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CONTENT

SHERPA AND TAFEI, COMPARISON OF TWO HUMAN ERROR IDENTIFICATION TECHNIQUES: A CASE STUDY

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Resumen: El siguiente trabajo, presenta un estudio de caso de análisis del error humano en una tarea ejecutada en un centro de reparación de equipos de cómputo. Por lo que se realizó un Análisis Jerárquico de Tareas, así como aplicación de dos técnicas de identificación del error humano, TAFEI y SHERPA. Como resultado, en TAFEI se elaboraron 11 SSD que ayudaron a identificar 5 transiciones ilegales y 5 modos de error, siendo uno de ellos catastrófico. Una vez analizados y comparados los resultados de TAFEI y SHERPA, se pudieron encontrar errores debido a la mala ejecución de la tarea, mal identificación de los equipos en reparación, daños por mal manejo de los materiales y errores en la colocación de los componentes.

Palabras clave: Ergonomía cognitiva, error humano, análisis jerárquico de tareas, TAFEI, SHERPA.

Relevancia para la ergonomía: Por medio de este trabajo se presenta un caso de estudio en donde se hacen uso de técnicas de identificación de error humano (SHERPA y TAFEI), las cuales a pesar de ser de gran importancia han sido muy poco aplicada en campo, por lo que se presenta como una posible referencia para todos aquellos que deseen implantar dichas técnicas.

Abstract: The following paper presents a case study of the analysis of human error in a task performed in a computer equipment repair center. Therefore, a Hierarchical Task Analysis was performed, as well as the application of two human error identification techniques, TAFEI and SHERPA. As a result, TAFEI developed 11 SSDs that helped identify 5 illegal transitions and 5 error modes, one of which was catastrophic. Once the results of TAFEI and SHERPA were analyzed and compared, errors could be found due to the bad execution of the task, bad identification of the equipment being repaired, damages due to bad handling of the materials and errors in the placement of the components.

Keywords: Cognitive ergonomics, human error, hierarchical task analysis, TAFEI, SHERPA.

Relevance to Ergonomics: This work presents a case study in which human error identification techniques are used (SHERPA and TAFEI), which despite being of great importance have been very little applied in the field, so it is presented as a possible reference for all those who wish to implement such techniques.

1. Introduction

The use of personal computers (PCs) has now become more ordinary, it's common to find them in homes, workplaces, schools, etc., resulting in PC repair facilities installed everywhere. One of the problems that have been generated within these facilities has been that of economic losses that have been caused by human errors. The analysis of human error is currently one of the main topics of study of cognitive ergonomics. According to Casares-Li, Rodríguez-Hernández, & Viña-Brito (2016), human error has been increasing due to the complex dynamics of current production and service systems. Due to the above, the use of techniques for the identification of human error (HEI) has been increasing. As to Reason (1990) state, not all possible faults are caused by human error, in order to be considered as a consequence of human error, these should not be the consequences of causal agents.
According to Mohammadian, Choobineh, Mostafavi Nave, & Hashemi Nejad (2012), virtually all human error identification techniques follow a common procedure: what acts can be done and how these acts cause human error, in addiction, Stanton, Salmon, & Rafferty (2013) recommend developing a Hierarchical Task Analysis before the application of any HEI technique. Hierarchical task analysis (HTA) is a powerful tool that gives the analyst an overview of how a process works, since HTA provides an analytical description of a process or activity, including the realization of a hierarchy of objectives, sub-objectives, operations, and task plans. The HTA was originally developed as a method for determining training requirements and is the oldest and best-known task analysis technique (Lorés & Granollers, 2017).
According to Stanton et al. (2013), one of the best HEI techniques is SHERPA, (Systematic Human Error Reduction And Prediction Approach), developed by D.E. Embrey in 1986, which has the objective of qualitatively and quantitatively evaluate human reliability and elaborate concrete recommendations to reduce the probability of human errors, especially as regards procedures, personnel preparation and equipment design (de Arquer & Nogareda, 1994). SHERPA has been used to identify pilot errors, errors during laparoscopic or keyhole surgery and errors that occur during the use of consumer products such as ticket machines.
We also have that TAFEI (Task Analysis For Human Error Identification) technique is one of the easiest HEI techniques to implement, in which an analyst can be quickly trained (Kuang, Hu, Zhang, & Gao, 2009; Stanton et al., 2013). TAFEI was developed by Baber & Stanton, (1994), and allows analysts to predict errors with the use of a device (artifact) by modeling the interaction between the user and the device analyzed.

1.1. Objetive

The objective of this work is: analyze human error, through TAFEI and SHERPA, in a task performed in a PC repair center, in order to compare both HEI techniques and provide suggestions in order to reduce human error in the task evaluated.

1.2. Delimitation

Only the analysis of human error in the selected task was performed, so the analysis of the entire operation was not performed, hierarchical analysis of tasks (HTA) was developed as a preliminary step in the application of the TAFEI and SHERPA techniques.

2. Metodology

In the elaboration of this work, the following methodology was used:

2.1. Selection of the task for analysis and elaboration of HTA

For the selection of the task to be analyzed, a survey was carried out among the personnel of the support center to determine the task whose consequences would have a greater impact and which, due to its poor execution, would cause irreparable damage to the equipment under reparation, as well as the workflow in the area and based on the results obtained, to proceed with the elaboration of the HTA.
In order to elaborated the HTA 6 steps should be observed (Stanton et al., 2013):

1. Define the task for analysis.
2. Data collection process.
3. Determination of sub-goals of the task.
4. Sub-goal decomposition.
5. Plan analysis

Once all sub-goals and operations have been fully described, plans need to be added. Plans dictate how goals are achieved. A simple plan would be: Do 1, then 2 and then 3. Plans do not have to be linear and exist in many forms, some examples are shown in Table 1.

Table 1. Types of plans for the HTA.

Plan	Example
Linear	Do 1, then 2, then 3
Nonlinear	Do 1, 2 and 3 in any order
Simultaneously	Do 1, then 2 and 3 at the same time
Bifurcation	Do 1, if X is present make 2, then 3, if X is not present Exit
Cyclic	Do 1, then 2 and then 3 and repeat until X
Select	Do 1, then 2 or 3

2.2. Analysis of human error by using of TAFEI.

In order to develop the TAFEI, three steps are necessary (Baber & Stanton, 1994):
1. Develop a Hierarchical Task Analysis (prepared in the previous stage).
2. Create a space-time diagrams (SSD).
3. Make a transition matrix.

SSD is the list of states which may happen in a machine. Each list has a common list under which is a list of output states (feedback) (Mohammadian et al., 2012) and, according to (Stanton et al., 2013) the Space-state Diagrams (SSDs) are constructions that represent the behavior of the device or product. Each of them represents one of the possible task states, listing the initial and final status, this is based on the HTA.

The transition matrix is an important step in TAFEI because all possible transitions in the execution of the task or the use of artifacts are introduced. These transitions are the change from one SSD to another. Three approaches are adopted to complete the matrix (Mohammadian et al., 2012):
- If the given transition is impossible, a dash is placed in the respective cell.
- If a given transition is possible and desirable (I. e., the user is moving towards the target), it's a legal transition represented by L in the table.
- If a given transition is possible but undesirable (deviation from the desired action), it's an illegal transition shown in the table, it's represented by an I.

When all possible intersections have been analyzed, the situations in which an illegal transition occurs (I) are analyzed.

2.3. Analysis of human error through SHERPA.

SHERPA human error identification technique consists of common questions and answers that distinguish similar errors at each step of task analysis. (Embrey, 1986; Stanton et al., 2013). The application of SHERPA is done in eight steps:
1. Elaboration of HTA, prepared in the first stage
2. Classification of tasks: Each step of the work is considered for the classification of errors from the lowest level of analysis:
   - Action: Press a switch or press a button to open a door;
   - Recovery: receiving information from a monitor or guide, etc.;
   - Verification: directing and managing a verification process;
   - Selection: select another strategy based on orders from higher authorities;
   - Communication of information: talking to other departments or groups

The following errors can be studied with this method:
- Action: this error is in fact related to the actions of individuals, i.e. individuals do not do their task properly or promptly;
- Recovery: the immediate action after an error to return the system to its original state;
- Verification: an error in which people do not perform verification in a timely or proper manner;

- Communication: an error in the process of communicating with other sections, that is, incorrect information is received;
- Selection: the operator selects the wrong option or forgets to select a step in the system control process.

In this step, and using a special checklist, shown in Table 2, the error code is determined and recorded in the error mode column, shown in Table 3.

3. Identification of human error: The classification of task steps leads the analyzer to verify action errors by classifying lower level errors. A description of the occurrence of each error is presented.
4. Consequence Analysis: Examining the consequences of each error for the system is the next critical step, which produces the applied consequences of the critical error. It is necessary for the analyst to provide a full description of the results together with the identification of the error.
5. Recovery analysis: The analyst must determine the recovery of possible errors identified in this step, i.e. the scanner decides what action is necessary to avoid this type of error. First, this action, obtained in the hierarchical analysis of tasks, is determined and the following step is entered.
6. Ordinal probability analysis: The necessary results and recovery have been obtained to estimate the probability of the error. Then the error probability is determined with respect to Table 4.
7. Criticality analysis: In this step, the severity of damage caused by human error is determined based on Table 4. After combining it with the probability of error, the relevant risk level is determined and recorded in the seventh column of Table 3.
8. Analysis of solutions: The final step in this method consists of strategies to reduce human error. They take the form of changes and modifications suggested in the system to prevent human error and are divided into four categories:
   - Equipment (redesign or modification of existing equipment).
   - Training (development of new curricula or educational and training programs, modification of training course).
   - Guidelines (providing new guidelines and instructions or revising old guidelines and instructions).
   - Organizational and management modifications.

Table 2. SHERPA Error Mode Checklist

Type of Error	Code	Error category
Operation too short / long	A1	
Untimely operation	A2	
Operation in the wrong direction	A3	
Too little / much work	A4	
Misalignment	A5	Action
Right operation on the wrong object	A6	
Wrong operation on the right object	A7	
Omitted operation	A8	
Incomplete operation	A9	

Incorrect operation on the wrong object	A10	
Omitted revision	C1	Verification
Incomplete revision	C2	
Correct revision of wrong object	C3	
Incorrect revision of right object	C4	
Untimely revision	C5	
Incorrect revision of wrong object	C6	
Unattained information	R1	Recovery
Wrong information obtained	R2	
Incomplete recovery of information	R3	
Non-relayed information	I1	Information communication
Incorrectly relayed information	I2	
Relay of incomplete information	I3	
Omitted selection	S1	Selection
Incorrectly made selection	S2	

Table 3. Information which must be included in the table of results

Step in the HTA	Type of Task	Type of Error	Description	Consequence	Reco-very	Risk Level	Corrective Measure
(HTA-Obtained)	Write the name of task	(Obtained from the error verification list, Table 1)	Description of the possible error	Consequence when error does not occur		(Obtained during the ordinal probability analysis and the criticalness analysis step of the methodology)	Propose corrective measures to prevent error from reoccurring.

Table 4. Risk evaluation range.

		Catastrophic	Critical	Marginal	Insignificant
Risk		1	2	3	4
Frequent	A	1A	2A	3A	4A
Probable	B	1B	2B	3B	4B
Occasional	C	1C	2C	3C	4C
Remote	D	1D	2D	3D	4D
Improbable	E	1E	2E	3E	4E

3. Results

3.1. Selection of the task for analysis and elaboration of HTA

The task selected for analysis, based on interviews between technicians, is to change and test the power supply (PS) of the PC, this is because the PS is responsible for providing the proper electrical current to all elements of the PC, so that in case of error and/or failure during this task all equipment is affected. According to the comments of the participants, the failures of the PS represent 16% of the total failures of the reviewed computer equipment. 13 participants were observed performing this task during different days and hours.

For the elaboration of the HTA, which is shown in Table 5, and following the steps described in the methodology, the following points were observed:

1. Task definition for analysis: The task determined to analyze in this work is: change and test the PS.
2. Data collection process: Data were collected through interviews and direct observation of the work done by the participants.
3. Determine the overall goal of the task: The main goal of the analysis is: Change of PS
4. Determination of sub-goals of the task: Test the PS, disconnect the PS, selection of the new PS, install a new PS, Test the equipment.
5. Sub-goal decomposition: each of the sub-goals was broken down into simple elements detailing the process of the task.
6. Plan analysis: a linear and selective plan was used to deploy 4 hierarchical levels for subtasks.

Table 5. Hierarchical Task Analysis pertaining to the task analyzed.

0. Change and Test of PS		
Plan 0: 1 if necessary: 2, 3, 4 and 5		
	1. Determine if PS change is required	
	Plan 1: 1, 2 and 3	
		1.1 Open the PC
		1.2 Place the tester in the PS
		1.3 Determine the condition of the PS
	2. Remove the PS	
	Plan 2: 1, 2	
		2.1 Remove the screws, ties and connectors from the PS
		2.2 Remove the PS from the PC chassis
	3. Selection of the PS	
	Plan 3: 1, 2	
		3.1 Check the specs of the defective PS
		3.2 Find the right PS from the spare parts
	4. Install new PS	
	Plan 4: 1, 2	
		4.1 Place the new PS into the PC chassis
		4.2 Place the screws, ties and connectors of the PS
	5. Test the PC	
	Plan 5: 1, 2 and 3	
		5.1 Attach the PC accessories
		5.2 Verify PC functionality
		5.3 Close the PC

3.1. Analysis of human error by using of TAFEI

From the HTA developed in the previous step, the SSD were developed and are shown in Figure 1. In this case, we had 11 different states. The SSD showed the possible state of the equipment under repair at different times during the execution of the task. Changes between states are indicated by a black line. The red arrows show the state where it is possible to generate an illegal transition and the number inside shows the state towards which it would be done, they are showed in the transition matrix in the Table 6.

Based on the transition matrix, the following illegal conditions, red arrows, were detected:

- From status 1 to 8.
- From state 2.2 to 7 and 8.
- From state 3 to state 8.
- From state 4 to state 6.

These errors occur when the equipment to be repaired is not correctly identified, so the technician confuses the state of the repair and sends it to the next process without having performed the task correctly. It can also happen that when the technician is reviewing the PC, he is distracted, skipping steps of the operation.

Table 6. Transition matrix

		To state										
		1	2.1	2.2	3	4	5	6	7	8	9	10
From state	1	-	L	L	-	-	-	-	-	I	-	-
	2.1	-	-	-	-	-	-	-	-	-	-	-
	2.2	-	-	-	L	-	-	-	I	I	-	-
	3	-	-	-	-	L	-	-	-	I	-	-
	4	-	-	-	-	-	L	I	-	-	-	-
	5	-	-	-	-	-	-	L	-	-	-	-
	6	-	-	-	-	-	-	-	L	-	-	-
	7	-	-	-	-	-	-	-	-	L	-	-
	8	-	-	-	-	-	-	-	-	-	L	-
	9	-	-	-	-	-	-	-	-	-	-	L
	10	-	-	-	-	-	-	-	-	-	-	-

3.2. Analysis of human error through SHERPA

In the case of the SHERPA analysis, the results obtained from the interviews with the technicians are shown in Table 7. From the SHERPA results, the highest risk error that can occur in the PS selection. Since it is a selection type error (S2, from Table 2) and probable and catastrophic (1B, from Table 4) , its necessary that the technician has the necessary capacity, during this stage, to carefully select the piece that will be placed in the equipment, due to the consequences that such action may have, the most serious of which would ultimately be the total loss of the equipment.

4. Conclusions and Recommendations.

The use of two HEI techniques in the same case study, not only assist to identify the same error, for example, thanks to TAFEI was detected that the lack of identification of the state of the PC under repair was important, while SHERPA helped to identify

the importance of the correct execution of the task, so together it was possible to identify the following situations where there would be an error: poor execution of the task, misidentification of equipment in repair, damage by improper handling of materials and errors in the placement of components. In order to avoid them, the following actions are recommended: elaboration of visual aids that indicate the due process to follow, adding an identification label that shows the state of the PC under repair, training technicians on the importance of having the proper handling of materials as well as their correct placement.
Finally, thanks to the use of the best HEI technique (SHERPA), as well as the easiest to implement (TAFEI) it was possible to detect the errors shown above, so it is recommended that the analyst consider the different HEI techniques that are available and apply the one that the analyst considers most suitable for their needs.

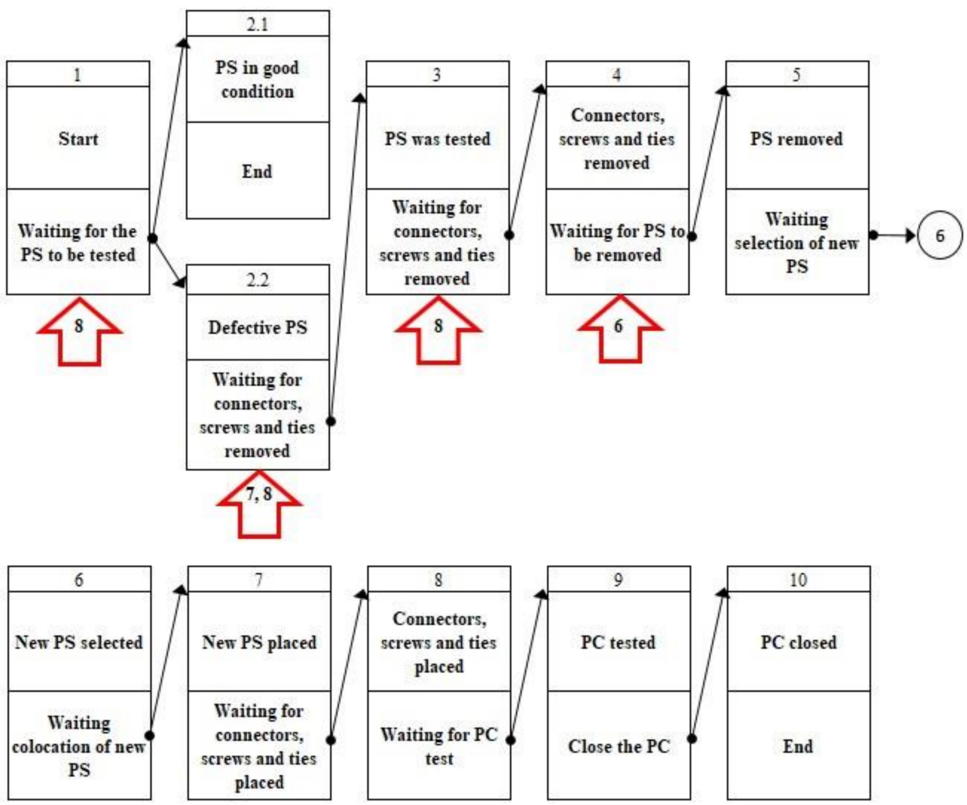

Figure 1. SSD developed from the HTA.

Table 7. SHERPA Results in the task analyzed.

Step in the HTA	Type of Task	Type of Error	Description	Consequence	Reco-very	Risk Level	Corrective Measure
1.3	Determine the condition of the PS	C4	PS verification is not performed correctly	Source can create a power overload and cause a short circuit,		1D	Perform the verification of the condition of the PS

				thus damaging the equipment entirely.			without omitting any steps.
2.3	Remove the screws, ties and connectors from the PS	A7	Action is performed carelessly	Component parts may get damaged, when this could have been avoided.		3D	Perform the action handling the object with greater care.
2.4	Remove the PS from the PC chassis	A7	Action is performed carelessly.	Component parts may get damaged, when this could have been avoided.		3D	Perform the action handling the object with greater care.
3	Selection of the PS	S2	The selection of the replacing part is performed incorrectly	Source can create a power overload and cause a short circuit, thus damaging the equipment entirely.		1B	Study carefully the characteristics of the part to be replaced.
4	Install new PS	A7	Connectors are installed incorrectly	The part doesn't work correctly, which may result in poor diagnosis or in another expense.		3C	Follow the directions included in the part.
							Study the power outlets and the cables available carefully.
							Understand thoroughly how the part works before installing it.

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