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ABSTRACT

This report discusses the current state of research into the visual effects of screen layout design, i.e., the arrangement of design elements on a screen. First, two types of design elements are described: technical (those things that engineers work with and that users have little or no control over), and comprehensibility (those elements that a designer, publisher, or programmer can control). Next, two types of research involving the study of the effects of screen design--single and multiple element research--are examined. A number of problems related to studies of the overall appearance of a screen and its effect on learner preferences are then reviewed in relation to "macroprocesses," or the processes and activities a student uses to learn. Conclusions drawn from these studies indicate that the overall visual design of the screen has little effect on macroprocesses, and that the research methodologies and measures employed are not sensitive enough to measure the effects of macroprocesses. It is argued that what is necessary is more precise concentration on the effects of screen designs on learner actions and processes, rather than focusing only on the major effects of learning. Two examples of research in this area are briefly described, and a number of dependent variables in investigating the visual effect of screen designs are proposed. (21 references) (CGD)

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Abstract: Research into the visual effects of screen designs has been slow in developing. The paper examines the current state of that research and suggests some avenues for future efforts. The basic theme is that changes in screen designs are small, though significant factors in the design of lessons. As small factors, it is unrealistic to expect major learning gains, instead researchers should look for small changes in learner behaviors or processes.

Introduction

Imagine David, with a sling, against Goliath. Imagine David standing over Goliath. Now, imagine David, without a sling, against Goliath. Imagine Goliath standing on David.

David, an unknown youth, was able to knock-off Goliath and, as a result, continue to grow and to make an impact on his era. But, without the proper tool, i.e., a sling, the outcome could have been much different. It's not that David wasn't any good or that he didn't have anything to offer, it's just that without the sling, David wouldn't have had a chance to become king, to lead, to grow, or to change things. However, truth or legend be told, David had a major tool and as a result made a major impact.

More recently, there came about the development of an instructional technology called "programmed instruction." Research into this technology led to findings that had major impacts on the way instruction is designed. Generally, one of the most important ideas to come out of the development of programmed instruction was "planning" — the application of learner and task analyses and behavioral objectives was a significant change in the way instruction had been developed. By significant, I mean an impact that could be measured in terms of gains in post-test performance.

It seems logical and obvious to assume that a significant intervention leads to a significant result. Hit a nail with a hammer with full strength and you expect to see a gross adjustment in its height. On the other hand, molecular interventions lead to molecular changes. Hit a nail with a pair of pliers instead of a hammer and you expect to see only a minor adjustment in height. Yet, in the world of instructional technology, this same logic is not as obvious as in the world of physics. In instructional technology, when we conduct an experiment which, in effect, is designed to produce only a minor change, we act surprised when the results are not "major league."

Return to David and Goliath. Imagine David as he approaches Goliath with a stone, but no sling. When we imagine David with a sling we "expect" David to succeed (we've been conditioned by the legend). But, when we think about David without the sling, our expectations are reduced and a large element of doubt enters the picture. Maybe David can get in a lucky throw. Maybe David can do some damage and get out before he's damaged. The point is, we reduce our expectations of results when the intervention loses strength.

In educational research, we often have great expectations for minor, though not unimportant, interventions. For whatever reasons (publication demands, ego, or lack of creativity), when we attempt educational research we try all kinds of small, controllable interventions but cling to molar effects on learning as our expectation, or measure of change. The area of screen layout design is a case in point.

Limitation: The Visual Impact of Screens

Screen layout design refers to the arrangement of design elements on a screen. These elements are numerous, as shown in Tables 1 and 2. This paper is limited to a discussion of these elements as used in layout. ***Layout*** is a publication design term used to refer to the planned, visual arrangement of text elements on a page or screen. The elements listed in Tables 1 and 2 fall into two general classifications: technical elements and comprehensibility elements.

Technical Elements

Technical screen design elements are those things that engineers work with and that users have little or no control over. They are factors that are built into the equipment or factors that can be controlled by lighting, or contrast and brightness controls.

A great deal of research has been performed investigating the human factors effects of the technical elements of a display. A discussion of this research is beyond the scope of this paper because the display, as constructed, is what we (instructional technologists) have to work with. However, it should be noted that this is not a static field. Research is continually going on to determine the best screen size, resolution, background colors, brightness, etc. In the field of legibility, this type of research is referred to as "visibility" research. Its focus is to determine the characteristics that make a display and its symbols most visible.

Comprehensibility Elements

Comprehensibility screen design elements are those elements that a designer, publisher, or programmer can control. I use the term "comprehensibility" because the use of these elements effect the readability and, ultimately, learner understanding of the content. Isaacs (1987) states that

> The functions of a CAL lesson screen are to present information to a student and to evince and receive responses from that student . . . . we must also see that the student receives information of a facilitative nature—information to help the student use the system . . . . (p. 47)

Each comprehensibility element has a potential effect on the readability and understanding of the document. As Table 2 shows, there are a large number of factors. This number goes beyond the sum of discrete elements because of the number of combinations available. Five, six, seven, ten or more of these factors may be operating together at any one time in a display, compounding and confounding significantly the research problem.

It is an interesting area of study, because there seems no shortage of overall screen design recommendations on how to combine the comprehensibility elements. These recommendations are usually general heuristics, such as use lots of open space, use highlighting, be consistent between screens, keep one topic to a screen, keep the screens simple, and avoid clutter. (Isaacs, 1987; Kearsley, 1985; Lundeen, 1982; Ng, 1986; Rambally and Rambally, 1987).

Many of these recommendations are based upon research that examined the effects of single elements. For example, directive cues, such as underlining, highlighting, or bold type, facilitate search tasks; or, headings in question form, can facilitate learning of essential information. However, heuristics

Table 1
Technical Screen Design Elements

Typographic Factors

symbol height
symbol width-to-height ratio

Environment

glare and reflections
viewing angle
visual fatigue

symbol resolution

Screen Factors

dot matrix size
chromacity
contrast ratio
dot shape and spacing
flicker
resolution
horizontal symbol spacing vs.
dot generated symbols
stroke width
luminance

Many of the items listed in this table are from Dwyer (1985).

Table 2
Readability Screen Design Elements

Typographic Factors

line spacing
line length
leading (vertical line spacing)
size of letters
font characteristics
case of letters

Organization Factors

paragraph indication
graphic devices
figure/ground separation
headings

Cueing Factors

highlighting
color
case changes
graphic devices

Control Factors

icons
command bars
status bars
maps
scrolling

such as "avoid clutter," "use lots of open space," and "be consistent" are open to interpretation. These types of recommendations are usually based on folklore and design practices developed from the visual arts. Recommendations about the best ways to combine several elements still need to be researched.

Single Element Research:

As a result of research into the effects of single screen design elements, we can make generalizations about the uses of directive cues, headings, indentation, line length, type size, and leading. Originally, much of this research was based on print (hard copy*) studies, but the past years have seen more and more research aimed specifically on the application of these elements to video display terminals.

The focus upon video display terminals has helped provide suggestions for using attributes specific to screen displays. For example, color is a feature that is expensive to implement in hard copy, but costs nothing on color display screens. Tullis (1981) found that color-coding proved superior to narrative format when teaching adults to discriminate among different signals that required some sort of action or interpretation. On the other hand, Baker (1986) pointed up a significant problem with the use of a program designed to use color on a monochrome display. Baker found that children were unable to discern critical features of a color graphic displayed on a monochromatic monitor unless it was designed to enhance figure/ground separation.

Single-element research is extremely important in identifying the strengths, weaknesses, and potential problems of using specific attributes on CRT screens. There are a wealth of topics specific to computer displays that need to be examined: single and multiple windows, navigation aids, icons, scrolling, etc. Single element research is a necessary first ste- in understanding how to combine these elements into overall displays.

Multiple Element Research:

Despite research into individual screen design factors, there is a dearth of research into effects of combinations of these factors. Multi-element research tends to be more complex than single-element research. Examination of single text elements usually stops with that element and its effects on narrowly defined tasks. But the examination of combinations of elements involves not just the text elements, but the perceptions of the viewers also. It is not just a question of functionality, but cognitive effects as well. That the overall appearance of a screen has an affect on viewer preferences was found by Champness and DiAlberdi (1981) and Grabinger (1984, 1987). Champness and DiAlberdi examined the affects of informational screens used in an implementation of videotext for voluntary users and found screen preferences that were classified into factors labeled attractiveness, clarity, and usefulness. Grabinger had student viewers examine content-free models of screens intended for instruction classified viewer preferences into factors labeled simplicity, structure, and organization.

The main point is that the visual "gestalt" of a scree.. has an affect on learner preferences. These preferences are formed from perceptions, perceptions that may also affect cognitive processes. The next logical question, then, is whether this affective response also effects the processes a learner chooses to use while studying the material.

The processes and activities a student uses to learn are referred to as ***macroprocesses*** by Tobias (1984). Tobias defines macroprocesses as

> . . . those relatively molar cognitive processes students use when they learn from meaningful instructions, such as reviewing, previewing, looking for clarification, and the like. Macroprocesses . . . denote only the cognitive processes used by students to learn from instruction. (p.4)

* **Hard Copy:** refers to paper documents, such as books or articles.

Tobias (1984) goes on to state that, "one assumption of instructional research in general is that alternate methods induce different types of macroprocessing (p. 5)."

The goal of research into the overall visual effect of the screen, then, is to identify macroprocesses effected by screen layout arrangements. Hopefully, by becoming aware of these activities, we can then identify specific designs to help control or enhance them.

The Problems of Research into the Overall Design of a Screen

And that brings up a major research problem. How do we identify the effects of a confusing combination of text elements and processes that are not physically visible? There are two main problems that arise with this question. First, the changes and effects of the appearance of a screen are molecular in terms of the overall instructional process. Second, as is always the case when trying to work with cognitive processes, the cerebrascope that examines the brain directly has not yet been invented, so research must rely on inferences.

For example, in a recent study (Grabinger and Albers, 1988) two fundamentally different screen designs were used in CAI programs for fourth grade students. One version incorporated plain text without color, graphic devices, highlighting, or other design enhancements. The other version was designed to incorporate indentation, highlighting, command bars, and boxes to make the screens appear more organized and structured. Dependent variables were immediate recall following the treatment, retention of material after a two-week delay, and average time spent on each screen. There were no differences between versions in recall or retention. There was, however, a difference in average time spent per screen with one of the enhanced versions. It was inferred from this difference in average time-per-screen that some different kinds of processing were occurring as a result of the altered screen design. It's an inference based on a small effect and one that is open to interpretation, but an effect that may stimulate further research.

Two possible conclusions may be drawn from this study. First, because of the lack of learning gains, it could be concluded that the overall visual design of the screen has little effect on macroprocesses. This is a possibility, because research regarding macroprocesses has discovered that students are not good at making decisions about which processes to employ or when to employ them. Lower ability students tend to employ learning strategies infrequently, while higher ability students tend to employ too many too frequently (Tobias, 1985)**. The design of a screen may suggest something, but it may not be explicit enough for most students. The purpose of design elements must be explained to students before they are encountered for them to have any effect (Fitzgibbon and Patrick, 1987).

A second possible conclusion is that the research methodologies and measures employed are not sensitive enough to measure the effects. In an effort to look at as many possible factors as possible Grabinger and Albers also added variables such as type of task (conceptual application or recall) and prior information about the screens. This may be a good multivariate design, but it also tends create so many cells in MANOVA designs that small scale effects become even smaller as degrees of freedom rise.

The basic argument is that we need to concentrate more precisely on the effects of screen designs on learner actions and processes, not just the major effects on learning. This is not to relegate the importance of learning to the closet. Learning, after all, is the primary goal of all instructional research. However, the point is that we must first identify ways in which cognitive processes are effected and then try to identify ways to control or to enhance them. It is only when we can exert some

** Training students in the use of macroprocesses has positive effects, as does explicit instructions to use a specific type of strategy.

control over the processes that we can then make statements about how that control may be exerted.

Two examples of this effort to identify effects on smaller learner behaviors were described earlier in Tullis (1981) and Baker (1986). In their research regarding the effects of color they found significant features that will effect design decisions. They're measures of effect were on search tasks and perceptibility. Both of those dependent variables represent activities that are smaller activities in the learning process. If they had relied on gross learning instead of smaller actions such as discriminations and perceptibility, their research may not have found anything.

In another example, Haas and Hayes (1985) compared the ability of students to find previously read information in paper, CRT and, large CRT versions. Rather than using learning as the primary indication of effect, they used student estimates of target sequence and vertical and horizontal location. Their findings indicated that the more a student sees at one time and the less a body of text is broken up, the better they remember where material is located in the text.

What, then, can we use as dependent variables in investigating the visual effect of screen designs? Some of the following measures may prove useful:

Audit trails. Implementations of hypertext and navigation options in traditional CAI programs leave users with a number of alternatives in how they "travel" through a program. Tracking a user's movements may provide information both about the program's and student's cognitive structure.

Eye movements. Saccade amplitude and fixations provide physical evidence of a user's response to a specific design. This can provide information about the salience of specific design features, such as boxes, command bars, and hierarchical structures.

Time. Time-per-screen and time-per-program may provide some indication of processing activity. This may either positive or negative, for a design that is too complex may increase time because of cognitive overload. On the other hand, a design that encourages deeper processing of essential information may also increase the time a student spends with a screen or program.

Subjective evaluations. User evaluations of screens in terms of helpfulness, aesthetic quality, organization, and structure are some of the qualities that may be used to provide information for the development of user-oriented screen design guidelines.

Search time and accuracy. Specific tasks, such as searching for something specific on the screen can be measured in time and accuracy to provide information about the quality of organization or highlighting.

Generative and reproductive outcomes. Outlines and graphic organizers can be used to get a subsequent "picture" of the effects of a design on a students own mental organization of the information.

Use of supplementary aids. The use of help screens, maps, glossaries, and indices may provide some information about the ability of a screen to help elicit "investigatory" responses from the learner.

(This list is by no means exhaustive, but meant to stimulate thinking.)

The other problem in the research on the visual effect of screens is in the area of identifying the processes learners are using. This information is important because it may effect learning in both positive and negative ways. It is important to identify designs that may cause cognitive overload as well as designs that facilitate constructive cognitive behaviors.

In more operational terms, we need to identify measures that we can use to draw inferences about design effects on cognitive processes. Of course, this is not a problem solely in the realm of screen design, but a tough problem in all cognitive research. In investigations that deal strictly with learning strategies and macroprocesses, three methods have predominated:

1) post-lesson interviews of students about cognitive activities used in the lesson (Winnc and Marx, 1982);

2) training of students in the use of specific strategies and then follow-up measures to identify the impact of that training on learning or learning tasks (Winne, 1982);

3) self-ratings by students on the amount of mental effort required for the learning task (Salomon, 1982).

All three of those methods may prove useful in the investigation of overall screen designs. Other techniques may be possible using generative and reproductive outcomes, multidimensional scaling, and factor analysis of audit trails and preferences.

Finally, after we find signs that certain types of screen design's effect student processing, then we must investigate the effects of those processes on learning. For example, if a highly structured screen design improves the quality of student outlines, has this supplanted their own processes and inhibited learning or has it enhanced their learning by improving their own organization? What kinds of students are these effects on? Is age important? What about training in the meaning of the features of a screen design type?

Conclusion

At this point in time, all we can say about screen design is that a well-designed CAI program teaches despite the design of the screens. However, this is something that can be said about most media studies and reflects that state of research in our field. We are at a point at which the focus of our research efforts is moving into the human mind. How can we help the mind function more efficiently and effectively?

We have broken the 4:00 minute mile. The improvements now come not in whole seconds, but in tenths of a second. We must design our research in such a way. We must look for the little things that make a difference in hopes that when we put a lot of little things together we will bump another tenth of a second off the clock. The task is to construct the kind of research that will allow us to infer that different designs will, in fact, lead to alternative cognitive processing for students. The intent of this paper was to stimulate discussion about a sequence and organization that will facilitate development of screen design research.

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