EFFECT OF COMPUTER ANIMATION ON USERS' PERFORMANCE: A REVIEW[1]

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RÉSUMÉ

EFFET DE L'ANIMATION SUR LES PERFORMANCES DES UTILISATEURS : UNE SYNTHÈSE

Avec les rapides avancées technologiques de la dernière décennie, les nouvelles formes de visualisation avancée, comme la réalité virtuelle ou l'animation, ont proliféré. Contrairement à l'idée reçue selon laquelle les animations améliorent la qualité des interactions homme-ordinateur, les recherches ne font pas toujours état de bénéfices sur le plan cognitif. Dans cet article, nous présentons une revue de 17 recherches sur les effets de l'animation dans plusieurs domaines, et notamment en éducation, interaction homme-machine et psychologie. Deux types de recherches sont rapportées: 12 recherches expérimentales, comparant une interface statique et une interface animée dans des conditions contrôlées, et 5 recherches de terrain, en milieu scolaire, comparant l'utilisation d'une interface animée à un cours traditionnel (en général pour la phase d'exercices).

En termes de performance générale, parmi les 12 recherches qui comparent interface statique et interface animée, sept études rapportent un effet positif de l'animation sur les performances (en général, temps et exactitude dans des tâches qui suivent l'observation du dispositif). Les cinq études restantes ne trouvent aucune différence entre les deux types de dispositifs. De même, trois des cinq études de terrain rapportent de meilleurs résultats pour le groupe bénéficiant de l'animation par rapport à un apprentissage papier-crayon. Ainsi, les résultats ne permettent pas d'apporter de réponse tranchée ni pour conforter, ni pour infirmer l'utilité de l'animation dans le cadre du travail.

Une meilleure attitude est d'évaluer la pertinence de l'utilisation d'une interface animée en fonction de la situation dans laquelle elle va être utilisée. Cinq facteurs se sont avérés d'une importance non négligeable: le type de contenu à transmettre, le niveau d'interactivité, l'objectif de l'animation, le design de l'interface animée et enfin les variabilités interindividuelles.

Pour conclure, cette synthèse souligne le manque de recherches de fond sur l'animation qui ne seraient pas dirigées par l'intuition mais par une réflexion sur les processus cognitifs que l'animation est supposée améliorer. Néanmoins, deux principes de conception se dégagent de ces recherches:

1/ le principe de concision, selon lequel l'information doit être transmise de la façon la plus claire et simple possible;

2/ le principe de correspondance conceptuelle, selon lequel l'animation doit être utilisée uniquement lorsque le contenu à transmettre implique un changement dans le temps.

Mots-clés: *Animation, Instructions sur ordinateur, Interaction homme-machine, Processus cognitifs.*

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1. Un texte en français proche de cet article peut être obtenu auprès de l'auteur.

I. INTRODUCTION

With recent rapid advances in technology and with increasing contact among cultures not sharing spoken languages, graphic devices have proliferated. However, the advances in the technology of producing attractive graphics often seem to drive and outstrip the development of tools and devices rather than cognitive principles derived from research on their utility. Graphics are not always effective, or put differently, not all graphics are effective in all situations. The early research comparing learning with graphics to learning with text alone is instructive. It gave mixed results, often in spite of enthusiasm for the pictorial devices (see reviews by Levie, 1987; Levie & Lentz, 1982; Mandl & Levin, 1989). Moreover, much of the early research used global comparisons between media and did not address the subtler questions of what accounts for facilitation when it occurs. As research progressed, the types of situations, graphics, tasks, and learners for which graphics are effective have become clearer (Levin, Anglin, & Carney, 1987; Peek, 1993).

One of the newer, attractive graphic devices is animation. Animation as a learning tool presents special challenges for education and interface design because of evidence that people often have difficulties in accurately perceiving and conceiving real-life animations (*e.g.*, Kaiser, Proffitt, & Whelan, 1990). Yet, there is a general belief that animation not only improves the user's understanding, but also makes one interface easier to use and more enjoyable. Are these beliefs supported by evidence?

Here we review research on computer animation in education, human-computer interaction and psychology. We first need to address the potential sources of misunderstanding between disciplines by considering the referential scope of key terms in our discussion, and especially the term animation itself. Then, the average findings of 17 studies (summarized in Tables 1 and 2, see appendix) are reported. On the basis of these findings, we review the factors which could influence the users'processing of an animated display and therefore its effectiveness. Finally, some guidelines for the design of computer animation are proposed.

II. THE DIVERSITY OF THE RESEARCH FIELD

One reason for the inconsistency of the research lies in the diversity of the research field in itself. Numerous empirical studies have investigated the effectiveness of computer animation, but very few have attempted to integrate these findings into an analytic framework (Scaife & Rogers, 1996). The sense of the term animation, the functions animation is supposed to serve, the objective of the study, and the comparison groups for the animation are among the variables affecting general conclusions about utility of animation.

II.1. What does the term "animation" refer to?

Inconsistencies among studies begin with the definition of computer animation (Baek & Layne, 1988; Gonzales, 1996). Baek and Layne (1988) defined animation as "the process of generating a series of frames containing an object or objects so that each frame appears as an alteration of the previous frame in order to show motion" (p. 132). Gonzales (1996) proposed a broader definition of animation as "a series of varying images presented dynamically according to user action in ways that help the user to perceive a continuous change over time and develop a more appropriate mental model of the task". This definition however contained the idea that the user interact with the display (even minimally by hitting any key).

From this review, computer animation refers to *any application which generates a series of frames, so that each frame appears as an alteration of the previous one, and where the sequence of frames is determined either by the designer or the user.* This definition is broader by design than either of the preceding definition. It does not stipulate what the animation is supposed to convey, and it separates the issue of animation from the issue of interaction.

II.2. What is animation used for?

According to Levin, Anglin and Carney (1987), illustrations in text can serve five functions: 1/ decoration—illustrations can help readers enjoy the text by making it more attractive; 2/ representation—illustrations can help readers visualize a particular event, person, place a thing; 3/ transformation—illustrations can help readers remember key information in a text; 4/ organization—illustrations can help readers organize information into a coherent structure; 5/ interpretation—illustrations can help readers understand the text.

The variety of forms animation can take and functions that it may subserve means that the effectiveness of animation does not reside in the animation per se but in the relation between the goals of the animation, the implementation of the animation and the tasks of the user. Different uses of animation are likely to have cognitive implications. In addition, in practice, animation often takes advantage of an independent feature of computers, namely interactivity. Clearly, interactivity in itself could lead to a cognitive advantage. Some studies have tried to separate the effects of interactivity and animation (Gonzales, 1996; Rieber, 1990*b*; Rieber, Boyce, & Assad, 1990).

II.3. What is the objective of the study?

Just as they vary in their conceptions and functions of animation, the studies also vary in their assessment of animation, in particular, in the alternative conditions animation is compared to.

In some of these, both the static and animated displays involved graphics (Baek & Layne, 1988; Kieras, 1992 (experiment 1); Harrison, 1995; Kaiser, Proffitt, Whelan, & Hecht, 1992; Pane, Corbett, & John, 1996; Rieber, 1989*a*; 1989*b*; 1990*b*; 1991; Rieber *et al.*, 1990), so that the results can be attributed to the animation device itself.

Other studies compared animated graphic display with text-only instructions (Palmiter & Elkerton, 1993; Palmiter, Elkerton, & Baggett, 1991). In these studies, the difference between conditions may be due not to the animation itself but rather to the medium used (*i.e.* text or graphics). However, in some cases, it would be difficult to design a static graphics condition since the visualization of the process involves several frames. An interesting alternative would be the sequential presentation of static pictures for each step of the procedure (as in Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Morrison, Zacks, & Tversky, 1999).

In studies comparing CAL (Computer Assisted Learning) to regular classroom learning (Grimes & Willey, 1990; Kinzer, Sherwood, & Loofbourrow, 1989; Lazarowitz & Huppert, 1993; Lowe, 1996; White, 1993), the effect observed in the animated condition could also be due to other factors such as the instructional changes induced by the use of a computer: type of practice, individualized vs. group learning, motivational aspects and so forth.

Some studies examining critical aspects of the animation aim to isolate which factors in computer animation affects user performance and preference (Baggett, 1984, 1987; Gonzales, 1996; Kieras, 1992; Mayer & Anderson, 1992; Mayer & Sims, 1994). These studies provide information about how to design an animated interface in order to improve its effectiveness, usability and enjoyability. However, they did not compare animated displays to equivalent static displays.

This brief discussion of the varying objective of the studies has made clear that in comparing among media, not all factors can be kept equivalent across conditions. Some of the other conditions that vary across studies are the mode of conveying textual information, spoken or written, time on task, and the equivalence of the information across media. Given the impossibility of completely equating the information given across conditions, results in favor or not of animation should be taken cautiously, with careful attention to the conditions under which this advantage appeared.

Among the 21 studies reviewed, 12 compared static and animated displays (of them, 2 compared static text vs. animated graphics), 5 compared a class using CAL with a regular class, and 4 examined the factors that might affect effectiveness of computer. In addition, most of the studies comparing animated to static displays also address the factors question. The first two types of studies are reviewed in section III in an attempt to extract general trends. Studies of the factors affecting the effectiveness of animation are reviewed in section IV.

III. EFFECT OF COMPUTER ANIMATION ON PERFORMANCE AND PREFERENCE

In this section, results of 17 studies which compared static and animated displays (or CAL class with regular class) are reported.

III.1. General learning performance

Out of the 12 studies which compared static and animated displays, 7 found positive effects of animation on performance, at least on one learning outcome, and sometimes under specific conditions (Table 1, see below). For example, Baek and Layne (1988) found that animation improves learning of a mathematical rule (relation between time, distance and speed) over static graphics and text only conditions. In that study, the animation was simply a cursor moving on the screen at various speed depending on the input. However, the static graphics condition in that study did not involve spatial information but just repeat the text information in a table-like format. Five out of the 12 studies found no significant differences between animated and static display. For example, Pane *et al.* (1996) compared animation to static graphics and to text, paying careful attention to have conditions informationally equivalent. The animation was a movie designed to teach the migration of the cells in the embryo. No difference in performance was found between conditions. Some studies found more intricate results. Palmiter and her colleagues (Palmiter *et al.*, 1991; Palmiter & Elkerton, 1993) investigated the effectiveness of animation to demonstrate simple interface procedures. Results showed that users in the animation condition were better at performing the procedures than users in the text condition during training, but not in a delayed test. Three out of the five CAL studies found clear evidence in favor of the CAL class (Table 2, see below). Most of the time, improvement was found only in some particular skills. The conditions under which animation augments performance will be discussed in section IV.

III.2. Users' preferences and attitudes

It is generally believed that animation leads to better enjoyment. However this assumption is not always supported by the data. The first problem is to find a reliable indicator, since subjects experienced only one version, static or dynamic. Usually, two indicators are used, either conjointly or not: the attitude towards the domain or the lesson content (after *vs* before the instruction, and/or between conditions) and the attitude toward the instruction (between conditions).

Two CAL studies aimed to measure the preference rating. Grimes and Willey (1990) found that the attitude towards the domain after instruction

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comparing animated display and static display

comparant interface animée et interface statique

	Conditions	Tasks	Dependant Measures	Subjects	Learning content	Results
ayne,	Animation *vs* still graphic *vs* no graphic Animation under user's control	Application and transfer problem solving	Accuracy and time on a pretest and postest	10th grade students acquainted with computers	Mathematics: relation between time, speed and distance	– Animation>still graphic> text only – no effect of color
)92 nent 1)	Static diagram *vs* animated diagram (color changes) *vs* no diagram	Fault diagnosis (energy flow through the system)	Accuracy and time	Undergraduate students, novices in the domain	Functioning of a engineering system	Animated > static > no diagram in malfunctioning situations (for accuracy but not for time)
)89*a*	Text *vs* text+animated visuals	Factual recall and application to problem solving	Accuracy to problem solving	Elementary school students	Newton's laws of motion	Equal poor performance across the three groups
)89*b*	Text+static *vs* text+animated	Problem solving	Performance to problem solving and continuing motivation	Elementary school students	Newton's laws of motion (material redesigned according to Rieber's (1989*a*) findings)	Animated > static graphics
)90*b*	2 factors: – graphics (animated *vs* static *vs* none) – practice (none *vs* ehavioral *vs* cognitive)	Solving problems falling into 6 categories (1 is implied from the animated only)	Performance to posttest (time and accuracy) and attitudes	5th grade students	Newton's laws of motion	– Overall animated > static=no diagram – Interaction between graphics and practice: animation improved performance only whith the behavioral practice
al., 1990	Idem Rieber 1990*b*	Idem Rieber 1990*b*	Performance to posttest (time and accuracy and attitudes	Adults	Newton's laws of motion	– Accuracy: no effect of visual elaboration – Time: animated> static=no diagram
	Animated *vs* static graphics, animation under user's control	Postest problem solving: – intentional learning: on explicit content – incidental learning: on content implied by the animation only	Performance to post-test (time and accuracy) and continuing motivation	4th grade students	Newton's laws of motion	Animated>static for incidential learning only
al., 1992	Animation *vs* paper (but no direct comparison) 4 experiments	Drawing of trajectories or recognition of the accurate animated trajectory	Accuracy	Undergraduates	Motion of a simple particle when part of an extended body system	Computer animation evokes more accurate judgement when only one dimension is dynamically relevant
n ett,	Demonstration *vs* written text	Execution of procedures either identical or similar to training procedures	Accuracy and time in training, immediate and delayed tests	Undergraduate students acquainted with computers	On-line help for hypercard programing	– Demonstration>text during training Identical and similar tasks: text group took faster and demo.Group took longer than training
:ton,	3 conditions: demonstration (Demo) *vs* spoken text *vs* demonstration and text	Idem *supra*	Idem *supra*	Idem *supra*	Idem *supra*	• Identical tasks: no difference across conditions. • Similar task: – Demo+Text group performed as Demo – Time and ccuracy:Demo > text during training, no difference or text better in the delayed test.
1995	2 factors: – graphic: none *vs* static vs animated; – commentary modality : spoken *vs* written	Execution of the procedure described in the instruction	Performance (accuracy and time) in immediate test	Undergraduate stu dents acquainted with computers	On-line help for hypercard programing	– Static=animated>no graphics – No effect of the modality
., 1996	Animation (movie+ simulation) *vs* still images *vs* text	Answering questions on: – text -still pict. – animation: either end results or process – attitudes	Performance on each type of question (accuracy and time) and attitudes	Undergraduate students acquainted with computers	Biology : the migration of cells in the embryo	– Equal performance on either type of questions – No effect on attitudes – Little use of the simulation