Feedback and Elaboration Within a Computer-Based Simulation: A Dual Coding Perspective

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Abstract: The purpose of this study was to explore how adult users interact and learn during a computer-based simulation given visual and verbal forms of feedback coupled with embedded elaborations of the content. A total of 52 college students interacted with a computer-based simulation of Newton's laws of motion in which they had control over the motion of a simple screen object — a ball. Two simulation conditions were studied, each differing in how the feedback of the ball's speed, direction, and position was represented: visual feedback consisted of animated graphics and verbal feedback consisted of numeric displays. In addition, half of the simulations were supplemented with elaborations of the content modeled by the simulation in order to investigate how to promote referential processing, a key component of dual coding theory. Results showed significant differences for both the use of the elaborations and simulations containing visual feedback in helping subjects gain both tacit and explicit understanding of the science principles. In addition to the quantitative analysis, a qualitative analysis was also conducted with 12 additional subjects. This analysis revealed interesting trends in how some subjects valued and used the elaborations and the two feedback representations of the simulation.

Physics has long been regarded as one of the most abstract and difficult subjects to learn. A common belief is that the students who do well in physics have a special aptitude for learning science and mathematics. It is easy to understand how many might believe that the only students who are going to "need" physics are future engineers and physicists. However, instead of reserving physics for a gifted few, many feel that technology offers the chance to change commonly help perceptions about who can or should learn physics (White, 1993). For example, complex systems such as physics can easily be modeled on desktop computers. Computer simulations make complex systems accessible for students of varying ages, abilities, and learning levels. The computer, instead of the student, can assume responsibility of processing the underlying mathematics in order to let the student begin exploring a complex system by first focusing on conceptual understanding.

Of course, many challenges to the *effective* design of simulations remain. Among the most difficult are questions about the design of a simulation's interface (Schneiderman, 1987). For example, designers currently can include a wide range of visual, textual, and aural elements in the development of simulations. As the range of available design options increases, so too does the complexity of design decisions. One of the most important considerations in a simulation's interface design is how to provide meaningful feedback to the user. Feedback has long been regarded by cognitive psychologists as one of the most critical sources of information to assist learners in restructuring their knowledge and supporting their metacognitive processes (Kulhavy & Wager, 1993). Given the range of ways computers can represent feedback in a simulation, research is needed to ensure that design decisions are made based on the psychological needs of the individual user and not simply on what the computer is capable of doing.

Much research demonstrates that the way information is represented matters greatly in the learning process, at least for memory tasks (Clark & Paivio, 1991; Paivio, 1990; Paivio, 1991). Research indicates that pictures are superior to words for remembering concrete concepts (Sadoski, Goetz & Fritz, 1993). Among the various theories that have been proposed to explain this, Paivio's dual coding theory appears to have the strongest empirical support (Anderson, 1978; Sadoski & Paivio, 1994; Sadoski, Paivio & Goetz, 1991). Dual coding theory divides cognition into two processing systems — one visual and one verbal. Although the research supporting dual coding theory is based almost exclusively on evidence derived from supplementing printed text with visuals (including paired associative tasks) (e.g., Sadoski, Goetz & Avila, 1995; Sadoski & Paivio, 1994), this theory also holds promise in guiding research in computer-based multimedia environments (Mayer & Sims, 1994; Rieber, 1996).

Dual-coding theory predicts three separate levels of processing within and between the visual and verbal systems: representational, associative, and referential. Representational structures (either visual or verbal) are formed depending on the nature of incoming information (i.e., visual and verbal information from the environment triggers the visual and verbal systems respectively). Associative processing leads to connections constructed *within* either the visual or verbal systems, whereas referential processing leads to connections made *between* the visual and verbal systems. Referential processing is particularly important because dual coding theory predicts that learning will be enhanced when information is encoded in both systems (i.e., dually coded). Information that is dually coded has twice the chance to be retrieved and used (Kobayashi, 1986). Instruction that promotes dual coding has obvious advantages.

Our past research has shown that the way feedback is represented also matters when learning from simulations of physical science concepts and principles (i.e., laws of motion). Subjects increased their tacit knowledge of physics when they interacted with a physics simulation given visual feedback, but they were unable to demonstrate increased explicit understanding based on the way the feedback was represented (see Rieber, 1996; Rieber et al., in press). Tacit understanding was measured by subjects' performance in a gamelike activity whereas explicit understanding was measured using a traditional performance test (i.e., multiple-choice question format). The increase in tacit learning given visual feedback indicated that representational and associative processing occurred almost exclusively *within* the visual system. Subjects' difficulty in acquiring explicit understanding of the physics principles modeled by the computer was attributed to the highly interactive nature of the discovery-based simulation. Simulations that model physical phenomena (such as physical science) may not provide the learner with sufficient time or guidance for interpreting the continual stream of feedback by *both* the visual and verbal systems. In other words, the "video game-like" quality of the simulation may have interfered with referential processing.

The purpose of this study was to investigate ways to facilitate or enhance referential processing as a user interacts with a computer simulation. Our previous research used a pure discovery-based approach — no instruction was included or embedded in the simulation. While the highly experiential nature of open-ended simulations appear beneficial in many ways, it does not seem to adequately promote reflection of the science principles. Reflection appears to be an important component for referential processing. Therefore, the use of brief elaborations of the science principles embedded throughout the user's experience with the simulation was studied in this research. It was hypothesized that supplementing the simulation with elaborations of the content would facilitate all three types of processing predicted by dual coding theory for explicit learning. Also, since previous research suggests the apparent dominance of the visual system during a user's interaction with simulations similar to these, it was also hypothesized that the embedded elaborations would promote more referential processing when subjects were given visual instead of verbal feedback.

A variety of data sources were used in this study. Traditional performance measures (e.g., question-based pretests and posttests) were used to assess subjects' explicit understanding of the science principles modeled in the simulation. However, such formal tests do not assess other levels of understanding which are embedded in a task. For example, bringing a car to a smooth controlled stop requires an extensive understanding of many motion principles. However, this understanding remains situated in the act of driving — the individual may not be able to explicitly describe the physical relationships at work. Although we recognize that a learner's ability to transfer conceptual understanding from one task to another (such as to a posttest) remains an important indication of learning, this study also used a measure of tacit understanding found useful in our earlier research. Subjects were asked to complete the simulation in a game-like context. Since an understanding of the motion principles is necessary to be successful at the game, the game score provides an alternative data source useful when compared with the subjects' scores on traditional performance measures. Finally, this study also included both a quantitative and qualitative phase. Rather than arguing in favor of one research methodology over another, we believe that the combination of methodologies provides a more complete understanding that either could provide separately.

Method

The quantitative methods and results of this study will be reported first, followed by the qualitative methods and results.

Subjects

A total of 52 subjects participated in the experimental phase of this study. Subjects were upperclass undergraduate students enrolled in an introductory computer education course. Participation was voluntary, though extra credit in the course was provided to students as incentive to participate.

Materials

The materials consisted of a computer-based simulation of Newton's laws of motion. Subjects had direct control over the motion of a simulated, free-floating object (called simply a "ball"). The simulation was presented in a game-like context with the goal of moving the ball to a specific screen location (called the "target"). All 52 subjects were given a total of 30 trials. It was anticipated that as subjects gained mastery of the game, they would become bored unless the challenge was increased. For the first 20 trials, all subjects merely had to guide the ball to the target. However, in the final 10 trials, all subjects had to guide the ball to the target *and* bring the ball to a stop while inside the target.

Subjects were able to move the object in two dimensions. They controlled the motion of the object by pressing one of four screen buttons that applied an impulse force to it, similar to a "kick," in one of four directions: left, right, up, or down. The magnitude of the force, or kick, did not vary. No other forces (e.g., gravity and friction) were included in the simulation. The computer calculated the resulting motion of the object (i.e., position, speed, and direction) and reported this information back to the user in real-time. In other words, the computer calculated the motion of the object about as fast as the user interacted with the simulation. The computer provided this information to the user in one of two ways, either as *visual* feedback or as *verbal* feedback. Visual feedback contained a graphic of the target and an animated graphic of the ball while verbal feedback consisted of numerical readouts of the screen positions of the ball and target. Half of the subjects were given visual feedback and the other half verbal feedback. Examples of these two forms of feedback are illustrated in Figures 1 and 2.

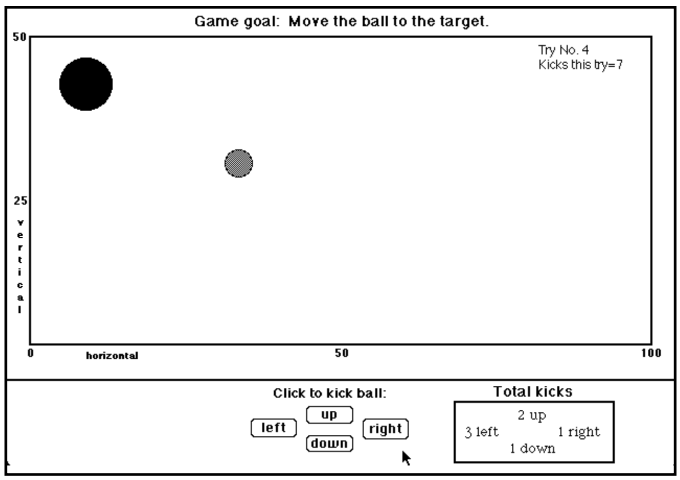

Figure 1. Snapshot of the computer screen during the simulation in which visual feedback was provided. Feedback about the ball's position was displayed by animating the ball on the computer screen.

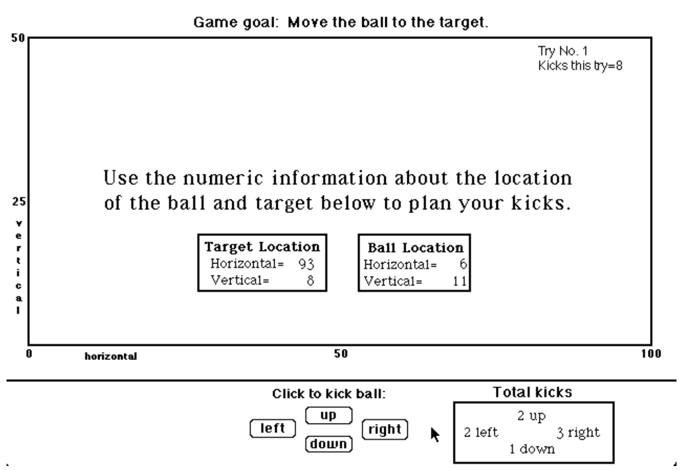

Figure 2. Snapshot of the computer screen during the simulation in which verbal feedback was provided. Feedback about the ball's position was displayed only in numerical form.

Subjects were also randomly assigned to one of two levels of Elaboration (Yes, No). Elaboration consisted of five separate explanative frames that explicitly described the motion principles using a combination of text and animated graphics. The five frames were presented in sequence, one elaboration frame after every two simulation trials (e.g., elaboration frame 1 after simulation try 2, elaboration frame 2 after simulation try 4, etc.). Therefore, each of the five elaboration frames was presented three times throughout the simulation trials. Half of the subjects were given these elaborations and half were not. An example of one of the elaborations is illustrated in Figure 3.

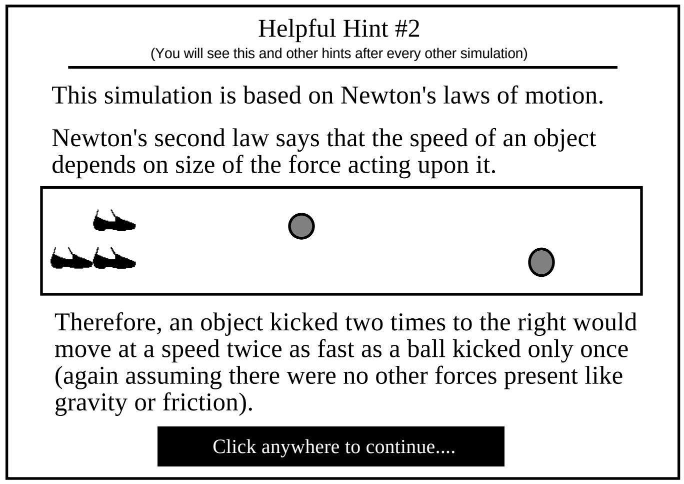

Figure 3. An example of one of the 5 embedded elaborations. The two balls were animated concurrently.

Dependent Measures

Performance. A 20-item test was used to measure subjects’ explicit understanding of Newtonian motion principles. The questions were designed to test for rule-using learning outcomes (i.e., principles) (as defined by Gagné, Briggs & Wager, 1992). Multiple-choice questions (1 answer and 4 distractors) were used as the testing format. Representative questions are shown in Figure 4. KR-20 reliability was .85.

Game Score. The time, in seconds, taken by subjects to successfully complete the game was used as a scoring feature. A subject's score for any one simulation trial was equal to the number of seconds elapsed at the moment the game was completed. Each trial had a time limit of two minutes. If time ran out before the subjects successfully completed the game, the computer automatically signaled the end of the simulation and a score of 120 was recorded for that try.

Interactivity. The total number of times subjects clicked either the “right,” “left,” “up,” or “down” button during each simulation was recorded by the computer.

Frustration. After each simulation trial, subjects were asked to rate their level of frustration on a scale of 0 to 8 where 0 was “no frustration,” 8 was “extreme frustration.”

Procedures

All of the simulation conditions and testing were administered by the computer. Subjects were randomly assigned to one of the four conditions (i.e., visual or verbal feedback with or without embedded elaborations) as they reported to the computer lab. The computer immediately administered the 20-item pretest. Subjects were then given two practice trials with the simulation as an orientation to the task. Subjects then were given a total of 30 attempts with their respective simulation condition with or without embedded elaborations. After each simulation try, the computer surveyed subjects on their level of frustration. Immediately upon completion of the simulation activities, the computer automatically administered the posttest consisting of the same 20 multiple-choice items. Approximately one hour was needed to complete the experiment.

Design

This study used a 2x2 factorial design involving two levels of two between-subjects factors: Feedback (visual, verbal) and Elaboration (yes, no). Statistical procedures included separate Analysis of Variance (ANOVA) tests on each of the dependent measures (a repeated ANOVA was used on the pretest/posttest performance measure).

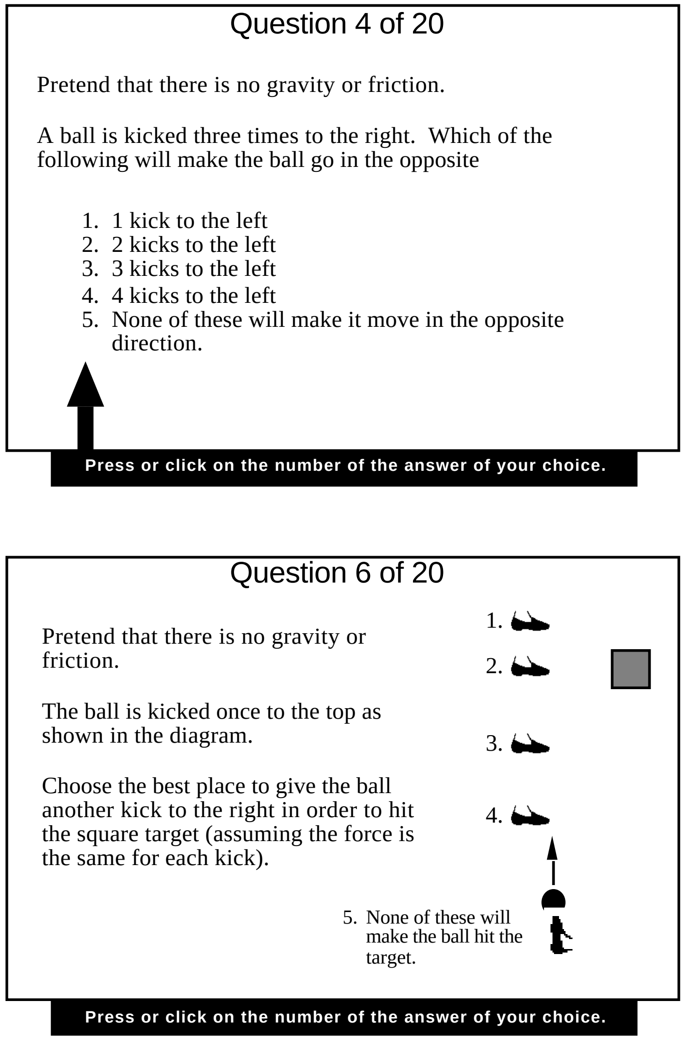

Figure 4. Two representative questions from the pretest/posttest. (The correct answer to the top question is "4" and the correct answer to the bottom question is "3".)

Results

Performance. Percentage means and standard deviations are contained in Table 1. A significant interaction was found between Elaboration and Performance, $F(1,48)=9.55$, $p<.01$, $MS_{error}=190.51$. All subjects scored similarly on the pretest (mean=53.2%), however, subjects provided with embedded elaborations scored higher on the posttest (mean=83.8%) than subjects who were not given the elaborations (mean=70.7%). There was also a significant interaction between Feedback and Performance, $F(1,48)=5.0$, $p<.05$, $MS_{error}=190.51$. Again, all subjects scored similarly on the pretest, however, those provided with visual feedback scored higher on the posttest (mean=84.8%) than those provided with verbal feedback (mean=69.8%). No interaction was found between Feedback and Elaboration: the embedded elaborations were equally beneficial to subjects regardless of which feedback type (visual or verbal) they were given in the simulation.

Given the main effects for both Elaboration and Feedback, a separate post hoc analysis was conducted on the simple effects between the four cell means using only the posttest scores to test for the additive effects of the elaborations combined with visual feedback. Results showed a significant difference between the four cell means, $F(3,48)=4.4$, $p<.01$, $MS_{error}=409.2$. Follow-up tests showed that subjects given both visual feedback during the simulation and the embedded elaborations scored significantly higher (mean=93.5%) than all other groups (mean=71.9%), as illustrated in Figure 5. Subjects given visual feedback combined with embedded elaborations attained near mastery on the posttest.

Table 1
Mean Percentage Scores and Standard Deviations for Performance

Feedback		Performance: Pretest	Performance: Posttest
		With Embedded Elaborations	
Visual	M	55.0	93.5
	SD	18.6	9.0
	n	13	13
Verbal	M	47.7	74.2
	SD	27.1	28.0
	n	13	13
		Without Embedded Elaborations	
Visual	M	54.2	76.2
	SD	18.8	12.4
	n	13	13
Verbal	M	55.8	65.4
	SD	17.9	24.9
	n	13	13

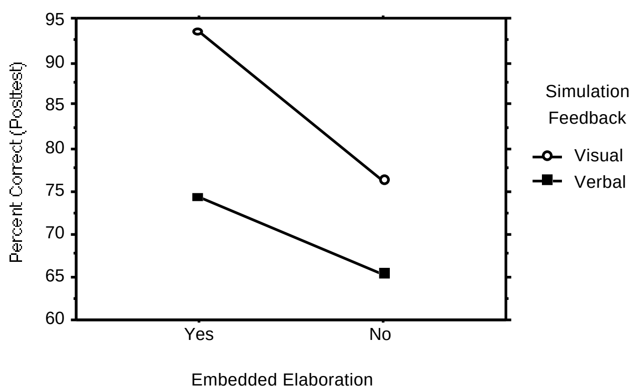

Figure 5. Means of subjects' posttest scores split by Elaboration and Feedback.

Game score. A significant main effect was found for Feedback, $F(1,48)=46.2$, $p<.0001$, $MS_{error}=223974.9$. Subjects given visual feedback scored better on the gaming activity than subjects provided with verbal feedback. This result is also consistent with previous research. Subjects level of tacit learning was facilitated more with visual feedback than verbal feedback. However, no significant differences were found for Elaboration: explicit information about Newton's laws of motion did not affect subjects' game scores in any way.

Interactivity. No main effects or interactions were found for Elaboration or Feedback. Subjects' frequency of interactivity (i.e., mouse clicks) was similar for all subjects in all treatment groups.

Frustration. A significant main effect was found for Feedback, $F(1,48)=12.9$, $p<.001$, $MS_{error}=2501.2$. Subjects provided with visual feedback were significantly less frustrated than subjects provided with verbal feedback.

However, there was no main effect for Elaboration: the presence or absence of the elaboration did not affect subjects' frustration levels.

Qualitative Methods

Triangulation is regarded as one important way to strengthen the understanding of phenomena under study. This can be accomplished by using different kinds of methods or data, such as a combination of both quantitative and qualitative approaches (Mathison, 1988; Patton, 1990). The qualitative method used in this study was designed to complement the quantitative analysis in order to enhance the validity of our findings.

Interview, coupled with participant observation, were the two primary methods used to collect the qualitative data. An unstructured interview protocol was determined in advance but each interviewer was free to take the interview in any direction deemed necessary. Each member of the research team acted as an interviewer for at least one subject. Subjects were also asked to use a "think aloud" protocol to verbalize freely what they were thinking throughout their experience. The goal was to "get inside the participant's head" and elicit what they were doing and why.

Twelve subjects participated in the qualitative research (these subjects were drawn from the same population, but they did not participate in the quantitative phase). These subjects interacted with a modified version of the simulation used in the quantitative study. Subjects had complete control over the selection (when and which) of the embedded elaborations. Participants were also given total control over which feedback type was chosen for the first several trials. Thereafter, the interviewer negotiated with the subject as to which feedback type would be chosen in order to avoid having a subject experience only one feedback type (such as visual). In order for participants' experience to closely match that of subjects in the quantitative study, participants were expected to complete at least 30 trials. Participants in the qualitative study were also required to complete the pretest and posttest. No help was given to participants on the pretest and posttest. Nevertheless, during the posttest participants were encouraged to explain reasoning or confusing they were experiencing as they answered the questions.

Observational field notes were taken by each interviewer while the subject interacted with the simulation. The collected data were then examined by each interviewer for concepts and categories that emerged from sessions. Finally, the research team met as a group to compare, contrast, and synthesize the findings.

Results

Two themes were derived from the qualitative analysis related to the embedded elaborations and the simulation itself.

Embedded elaborations. There was a wide variation in how participants used and valued the elaborations. Almost all subjects thought that the embedded elaborations were beneficial, but most subjects did not feel that they were actually relying on the hints to any great extent in the simulation. However, an interesting pattern was noticed in several of the participants. They seem to be reassured that the elaborations were available even though they did not feel the need to consult them often. Still others were a little confused about how the hints were supposed to help them in the simulation as they did not see a strong connection. Most participants did not initially choose to click on the hints and instead opted to immediately begin interacting with simulation. However, several participants turned to the hints for help if they became disoriented in the gaming activity. Finally, participants tended to consult the hints sequentially and seldom consulted the same hint twice.

Interaction within the simulation. Almost all participants showed a strong preference for the visual feedback early on. However, this preference varied among individuals as they gained experience with the simulation. Two profiles of participants' reaction to the feedback were observed which we've chosen to name "clickers" and "strategists." Clickers did not employ any apparent strategies and either seemed just to be trying to complete the exercise or were interacting with the simulation in a very experiential way with little or no reflection. Strategists, in contrast, clearly were involved in building and testing strategies for improving their ability to play the game. Two distinct strategies emerged: one-dimensional versus diagonal. The one-dimensional strategy involved moving the ball along one dimension and stopping it when it lined up with the target. They then proceeded to move the ball to the target by way of the other dimension. The one-dimensional strategy seemed to work equally well in either feedback situation. In contrast, the diagonal strategy involved getting the ball to move along one dimension and then carefully timing when to give the ball another kick along the other dimension. Since the ball had not come to a stop, the ball resulted in a diagonal motion. This strategy tended to work well given visual feedback, but was often disorienting when given verbal feedback, especially if subjects missed the target on the first try. As to the relative benefits of these two types of feedback, one participant commented that "you have to think with textual feedback," while in graphical feedback "you can concentrate more on concepts without worrying about techniques." This comment reflects well the experiential nature of the visual feedback. It also demonstrates the tendency by many strategists to eventually switch their preference to the verbal feedback because it was more consistent with strategies they were developing plus it provided an extra challenge (most were getting bored after about 15 tries).

Discussion

The purpose of this study was to investigate ways to facilitate or enhance an individual's learning of physics principles while interacting with a computer simulation using a discovery-based approach. Many facets of learning were studied in this research, such as tacit versus explicit understanding as well as patterns of interactivity and frustration. While computers afford the design of highly interactive open-ended learning environments such as simulations, decisions about how to design the interface of a simulation are often made with little understanding of how the user will perceive, process, and interpret the resulting feedback that the simulation provides. This study was designed to explore the effects of some of the most basic interactive attributes of simulations on cognition.

Previous research on discovery learning in a computer simulation has shown that although the way a simulation's feedback is represented can greatly influence subjects' performance in game-like activities, differences in feedback did little to promote explicit understanding of the science principles necessary on traditional performance measures such as question and answer tests (Rieber, 1996). The present study was designed to follow-up the results of Rieber (1996), but with some important changes. For example, subjects found the content of the simulation used in Rieber (1996) — acceleration and velocity — very demanding. The difficulty of the task may have interfered with understanding. In contrast, the simulation used in the present study involved a simpler model of Newtonian mechanics and was designed with greater sensitivity to motivation — challenge was increased at about the time subjects were expected to begin getting bored. This study also increased subjects' experience with the simulation — subjects had 30 separate trials with the simulation (as compared to 20 in previous research). The present study also included one additional factor — embedded elaborations — to investigate means of enhancing referential processing without seriously interrupting the interactive nature of the simulation (as would a complete tutorial).

This research was guided by dual-coding theory which predicts that more and effective learning should result when information is encoded both visually and verbally and if connections are made between these visual and verbal codes (Paivio, 1990). Information that is dually coded doubles the chance for retrieval since learners have two ways to access the information. According to dual coding theory these connections are established through referential processing. However, there has been little application of dual coding theory to simulations and other interactive learning environments. The highly interactive nature of many computer simulations creates an interesting dilemma. On one hand, the experiential nature of an educational simulation is very compelling — users often become very active and engaged in a simulation, similar to the experience of playing a video game. However, the intense and demanding interactivity of many simulations may not provide adequate time for the user to carefully reflect on the principles being modeled by the simulation. Without sufficient guidance or time and opportunity for reflection, referential processing may not take place. Therefore, while the simulation may lead to successful tacit learning (i.e., success at completing the simulation activities), the simulation may actually hinder or interfere with explicit learning. This research tried to gain insight to this issue by studying the influence of the way a simulation's feedback is represented in combination with the embedded elaborations.

In contrast to Rieber (1996), visual feedback (consisting of continually updated animated graphics) during a simulation was more effective than verbal feedback in helping subjects gain both tacit and explicit learning of Newton's laws of motion. Not only did the subjects who were given visual feedback outperform other subjects on the simulation's gaming activity (i.e., tacit knowledge), their gains from the pretest to the posttest were also greater.

The embedded elaborations were very successful learning aids even though they were exceedingly brief (one frame each). Subjects who given the elaborations gained significantly more explicit understanding of the science principles than those who were not given the elaborations. Not surprisingly, the elaborations were of little help to subjects as they played the game. From a dual coding perspective, the elaborations in tandem with the simulations promoted representational, associative, *and* referential processing. The elaborations were equally beneficial to all subjects — there were no differentiated effects based on the type of feedback provided. This was surprising. It was expected that subjects given the visual feedback would be in a better position to make meaning out of the embedded elaboration than subjects given the verbal feedback. Of course, the embedded elaborations used here contained both visual and verbal elements. The elaborations may have influenced mental imaging for subjects given verbal feedback. The qualitative results, however, suggest that although subjects thought the elaborations were generally beneficial, they tended not to use the elaborations much because they did not see them as an aid in achieving greater success at the game. Subjects largely failed to focus on the more global goal of using the simulation *and* the elaborations as a means of learning about the laws of motion. The phenomena of users not choosing to select options from which they clearly could benefit is reminiscent of the research on learner control (Clark, 1982; Milheim & Martin, 1991; Steinberg, 1989).

The additive effects of the visual feedback coupled with embedded elaborations deserves special attention. As indicated in the post hoc analysis of the simple effects on the posttest, subjects given both visual feedback and elaborations reached near mastery on the posttest (average score of 93.5%), outperforming all other subjects. These results, though still preliminary, suggest an interesting approach to optimizing the experience of learning by simulation. Unlike traditional approaches where simulations are usually used as follow-up practice activities to tutorials (see, for example, Alessi & Trollip, 1991), it may be possible to center learning around the highly interactive and experiential nature of a simulation. Certainly, there seem to be cognitive advantages to students making meaning through personal discovery and exploration. Every "secret" they discover, recognize, and articulate becomes *their* knowledge, not someone else's. Of course, the promise of personally constructed knowledge comes with increased responsibility on the part of each learner. Computer simulations afford learners with the chance to interact with information-laden representations of complex domains (e.g., physics, mathematics, chemistry, history, etc.). In many simulations, students face the burden of making meaning from a continual stream of information about the physical properties of screen objects. These results suggest a way to supplement a simulation to help students meet the difficult task of learning in a simulation.

It is important to note the task specific nature of the visual representation of feedback produced by a computer simulation. A conclusion of this study is that different representations will lead to different outcomes for certain tasks and *not* that visual feedback is generally "better" than verbal feedback for *all* tasks. The design challenge is to match the demands of the task with appropriate representations. Certainly in this study, the visual feedback was very consistent with learning about the laws of motion. However, as the qualitative data suggest, many "strategists" often came to prefer the verbal feedback after sufficient experience with the simulation because they began to develop creative strategies to further their success and enjoyment in playing the game.

The lack of main effects on interactivity is in contrast to that found in previous research (Rieber, 1996; Rieber et al., in press). Previous research found that subjects interacted far less when given visual feedback even though their game scores were better. This difference is probably due to the simpler nature of the simulation and backs up the hypothesis that subjects often increase their level of overt interactivity when disoriented (users seem to revert to "frantic clicking"). The fact that subjects reported being more frustrated when given verbal instead of visual feedback is consistent with our previous research. Visual feedback is much preferred by subjects given such physics simulations. The relationship between imagery and motivation is also consistent with dual coding theory (Clark & Paivio, 1991). Of course, the qualitative data suggesting that some (but not all) subjects eventually switch their preference to verbal feedback to match certain strategies they are constructing attests to the need to design simulations with a range of feedback options.

Several questions for future research remain. More research is needed on the effects of the visual and verbal elements of the embedded elaborations so as to better understand how they interact with different feedback representations in the simulation. Also, more precise information on the contribution of the embedded elaborations *versus* the simulation experience is needed. That is, the issue of how much learning is taking place just by having subjects view the elaborations *without* participating in the simulation is open to question. Future research should also expand on the delicate demands of optimizing challenge to maintain motivation in game-like activities embedded in a simulation (see Lepper & Malone, 1987) and the use of certain games as measures of tacit knowledge.

In conclusion, the results of this study point to a simple yet powerful means of facilitating referential processing in a simulation. The use of simple elaborations of the content modeled by a simulation coupled with appropriate matching of the simulation's feedback to the task appears to be a surprisingly effective way to guide students to focus on the most important principles in the simulation without subverting personal discovery or risking decreased motivation. The qualitative data, however, tempers this enthusiasm by reminding us of the complex way a user perceives value and relevance to these elaborations. Users may feel reassured that additional guidance is available, but yet may not choose to consult such help at appropriate times if they fail to see the connection of how embedded elaborations will lead to greater success in completing a simulation or game.

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