

Operations and Strategy Learning in Edutainment Interfaces

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Introduction

What is Learned in an Edutainment Environment?

An *edutainment environment* is an umbrella term that encompasses educational games, simulations, educational simulations, and microworlds. These all share similar attributes: they often deal with a computer-generated model of reality; a student has an existence “inside” the model; there is a learning goal or purpose to the model (Miller, Lehman, & Koedinger, 1999; Schank, Berman, Macpherson, 1999.)

There are three levels of learning that take place in an edutainment environment. They differ primarily in their *transfer value* beyond the game. That is, while each type of learning is not necessarily different, only some of the learning is usable and valuable outside of the edutainment environment. We hypothesize three types of learning that occur:

1. **Operations:** Operations refer to the “legal” movements and actions that a player can make while “inside” the game. These include routine operations such as turn-taking, picking up objects, reading instructions, determining feedback, onscreen movement, character interaction, and others. This type of learning can be attained through a pre-game tutorial, through a set of instructions, through on-going access to help screens, or (more commonly in game situations) simply through trial and error of playing the game. Hints might also be provided in an intelligent game.
2. **Strategy:** Strategy learning refers to the overall “plot” or mission of the game. Many simulation games have an overlaid story that is intended to provide context for the user actions. In some cases, this story is entirely irrelevant to the intended instructional goals and outcomes. For example, a plot that involves dragons and magic may be totally irrelevant to the intended learning, which might deal with concepts of science. However, the involvement of these fantasy elements might make a game more engaging as is the case with many pure entertainment games.
3. **Instructional Goals and Outcomes:** Most instructional interventions are designed with specific educational goals in mind, based upon needs in work situations or educational systems. Instructional outcomes, then, are the intended classroom or training outcomes for the edutainment game that have value *beyond* the game itself. These goals and outcomes could be attained in other ways, and therefore, the choice to use edutainment is one of power or efficiency. However, these learning outcomes are those that ultimately have demonstrable value.

Strategy elements in simulation games are referred to as both “mission” and “scenario operations by Schank et al. (1999), who make the distinction between the overlaid story and the techniques

that must be learned. However, no operational mechanisms are provided to measure these constructs. Norman (1988) has suggested a fine-grained approach that looks at seven stages between a goal and its execution, similar to the operations/strategy distinction. While his model is broad and widely applicable, there are no specific metrics or techniques that can be used in edutainment. More rigorous distinctions between types of learning have been proposed in computer interfaces (see Card, Moran & Newell, 1983) although not specifically in edutainment.

Instructional Expenses

The goals of game designers and instructional designers are quite different. The goal of professional game designers is to engage a player for long periods of time. In short – to provide fun and amusement. (Adams, 2003). However, instructional design goals must primarily focus on learning. Essentially, if it doesn't facilitate learning, it has no instructional value. It is possible that in some situations, the learning of operations may actually contribute to the instructional goal – in the case where a game was designed for students to learn certain computer operations such as pointing or clicking, for example. However, in a more advanced game, it is more common that the operations (and sometimes the strategies) learned have little or no instructional value. For example, when a student learns the operations and strategy to “use a magic scroll,” there is no instructional value to it (i.e., it will not transfer to real life). While a magic scroll may be an interesting game strategy element, it is not an instructional outcome.

Often games are cited as having more motivational value, but it is clear that students have complex reasons for self selecting instructional approaches (Yacci, 1994; Yacci & Hyman, 2001). For example, while students often report positive attitudes toward simulation games, this motivational benefit does not necessarily translate into grades or skill (Wolfe, 1990). Additionally, instructional games are rarely studied on instructional “engineering” aspects of efficiency and reliability (Heinich, 1984). Clearly, edutainment environments demand a certain amount of effort and learning that is irrelevant, and this extra effort (no matter how motivational or fun it may be) might be thought of simply as an instructional *expense*. An expense is a cost that is used, presumably, to bring back a return. In this sense, the additional effort and learning that accompanies edutainment may be a justifiable expense as long as it returns the instructional goals and outcomes.

Since some of the learning and associated effort that must happen during edutainment is irrelevant, an interesting question is: What is an appropriate trade-off between the amount of relevant and irrelevant learning. In other words: At what point are these “expenses” no longer worth the time and student effort, given the instructional outcomes? To answer this question, we are attempting to develop metrics to determine how much student time and effort is an “expense” when engaging in edutainment.

To date, there has been little investigation of edutainment at this level. There are guidelines for the design of educational games, and there are rules of thumb for the design of entertainment games. However, these two design approaches must be balanced to achieve learning efficiency and transfer power. To begin this debate, we are attempting to determine a mechanism for measuring both *operations* learning and *strategy* learning.

We believe that we can separate these two types of learning and can quantify the amount of expense in an edutainment environment.

Scanpaths and Clickpaths

Scanpaths refers to sequences of eye movements. That is, a scanpath keeps track of what a student looked at, in what order, and for how long. A scanpath is created using an eye-tracker connected to computer software. The eye-tracker enables the researcher to monitor where the

student's eyes travel, and the duration of any eye fixations. A clickpath is our name for a similar sequence of onscreen mouse movements and mouse clicks. A clickpath determines what a student clicked, in what order, and at what point in time. (This is captured internally by the computer.) Our study uses scanpaths to measure *strategy* learning within the environment, while it uses clickpaths to measure *operations* learning.

The Study

Operations learning, in this study, refers to clickpath patterns in which the subject performs only legal operations in the environment. As a subject learns how to operate in the environment, there should be fewer “illegal” mouse clicks. When the student stops performing illegal movements, we can claim that operations learning has happened. Additionally, when the student begins to repeat clickpath sequences that enable more complex operations, we can also claim that complex operations learning has occurred. The mouse clicks and timing that entail the clickpath (i.e., what was clicked upon, in what order, and at what time) are captured automatically by the treatment environment.

Strategy learning, in our study, refers to scanpath patterns that more closely approach an “ideal” scanpath. A user who has already “learned” a strategy within an environment will perform a sequence of eye movements that we label *ideal*. Initially, a new learner's scanpath will differ from the ideal; as strategic learning occurs, we expect the learner's scanpath to become more similar to the ideal. We are using a head-mounted eye-tracking monitor and flat screen display to monitor and record eye-movements. Eye movement analysis, via eye tracking, is a useful methodology because data can be collected at a fine temporal grain size and users require little training in order to produce informative data. Moreover, the procedure is non-intrusive and does not significantly affect user behavior (Salvucci and Anderson, 2001).

Both operations learning and strategy learning may be evidenced by shorter time on task. The operations learning task should be learned relatively quickly, and should make the operations learning time on task very short, very quickly. The strategy learning task will take more trial and error, and task completion times will take more time to improve.

Research Treatments

The research treatments consist of a series of short segments of a hypothetical edutainment environment, designed to allow for the manipulation and measurement of operation learning and strategic learning. The experimental treatment does not have any direct instructional outcomes at this point.

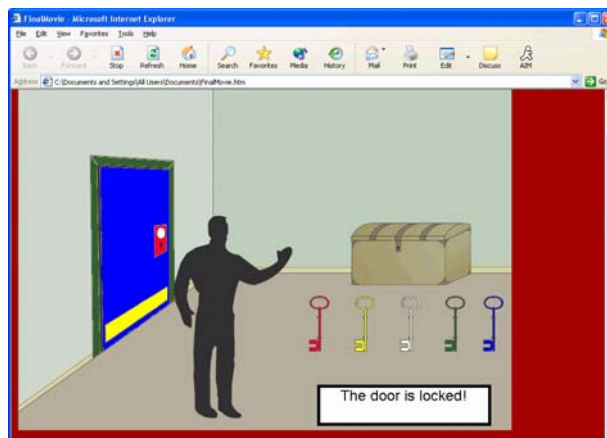


Diagram 2: The research treatment edutainment environment

The treatment environment (see Diagram 2) shows an empty room with four major elements: (1) a player icon, (2) several color-coded keys, (3) a door, and (4) a chest. The strategic task for the user is to “go through the door” shown onscreen. However, there is a hidden strategy rule of which the user is unaware: only a correctly colored key will open the door.

The operations in this study are quite limited. The learner can click on the player icon, click on a key, click on the door, or click on the chest. All clicks provide feedback, such as “The door is locked” or “The chest is locked.” Picking up a key requires the student to (1) click on the player icon and then (2) click on a key. When this sequence occurs, text and visual feedback confirm that the player has picked up the key. Finally, to try the key in the door, the proper operation sequence requires the learner to (1) click on the player icon, (2) click on one of several keys, and then (3) click on the door. When this sequence occurs, either the door is unlocked, or the student is told that “the key did not work as has been discarded.” This keeps the student from getting stuck in a loop of selecting keys, and ensures that the student will eventually find the correct key.

The strategy rule is a simple color-coding that determines which key is the “correct” key. Different door elements are different colors (the door itself, the doorknob assembly, the kick-plate, the door sill). The color of the kick-plate determines the “correct” colored key that will unlock the door.

There are 8 such treatments, each one differs slightly in the order of the color coded keys and the color coding of the door area. However, the operations that are allowed are identical. Additionally, the color-coding rule is identical in all environments, even though the onscreen placement of stimuli may differ. It should be noted that the door opening task is based on a common task in many edutainment and entertainment environments.

Research Procedures

Each subject (N = 12) is given a short introduction to the experiment. The head-mounted eye-tracker is calibrated prior to the start of the experiment. The subject is told of the task, to open the door in the edutainment environment. Each subject is given no explanation of how the interface operates, nor of any special rules that may exist in the edutainment environment.

Mouse clicks are recorded and later analyzed to search for operation patterns. Eye-tracking data is recorded on videotape for later coding and analysis.

Analysis of Results

Operations Learning

Clickpath data was recorded and analyzed to determine when *operations* were learned. Learning criteria was determined to be the point in which the learner repeated the sequence of clicks to pick up a key and insert it into the lock (a three click sequence: clicking on (1) player icon, (2) key, and (3) door). During this phase of the analysis, whether or not the subject picked up the *correct* key was ignored. (Determining the correct key is a *strategy* concern).

The average clicks until learning criterion was 41.6 mouse clicks, SD = 30.29. The average time until learning criterion was 91.08 seconds. The average time per trial was 19.81 seconds.

Avg Clicks Until Learned	41.6	SD = 30.29
Avg. Time Until Learned	91.08 sec.	SD = 79.19
Avg. Time Per Trial	19.81 sec.	

The average clicks until learning (CUL) is a good estimate of how much exploring the subject needed to do until he or she determined what was clickable, and how to activate the player icon to pick up a key. While times varied considerably (as indicated by the large SD), there was generally a fairly short time to actually learn this interface. We would suspect that the overly simplified nature of this interface contributed to its learnability; there were few distractors, and there was also clear, text-based feedback which would be more directive than might be found in some entertainment systems.

As metrics of *operation learnability*, such computed numbers might be useful in comparing two different interfaces for their inherent “obviousness.” As a measure of instructional expense, a lower number would imply that there is little wasted effort in learning the edutainment interface. In this case, there was relatively little time nor clicks wasted to learn the interface.

Optimal Matching Analysis

A second measure of operation learning was used to examine the similarity between clickpaths. Optimal matching analysis is a technique that compares an optimal pattern or sequence with other sequences, in a pair-wise manner. In this case, the optimal (learned) pattern was used as a criterion and was compared in each subject on a trial-by-trial basis. The same legal sequence described above was used – the “man-key-door” sequence. While the overall patterns are interesting, our analysis concentrates on the point in which operation learning occurred, and the degree to which it occurs over the eight trials. By reading across the table, one can see how each trial compared with the optimal sequence. In this analysis, a lower number represents more similarity between sequences. Adjustments were made in the analysis so as to factor out the *strategy* component from the *operations* components. (This was done by weighting the colored *keys* in the treatment equally – eliminating the need for the subject to have determined the strategy.)

Trial	T1	T2	T3	T4	T5	T6	T7	T8
Criterion	0.929	0.750	0.000	0.000	0.000	0.250	0.000	0.000

Table 1. Similarity Matrix for S6

Table 1 shows that the subject appeared to learn the legal operations during Trial 2 (T2). From then onward (Trials 3-8), the subjects operations are flawless, except for minor errors during Trial 6. Hence, as a metric for learnability, the optimal matching analysis shows the points in which the subject performed *optimally*.

Strategy Learning

Scanpath data gathered from the head-mounted eye-tracker were analyzed to explore when a subject discovered the strategy rule regarding matching the appropriate colored key to the door component. Strategy learning is defined to be the point in which the subject discovered the “color matching” rule that associates the proper key with the door. Eye tracking allows tracking the student’s gaze, looking at different elements of the door, and searching for an appropriate colored key.

Task completion times will show how long it takes for the student to solve the strategy task. Scanpaths show the sequences of eye fixations and as learning occurs, these sequences will become more efficient. That is, a skilled student will look at the door kick-plate, then search for a key to match. This analysis is ongoing, and will be reported at the conference.

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