REVIEWS
SYNTHÈSES

EFFECT OF COMPUTER ANIMATION ON USERS’ PERFORMANCE: A REVIEW

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RÉSUMÉ

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

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 n’ont pas toujours été de bénéfices sur le plan cognitif. Dans cet article, nous prêtons 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’entraînement).


Une meilleure attitude est d’analyser la pertinence de l’utilisation d’une interface animée en fonction de la situation dans laquelle elle doit être utilisée. Cinq facteurs se sont avérés d’une importance non négligeable: le type de contenu à transmettre, le niveau d’interaction, l’objectif de l’animation, le design de l’interface animée et enfin les variables individuelles et contextuelles.

Pour conclure, cette synthèse souligne le manque de recherches de fond sur l’animation qui ne se rattachaient pas directement à l’animation 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 concise et simple possible.
2) Le principe de correspondance conceptuelle, selon lequel l’animation doit être utilisée uniquement pour transmettre des informations, et non pas pour améliorer la performance cognitive.


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

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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; Peck, 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 user’s 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, 1990b; 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; Richer, 1989a, 1989b, 1990b; 1991; Rieber et al., 1990), so that the results can be attributed to the animation device itself.

Other studies compared animated graphic displays with text-only instructions (Palmiter & El ketogenic, 1993; Palmiter, El ketogenic, & 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, & Loo-fbourrow, 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 enjoyment. 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 of 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 questions. 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 & El ketogenic, 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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<th>Conditions</th>
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<td>92(Hen)</td>
<td>Accuracy and time on a problem-solving task</td>
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<td>92</td>
<td>Accuracy and time on a problem-solving task</td>
<td>Accuracy and time</td>
<td>- No difference in performance between the two groups.</td>
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<td>389</td>
<td>Accuracy and time on a problem-solving task</td>
<td>Accuracy and time</td>
<td>- No difference in performance between the two groups.</td>
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<td>909</td>
<td>Accuracy and time on a problem-solving task</td>
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<td>1996</td>
<td>Accuracy and time on a problem-solving task</td>
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*Note: The table above shows the comparison of animated display and static display conditions in terms of dependent measures such as accuracy and time on different tasks. The results indicate no significant difference in performance between the two groups for the conditions tested.*
was more positive in the computer simulation group than in the regular class group. Lazarowitz and Huppert (1993) found that students had positive attitudes toward the integration of CAL in class. However, in the CAL studies, the preference rating could be highly related to the use of a computer instead of paper.

Of the 12 studies in Table 1, only 5 use reliable indicators to measure learners’ attitudes. Pane et al. (1996) and Rieber (1990b) found equivalent positive attitudes towards the instruction in all conditions. By contrast, Palmiter and Elksyton (1993) found that subjects in the animation group enjoyed the instruction more than subjects in the text group. Another interesting indicator is the continuing motivation, which could be defined as “an individual’s willingness to return to an activity once external pressure to do so has ceased” (Rieber, 1991). Rieber (1989a, 1991) found that computer simulation was overwhelmingly chosen in a free-choice situation over other computer activities. This suggests that computer animation holds motivation.

As evidenced by the review of these 17 studies, it seems that the motivational appeal of computer animation could not be totally attributed to the use of a computer. By contrast, the findings concerning the overall performance are inconsistent. Lowe (1996) accounted for this as follows: “Given the variety of contextually-specific factors in learning from graphics that could be involved and the considerable possibilities of confounding, it appears highly unlikely that such a simplistic dichotomy will be found to exist” (Lowe, 1996, p. 41).

Therefore, as for any research dealing with the effect of a type of medium, factors related to the general situation need to be taken into account, such as the subject matter to be learned, the specific learning material (or content), the educational setting (mainly the style of teaching) and the observed learning outcomes. (Ferguson & Hegarty, 1995; Schiefe & Rogers, 1996). The next section reviews the factors affecting the effectiveness, accounting for them with cognitive principles.

IV. CONCEPTUAL DESIGN ISSUES

Five aspects of the learning situation are highlighted: instruction content, level of interactivity, learning objectives, interface design and individual differences.

IV.1. THE CONTENT TO BE ANIMATED (OR NOT?)

The first question a computerized instruction designer is likely to ask is “when should I use animation?”

To use a visualization or not?

As noted earlier, computer animation is a subset of instructional visuals (Rieber, 1990a), and thus it shares some visualization attributes with static visuals. Indeed, the advantages of the adjunct of illustration in

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<td>Kaiser et al., 1989</td>
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<td>White, 1993</td>
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<td>Lowe, 1994</td>
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text are well-known: pictures are computationally more effective than text for encoding relationships between objects or events (Larkin & Simon, 1987), they are effective mnemonics aids (Paivio, 1991) and they are effective attention-gaining and appealing devices (Rieber & Kini, 1991).

A further consequence of the fact that animation involves visuals is that guidelines generated from the large body of research on static visuals apply to it, though they not fully account for its possible effects. First, an animated visual is not likely to be useful if a visual is not necessary. This is the case when learners have already built a mental model of the content (experts of the domain), or if the content is highly imaginable on its own. Rieber (1990a) noticed that some studies (Carabello, A., 1985; Carabello, J., 1985) may have failed to find any effect of animation compared with static graphics or no graphics simply because the visuals may have been not necessary for the learner to understand.

Second, a picture helps only if it is carefully designed to fit to the learning situation; this point is beyond the scope of this article and has been investigated in other reviews (Levic & Lentz, 1982; Mandl & Levin, 1989; Willow & Houghton, 1987). For example, a realistic picture of the components of a system will be appropriate when users have to recognize them, whereas a schematic diagram would be more adapted if users have to assemble parts of the system (Stone & Glock, 1981).

**Animation or static diagram?**

A second important question is when would an animated display be more effective than a static one? Using computer animation in learning produce additional costs both for the designer of the instruction and for the learners whose cognitive task becomes more demanding. Indeed, previous research has shown that learners experienced difficulties in trying to keep track of the changes that were occurring in the animation, and in extracting the relevant information from the continuous flow of images (Lowe, 1996). Moreover, the research on mental animation of pulley systems in functioning (Hegarty & Sims, 1994) has shown that people could mentally animate the motion of a single part of the system at a time.

Rieber and his collaborators (Rieber, 1990a; Rieber & Kini, 1991) claimed that animation is likely to improve learning in two situations: 1/ conveying a concept or rule over time, a motion in a certain direction or a relation between time and space; 2/ and conveying a dynamic process that is difficult for learners to imagine on their own. In short, animation helps to reduce the computational difficulty of mentally processing temporal ideas. Moreover, a static display would need complex graphical devices to convey change over time, such as arrows, series of pictures, which would increase the learner cognitive load required to process the instructions. For procedural instructions, Palmiter and Elkerton (1993) noticed that animated demonstrations not only identify what objects are relevant, like static pictorial instructions, but they also show the orientation of actions, which can be always a difficult aspect in instructions (Stone & Glock, 1981).

**Computer animation on users' performance**

Conversely, if the instruction required understanding of relationships between objects which do not imply dynamics, static graphics may be preferred since animation increases users' cognitive load and can be distracting. In the Kinzer et al. (1989) study, animations drew learners' attention to the action of eating or running away and thereby distracted learners from the critical information, in this case the relationships between species in a food chain pyramid.

**IV. 2. THE LEVEL OF INTERACTIVITY**

In actual situations, animation typically entails user interaction. Interactivity can be on two levels: in instruction and in practice. Interactivity in instruction is usually limited to tape recorder functions, play, stop, rewind, etc.; in practice, the level of interactivity is increased since the animation should vary as a function of the learner's input. These different levels of interactivity influence the processing of the instruction, but do they lead to specific effects?

**Interactivity in instruction**

It is usually observed that interactivity in learning improves understanding and enjoyment. In fact, studies that used animation with a minimal level of interactivity (Kinzer et al., 1989; Palmiter & Elkerton, 1993; Palmiter, Elkerton & Baggett, 1991) reported no improvement from the animation. But in all cases these findings may also be due to other factors. Gonzales (1996) designed a study to evaluate interactivity in an animated instruction and found that an increased level of interactivity significantly improved the subjects' accuracy and enjoyment in a decision making task. As Palmiter and Elkerton (1993) suggested, this effect could be due to the fact that an interactive display induced a deeper processing of the animation. Moreover, it enabled users to link their input with the system response, and consequently could improve their ability to anticipate the result of their actions.

**Interactivity in practice**

As Rieber (1990a) pointed out, computer animation often uses an interactive learning situation, so that it is difficult to assess whether the observed effect is due to animation or to interactivity. Therefore Rieber (1990b) and Rieber et al. (1990) segregated the effect of interactivity and visual elaboration in a factorial design, in which the factors were practice (none, behavioral, cognitive) and visual elaboration (none, static graphics and animated graphics). For children, a significant interaction was found between visual elaboration and practice: If no practice was provided, the positive effect of visual elaboration was eliminated. With the behavioral practice (based on reinforcement), animation led to the best performance. Finally, cognitive practice that raised conflicts between the old cognitive structures and the knowledge to be learned improved performance in all conditions, with best performance using animated visuals.
IV.3. Objective of the Animation

The effectiveness of animation is also related to the task users have to perform with the instruction.

Non-functional distinctions

Most of the studies focused on the difference between procedural knowledge (involving procedures to reproduce) and declarative knowledge (involving facts to memorize) (Pane et al., 1996). As procedural learning involves order in time, it is reasonable to expect that animation would improve procedural knowledge acquisition. But the findings in Table 1 do not suggest a constant advantage of animation for procedural knowledge. In procedural instruction however, the segmentation of the task is the critical feature (Lowe, 1996) which is sometimes not assisted by a continuous animation (Palmiter & Elkerton, 1993, sec 4.3). Moreover, most learning contexts involve both procedural and declarative learning. Rieber (1990a) distinguished between fact and rule learning. Both the studies where the content involved only facts (Kinzer et al., 1989; Pane et al., 1996) failed to find any improvement from animation. But once again, studies are difficult to distinguish on the basis of the type of knowledge involved.

Explicit and Inference Knowledge

A better approach is to focus on the observed outcomes. More precisely, do users answer on the basis of the explicit content or on the basis of inferences drawn from this explicit content? If animation facilitates learners' constructing an accurate mental model, then animation should facilitate inferences from knowledge structure, but not the construction of knowledge structures per se. Indeed, inferences are thought to be drawn from mental models, whereas explicit knowledge can be retrieved from surface processing structures (such as the text-based representation or the mental image of the picture). The information needed to elaborate the explicit knowledge can be found in text and in static pictures, whereas the animation provides information about the "functioning" of the object to be learned (natural or artificial system, rule, aso.). Therefore it can be assumed that animation is more likely to facilitate the construction of a mental model of the functioning of a system, rather than the memorization of explicit knowledge.

Out of the 17 studies, 5 compared performance on explicit knowledge or inferences (Grimes & Willey, 1990; Kieras, 1992; Lazaronowicz & Huppert, 1993; Palmiter & Elkerton, 1993; Palmeter, Elkerton & Baggott, 1991). Three found improvement for inferences or problem solving but not for explicitly taught content (Grimes & Willey, 1990; Kieras, 1992; Lazaronowicz & Huppert, 1993). Additionally, Mayer and Anderson (1992) found that animation with concurrent narration (narration simultaneous to the animation) increased performance compared to successive presentation of animation and narration (narration preceding or following the whole animation) for transfer problems but not for retention.

Results from the Palmeter et al. (1991) and Palmeter and Elkerton (1993) studies are more complex. In both studies, in the immediate test, the animation group took longer to perform similar tasks (inferred from learned tasks) than the initial training task, whereas the text group required less or identical time. The authors suggested that negative transfer occurred for the animation group. Nevertheless, the time required to solve similar tasks was not significantly longer in the animation group than in the static text group. Moreover, Palmeter & Elkerton (1993) found that in the immediate test, the animation group was more accurate than the text group for similar tasks but not for identical tasks, where the two groups were equivalent.

Incidental learning

Incidental learning refers to the acquisition of information that is implied through contextual cues provided in the animated display but is not directly taught. For example, in Rieber's (1991) study involving Newton's laws of motion, only a specific application of the second law was explicitly taught, which holds that the initial acceleration of an object is proportionally related to forces that act upon it. The incidental learning outcome was an application of Newton's second law which predicted that the initial acceleration of an object produced by a given force decreases as the mass of the object increases. This application could be seen only in the animated display and not in the static visual representation. The results showed that animation allowed incidental learning without decreasing performance on explicit learning. However, the animated display led to greater overgeneralization, since the subjects tended to incorrectly apply these principles to other contexts (i.e., the context of gravitation). This finding is related to the general observation that novices reason around superficial information, whereas experts in the domain organize information around the essential underlying principles. To some extent, animation may increase novices' tendency to rely on surface-level features.

IV.4. Design of the Animated Interface

In some situations, the animated display could have failed to achieve its objectives because of its poor design (Rieber, 1990a; 1990b). But even with careful attention to design, the issue of what are the important factors in design is not yet elucidated.

The direct-mapping principle

Especially when users are novices, attention must be drawn to the critical features of the animation, so that users focus on the correct aspect.
of the animation. Creating a simple uncluttered animation where the conceptual information is directly mapped to the visual information can facilitate extracting the essential information from an animated display. (Baek & Layne, 1988; Lowe, 1996; Rieber, 1990a). Baek and Layne (1988) did this successfully by using the motion of a cursor on the screen to indicate rate and distance in algebra problems. Rieber (1989b) improved users performance in breaking the instruction into frames, so that each frame contained only a single piece of information and a single format (either text, static diagram or animated diagram). Though careful attention was paid to highlight critical features of a weather map (by providing multiple options of indicator display), Lowe (1996) obtained mixed results of animation due to the fact that learners were still unsuccessful in knowing where to look, how to look, what to notice and to link different frames of information. This result reinforces the point that training is sometimes needed for learners to take advantage of the animation.

**Realms of the animation**

Though many have claimed for using realistic rather than schematic images (e.g., Gonzales, 1996), in many cases schematic animations can draw the learners' attention to the critical features of the learning material (Baek & Layne, 1988; Rieber, 1991). The literature on realism in static pictures (Dwyer, 1982/1983) suggests that this choice depends heavily on the task to be completed; and is not specific to computer animation. In the case of computer animation, an important aspect of realism concerns how the motion of the system is implemented (Ferguson & Hegarty, 1995; Kaiser et al., 1992). Gonzales (1996) found that smooth transitions between frames produced better results than abrupt transitions. However, in procedure learning, segmented animation can facilitate structuring the task (Palmer & Elkerton, 1993). Once again it depends on what the animation used for: for continuous motion, smooth animation is probably better, because it matches with the perceptual processing of the real phenomenon. However, if the dynamic system involves several distinct steps, such as cause-and-effect systems or procedural learning, segmentation should aid parsing the events (Palmer & Elkerton, 1993) and constructing an accurate mental model. Segmentation can be provided by a concurrent narration (Mayer & Anderson, 1992; Mayer & Sims, 1994). It is then possible that sequential presentation of discrete steps would be as or more effective in some cases.

**Ordering media**

One important question in multimedia learning is the order in which each medium is presented. Baggett (1984) compared three conditions teaching associations between a visual illustration and its verbal label: visual concurrent with verbal, visual before verbal, and verbal before visual. She found that the performance was better when the visual was presented concurrently or just before (7 s. max.) the verbal label. Similarly, Mayer and Anderson (1992) found that using an animation with concurrent narration yielded better performance in transfer problem solving than successive display of each medium (narration preceding or following the animation). Moreover, Mayer and Sims (1994) provided evidence that contiguity of verbal commentary and graphics significantly improved performance only for high-spatial ability subjects.

### IV. 5. INDIVIDUAL DIFFERENCES

The efficacy of animation or any teaching tool depends on characteristics of the learners: expertise in viewing animations, cognitive ability in visuo-spatial tasks, and finally expertise in the domain of the subject to be learned.

**Training the ability to process animated visuals**

Processing graphics is a costly process, for which learners may need training (Peek, 1993). This is true for static graphics and even more for animated graphics, that are more cognitively demanding (Lowe, 1996). Learners do not always attend to illustrations in text if not explicitly told to do so (Peek, 1987, 1993). Indeed, Pane et al. (1996) found that subjects did not run the simulation if they were not explicitly told to do so, which might explain why the simulation did not help in this experiment. Moreover, for many types of diagrams, the users must learn new rules of interpretation, and this overhead must be taken into account (Kieras, 1992; Scafe & Rogers, 1996).

**Visuo-spatial ability**

One characteristic of learners' cognitive style that seems particularly relevant for computer animation is visuo-spatial ability (ability to mentally rotate or fold objects). Hegarty and Sims (1994) showed that high-spatial ability subjects were more accurate in verifying statements about the motion of a system component than were low-spatial ability subjects. Moreover, they found that spatial ability predicted accuracy on mental animation and diagram comprehension but not on sentence comprehension and text-diagram integration. Mayer and Sims (1994) found that high-spatial ability students benefited more from an animated graphics than did low-spatial ability students.

**Expertise**

Ideally, the degree of abstraction of material should be appropriate to the user's ability (Scafe & Rogers, 1996). Novices need concrete, simple and well-documented diagrams whereas expert users can take advantage of abstract complex representations.
V. CONCLUSION: SOME GUIDELINES FOR THE DESIGN OF EFFECTIVE COMPUTER ANIMATION

Computer animation is not a panacea in itself, but under certain circumstances, it can improve users' performance and attitude. Successful computer animations take account of the situation in which the animation is going to be used and the characteristics of individuals who are going to use it. Based on the literature, following are guidelines to improve the probability of designing effective animation.

V.1. WHEN SHOULD ANIMATION BE USED?

An animation is likely to be useful when the learning material entails motion, trajectory or change over time so that the animation helps to build a mental model of the dynamics. A well-designed animated display can be expected to facilitate drawing inferences more than remembering information or, in other words, transfer rather than learning. Animation can lead to cognitive overload, so that if users are not convinced of the necessity of the animation, or if the animation is too demanding, they may simply not use it.

V.2. GUIDELINES FOR THE DESIGN OF ANIMATED DISPLAY

On the basis of the reviewed research, two principles emerged as necessary conditions under which computer animation may be effective: conceptual mapping and concision. In other words, an effective graphics directly and simply maps the information to be conveyed into aspects of the display. For animations, the information to be conveyed is about changes over time and should be directly mapped to simple changes in the display.

Creating effective animations is not easy, but it requires understanding the knowledge to be conveyed and the user's mental space. Mapping conceptual information to dynamic displays is obvious and intuitive only after the fact. The rotating clock and slider bars in graphical user interfaces are examples of effective animations. These, however, are very simple uses of animation. Here we have focused on animations used to convey complex conceptual information such as those needed to understand weather, physics and machines.

The initial enthusiasm for animation as a motivator and a teacher has not been supported by the data. Yet, those experiments, some hinting of support, many not, have refined our views of what animation is and on what occasions it may be effective.

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Computer animation on users’ performance


ABSTRACT

Advanced graphical visualizations, such as virtual reality and animation, are at the forefront of technological development. Despite claims that much can be gained from interacting with animation, researchers did not consistently demonstrate cognitive benefits. In this paper, we review research on effects of computer animation in several domains, including education, human-computer interaction and psychology. No clear cut evidence emerges either to support or to invalidate the utility of animation at the work place. Instead, animation seems to be effective when a) dynamic information is to be conveyed and b) the animation conveys that information clearly and simply.

Key words: Computer Animation, Computerized Instructions, Human-Computer Interaction, Cognitive Processes.

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