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FINDINGS FROM BEHAVIORAL RESEARCH IN VISUAL INTERACTIVE SIMULATION

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ABSTRACT

The use of a Visual Interactive Simulation (VIS) as an experimental tool, where a user interacts and tests out ideas at will, is controversial. We have used an experimental laboratory setting to investigate the use of VIS in this way. Our findings show that performance is mediocre, at least compared to a know 'best' solution, but that subjects generally improve on a pre-conceived solution. Encouragingly, performance is consistently related to use of the animation and confidence in decision. Further, subjects obtaining correct solutions are far more efficient in their use of the VIS than those obtaining incorrect solutions.

1 INTRODUCTION

Visual Interactive Simulation (VIS) is now an established approach to simulation (Bell 1991; Bell and O'Keefe 1987). Commercial simulation packages emanating from England (where the seminal work was done), such as WITNESS (from Istel) and GENETIK (Insight Logistics), are finding a worldwide market. In addition to providing animation capabilities, these packages not only allow the user complete freedom in interacting with a running model, but encourage it. Newer versions of American tools such as SLAMSYSTEM, SIMAN/CINEMA and ProModel increasingly provide for user interaction. Present research is addressing, for example, different simulation representations for VIS (Vujosevic 1990), and 'smarter' methods for generating the visual component (Bishop and Balci 1990).

Although the use of animation for validation and 'selling' projects is generally accepted, beyond that there is a deep mistrust of using VIS for experimental analysis. A panel discussion at the 1990 Winter Simulation Conference addressed this (Matwiczak et al. 1990), and every speaker (at best) expressed concerns about this trend. Some analysts, for example Law and McComas (1989) and Bookbinder and Kotwa (1987), have even suggested that using VIS for experimentation borders on the unprofessional; they argue that in every simulation study there comes a time when it is necessary to shut off the visual display and run properly designed statistical experiments.

Discussion of using VIS as an experimental tool is largely based upon anecdotal experience. For the past four years, we have been pursuing research that attempts to go beyond this: we have implemented four laboratory experiments where subjects have used a VIS model to solve a problem. This task-based behavioral approach provides quantitative data about performance with VIS, and allows us to consider VIS for experimental analysis based upon an understanding considerably deeper than that based upon anecdotes and folklore.

2 THE EXPERIMENTAL TASK

The task used in all four experiments was based around a simple queuing and resource allocation problem concerning trucks moving coal - the Thompson Mining and Smelting case (Haehling von Lanzenauer 1975). Briefly, an open pit mining operation is composed of three distinct pits, each with its own shovel. Coal is transported from the three pits to a single crusher by trucks that can hold 20 ton loads. Trucks are allocated to a pit, and must queue both to load coal at their allotted pit and to unload at the crusher. The durations for travel to and from the crusher are constant, but different for each pit, and service times for loading and unloading are negative exponential. The manager of the operation has the objective of producing at least 35,000 tons per week in five eight-hour shifts (i.e., averaging at least 7,000 tons per shift), without adding a second crusher or extending shifts. The problem is, therefore, to minimize costs (there is a cost per shift associated with each pit and each truck) by determining the number of trucks that should be used, and how they should be allocated to the three pits.

The case clearly states that the allocation of two trucks to each pit (i.e. 2,2,2) will not produce enough coal. The issues that need to be considered are then:

(1) Can six trucks be reassigned to take advantage of the closer pits and hence increase output (e.g., 3,2,1) ?

(2) If not, can seven trucks produce enough coal ?

(3) Can costs be reduced by closing a pit (e.g., 4,3,0) ?

It transpires that seven trucks are necessary (thirty replications of 2,2,2 produces a mean of 6900.0 tons per shift) and these need to be allocated to the pits approximately equally; closing a pit is not practical since seven trucks can not generate enough coal from two pits alone. Thus the *correct* solution is any combination of seven trucks, i.e. 3,2,2 (7548.67 tons per shift) or 2,3,2 (7501.33 tons per shift) or 2,2,3 (7518.67 tons per shift).

Thirty replications of each combination does not show a statistically significant difference between them, but it is obvious that if the extra coal can be used then the seventh truck should be allocated to the nearest pit. Hence the permutation 3,2,2 can be considered as the *optimal* solution.

3 THE EXPERIMENTS

A VIS that provided three alternative displays - an animation using text characters, a dynamic histogram built up with characters, and a listing of the executed events - was developed and used in an exploratory experiment at Rensselaer Polytechnic Institute in 1988. The details and experimental results are published in O'Keefe and Pitt (1991).

Subsequently the VIS was further developed, and used in an experiment with 52 MBA students at Western Business School in the spring of 1989, and another 129 students in the fall of 1989. After these exploratory studies and tests, we completed a final version of the experiment at Western in the fall of 1990 with 51 students. We will refer to these four experiments as I, II, III and IV. Performance and display preference in all four experiments is summarized in Table 1.

When using the present VIS for Thompson Mining and Smelting, the user is provided with three windows:

(1) An *animation window*, in which a simple iconic animation can be run. The animation shows a time clock, the pits, the crusher, and icons representing trucks queuing at the pits or crusher.

(2) A *histogram window*, in which a dynamic histogram is accumulated. The histogram shows a time clock, and a bar for each area with the present output of coal for that area written at the top of the bar. The histogram is updated at the end of each simulated hour.

(3) An *interaction window*, containing menu options. The available options are:

Run: run the simulation from the present clock time until the end of a shift or until any interaction.

Trucks: allocate the number of trucks at each pit (this also resets the simulation to the start of the shift).

Output: show the present output for each pit plus the total output.

Displays off: turn all visual displays off.

Animation: turn the animation on.

Histogram: turn the histogram on.

Quit: finish using the simulation.

The animation and histogram cannot run concurrently; the user can only have one (or neither) active. Thus preference for a display can be observed. The animation provides information focusing on queues and the trucks; the histogram provides information about pit output. Thus each gives different, but complementary, information, as typically used in a VIS model (Bell et al. 1990).

In experiments I, II and IV, each simulation run of an eight hour shift took approximately 2 minutes of computer time irrespective of display settings, so any observed differences between display preference were not due to the time taken to run a replication. In experiment III, we set the VIS up so that the simulation executed as quickly as possible. A replication with an animation took 2 minutes, but only 10 seconds with a histogram and 6 seconds with no display active.

Table 1: Performance and preference for display in the four experiments (*significant at p<0.1, **significant at p<0.05)

Experiment	Place	Year	Number of Subjects	Optimal Solution	Correct Solution	Animation	Histogram	None
I	RPI	1988	25	6	12 (48%)	0.31	0.11	0.58*[1]
II	UWO	1989	52	8	11 (21%)	0.36	0.18	0.46*[1]
III	UWO	1989	129	22	38 (29%)	1.29 mins	24.1 mins	6.4mins
IV	UWO	1990	51	6	20 (39%)	0.33	0.65**	0.02

[1]subjects in experiments I and II may have believed that the simulation ran faster with all displays turned off.

Table 2: Differences between groups for correct and incorrect solutions in the four experiments; occurences of higher and smaller values for the correct group are shown (*significant at p<0.1, **significant at p<0.05)

	Higher Values		Smaller Values		
Experiment	Animation Usage	Confidence in Decision	Simulation Time	No. of Interactions	No. of Alternatives
I	Yes	Yes*	Yes	Yes	Yes
II	Yes	Yes	Yes	Yes*	Yes
III	No[1]	Yes*	Yes*	Yes	Yes*
IV	Yes	Yes	Yes	Yes*	Yes**

[1]but correct group used the histogram significantly less

4 A COMPARATIVE ANALYSIS

Our intention was to execute a single experiment that tested formal propositions regarding performance with a VIS. This we managed to do in experiment IV, following our previous experience, and this is discussed in detail in Bell and O'Keefe (1992). However, a comparative analysis across all four cases affords another opportunity to gain insights from our work. This is complicated by the fact that (a) we changed the case between experiments, (b) we changed and enhanced the VIS, (c) we measured different things in each experiment, and (d) our experimental methodology got better as we executed different experiments. Despite this, a number of consistent findings do emerge.

Overall, compared to an exhaustive experimental approach, performance was mediocre. The number of correct answers never exceeded 48% (experiment I). However, this takes the view of VIS as a vehicle for traditional simulation (O'Keefe 1987). When, in experiment IV, we looked at subject solutions *before and after* use of the VIS, we found that the VIS performed reasonably well as a tool to support decision improvement. Thus we confirmed the view of VIS as a beneficial approach to decision support (O'Keefe 1987).

Over all four experiments a consistent picture emerges regarding the following relationships:

(1) Animation and performance.

(2) Confidence and performance.

(3) Efficiency (i.e. how efficient users were in doing the task) and performance.

Supporting evidence is shown in Table 2.

4.1 Animation

In experiments I and II, subjects made more use of the animation, and frequently turned the displays off. However, we think that subjects inferred from our instructions that the simulation ran faster with displays off, which was not the case. In experiment III, more use was made of the histogram, because the model did execute faster in this case (10 seconds vs. 2 minutes for the animation). For experiment IV we redesigned the displays, and a preference for the histogram emerged.

Overall, whatever displays are provided, *animation usage has been consistently related to correctness*. The groups that obtained correct solutions made more use of the animation than the incorrect group in experiments I, II and IV, although this is not significant in any individual experiment. In experiment III, where the simulation ran faster without the animation, the animation was used much less. However, here subjects in the correct group used the alternative dynamic histogram display significantly less.

4.2 Confidence

Similarly, *confidence in decision, as measured on a ten point scale following the task, has been consistently related to correctness*. In all four experiments the groups that obtained correct solutions had higher confidence scores, and this was significant in experiments I and III.

This is good news for proponents of VIS as an experimental tool - it suggests that confidence in decision may be warranted. In any case, in a real setting any good manger would not implement a solution they did not feel confident in.

4.3 Efficiency

Efficiency, in terms of (a) using less simulation time, (b) interacting less, and (c) looking at a smaller number of alternatives, has been better for the groups that obtained correct solutions. In some instances these have been significant differences - the correct group used significantly less simulation time in experiment III, had significantly fewer interactions (measured as any interaction through the keyboard) in II and IV, and investigated significantly less alternatives (defined as an allocation of trucks) in experiments III and IV.

Subjects who get better solutions are, thus, actually doing less work. This is markedly different from much experimental work in MIS, where, as might be expected, subjects that acquire more information can perform better. We posit that they have a better strategy for using the VIS, possibly derived from a better understanding of simulation. In Bell and O'Keefe (1992) we look at what this strategy is. (Briefly, subjects that performed well were more likely to use an 'alternatives' based strategy where they investigated by alternative, rather than focusing on a particular attribute and then considering that attribute across a number of alternatives. Interestingly, this is in direct conflict with the approach implicit in a number of packages whereby it is easy to change alternatives while keeping a display constant, but not necessarily easy to do the reverse.)

5 CONCLUDING REMARKS

Experimental analysis with VIS is typically used in situations where there are many criteria, objectives are difficult to define, and some or much of the model may be a considerable approximation. Thus the concept of a correct, let alone optimal, solution is largely irrelevant. What is important is that the decision maker (or makers) come away with an agreeable feasible solution that is an improvement over that considered prior to use of the VIS, or conversely, evidence that what had been considered can not be easily improved upon. Sometimes more detailed analysis (both in terms or model formulation as well as output analysis) will be required; a traditional simulation may then supplant the visual.

VIS is certainly a good vehicle in this situation. We have shown that animation is valuable, that confidence in decision is warranted, and that use of a VIS under a particular strategy leads to more efficient and better use of the model. The argument over whether or not VIS should be an experimental tool is futile. Rather, the argument should be about how VIS can be properly employed, which is subtlety but substantially different.

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