Assessment of a Knowledge-Acquisition Tool for Writing Medical Logic Modules in the Arden Syntax

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We have created a tool that allows users unfamiliar with the Arden Syntax and our underlying database to create Medical Logic Modules (MLMs). In a study of this tool (N = 16), subjects found it easy to use (mean score = 4.69 on a scale of 1-5, 5 being best). Each subject created 3 MLMs of varying complexity following a protocol. On average, subjects required 312, 308 and 318 seconds, respectively, to complete each MLM. Comparison of clinicians to non-clinicians and those with to those without knowledge of Arden showed no significant difference. Of the 48 MLMs, 47 compiled and executed with appropriate output. Independent manual review of the MLM correlated well and found few errors. We conclude that our tool is easily used by inexperienced persons to write MLMs in the Arden Syntax.

INTRODUCTION

The Arden Syntax for Medical Logic Modules, developed in part at Columbia-Presbyterian Medical Center (CPMC), has been promoted as an open standard for the procedural representation and sharing of medical knowledge [1]. Implemented using a clinical event monitor at CPMC, MLMs provide over 1000 clinical alerts and many research messages each month [2].

The creators of the Arden Syntax hoped that clinicians would be able to understand Arden Syntax knowledge bases with little training. While they expected that adding to the knowledge base would be more difficult, formulating a language that people could read and write easily was a critical goal [3].

Recently, we have received increasing numbers of requests for MLMs that produce alerts or provide notification regarding patients or potential subjects in research studies. Unfortunately, in our experience, clinicians and programmers have difficulty learning to write MLMs because of the need to understand our local query syntax and data structures--features not defined in the Syntax and left to local implementation [4]. Moreover, busy clinicians and researchers are reluctant to spend time to master these complexities when they require only one or two MLMs. This problem has hindered the growth of our knowledge base.

Although other workers at our institution and elsewhere have created MLM editors, these have varied from slightly augmented word processors to text editors with varying degrees of syntax support [5-7]. Both a previous editor constructed at our institution and at Linköping University [5] provide syntax checkers but still require the user to enter syntax directly. A knowledge base manager has been developed as part of the HELIOS project that provides a set of tools for each slot in a MLM [7]. However, we are of aware of no formal evaluations of these tools in terms of ease and speed of use.

Therefore, in order to facilitate the expansion of our Arden knowledge base, we have created a tool that allows a user to compose MLMs. In distinction to some prior published work, this tool shields the user from the Syntax in order to assist persons with no knowledge of it write MLMs without difficulty. In addition, in order to demonstrate the utility of this tool, we studied it in an experiment with a diverse group of subjects.

METHODS

Architecture of the Tool

We used the Visual Basic graphical authoring environment to create the user interface. Users of the tool are guided through three major phases in the process of composing a MLM, iconized as an ordered set of persistent buttons at the top of each screen (Figure 1).

In the first phase, corresponding to the "library" category of a MLM, the tool prompts the user to enter data such as author and specialist names, MLM purpose, and keywords. Defaults, such as the institution name and file name are hidden from the

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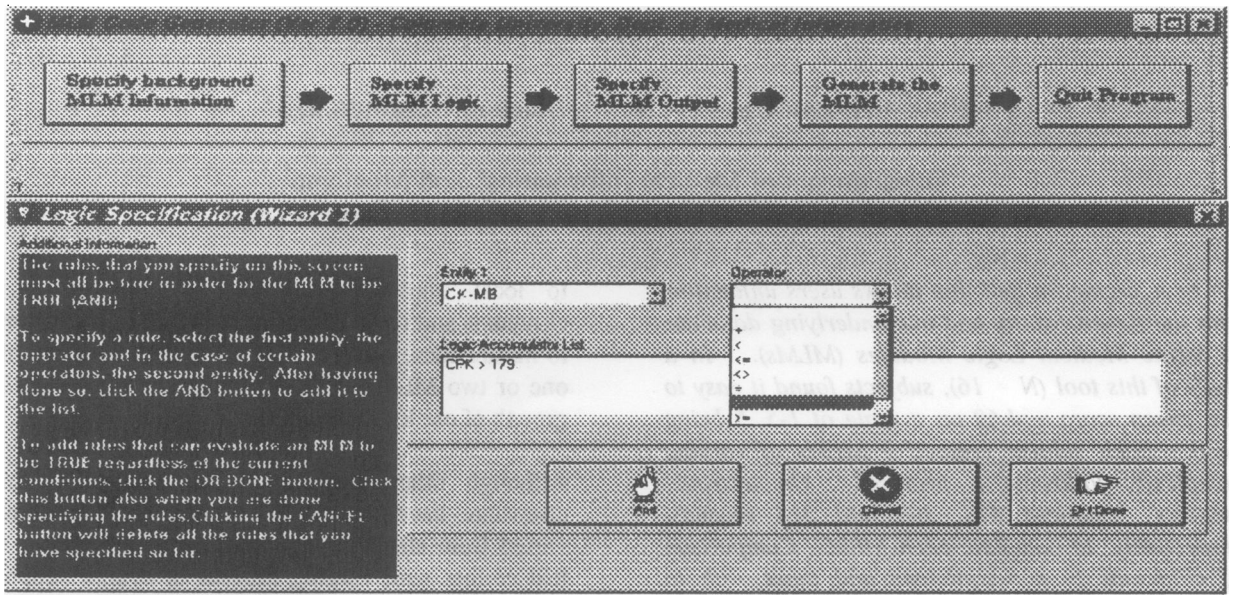
Figure 1. Navigation buttons and logic capture.



user. Drop-down pick lists are provided as an input tool for other information.

In the second phase, the user specifies the logical conditions that, if fulfilled, will cause the MLM to generate a message. However, the entry here is constrained in order to hide the details of the Syntax from the user. Instead, the user can pick from a controlled vocabulary of data elements already mapped to previously defined queries to the clinical database. In a similar way, the user can pick a comparison operator, which in turn permits entry of a second operand if the operator is binary. These individual conditions can be specified as disjunctions (the default) or conjunctions to achieve conditions of arbitrary nesting. As conditions are created, they and their connectives (conjunction or disjunction) are displayed in a logic "accumulator."

In the third phase, the user specifies the content of the alert message. Again, this is done by picking from a controlled vocabulary already mapped to data queries. Unconstrained text labels also may be entered. Users also can enter trigger elements from a controlled vocabulary.

Both the second and third phases require a collection of data elements already mapped to queries that, when executed, retrieve the relevant data element from our central repository. Choosing a data element in either phase places the appropriate query into the MLM; redundancy is checked and eliminated. We use Microsoft Access to map the data elements to the relevant queries, retrieving them using the Open Database Connectivity (ODBC) protocol. This preserves modularity and allows databases of queries from other sites to be used instead. The queries in this database are the most frequently used queries in our current knowledge base. Once inserted into a MLM, a query may be edited directly by the experienced user in order to refine it, but we find that the collection of queries from our current knowledge base suffices for most clinical research purposes. We are interfacing a separate query-building tool to provide additional support for this process.

Once all three phases are completed, the user then may click a button to generate the MLM. Until that point, he or she may return to any phase and edit previous selections as desired. Direct editing of the file is permitted. When the MLM is generated, it is stored in a text file that then can be uploaded to our decision support system for execution.

Throughout the tool, context-sensitive "balloon" help text and message bars assist the user in the process of constructing the MLM.

Experimental Design

We solicited subjects from a variety of groups, including staff physicians who previously had requested MLMs, staff programmers, and graduate students and faculty in medical informatics. The CPMC Institutional Review Board approved the

study, and all subjects provided written, informed consent.

Each subject was given an instruction sheet detailing three scenarios and was asked to use our tool to construct three MLMs in accordance with the scenarios. Each scenario briefly described the clinical condition of interest and the situation that should prompt the MLM to generate an alert. Scenario #1 used a single simple condition (a > b) to detect possible acute pancreatitis based on hyperlipasemia. Scenario #2 used a conjunction of two simple conditions ((a > b) AND (c > d)) to detect myocardial infarction based on total creatine kinase and MB fraction values. Scenario #3 used a still more complex condition |((a > b) AND (c > d)) OR (e < f)| to flag risk for coronary artery disease based on high values for total cholesterol and LDL-cholesterol or low values for HDL-cholesterol.

For slots with unconstrained text entry, such as title and explanation, we asked the subjects to complete them in a way that reflected the subject matter of the MLM.

The time required for each user to complete each MLM was recorded. In addition, after completing all three MLMs, each user completed a questionnaire that queried his or her level of clinical experience (physician or not), frequency of computer use, previous computer programming (yes or no), and previous Arden programming (yes or no). In addition, using a 5-point Likert scale (1 = worst, 5 = best), users were asked to assess the ease of use, the clarity of the on-line instructions and the flow of the program.

The resulting MLMs were compiled and, if possible, executed in testing mode on our decision support system to verify correct function. In addition, two expert Arden writers independently assessed the text file of each MLM for omissions and erroneous inclusions. Observers were blinded to the identity of the subjects during data interpretation.

RESULTS

Sixteen subjects from a variety of backgrounds were recruited. Characteristics of the subjects are detailed in Table 1.

The physicians included residents, clinical fellows and attending faculty. The non-physicians included graduate students in medical informatics, staff programmers and administrative personnel. All subjects had extensive experience as computer users, logging on to a machine more than ten times a week. However, only a minority had composed MLMs.

Table 1. Characteristics of study subjects.

TOTAL SUBJECTS	16
CLINICAL EXPERIENCE	
Physicians	7
Non-Physicians	9
ARDEN EXPERIENCE	
Yes	4
No	12
PROGRAMMING EXPERIENCE	
Yes	15
No	1

Each of these subjects completed three MLMs, resulting in a total of 48 MLMs. Of these, 47 compiled correctly. The one that did not compile had an error in the filename slot introduced by a bug in the tool, which fills that slot automatically based on a function of user-specified background information.

Two expert MLM writers independently assessed the text file of each MLM for appropriateness of slot content and for logical correctness compared to the written scenarios provided to the subjects. Minor errors were noted, but these occurred primarily in the "action" slot of the "knowledge" category. Typically these were caused by subjects failing to include a requested item in the output or by specifying more output information than requested. No errors adversely affected the function of the MLMs. The two evaluators disagreed on the assessment of the evocation slot of the most complex MLM (#3), but this disagreement arose from whether to include a test used previously in our laboratory but no longer actively used (and thus unable to trigger a MLM).

After creating three MLMs each, subjects were asked to evaluate the tool for three different characteristics: ease of use; understandability of instructions and help screens; and flow of the program. This evaluation is presented in Table 2. We compared pairs of subgroups (physicians versus non-physicians and Arden writers versus those without Arden experience) for each category in order to determine if these characteristics affected the response. A two-tailed t test was used to assess significance. No

significant differences were seen, and the responses were uniformly positive.

In addition, we timed each user as he or she created each MLM from scratch in order from scenario #1 (corresponding to MLM #1) to scenario #3 (MLM #3). These data are presented in Table 3. Again, as in Table 2, we compared pairs of subgroups to determine if these characteristics affected speed of composition. Significance was assessed with a two-tailed t test. Physicians tended to compose MLMs faster than the non-physicians, but this trend was not statistically significant. Although those with previous experience of Arden wrote MLM #1 more quickly than those without experience, the opposite effect occurred for the more complex MLMs; however, none of these differences was statistically significant.

Table 2. User evaluation of tool. STD is standard deviation. NS denotes not significant. The best score is 5.

CATEGORY	MEAN	STD	P VALUE
EASE OF USE (overall)	4.69	0.60	
Non-Physician	4.67	0.71	NS
Physician	4.71	0.49	
Non-Arden writer	4.67	0.65	NS
Arden writer	4.75	0.50	
TOOL HELP (overall)	4.56	0.60	
Non-Physician	4.67	0.50	NS
Physician	4.43	0.79	
Non-Arden writer	4.58	0.51	NS
Arden writer	4.50	1.00	
FLOW OF TOOL (overall)	4.38	0.80	
Non-Physician	4.56	0.53	NS
Physician	4.14	1.07	
Non-Arden writer	4.50	0.52	NS
Arden writer	4.00	1.41	

All subjects said they would use the tool in practice.

DISCUSSION

All subjects, regardless of past experience, found that our tool was easy to use, offered understandable assistance in its function, and afforded a facile flow of work. Moreover, even persons unfamiliar with the Arden Syntax--a majority of the subjects--were able to create practical MLMs. They did so in a reasonably quick time: typically between five and six minutes for a MLM. Although we did not compare our tool to construction of a MLM without any tool at all, we assume that the clinical user without knowledge of Arden--the target audience for our tool--would take considerably longer than this to fashion functional MLMs and would have to master the relevant programming skills in the process. Although we have found no other published data to compare our tool to others on this variable (time), our data suggest that our tool can be used quickly and easily.

In turn, this illustrates the importance of information hiding in this tool. By shielding the user from the target language and providing an easy-to-use graphical interface for the capture of domain knowledge, our tool permits even busy clinicians with no prior experience to create significant MLMs without needing to know the target procedural language and database structure.

Table 3. Timing of MLM composition (in seconds). STD is standard deviation. NS denotes not significant.

CATEGORY	MEAN	STD	P VALUE
MLM #1 (overall)	312	95	
Non-Physician	313	76	NS
Physician	311	122	
Non-Arden writer	324	101	NS
Arden writer	277	76	
MLM #2 (overall)	308	115	
Non-Physician	326	131	NS
Physician	284	95	
Non-Arden writer	304	123	NS
Arden writer	319	103	
MLM #3 (overall)	318	136	
Non-Physician	336	167	NS
Physician	295	91	
Non-Arden writer	305	120	NS
Arden writer	357	194	

Of course, such information hiding comes at a cost: reduced expressive power of the tool. As a result,

some direct editing of the MLM, such as that afforded by our query-building tool, may be required. However, this matches the needs of our target audience: clinicians who want to compose rules but who do not want to learn a programming language in order to do this. Thus, we need to balance expressive power and interface complexity.

In this regard, though our subjects easily used and approved of the tool, the vast majority were experienced computer users, and this may have biased the results in the positive direction. Also, the relatively small sample size may detract from the overall results as well as the subgroup analysis. In partial rebuttal, subgroup analysis revealed no significant difference in user opinion or speed of composition based on clinical or Arden experience. Moreover, no matter the level of experience, all but one test MLM compiled and executed correctly.

FUTURE WORK

We plan to convert the current user interface to one compatible with the World Wide Web. In addition, to overcome the need for direct editing to create complex queries, we will interface this software to a query-building tool (Hripcsak G. Personal communication) that provides additional support for constructing queries in our data environment.

Finally, we will incorporate this tool into an integrated MLM authoring and testing environment. This integrated tool will allow the user to create new MLMs; download and edit old MLMs from a central repository; activate new MLMs in the repository; test the MLMs against a local database remote from the hospital production environment; filter clinical data from our central repository to serve as test data; and insert sample data into the local test database.

SUMMARY

Responding to the need to expand our Arden knowledge base, we have created a tool that allows clinical researchers to compose MLMs rapidly without having to know or even look at the underlying procedural code. A group of experimental subjects, mostly persons who never have written a MLM, found this tool acceptable and easy to use. MLMs produced with the use of this tool were syntactically appropriate and functionally accurate.

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