system responded by showing the corresponding sequence of the animation (play forward and play backward buttons), stopping (stop button), or showing the next or previous step and stopping (step forward and step backward buttons).

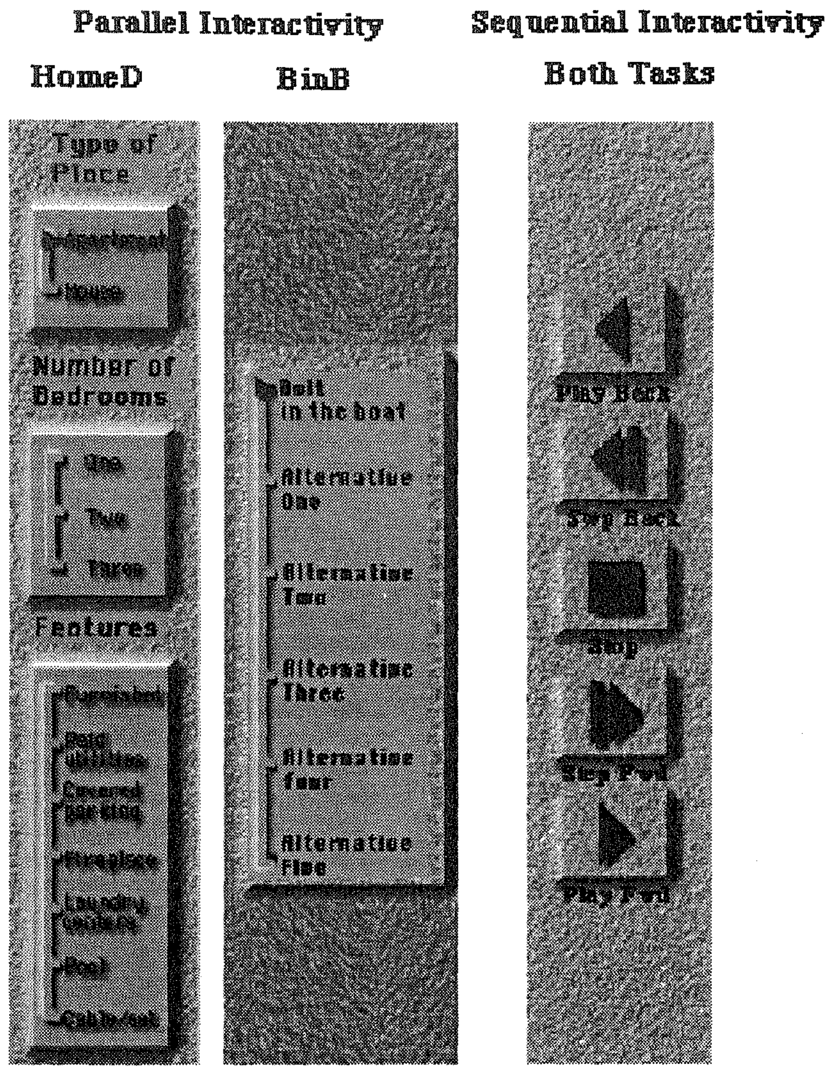

Figure 3. The Manipulation of Interactivity as Parallel and Sequential

In both types of interactivity, the user selected one alternative by pointing and clicking on the graphical elements in the image's area of the screen. These actions caused a movable window to appear on the screen from which the user could select or cancel the alternative. This technique was used to reduce the complexity of the display, and to allow the user to focus on detailed information [1].

Other Experimental Materials

The user's visual abilities and experience were gathered by two post-experimental questionnaires. The Vividness of Visual Imagery Questionnaire (VVIQ) as formulated by Marks [11] was used in this research to obtain data concerning the quality of the mental images formed by the subjects and to explain possible differences in performance due to subjects' visual ability differences. To determine user's experience, a questionnaire containing the three main dimensions suggested by Nielsen [12] was developed in this research. The questionnaire contained five factors explaining the user's experience in computers in general, experience with the two task domains, and experience with animation use and development [7].

Experimental Procedure

Subjects were tested in groups of eight during five days. Each session of the experiment lasted from 30 to 40 minutes. Before the session started, headphones were attached to the eight computers and run-time versions of the prototypes were pre-loaded. By using a dialog box, the researcher input the user information: the number, the starting task, the file on which to store the information, and the treatment number.

A set of instruments consisting of written instructions, task descriptions, and questionnaires were prepared for each subject before the experimental session. To ensure that the instructions were delivered to the subjects consistently and clearly, both written instructions and verbal instructions via videotape were provided. After receiving the instructions, the subjects started the laboratory work.

The computers used were Power Macintosh configured with 13-inch color monitor and 8 MB of RAM. The computer process began with a Welcome screen. Wearing headphones, the users started the execution of the first task by clicking on the button at the right-hand side corner of the screen. After executing the first task, a screen indicated the end of it and a subjective ratings questionnaire pertaining to that task was completed. The user started the execution of the second task by clicking on the button at the right-hand side corner of the screen. After executing the second task, a screen indicated the end of the session and a subjective ratings questionnaire pertaining to that task was completed. The user then clicked on the button at the right-hand side corner of the screen to find out about the extra monetary prize shown on a message box. Subjects answered the VVIQ and experience questionnaires at the end of the session.

DATA ANALYSIS AND RESULTS

The mean values of accuracy, time, ease of use, and enjoyability for the two types of images, transitions, and interactivity styles indicated that realistic images, gradual transitions, and parallel interactivity produced better decisions. The statistical significance of these observations was investigated using StatView 4.0 for Macintosh and SAS for Vax. The principal statistical procedure was the General Linear Model (GLM) to perform repeated measures analyses of variance (repeated ANOVAs) evaluated with the F-statistic at a .05 level. Statistical assumptions, practice effects, and interaction effects were verified. Partial correlations between visual abilities (VisualA), total experience (TotExp), and time over the dependent measures (accuracy, time, ease of use, and accuracy) were investigated to determine the inclusion of these variables as covariates. Statistical models including these variables as covariates were used in the analyses. Table 2 provides an overview of the main significant main effects found in this study.

	Decision Making Performance			
	Accuracy	Time	Ease of Use	Enjoyability
Task			■	■
User				
TotExp		■		
Interface				
Image	■	■	■	■
Transition	■			
Interactivity	■			■

Table 2. Overview of Main Significant Effects

Interface Main Effects

The analyses of accuracy showed that in both tasks, the use of realistic images provided more accurate responses than the use of abstract images in animated interfaces. A repeated measures ANOVA showed that the difference in accuracy caused by the use of realistic versus abstract images was significant across tasks ($F(1,78)=10.29$, $p<.05$). The analysis of time showed that in both tasks, subjects exposed to animation with abstract images took longer to make a decision than subjects exposed to realistic images. A repeated measures ANOVA showed a significant difference in time between realistic and abstract images across tasks ($F(1,78)=7.13$, $p<.05$). The analysis of ease of use showed that in both tasks, subjects using animation with realistic images perceived the systems more easily than those using animation with abstract images. The difference in ease of use caused by the use of realistic versus abstract images was significant across tasks, as showed by a repeated measures ANOVA ($F(1,80)=4.41$, $p<.05$). The analysis of enjoyability showed that animation with realistic images was more enjoyable than animation with abstract images in both tasks. These observations were confirmed with a repeated measures ANOVA ($F(1,80)=17.14$, $p<.05$).

Observations of accuracy data indicated that animation with gradual transitions produced more accurate responses than animation with abrupt transitions. These observations were statistically significant across tasks ($F(1,78)=5.84$, $p<.05$). The analyses of time for gradual and abrupt transitions showed no significant differences between gradual and abrupt transitions at the .05 level. The analyses of ease of use showed a significant interaction between the transition manipulation (Gradual, Abrupt) and the order in which the tasks were presented for the ease of use measure ($F(1,81)=4.77$, $p<.05$). No main effects of the transition factor on ease of use can be claimed due to this significant interaction. Observations of the enjoyability data indicated that gradual transitions caused subjects to enjoy the animation more than abrupt transitions; however, these observations were not statistically significant at the .05 level.

The analyses of accuracy data showed that in both tasks, subjects were more accurate in their decisions when they used animation with parallel interactivity than when they used sequential interactivity. A repeated measures ANOVA showed that the difference in accuracy caused by the use of parallel versus sequential interactivity was significant across tasks ($F(1,78)=12.70$, $p<.05$). The interactivity types did not make a significant difference in the decision making time for any of the two tasks at the .05 level. The analyses of the ease of use data showed a significant interaction between the interactivity type (parallel, sequential) and the task domain (HomeD, BinB) ($F(1,80)=4.49$, $p<.05$). This interaction was further investigated with two separate ANOVAs by task. The results showed a significant difference in the user's perception of ease of use for parallel versus sequential interactivity only for the BinB ($F(1,88)=4.83$, $p<.05$). Observations of enjoyability data indicated that parallel interactivity caused the subjects to enjoy more the animation than sequential interactivity in both tasks. The results from the repeated measures ANOVA showed that the difference in enjoyability caused by the use of parallel versus sequential interactivity was significant across tasks ($F(1,80)=4.37$, $p<.05$).

Task and User Effects

Observations of the ease of use and enjoyability data indicated that the HomeD task was considered easier and more enjoyable than the BinB task. The repeated measures ANOVA analyses showed significant effects of the task domain for accuracy ($F(1,78)=6.53$, $p<.05$), time ($F(1,78)=8.88$, $p<.05$), ease of use ($F(1,80)=8.57$, $p<.05$), and enjoyability ($F(1,80)=6.51$, $p<.05$).

The investigation of the visual abilities and experience as covariates showed some correlations (>.10) between VisualA and the subjective measures of performance, and between TotExp and the objective measures of performance. The users' visual abilities, however, did not have a significant effect on any of the dependent measures at the .05 level. The users' total experience appeared significant across tasks only for the time measure ($F(1,78)=7.43$, $p<.05$). More experienced users finished the tasks faster than novice users.

DISCUSSION OF THE RESULTS

The results from this study provide evidence for the effects of different animation design elements, task characteristics, and user characteristics on the performance of decision making tasks.

Interface Effects

This research showed that decision making accuracy, time, ease of use, and enjoyability in animated interfaces are influenced by the form of image representation, the transition effects, and the form of interactivity.

The findings of this study provide additional support for pursuing realism in the representation of information. Previous studies have demonstrated the positive effects of image realism by using 3D wireframe versus 3D shaded static images for mental rotation tasks [3]. The benefits of using 3D versus 2D images, however, are controversial. This study demonstrates the positive effects of image realism in comparing 2D geometrical representations versus 2D maps and photo-realistic pictures in animated interfaces. The accuracy and time of the decision, and the subjective perception of ease of use and enjoyability improve when cues of realism are added to the images in animated interfaces. The effects of realistic versus abstract images, however, may be stronger or weaker, according to the task domain. In the HomeD the user may be less aware of his/her manipulation of the mental model than in the BinB [16]. Therefore, cues for realism may be more important for domains that require making value judgments than for problem solving in Physics.

The findings in this study provide theory-based data that support the design of smooth animation to increase the accuracy of the decisions. Although smoothness is considered a basic principle of animation design [17], the effects of smooth presentations have not always shown to be effective. This research isolated the transition effects from the effects of images and interactivity, and showed that smooth animation has positive effects over abrupt animation in the accuracy of the decisions across two decision making domains. Subjects using animation with gradual transitions were more accurate than subjects using animation with abrupt transitions. The effects of transitions, however, seem to be more important for Physics problems (BinB) than for problems requiring value judgments (HomeD). Making value judgments is a more discrete domain than problem solving in Physics [16]. The HomeD did not involve changes of the objects' position (movement) but involved the appearance/disappearance of objects, while the BinB required mainly the transformation of the objects' positions on the screen. It seems that when the visualization of the movement of the objects is critical to understand the task, gradual transitions are more important to ensure accurate responses than in situations that do not require the objects' movement.

Finally, this study provides additional support for animation as an interactive technique rather than as a presentation technique. Animation has been considered in two states: passive (classical animation) and completely interactive (real-time animation). This research used animation in an intermediate type of interactivity. Differences in performance due to different interactivity techniques have not been studied. This research showed that interactivity per se is important for the accuracy and enjoyability of decision making tasks in animated environments. Subjects using parallel interactivity were more accurate in their decisions and enjoyed more the animation than subjects using sequential interactivity, regardless of the type of image and the animation smoothness. The effects of different interactivity techniques on the perception of the ease of use of animation, however, may depend on the task structure. The interdependent attributes in the HomeD may have caused a better processing with sequential than with parallel interactivity. Besides, the interactivity panel for the HomeD was organized by attribute while the panel for the BinB was organized by alternative. The organization by attribute may have caused an insignificant difference between parallel and sequential interactivity in the HomeD.

Task and User Effects

The results from this empirical investigation indicate that the task domain is a significant factor of decision making performance in animated interfaces. This research found no significant effect of the user's visual abilities on any of the measures of decision making performance, and significant effects of the user's experience only on decision making time. In this study, however, the user's visual abilities and experience scores were used as statistical ways to reduce the experimental error rather than as experimental means. The data collected from the user's visual abilities and experience revealed that on average, the subjects that participated in this experiment were novices and good visualizers.

CONCLUSIONS

This research supports the idea that to be an effective decision support tool, animation must be smooth, simple, interactive and explicitly account for the appropriateness of the user's mental model of the task. The theory-based data indicated that:

a) To ensure more accurate decisions, with which the subjects feel satisfied, designers should base their animation on realistic graphical representations rather than on abstract images.

b) To ensure more accurate decisions, animation designers should determine the required changes on images and transition effects that would make the animation smoother. They should also determine changes in graphical objects according to the type of visual characteristics, and define transition effects according to the task structure.

c) To ensure more accurate decisions and more enjoyable interactions, the designer should allow the user to manipulate directly different segments of the animation in a parallel

rather than sequential order. Animation designers should provide parallel interactivity if the successive steps in the task structure can be executed in any order.
d) To ensure faster decisions, animation designers should take into consideration the subjects' experience with computers in general, with the task and with animation use and development.
e) The design of animated interfaces should be based on both the characteristics of the task domain and the structure of the task(s) the user performs. Knowing the characteristics of the task domain, the designer may define the best decomposition, representation, and retrieval of the task. By defining the structure of the task, the designer is better able to decompose the task into animation segments and understand the sequence and type of interactivity that would allow the design of more comprehensible animation, thus supporting the user's awareness of the events and accounting for human memory capabilities. These characteristics would determine particular design decisions of the visual representations, the order of the presentation of alternatives, and the type of interactivity allowed.

The results of this study show that decision making performance is highly contingent on the properties of the animation user interface such as image realism, transition smoothness, and interactivity style, and also sensitive to the task domain and the user's experience. However, many other issues need to be investigated in the effective use of animated interfaces for decision making. First, further development of interactive animation design theories is required in HCI. Second, the development of a formal taxonomy of interactivity styles would be extremely important in the research of interactivity in animated interfaces. Third, further empirical investigation of the propositions of the AUID framework is required to objectively evaluate its predictive potential. Fourth, knowledge on differing task environments is very important to improve the use of animation in decision making and to guide animation interface design. Finally, the use of animation in more realistic and complex environments is required to support the external validity of these findings.

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