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ABSTRACT

This paper rejects the hardware-based "levels of interaction" made popular in interactive video literature to describe human-machine interaction in favor of a new taxonomy of learner-media interaction based on the type of cognitive engagement experienced by learners. Interaction can be described on three levels, based on the quality of the interaction. A reactive interaction is a response to presented stimuli, such as an answer to a specific question. Proactive interaction emphasizes learner construction and generative activity. The learner goes beyond selecting or responding to existing structures and begins to generate unique constructions and elaborations beyond designer-imposed rules. Mutual interaction is characterized by artificial intelligence or virtual reality designs in which the learner and system are mutually adaptive, each capable of changing based on encounters with the other. Reactive, proactive, and mutual interactivity can be described at five functional levels: confirmation, pacing, navigation, inquiry, and elaboration. The transactions (mechanics of how interaction is accomplished) can also be described in terms of their functions and levels of interactivity. Although several transactions can be employed at all levels of interaction, as interaction reaches for higher levels of engagement with learners, generative transactions are required. One of the major implications this taxonomy carries for instructional design relates to learner control. As levels of interaction are ascended by the instructional developer and reflected in the design of interaction, the amount of control abdicated to the learner changes. At the reactive level, the instructional developer retains almost complete control over the content, its presentation, sequence, and level of practice. While research in the area of learner control is relatively new, some tentative advice is available from the literature. Inherent in this emerging literature is the concept of learner control, an issue which will occupy a central position in multimedia research during this decase. (Contains 27 references.) (KRN)

A Taxonomy of Interaction for Instructional Multimedia

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Abstract

This paper describes a new taxonomy of interaction based on the type of cognitive engagement experienced by learners, and rejects the hardware based "levels of interaction" made popular in interactive video literature. Reactive, proactive and mutual levels of interaction, and their associated funtions and transactions are discussed. The paper also explores principles for designing interactive multimedia instruction derived from the taxonomy and current research on learner control.

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This paper has two objectives. First, it will attempt to describe the need for and characteristics of a new taxonomy for interaction. Second, it will discuss several principles of learner control derived from the taxonomy and recent research.

Levels of Interactivity

Commonly accepted labels for levels of interactivity are Level I, II, III, and sometimes IV, depending on your reference (Iuppa, 1984; Katz and Keet, 1990; Katz, 1992; Schwartz, 1987; Schwier, 1987). These are hardware-specific categories drawn from the literature on videodisc, and they have achieved common acceptance (Figure 1). Each level depends on a particular equipment and software configuration. For example, Level II software is useless on a system which is only capable of playing Level I or III applications; Level I applications can be *repurposed* into Level III applications by adding a computer to the system and writing a program to drive the application. These categories are therefore confining, and not sufficient to describe the nature of interaction available in multimedia systems. According to this designation, every multimedia application would be a Level III or IV application, regardless of the nature of the program, merely because a computer is at the heart of the system.In addition, these levels say little about the quality of interaction engaged by the learner. What is the relative quality of cognitive engagement experienced by a learner who presses buttons on an RCU (Level I) versus a learner who touches the screen (Level III)? Many would argue that there is little difference, if any, in the level of thought required in the actions, yet they are categorized as dramatically different levels of interaction.

However convenient this designation may have been or continues to be for interactive video, for multimedia environments it is more productive to characterize interaction according to the sophistication and quality of interactivity available to a learner in a particular program.

Figure 1. Commonly accepted levels of interactivity for videodisc.

Level I	Least amount of interactivity. CAV or CLV discs can be used. Program largely linear—not controlled by software. Picture stops may be encoded on videodisc. Chapter and frame search enabled. User can access parts of disc manually.
Level II	Intermediate degree of interactivity possible. Control program permanently recorded on disc. Program code must be compatible with playback system. Manual (RCU) control possible by overriding program. Typically uses single keypad-entry user input. Requires that program be submitted with edit master tape. Ideal for unchanging content.

Level III	System combines external computer and videodisc. Ideal for volatile content or treatments. Higher degree of interactivity possible. Various hardware configurations possible. Computer can perform as navigator, partner, or pedagogue when combined with videodisc.
Level IV	All visual/audio/computer sources on single monitor. Sophisticated user interfaces such as touch screen. Theoretical repository for future interactive innovations.

A Taxonomy of Interaction for Multimedia Instruction

Multimedia, by its nature, offers a range of interactive possibilities which are remarkably similar, regardless of the system used to deliver the instruction. A computer acts as the heart of the system, and also provides the means for learners to communicate with the instruction. Because most multimedia computer systems have similar devices for communicating (e.g., keyboard, mouse, touch screen, voice synthesis), the quality of interaction is more the product of the way instruction is designed, and less the result of the system on which it is delivered. In order to describe a taxonomy of interaction for multimedia instruction, this paper will suggest three levels of interaction, examine functions played by interaction within these levels and enumerate several types of overt transactions available at each functional level of interaction.

Figure 2. A taxonomy of interaction for multimedia instruction.

Levels	Functions	Transactions
Reactive	Confirmation	Space Bar/Return
Proactive	Pacing	Touch Target
Mutual	Navigation	Move Target
	Inquiry	Barcode
	Elaboration	Keyboard
		Voice Input
		Virtual Reality

Levels of Interaction

Interaction can achieve at least three levels, based on the quality of interaction. Interaction can be characterized as reactive, proactive or mutual.

A reactive interaction is a response to presented stimuli, such as an answer to a specific question (Lucas, 1992; Thompson and Jorgensen, 1989). In other words, a learner *reacts* to given stimuli. Such approaches emphasize coaching, tutorial or Socratic designs wherein the learner and computer are engaged in a responsive, albeit preordained, discussion.

Proactive interaction emphasizes learner construction and generative activity. The learner becomes the protagonist. The learner goes beyond selecting or responding to existing structures and begins to generate unique constructions and elaborations beyond designer-imposed limits.

The highest level of interaction, mutual interaction, is characterized by artificial intelligence or virtual reality designs. In such programs, the learner and system are mutually adaptive, that is, capable of changing based on encounters with the other. Sometimes, this is referred to as recursive interaction. Recursion is based on the mathematical notion of indefinite repetition, and in multimedia, it suggests a conversation which can continue indefinitely. This is a useful distinction, but it will fall short of the capabilities of multimedia systems in the future. We choose the term mutual, because multimedia systems may ultimately be capable of cybernetic conversation--actually learning from and adapting to conversation with a learner. At a less sophisticated level, mutual interaction can be used to describe the appearance or trappings of meaningful conversation. Mutual interactivity is still in its infancy, but we suspect this is an area into which interactive multimedia will expand.

The categories are not necessarily exclusive. Interactive multimedia programs may incorporate a combination of reactive and proactive approaches (few currently incorporate mutual approaches). The levels are hierarchical, in that one subsumes the other. In other words, Mutual interactions contain proactive elements, and proactive interactions contain reactive elements. For example, when learners generate new questions and approaches (proactive) they can, in turn, be used by the system to formulate new conversation (mutual). Similarly, when learners generate their own strategies (proactive) they are responding to existing stimuli at a sophisticated level (reactive).

Functions of Interaction

Within each level, interaction can serve several functions. Hannafin (1989) identified five functions of interaction: confirmation, pacing, inquiry, navigation and elaboration. Confirmation serves to verify whether intended learning has occurred, say, through learner responses to embedded questions. Pacing relinquishes program time control to the learner; that is, the learner determines how quickly instructional content is encountered. Navigation manages learner access to instruction by facilitating access to some material and restricting access to other material. Inquiry allows learners to ask questions or construct individual pathways through instruction, for example, through access to supplementary material. Elaboration involves the learner combining existing knowledge with new instructional content, creating transitions and contexts for moving from known to unknown information.

Each function is expressed differently during instruction, depending upon the level of interaction. For example, reactive navigation is typified by menus or prescribed branching options presented to learners. Proactive navigation, by contrast, would permit the learner to initiate searches or participate in open-architecture movement throughout material. Mutual navigation might happen when a program anticipates navigation routes of the learner based on previous movement, and advises the learner about the nature of choices made. In mutual navigation, the learner could could follow or ignore the advice, and also advise the system about about the nature of navigation opportunities desired. Figure 3 gives one example of interaction obtained at each functional level of the taxonomy. These examples are meant to be illustrative, not comprehensive.

Transactions During Interaction

Transactions are what learners do during interaction; they are the mechanics of how interaction is accomplished. For example, learners type, click a mouse, touch a screen or scan a virtual environment. Learners can also engage in many productive types of covert transactions, mentally engaging themselves in the construction of metaphors, questioning the validity of content, constructing acronyms to remember material and the like. This discussion will focus on overt transactions, but the reader should realize that covert transactions can be employed whenever overt transactions are unavailable to the learner. Also, the use of one does not preclude the use of another.

The level of interaction can be influenced by the type of interaction permitted by hardware configurations and instructional designs, and therefore the transactions. Several reactive events cannot be easily adapted to higher levels of interaction. For example, the range of possible interactions is confined if a spacebar is the only method of interaction available to the learner; in this case, reaction would be the only possible overt interaction. Devices such as touch screens and instructional design strategies such as menus do not permit the learner to ask unique questions or construct unrestricted paths through instruction, thereby working in a proactive or mutual orientation. For example, a learner can use a touch screen or use a single keyboard entry to make menu selections or answer questions--a reactive level of interaction. Touch screens and single keyboard entries are too restrictive, however, to be used for generative interactions such as on-line note taking--a proactive level of interaction.

Figure 3.Example of an interactive event each functional level of interaction.

	Confirmation	Pacing	Navigation	Inquiry	Elaboration
Reactive	Learner matches answer given by system	Learner turns page when prompted	Learner selects choice from a menu	Learner uses "help" menu	Learner reviews a concept map
Proactive	Learner requests test when offered	Learner selects an abbreviated version of instruction	Learner defines paths through instruction	Learner searches text using keywords	Learner generates a concept map of the instruction
Mutual	System adapts to progress of learner and learner may challenge assessment.	System adapts speed of presentation to the speed of the learner	System advises learner about patterns of choices being made during instruction	System suggests productive questions for the learner to ask, given previous choices	System constructs a metaphor based on learner input, and revises it as learner adds information

Conversely, however, transactional methods available for proactive or mutual interaction can also perform reactive functions. For example a keyboard synthesizer can be used by a learner to compose a new song as input into a program (proactive), while the same keyboard synthesizer can be used to have learners play a score displayed by a program (reactive). In this way, transactions conform to the hierarchy of this taxonomy. Transactional events available for higher levels of interaction can be adapted to lower levels of interaction, but the relationship is not reciprocal.

Figure 4 lists several transactional events which can be employed at reactive, proactive and mutual levels of interaction. While the list of transactions is not exhaustive, it illustrates some interactive strategies employed in IMI programs. The figures illustrate the notion that as interaction reaches for higher levels of engagement with learners, generative transactions are required.

Figure 4. Some examples of transactions available to serve different functions and levels of interaction.

	Reactive	Proactive**	Mutual***
Confirmation	Touch Target Drag Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Pacing	Space Bar/Return Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Navigation	Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Inquiry	Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Elaboration	*	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality

* **Note:** At a reactive level of interaction, elaboration would be restricted to covert responses to stimuli, such as, "Think about this image." Therefore, physical transactions are not required for elaboration.

Note: Because the learner must generate original input to be truly proactive, only overt transactions which permit generation of complex information were identified. In some cases, individuals might argue that modest forms of proactivity can be accomplished with other types of transactions.

***Note:** Mutuality implies sharing complex information between user and system. While systems may be able to adapt programs based on a series of simple interactions, truly mutual instruction requires complex dialogue.

Implications of the Taxonomy for Designing Multimedia

The taxonomy carries implications for instructional design, primarily concerning questions of learner control and instructional intent. An instructional developer constantly weighs the need to be prescriptive versus the need for learners to explore. There is certainly no absolute set of principles, yet some guidelines and tentative principles are possible. This section of the paper will enunciate several principles for designing interactive events in instructional multimedia without a great deal of elaboration. Original sources are identified, and the reader should refer to Schwier and Misanchuk (in press) for additional information.

How does learner control converge with the proposed taxonomy? *Learner control* may refer to a number of things. Learners may be granted or may require control over:

- Content of instruction.
- Context for learning.
- Presentation method of the content.
- Provision of optional content.
- Sequence of material to be learned.
- Amount of practice.
- Level of difficulty.
- Level of advisement.

The taxonomy is meant to be descriptive, not prescriptive, yet each of these points of control represents a decision point for an instructional developer. As levels of interaction are ascended by the instructional developer, and reflected in the design of interaction, the amount of control abdicated to the learner changes. At a reactive level of interaction, the instructional developer retains almost complete control over the content, its presentation, sequence and level of practice. A proactive level of interaction relinquishes much of the developer's control over instruction, as the learner determines what content to encounter, the sequence and how much time to devote to any particular element, and whether additional content will be explored or ignored. In proactive designs, the learner holds a high degree of control over all elements of instruction, and this may not always be beneficial to the learner. Curiously, at the highest level of interaction the system and the learner wrestle for control of instruction. The learner engages the instruction and makes decisions, but as instruction proceeds, the system adopts the role of wise advisor (or tyrant) and attempts to structure the instruction for the learner, based on revealed needs. Thus, the amount of learner control is moderate, or shared, at a mutual level of interaction.

One problem for an instructional developer is to decide when to assert and when to relinquish control. This decision will, in turn, influence which level of interaction may be appropriate to employ in the design of instruction. This is part of the art of instructional design, and control options have increased with newer generations of multimedia systems. While research in the area of learner control in IMI is relatively new, some tentative advice is available from the literature (Schwier and Misanchuk, in press).

General Conclusions About Control

- Learner control may increase motivation to learn (Santiago and Okey, 1990; Steinberg, 1977).
- Learner control does not necessarily increase achievement and may increase time spent learning (Santiago and Okey, 1990).
- Learner control may permit students to make poor decisions about how much practice they require, which are reflected in decremented performance (Ross, 1984).

Control Issues Related to Learner Characteristics

- Learners who are generally high achievers or who are knowledgeable about an area of study can benefit from a high degree of learner control (Borsook, 1991; Gay, 1986; Hannafin and Colamaio, 1987).
- Naive or uninformed learners require structure, interaction, and feedback to perform optimally (Borsook, 1991; Carrier and Jonassen, 1988; Higginbotham-Wheat, 1988, 1990; Kinzie, Sullivan, and Berdel, 1990; Schloss, Wisniewski, and Cartwright, 1988).
- The effectiveness of learner control is mitigated by such learner characteristics as ability, previous knowledge of the subject matter, and locus of control (Santiago and Okey, 1990).

Control Issues Related to Program Variables

- Learner control with advisement seems to be superior to unstructured learner control for enhancing achievement and curiosity, promoting time-on-task, and stimulating self-challenge (Arnone and Grabowski, 1991; Hannafin, 1984; Mattoon, Klein, and Thurman, 1991; Milheim and Azbell, 1988; Ross, 1984; Santiago and Okey, 1990).
- Learner control of presentations has been shown to be beneficial with respect to text density (Ross, Morrison, and O'Dell, 1988) and context conditions (Ross, Morrison, and O'Dell, 1990).
- Courseware should be adaptive. It should be able to alter instruction dynamically, based on learner idiosyncracies (Borsook, 1991; Carrier and Jonassen, 1988).
- One opinion holds that learners should be given control over contextual variables such as text density, fonts, and backgrounds, but not over content support variables such as pacing, sequence, and examples (Higginbotham-Wheat 1988; 1990).

These results, however inviting, should be approached with caution. Not only are they inconclusive, they are contradictory in some cases. For example, the advice offered by Higginbotham-Wheat (1988; 1990) can be interpreted to mean that learners should influence only variables which have little instructional significance, and be denied control of significant instructional variables. Certainly this contradicts the intentions and findings of many of the other studies cited. Indeed, some argue that we need to go beyond objective and prescriptive designs, and embrace generative and constructivist approaches (Jonassen, 1991). Inherent in these arguments is the concept of control, an issue which will occupy a central position in multimedia research during this decade.

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