LICAI+: A Comprehension-Based Model of Learning for Display-Based Human–Computer Interaction

Muneo Kitajima
National Institute of
Bioscience and Human-Technology
1-1 Higashi Tsukuba Ibaraki 305, JAPAN
Tel: +81 (298) 54-6730
E-mail: kitajima@nibh.go.jp

Peter G. Polson
Institute of Cognitive Science
University of Colorado
Boulder, CO 80309-0345, USA
Tel: +1 (303) 492-5622
E-mail: ppolson@psych.colorado.edu

ABSTRACT
This paper describes a model of comprehension-based learning, LICAI+, an extension to the comprehension-based model of display-based HCI, LICAI [5], that simulates a user who performs tasks given as instructions. LICAI+ models users' learning of task performance by incorporating a process for encoding events during the task performance. A simulation of encoding and recalling events is described.

Keywords
cognitive model; learning; display-based human–computer interaction; construction–integration theory.

INTRODUCTION
This paper describes a model of how experienced users of an environment (e.g., Mac OS or Windows 95) learn to use a novel graphing application like Cricket Graph III. We assume that the user has an explicit task goal (e.g., Hide Legend), and that she generates the correct action sequence by being given hints of the form "Pull-down the Options menu" or successfully discovering steps by exploration. After successfully performing the task for the first time, the user is asked to perform the task again after a delay. The task goal and the displays generated by the application interface are the only retrieval cues given to the user.

In a previous paper [5], we described LICAI, **LI**nked model of **C**omprehension-based **A**ction planing and **I**nstruction taking. It simulates the cognitive processes involved in comprehending and following hints and successfully performing steps by exploration. This paper extends LICAI by incorporating learning processes. We want to understand the relationship between users' recall performance and their representation of the task and the application displays. Franzke [1] found that both the probabilities of successful exploration and later recall were determined by overlap of users' task goal descriptions with the labels of correct menu choices.

THE LICAI+ MODEL
LICAI+ incorporates learning mechanisms derived from the memory for text [3]. We start by describing LICAI for comprehending hints and successful exploration (see [4] and [5] for details). Then, we describe how LICAI+ encodes successful actions and later retrieves them using a task goal and application displays as retrieval cues.

The Construction–Integration Architecture
LICAI is comprehension-based model of instruction following and exploration. The cognitive processes specified in LICAI are implemented using the construction–integration (C-I) architecture developed by Kintsch [2], which has been applied successfully to model cognitive processes involved in text comprehension [2], word problem solving [2], and action planning [4].

In the *construction* phase, a C-I cycle generates a connectionist network that represents alternative meanings of a sentence or alternative actions that can be performed on a given step in a computer-based task, and the knowledge necessary to select among the alternatives. The *integration* phase uses spreading activation to implement a constraint satisfaction process that selects a contextually appropriate alternative consistent with the users' goals. The nodes in the network are propositions. Links in the network are established by common arguments of propositions; when two nodes share a common argument, they are connected. The constraint satisfaction process is controlled by the pattern of interconnections.

Comprehending Hints and Exploration
Kitajima and Polson [5] describe in detail the processes in LICAI that simulate comprehension of hints like "Pull-down the Options menu." This hint specifies actions to be performed on an object on the screen. LICAI transforms the propositional representation of the hint into a representation that controls the action planning process, a *do-it goal*.

However, even without hints, the action planning process can discover correct actions by exploration. A task goal like Hide Legend does not contain any information about the correct action sequence. However, the action planning process can discover the correct action sequence if labels of screen objects like a correct menu choice overlap with the task goal. If the interface to a graphing program had a Hide menu and Legend was a menu item, the action planning process would be able to discover the correct actions utilizing knowledge about the interface stored in long-term memory. For example, the model knows that Hide is a menu label, that menus can be pointed at, that press-and-hold is a legal action, and that press-and-hold will pull-down the menu.

Encoding Results of Performing Actions

LICAI+ defines an encoding process that operates after LICAI's action planning process. This encoding process comprehends the results of the action just executed by the model, generating a memory trace as by-product of the C-I cycle that comprehends the result of the last action.

When an action causes a significant display change (i.e., appearance of a pull-down menu of an application window, etc.), a specialized comprehension schema is used for constructing a propositional representation of the event. The comprehension schema generates a proposition including the following arguments: 1) the current task-goal, 2) the current do-it goal, 3) the label of the acted-on object, and 4) its current state. This proposition is incorporated into the network during the construction phase. During the integration phase, the amount of activation received by this proposition is determined by the pattern of links in the network which is determined by overlapping labels. The pattern of activation then determines the strength of the memory trace of this event.

SIMULATION: ENCODING AND RECALLING

We modeled learning of the steps for the task Hide Legend using Cricket Graph III. We assume that a user is an experienced user of the Macintosh OS who has had no experience with this application. Rodriguez and Polson [6] have shown such users cannot perform the first two steps of the task (Pull-down the Options Menu, Select Show Graph Items…) without hints. We gave the simulation hints that enabled it to perform these two steps successfully. LICAI+ comprehended the hints and converted them to do-it goals, followed by execution of the first two steps. Display changes triggered the encoding processes. Figure 1 shows the elements in the network that participated in the encoding process.

Releasing on "Show Graph Items…" caused a dialog box to appear for showing or hiding elements of the graph like the legend. Each element had a check box next to an associated label (e.g., Legend). The graph item described by a label was hidden by clearing the associated check box and clicking on the button labeled "OK." These two steps can be successfully performed by the model and subjects by exploration. We simulated doing these steps by exploration where the original task goal Hide Legend controlled the process. The resulting encoding of the outcome of an action has no do-it goal (see Figure 1).

Step No.	Task-Goal	Do-It Goal	Label of Acted-on Object	State of Acted-on Object
1	Hide Legend	select 'Options'	'Options'	Highlighted
2	Hide Legend	select 'Show Graph Items'	'Show Graph Items…'	*not visible*
3	Hide Legend	*none*	'Legend'	Legend Check-Box Cleared
4	Hide Legend	*none*	'OK'	*not visible*

Figure 1. The elements in the network used for encoding events during Hide Legend task using Cricket Graph III.

Recalling Memory of Events

Retention of the four steps performed during the learning session was tested by using the task goal, Hide Legend, and the initial display as retrieval cues. Figure 2 shows the activation values of the encoded events in the recall session. The most highly activated event representation is the representation of Step 3, clearing the legend check box.

Actions Involved in Events	*Activation Values*
Pulling-Down "Options"	0.0275
Releasing "Show Graph Items…"	0.0330
Clearing Legend Check-Box	0.1631
Clicking "OK"	0.0329

Figure 2. Retrieval of events from memory cued by the task description, "Hide Legend" and the initial display.

The memory retrieval process, like the action planning process is dominated by the overlap between the goal and labels of objects on the display. Observe that the model retrieved this step even though the object to be acted on, the check box, was not yet on the display. Additional cognitive processes would be required for selecting the encoding of the first step of the task, pulling down the Options menu. This suggests that performance of the actions that were hinted in the learning session can be still difficult to recall consistent with Franzke [1].

To conclude, the encoding process in LICAI+ generates weak memory traces for the actions on objects that do not have labels that overlap with the task goal. This result suggests that subjects will have difficulty recalling the steps from memory in a task that required hints (i.e., cannot be successfully performed by exploration).

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