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INITIAL DEVELOPMENT OF AN AUTOMATED TASK ANALYSIS PROFILING SYSTEM

C. C. Jorgensen

Reliability and Human Factors Group
Oak Ridge National Laboratory
Oak Ridge, Tennessee

ABSTRACT

A program for automated task analysis is described. Called TAPS (task analysis profiling system), the program accepts normal English prose and outputs skills, knowledges, attitudes, and abilities (SKAAs) along with specific guidance and recommended ability measurement tests for nuclear power plant operators. A new method for defining SKAAs is presented along with a sample program output.

INTRODUCTION

In recent years considerable attention has been given to job task analysis as a critical element in both training program development and personnel requirements identification. As a result, proceduralized definitions for task analysis have been developed as part of integrated approaches to instructional system development such as the AFP 50-58 (Handbook for Designers of Instructional Systems). Unfortunately, when training developers actually begin to apply the handbooks, they rapidly discover there is a gap between the desired degree of end-product specificity and the technical tools actually provided to produce them.

The procedures available for task analysis are a case in point. In practice it is generally a highly subjective process that draws on observations of job performers behaviors and combines them with an analyst's expert knowledge of systems to produce a functionally useful set of skills, knowledges, abilities, and attitudes (SKAAs). The procedure often winds up being an art rather than a science and as a result is subject to a variety of shortfalls characteristic of highly subjective procedures. Task analysis is thus very sensitive to the experience of the analyst, the adequacy of the job description, and the observation sample used.

Because task analysis is used for a variety of purposes including courseware development, entry level skill identification, performance standards development, and personnel selection, large variations in task analysis quality can be very costly in time and resources. Unanticipated costs often occur as a result of repeated site visits to extract missed information, correct erroneous assumptions, or modify incorrect courseware materials.

The greater the complexity of the equipment, the more severe the problem becomes. The end result is growing pressure for faster, more economical methods to support training

development. As part of a contract with the Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, initial development of an automated task analysis system designed to assist training developers in nuclear power plants has been completed. Called TAPS (task analysis profiling system), this tool is designed to accept normal English descriptions of reactor operator actions and automatically generate an analyzed list of SKAAs along with associated application principles and in the case of abilities, recommended performance measurement tests. The following paper describes how TAPS deals with the problem of SKAA identification, what features the current version of TAPS possesses, and needs for future research.

The Problem of SKAA Identification

The process of task analysis consists largely of a content analysis of the behaviors occurring during job performance. As Gael (1983) points out, a typical task involves a mixture of decisions, perceptions, and/or physical activities required of one person. It may be of any size or degree of complexity and is directed toward a specific purpose. Unfortunately, there is not general agreement on one definition for tasks and many have been proposed:

o An action or sequence of actions performed closely together in time and directed toward an objective, common goal, or outcome.

o A unit of work that is a consistent and significant part of a duty or is a logical and necessary step in the performance of a duty.

o An orderly, homogeneous grouping of goal-oriented human activities applied methodically to things or equipment and usually performed by one person in less than a day. Task activities have an observable start and stop and are composed of elements or simple discrete responses that are carried out in a cumulative and progressive sequence.

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o A series or set of work activities needed to produce an identifiable output that can be independently consumed or used or can be used as an input in a further stage of production by the performer or someone else.

For the purposes of TAPS, the functionally most important distinction is one which separates information pertaining to the significance of the task for the entire job (such as importance, difficulty, and frequency) from information associated with the performance resources necessary to execute the task-behaviors (the SKAAs).⁵⁰ The former case has been addressed through another automated tool (Jorgensen, Haas, Selby, and Lowry, 1983) and will not be discussed here. The latter, however, presents particularly difficult problems for three reasons. First, there is tremendous ambiguity associated with existing definitions for SKAA elements. Second, off the shelf lists of SKAA elements do not exist which consider the full range of behaviors associated with skilled human performance even though tremendous amounts of work have been put into the development of psychological taxonomies (e.g., Bownas and Cooper, 1978). Finally, for those SKAAs that do exist, there have been few efforts to systematically aggregate adequate measurement tests (Finley, Obermayer, Bertone, Meister, and Muckler, 1969) or training principles (Wheaton, Fingerman, Rose, and Leonard, 1976) which should be associated with general SKAA items.

SKAA Definition for Automated Analysis

To overcome the problem of definition of terms, a new way had to be found to describe SKAA elements that would be suitable for machine analysis of English text. The area of "natural language processing" has become very active in recent years due to the rise in awareness of artificial intelligence techniques (Marcus, 1980; Dyer, 1983) and has provided a good deal of insight into the true complexities associated with text understanding.

Unfortunately, although techniques are available, the application of those techniques to specific knowledge domains comprises formidable problems. In the case of TAPS, these problems crossed theoretical, practical, and computational bounds. For example, a definition of a human ability such as "perceptual speed" has generally relied upon text descriptions and the opinion of a task analyst such as the following:

Perceptual Speed

"The ability to compare sensory patterns quickly in order to determine identity or similarity."

Although appearing easy to use, such a highly general definition can lead to a great

deal of disagreement over what constitutes a "perceptual speed" instance. For example, it may be understood that perceptual speed is a visual ability combined with a cognitive activity of recognition or recall. It is not clear, however, if the "sensory patterns" could also refer to other senses, e.g., auditory recognition of mores code strings, or tactual recognition by a pilot of changes in g-forces. Thus, from the standpoint of an automated tool to identify "perceptual speed," a more precise method of definition is needed. Mallamad, et al. (1982) recognized the same problem and proceduralized some ability definitions through a series of question/answer flowcharts that eventually led to the identification of individual abilities (if the right questions are answered in the right order or even asked in the first place). Unfortunately, such a system, and efforts to automate them (Rossmeliss, et al., 1982), place a tremendous resource demand upon a user since each task must be scanned for an individual ability through a separate question/answer path. To apply such an approach to the field analysis of SKAAs would quickly produce massive resource demands on the analyst that would outweigh the benefits of the faster, albeit "noisier" subjective approach.

TAPS has taken another approach in that it recognizes from the onset that resource demands on the user are a critical component in the ultimate implementability of a training development tool. The key to the success of the approach lies in its ability to define task instances in a flexible manner capable of accepting many different potential sentence variations of the same underlying idea. Thus, "rapidly spotting a change in a temperature gauge" or "detecting a panel meter deviation in less than ten seconds" must both be recognized as an instance of "perceptual speed" by the definitional rule.

TAPS accomplishes this flexibility through an approach analogous to choosing dinner items from a "Chinese menu." In a typical Chinese dinner an acceptable "meal" is defined as picking one item from Column A, one from Column B, and one from Column C:

	<u>A</u>	<u>B</u>	<u>C</u>
	Item 1	Item 1	Item 1
	Item 2	Item 2	Item 2
"meal" =	Item 3		
	Item 4		

If Item A-4 was fried rice, Item B-1 was pepper steak, and Item C-2 was lychee, "meal" would be [fried rice, pepper steak, and lychee], on the other hand, another perfectly acceptable instance of "meal" could have been [chicken chow mein, white rice, and sherbert] which would represent a different path through the columns. A similar logic may be applied to defining

skills, knowledges, attitudes, and abilities. For example, another way to define perceptual speed could be:

	A	B	C
"perceptual speed"	Sees Hears Spots Observes Notices	In Less Than Before In Under	Visual Acuity Test <u>*Auditory</u> <u>Reaction</u> <u>Time Test</u>

Keep columns within shaded area.

where one acceptable instance of a "perceptual speed" indicator is [spots in less than].

If, as is the case in task analysis, the process is now reversed and we are presented with an instance which may represent "perceptual speed" embedded in other information such as:

"I must hear the change in charging pump frequency in less than 10 seconds."

then "perceptual speed" could be detected in the sentence by using a pattern recognition technique to spot the underlined word combinations and recognize they correspond to an acceptable "path" through Columns A and B. To go further, however, once "perceptual speed" is identified, the ability name in turn can function as a pattern that points to an acceptable performance test such as the "auditory reaction time test" in Column C.

To accomplish the pattern matches it was helpful to develop rule processing procedures in a computer language suited to manipulation of sentence strings. Because of its ease of use and highly readable code, a simplified version of the LISP language called LOGO was used to initially code the procedures.

Two of the key LOGO pattern match routines are presented in Fig. 1. Their routines can find definitions created by arbitrary numbers of columns (the perceptual speed example used only two) as well as variable numbers of words within each column's items ("within" vs. "in less than"). Thus, the definitional scheme provides two major benefits. First, definitions can be as simple or complex as desired within the same program. Thus, SKAAs can be sought at general "function only" levels or at highly specific "critical instance" levels of detail. Second, definitions can be changed literally in seconds making adjustments and changes trivial operations rather than having the understanding process "hard wired" into the code. That is, the guidance of the program to locate SKAA definitions resides in

Figure 1. Two key pattern match routines in TAPS used to implement "Chinese menu" definitions

```
ms (match string): used to scan multiple columns
in menu definitions
to ms:t:x
if:x = [] [op 0]
if M:t s1 first:x [ct (pr [found] first:x) op 1]
[if:maxx first first:x [op 0] [op ms:t bf:x]]
end

m_(match pattern): used to locate single or
multiword patterns within a menu definition'

to m:s:t
if empty:t [op "TRUE"]
if empty:s [op "FALSE"]
if wordp:t [if first:s = :t [op "TRUE"] [op m
bf:s:t]]
if first:s = first:t [op m bf:s bf:t] [op m
bf:s:t]
end
```

a data base not the program. Thus, applications to new environments outside the nuclear industry are greatly simplified.

SKAA Taxonomy Development

Because readily usable SKAA lists did not exist in "Chinese menu" definition forms they had to be generated. Existing taxonomies were surveyed and evaluated as to usability. It soon became apparent that an evaluative criteria for inclusion or exclusion had to be developed and in some cases (for example, cognitive skills) entirely new elements needed to be produced. To facilitate this process a model of skilled human performance was generated. The model proved particularly useful for the analysis of cognitive behaviors and will be considered in a later paper. The transformation of existing taxonomic elements into menu forms was accomplished in two steps. First, all available definitions were compiled for taxonomic items along with an analysis of key word patterns which occurred in the examples presented as definition instances. Second, key word patterns were subjected to a computerized thesaurus to find as many equivalent terms as possible. The resulting lists were then screened for applicability and entered into the structured data base described above. The result was a large set of "menu" definitions, one of which is shown in Fig. 2. Since the primary focus of TAPS was to quickly identify abilities associated with entry level requirements of nuclear power plant operators, lists of usable measurement tests were generated for each ability and rank ordered by factor loadings. TAPS code was written so as to automatically reference these lists whenever a task analysis identified a particular ability as present. In order to illustrate the full potential of the

technique, other types of lists were also generated for skills, knowledges, and attitudes. These lists allow the automated

LIST NAME: ABILITIES	
COMPONENTS	VERBS, Q/Q, TESTS
Perceptual Speed (PS)	
PSVERBS	
Recognize	
Identify	Columns within shaded areas
Detect	
Spot	
Notice	
Discover	
PSQ/Q	
in-less-than	
within	
in-under	
before	
PSTESTS	
Dial and Table Reading (178)	
Coordinate Reading (178)	
Speed of Identification (154)	

Figure 2. A sample "menu" definition with an associated principles list.

printing of applications, principles, potential safety risks, and even generate customized advice which can be used by a training developer. Lists were developed for every taxonomic item, however, a rigorous compendium of human factors information was not attempted within the scope of this effort.

Features

TAPS has incorporated a variety of features designed to simplify the task analysis process. Figure 3 illustrates some of an actual output for a sample sentence that illustrates TAPS capabilities. At the top of the figure is the original sentence which shows errors in capitalization, punctuation, and includes technical abbreviations. The second sentence is the result of the first analysis step in which TAPS cleans up obvious errors and expands the abbreviations to their full length. Thus, HPCI becomes high pressure coolant injection, capitalization is normalized, and punctuation is removed. Although the example uses a single sentence, TAPS is not text limited, and works just as efficiently on paragraphs or even multiple pages of typed descriptions.

The analysis then proceeds to systematically output skills and the information associated with them, knowledges, then attitudes, and finally abilities. The skill detected in Fig. 3 illustrates the ability of the program to serve as an automated source of specific guidance to a training developer by listing human factors insights associated with skill categories. Knowledges illustrate another capability of the program.

<p>The original typed task was:</p> <p>Based on abnormal sonic probe readings, infer from NRC bulletins on corrosion that HPCI, safety limits require circuit breaker maintenance!</p> <p>The TAPS expanded task used for computer analysis was:</p> <p>based on abnormal sonic probe readings infer from nuclear regulatory commission bulletins on corrosion that high pressure coolant injection safety limits require circuit breaker maintenance</p> <p>Skill detected: diagnosis</p> <p>*** some important principles are: ***</p> <p>—Be particularly careful of this task if it involves maintenance, diagnostic skills can have wide individual differences</p> <p>Knowledge requirement for: reg. guides</p> <p>Relation of nuclear regulatory commission bulletins to plant operations. Literacy level for proper reading of nuclear regulatory commission bulletins.</p> <p>Attitude detected: personal responsibility</p> <p>*** points to consider and possible impacts are: ***</p> <p>This task probably involves unsupervised action, careless individuals may not be suited for it.</p> <p>Be alert for emotional situations that could impact safety such as marital problems.</p> <p>Ability detected: deductive reasoning</p> <p>*** some acceptable tests are: ***</p> <p>— Complex deduction test #181</p> <p>— Logical reasoning test #168</p> <p>Figure 3. A sample excerpt from a TAPS sentence analysis.</p>

After a general knowledge category such as "regulatory guides" was detected, the program retains specific information about the particular instance of regulatory guide that was found. It then inserts the information into a sentence frame so as to produce customized textual material specific to the task being analyzed. The advice can be as detailed or general as desired but only very simple principles are used in the present TAPS version. The detection of attitudes illustrates the capability of TAPS to use indirect clues. Since attitudes generally have to be inferred, TAPS recognized that the HPCI was a safety related system and that the sentence was referring to maintenance behavior. Consequently, an individual's attitude toward "personal responsibility" could have a significant safety impact if maintenance was done unsupervised or in a slipshod fashion. Finally, the "deductive reasoning" ability illustrates that TAPS could be used to produce customized tests in real time.

CONCLUSIONS

TAPS is currently running in a demonstration mode on an IBM-PC in digital research LOGO and in developmental form on an IBM 3033 mainframe. Although capable of analyzing the entire definition base, the execution speeds of the PC are slow compared to a mainframe computer and it is being used primarily as a code development tool. The high speed system under development for an IBM 3033 has tested out about 2000 times faster in execution times. Preliminary analysis indicates a typical 500 task analysis would require about 2 minutes not counting printer delays. The full version will have additional features such as verb tense flexibility, multiple function switching to permit the results to be used for test development as well as instructional development, and data base linking. The latter capability would permit TAPS to function as a front end to existing data bases of task information so as to permit rapid re-analysis of existing information. In summary, TAPS in its current form provides a promising indication that automated task analysis is possible and can be constructed in such a manner as to be highly situation general. Considerable work should be done to examine the generalizability of the "Chinese menu" approach and to link existing bodies of human factors principles to taxonomies. TAPS does, however, appear to provide a research basis for a significant advance in moving task analysis toward a faster more standardized technology.

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