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Cognitive Task Analysis Method for System Interface Design

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***Abstract*—**Poor perception from human interpretation on system interface design may deviate human critical judgment about state of a system. As a result accidents may occur due to misinterpretation on displayed information available on the screen. In relation to that, this paper describes designing scenarios for system interface design which reflects with user's working context. System interface design that familiar with working context will help to increase user's satisfaction and the ease of use of a particular system. Moreover, through the process in designing scenarios also leads to the identification of problems and how experts deal with challenging tasks in using the system. Human abstract thinking which could not be gather in a quantitative way motivate authors to employ Cognitive Task Analysis method in collecting system interface design requirements from the experts as to design task scenarios. In general experts involve in this study are from the manufacturing industries where their daily scope of work is in system maintenance tasks. There are five phases involve in Cognitive Task Analysis; define tasks, select participants, task observation, task diagram and knowledge audit. Results from the interview and observation session will give an essential clue in designing scenarios for system interface design. This is because in knowing a correct problem to solve and provide cues at a needed point in time will help users to interpret information on system interface design.

Keywords – human cognition; interface design; human computer interaction; human perception

1. INTRODUCTION

Social Security Organization (SOCSO) under the Ministry of Human Resource Malaysia claimed that accidents at workplace had increased by 3.5 percent, from 34,376 cases in 2009 to 35,603cases in 2010 [1]. In relation to that, if an accident occurs either the employee will suffer permanent disabilities in life or it may cause death. Thus, this situation will affects not only to family but also the organization as a whole. In other words, it is costly and time consuming to train employees to be able to handle a system. To provide meaningful and relevant information for users in system interface design, researchers will help users to manage the system in an efficient way.

Errors in human-system interface are deviations from desired conditions [2]. In order to make a correct judgment, decision makers sometimes try to recall their experiences, tasks at hand, cognitive processing capabilities and use available decision making. Three factors that influence human decision making in dealing with a system are [3]:

- human characteristics,
- task characteristics, and
- user interface design

This paper will discuss problems faced by experts in the field of manufacturing industries, in particular a system that produce glass bottles. Safety and productivity is essential in producing bottles because it involve accuracy and immediate response from a person who control the system. For instance, overheat temperature cabinet to mold the bottles may cause fire, while in balance air pressure and heat will produce rejected bottles. To avoid disaster from happening, thus it is essential to know types of errors usually users encounter, types of information or cues that the user need, factors that help users to increase ease of use of a system and the ability of experts to sort problems if the system in a faulty conditions.

In addition, as stated in the Ninth Malaysian Plan under Thrust One, Malaysian government will highlight on the application of high technology and production of higher value added products. Therefore, it is the role of the researchers to bridge the gap between human and systems so that future system is more users friendly and easy to learn. Some of the researcher that discusses human cognition related to complex system design is [4], [5] and [6]. As human performance depends on how human process available information conveyed to them via the system interface design, researcher also concern on how the system design able to provide useful information to be used by different types of users' background [7]. For instance, to design systems that will be able to use by skill users, intermediate users or novices users who are generally depends on the available information conveyed to them so that it is easy for them to use the system. Besides, with the current trend of technology, systems could possess more cognitive like capabilities to enhance user's performance.

FIGURE 1: Number of industrial accidents reported, 2006-2010 [1].

2. COGNITIVE THEORY

Theoretical framework that will be used in this research is Rasmussen Skill-Rule and Knowledge Cognitive Control Model. Since human cognitive processes involve several phases, the role of cues in system interface design is vital as cues from the system will guide user to perceive relevant or irrelevant information that may leads to user's reactions towards the system. In conjunction to SRK Cognitive Control Model, this model gives broad information related to human performance [7]. Since human performance varies from one another, SRK Cognitive Control Model allows the researcher to study human performance at three different levels of users. Firstly is the Skill-user (expert), Rule-user (intermediate user) and finally is the Knowledge-user (novice).

The skill user usually depends on cues that available around them to give response in terms of actions. In deed the cues automatically activates user's actions without even knowing consciously which information exactly help them to generate the response [7]. Whilst for rule based user, they need a variety of information. The cues help rule based user to recall and relate information stored in their long term memory to perform actions. However if rule based user could not think of any solutions or actions, a person may switch to the category of knowledge based user. Knowledge based user usually need more information from environment to generate ideas and hypothesis on a particular situation. However knowledge based user only generate the best action to be executed, and if the actions fail they will generate a new solution and evaluate until a suitable one is selected [8].

The role of system interface design is essential as the graphical or cues used by the system could help users to control a process or application of the system. Research on the notion of perceptual user interfaces [9] focus on the traditional work on human perception and [10] concentrate on perceptual bandwidth of the interaction. In addition, Shannon-Weaver model was design to deal with functioning of a communication system [11].

In the context to increase the ease of use of a system, users action were no longer seen as exclusive outcome of mental activities but it is an intertwined with system design and cues available in users environment. In deed the use of system design and cues became a key activity in the study of applied cognition [12]. Consequently study on designing scenarios for system interface prototype usability testing will contribute to the notion of a system that will help users to enhance their performance in using the system.

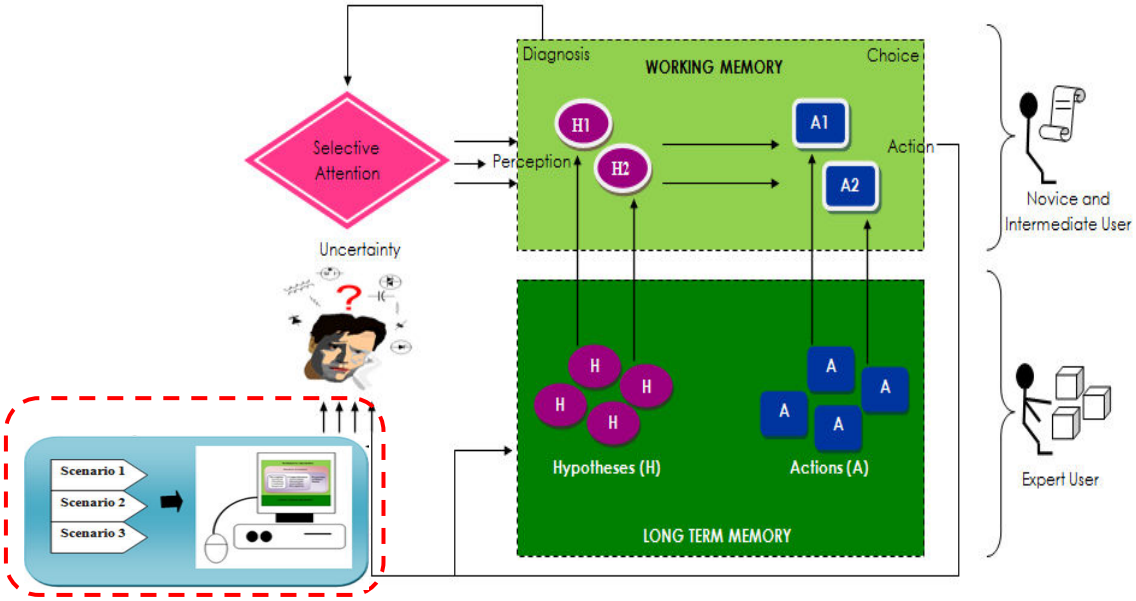

FIGURE 2: Human cognitive control model in system interaction design adapted from [7].

A. *Scenarios*

Scenario is a description of the activities a user might engage either using text or storyboard. In addition, scenarios also highlight goals suggested by the appearance and behaviour of the system. For example, through scenarios we are able to know possible actions that the user will consider in dealing with the system, types of procedures that the user will choose in guiding them to make a good interpretation towards the system.

Besides, scenarios will help system designer to explore ideas and the outcome of design decision in a particular situation. In fact, designing scenarios is important because system designers will be able to improve users interaction between the system and hence to anticipate problems encounter at the stage of system usability testing. As in this study we will only discuss on the process of designing scenarios for system interface design usability testing.

Additionally, scenarios can be used to validate other models. For example, a detailed scenario can be used in task model representations or dialog and navigation models [13]. Also, scenarios are used to evaluate the applicability of psychological theories to usability [14, 15].

3. COGNITIVE TASK ANALYSIS (CTA) METHOD

Cognitive Task Analysis is one of the method that describe the cognitive processes happens in human memory. CTA method is an extension of task analysis method that explains about knowledge, thought processes and goal structures which underlie observable task performance [16]. In other words, CTA methods bring together goal generation, decision making and judgment into human cognition [17]. Indeed from CTA we can get inputs for system interface design, designing procedures and processes of a particular system, allocation of system functions, procedures to conduct training session and information related to users or group performance within the system.

One of the reason we employ CTA method in this study is because CTA offers an analysis of cognitive processes which in line with human decision and selected actions. Two of the CTA techniques used are interview and observation techniques. Interview sessions with the experts are important as their skills and knowledge in solving critical problems in handling the session will give inputs to the author to design system scenarios. Designing tasks for scenarios is critical because from the analysis we will be able to provide useful information in guiding users to use the system efficiently. CTA procedures are adapted from [18] and discuss as the following.

A. Define Tasks

Task Analysis in this study is define by focusing on designing scenarios for system interface design which will help to increase the ease of use of a system. Familiar context gain from scenarios design will provide useful information for users in supporting them to better utilize the information available on system.

B. Select Participants

In general CTA method in this study is based on interview and observation data and for that reason cooperation from experts are needed since it involve longitudinal interview process. Indeed considerable time and effort is required to conduct the whole complete CTA sessions [18]. In this study, we will interview engineers from the manufacturing production system who has a wide knowledge and experiences in handling the system. Their role is to help the author to design CTA scenarios for prototype usability testing in this study. However this paper only discuss on CTA scenarios design from the experts.

Three experts involved in this study whereby one of the experts is an IT Instructor and another two are engineers from the manufacturing industries. Additionally, in heuristic analysis, three to five evaluators are sufficient. In addition, Nielsen found that using five evaluators would be sufficient for the discovery of about 75% of the overall system evaluation problems and it is possible to achieve substantially better performance by aggregating problems from several evaluators [19, 20]. Most of the experts have more than five years of experience in system maintenance and their daily job is to make sure that the system will runs smoothly. If there are problems with the system they need to resolve it within a limited time. Perhaps this is due to the bottles production process target whereby the production department needs to meet company's daily target in producing the bottles.

C. Task Observation

To design scenarios that include an involvement of users to perform their tasks, observation on the real working context also need to be done to allow the researcher to fully understand the tasks and user's role in using the system. For this study, the tasks and scenarios will be design through an analysis on the machine's fault history archive and to consider if problems that occur while using the system affect the manufacturing production process.

D. Task Diagram Interview

Purpose of having the task diagram interview session is to get an overview of the tasks analysis in a form of a diagram. At this stage experts need to decompose the tasks into relevant sub tasks. Some of the questions that can be used in this session are:

- Think about what do you do when you perform the task under analysis
- Can you break this task down into less than six but more than three steps

The questions used for interview sessions were adapted from Rasmussen CTA framework. Keywords and evaluation criteria in Table 1 will be used by the author to guide them for the interview sessions. In general the questions is related on what, why, who, when and how the experts usually come out with solutions when dealing with certain problems or tasks in dealing with the system. Once the task is categorize into different subtasks, the experts then will be asked to identify which of the sub tasks involve decision making, thinking skills and problem solving.

Task diagram interview sessions will be analyzed using verbal protocol analysis in order to map up with the tasks diagram drawn by the experts with the recorded data. Verbal protocol analysis is an observation where the user is asked to talk through on what the user is doing during the observation stage [13]. For instance, the user is free to talk about his actions, feelings, decision or anything that he is trying to do.

One of the advantages in using verbal protocol analysis are, CTA method able to record abstract data from users where certain information gain from the users usually could not be measured quantitatively. For instance data which involve feelings, happy or sad in using the system interface design and what actually makes them to have such feelings will be very easy to explain through words rather than writing.

TABLE 1: Rasmussen CTA framework

Keyword	Criteria to be evaluated using CTA framework
Evaluate	Performance criteria
Interpret	Consequences for current task, safety, efficiency
Identify	State of the system
Observe	Information and data
Activation	Detection of need for action
Define	Task or select change of system condition
Formulate	Procedure, plan sequence of actions
Execute	Coordinate manipulations

E. *Knowledge Audit*

At the knowledge audit stage, the subtasks or instances will be finalized in accordance to the tasks analysis within the context of user's interaction with a system interface design. For instance, specific critical cues and decision making strategies could be asked to the experts for instances identification.

4. FINDINGS AND DISCUSSION

It is a challenge to find solutions to sort a faulty system that did not give much information to users. Therefore, it is crucial to design scenarios that will meet the system working context. For instance, an evaluation that is done using design scenarios will make the research context more focus and able to highlight the needs of a particular research objectives. For this study, our aim is to design scenarios that will highlight cues that help users in handling the system.

A. Task Observation Findings

Besides interviewing the experts, we also analyzed problems archived in the events history of the servo system. Through the archived data we are able to retrieve common system faults from the system. This will be a good input to design scenarios that will focus on such problems and furthermore will lead us to include appropriate cues for system interface design.

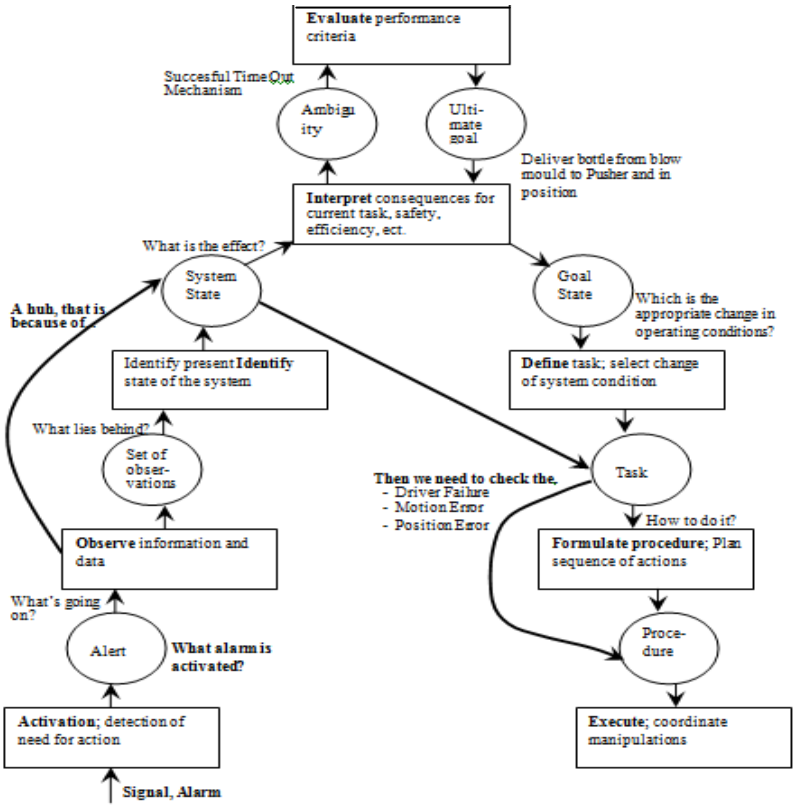

FIGURE 3: Experts cognitive task analysis framework in maintaining system operation

Experts also claim that they will continuously monitoring the system and once the problem strike, they will check for the types of problems, and then they will think of the right solutions to solve the problems. Usually, the problems were recorded according to date, time, code and description. Although, the description represents a short description on the types of problems occur during the production process, the system did not give any cues or solutions about the stated problems and therefore, experts need to think of what is the best solution to solve the problems.

This may not give much trouble to the experts, but for the novices it will take more time for them to understand the problems. Thus, it is essential to provide meaningful cues or information to system users.

In this production system process, there are four types of events history; Distributor EGD200, Timing EFC200, Servomechanism SMC450 and Driver FMC200 included in the system. Nevertheless we only focus on Servomechanism and Driver event history because feedback from the experts shows that these two events were actually critical and usually occur if an alarm strike. Moreover experts also claimed that for both Servomechanism and Driver are derived from the failure of the system driver, motion and position (cable) failure.

B. Task Diagram Interview Findings

Findings show that experts come out with specific framework in their mind by recognizing or diagnosing some of the cues available on the system and with the goal to solve problems in a very short time. Time is a critical factor for the production team because this will affect the production process in producing the bottles.

Experts also reported that some of the manuals and procedures for the servo system are not available on the manufacturing production system. There are no cues to visualize the manuals or procedures on the system because it is kept in a hard copy version. Experts need to flip and look through all the manuals in a traditional paper based files in order to look for the solutions. Therefore more time is needed to go through all the searching process. In addition, the experts also mentioned that at certain point, they need to memorized system's problem solving procedures and make their own short notes with the aim to remember some of the solutions purpose of remembering the solutions.

In addition, figure 3 illustrates the task diagram whereby the experts did not experience any difficulty in recalling the formulated procedures in their mind as the information is stored in their long term memory. By observing cues such as alarm signal, the experts able to think about solutions that they need to take, formulate the tasks and execute necessary actions to solve the problems. But for rare or new problems that strike on a system, the experts still need to refer on the system manuals and procedures. Even if the experts have gone through the electrical drawing, if they still fail to solve the problems, the last remedy is to inform the system supplier about the system. Due to the long process of effort to solve the problem system should be design to support users in any critical condition that faced by users when they are having direct interaction with the system.

C. Knowledge Audit Findings

At the knowledge audit stage, experts will be asked to decompose instances for the tasks in a form a CTA tasks diagram. The experts will be asked to structure out the tasks solution for the three system failure which has been identified at the observation tasks stage. In relation to that, the structuring process begins from an overall system process up to the individual component of the system. Then the idea of structuring the solutions will be visualized in a form of tree diagram which also consists of flow of the product, functions, process, components and materials (Figure 4).

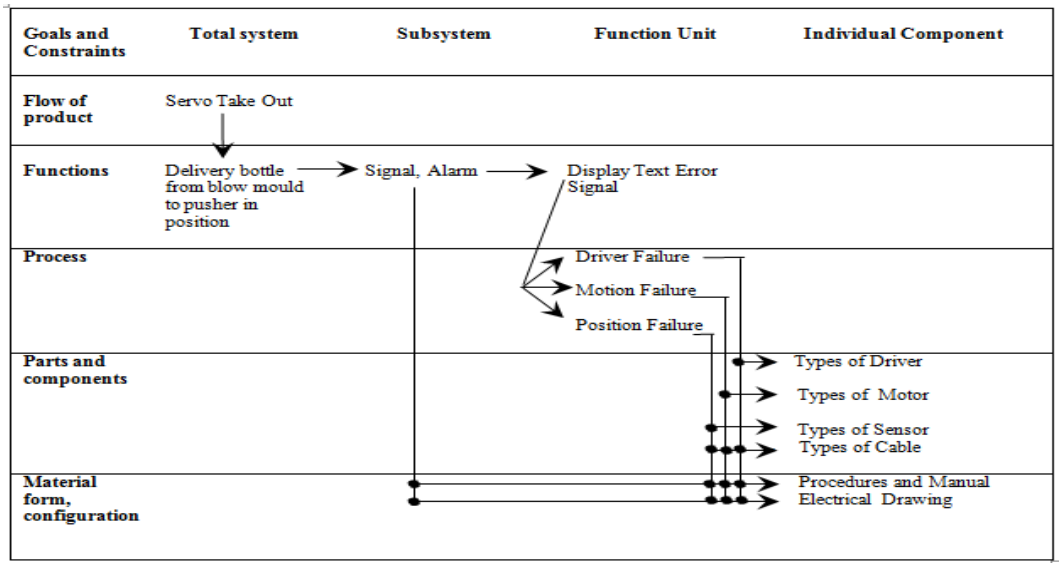

FIGURE 4: Experts Cognitive Task Analysis Task Diagram

For the driver equipment failure, the expert suggested that usually the driver itself will be the first equipment to be diagnosed. The experts need to check if the driver is connected appropriately within the main machine and if the alarm is still ON, then the experts need to check the cable connections. If the experts still could not resolve the problems, then the experts need to change to a new driver. After both the driver and cable connections are diagnosed, the final solution is to get some solutions from the manuals or electrical drawing of the bottle production system.

According to the experts, in order to solve the problems related to the Motor failure, first the experts need to diagnose the motor connections whether it is connected appropriately. If there is no change and the alarm signal is still ON, then the experts recommended that Motor condition also need to be checked just in case if the motor failure is overheated. Overheated motor will make the machine stop in producing the bottles. If it is still fail then the experts need to check the cabling connection attached to the machine. If the alarm is still strike, perhaps motor belting for the gear box could be change for new motor belting. Besides manuals, again electrical drawing also could be used to find the best solutions if problems occurred related to motor equipment.

Experts claimed that the position failure is associated with cabling problems. Since sensors is very sensitive equipment therefore the cabling connections with the sensors is crucial in system production process. For example, sensors are used on bottles conveyor as to make sure that the bottles are arranged and produced accordingly. Consequently, if the alarm is ON, sensors connections need to make sure that sensors are all well connected. But if there is still no sign of any solutions for it, then once again connections among driver, motor and positioning sensors need to be in a great condition if not, then experts suggested that manuals and electrical drawing could be used solve the problems.

5. CONCLUSION

From the analysis we have identify three common problems occur in handling bottles production system. This is because once the signal or alarm is ON, then users need to take accurate and fast action as to make sure the production process runs smoothly. Consequently, results from this study will be used to design tasks scenarios for prototype usability testing. In addition system that applies scenarios will make the system evaluation more focus where it is map out with the real context in producing the bottles.

Moreover CTA framework that is used to design CTA scenarios, involve cognitive skills because in diagnosing certain system, it involves problem solving, solving errors in the system, decision making, accurate selection of actions and thinking. Perhaps in using the CTA framework in designing the scenarios and the tasks to solve the problems discussed will be further utilized for the prototype usability testing. Scenarios which include human cognitive skills into the system interface design is essential in system interface design because the main goal of system interface system designer is to design a system that will help users to make a good decision in handling the system.

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