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Saad Aldoichi, Omar Hammami

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Evaluation of Invisible Physical and Mental Exertion from CT Scan Operation in Saudi Arabian Hospitals

Saad Aldoihi

Computer Science and Systems Engineering
ENSTA PARISTECH
Palaiseau 91762 Cedex, France
saad.aldoihi@ensta-paristech.fr

Omar Hammami

Computer Science and Systems Engineering
ENSTA PARISTECH
Palaiseau 91762 Cedex, France
Hammami@ensta-paristech.fr

Abstract—Advancement in science and technology has increased work exertion tremendously. Many researchers and professionals have noted the importance of work exertion in correlation with the work environment. However, there is no mention of the principle of invisible exertion correlated with the current advancement of science and technology. This paper evaluates the invisible physical and mental exertion for CT scan technicians. Fifty-seven CT scan technicians were surveyed to determine the extent of their invisible physical and mental exertion. The overwhelming majority of technicians reported significant exertion while operating the CT scan. The invisible physical and mental exertion occurred differently in accordance with demographic characteristics. Gender is a significant factor, where male technicians reported more physical invisible exertion than female technicians. The invisible physical exertion occurred more than invisible mental exertion.

Index Terms—invisible exertion, CT scan invisible exertion, CT scan overload effects

I. INTRODUCTION

Heuristics is a popular method to evaluate system and product usability, and it proposes improvements during and after the development. A key component of the success and rising popularity of heuristics is its low cost and effectiveness.

In academia, there are 152 usability attributes [1]. As a customary practice in industry and academia, usability is constructed from a list of attributes to constitute the dimensions of the cohesive whole. Geisen and Bergstrom [2] referred to these dimensions as metrics for evaluation. It is clear from the literature that usability lacks uniformity and unity of dimensions, which has caused some ambiguity among new researchers.

However, it is vitally important to state why usability diverges in dimensions. An important reason is that usability is used to evaluate various products and systems that hold different execution goals and purposes. According to Ferre et al. [3], usability can only be defined in accordance with the intended system and the intended users. They illustrated their argument regarding a museum kiosk where the dimensions must emphasize minimum training since kiosk users are most likely to use it only once in their lifetime.

Similarly, usability attributes should be representative of the overall environment where the larger scope must be counted as an attribute. For instance, the incorporated usability considers the local environment of the work, including the managerial target and departmental duty that measures the invisible exertion, which can contribute to and affect usability. The obvious objective is to use the usability evaluation to consider human factors that are associated with the work and managerial environments. When evaluating usability attributes, there is a clear indication that they lack an exertion evaluation, such as for physical and mental exertion. Consequently, many authors [4] [5] [6] have included NASA-LTX for a usability evaluation as a substitute for physical and mental exertion, which is lacking in popular heuristic methods.

One of the ISO 9241 usability evaluation settings is “context of use.” In essence, it implies that evaluation usability must consider the work atmosphere in which the device or system would operate. For instance, when evaluating a newly developed CT scan, the natural everyday busy setting of an over-crowded and understaffed hospital must be considered, including the management target and duty expected from the operators. In other words, exertion delivered from any source should be included in an operator’s human factor and usability evaluations. Dimensional attributes such as safety, operator satisfaction, and productivity are the essence that constitutes the overall usability [7]. Furthermore, impeding attributes that consider the organizational context would add more accuracy and validity of the overall usability.

The overall objective of this study is to identify invisible exertion existence while operating CT and to identify whether the Radiology Department duty and management targets can be transformed into invisible physical and mental exertion. To the best of our knowledge, there is no existing study that measures the invisible exertion of CT scan technicians and correlates the management process to influence technician exertion. The area of this research has not been exploited by other researchers; thus, the authors hope that this study will open a new area of research that considers invisible exertion of whatever kind and correlates it to the overall evaluation.

II. BACKGROUND

A. Usability as a factor in medical devices

From the beginning, medical devices have been implemented on the premise of assisting the examiner by providing vital information that could alter the examiner's decisions regarding the patients. As the devices gain more computing power and advanced sensing technology, more functionalities and connectivity with other devices present more challenges to the novice user. Consequently, evaluation methods have been suggested from different fields. In recent years, usability evaluations have dramatically shifted focus to medical devices.

Designing usability for medical devices is not like other electronic devices for the following reasons. Medical devices provide data on decisions regarding the actions of doctors. Medical device usability has a limit, where user characteristics and preferences count for the overall outcome. Aldoihi and Hammami [6] showed that CT scan operators indeed differ in perceiving the usability attributes according to gender and years of experience.

B. Cognitive and Physical Exertion

Cognitive load is deeply involved in psychology. An obvious sign of such involvement is that cognitive load is only clarified through psychology or behavioral lenses [8]. Key components of cognitive load are the nature of the work and how memory can correspond with it [9]. Mental load has been perceived by early psychological theorists as a multi-dimensional phenomenon where the interpretation of phenomena comes as a result of the outcomes of the interaction between subjective individual characteristics and objective task characteristics [10] [11]. Subsequently, mental load resulting from indirect (invisible) work has not been properly studied.

Mental load studies have heavily concentrated on the direct aspects and have somehow neglected indirect aspects. It is essential to include invisible elements to understand the overall characteristics of the mental load since the mental load is multi-dimensional by nature. Mental load exists whenever there are intractable tasks that demand a great deal of control. There are three main aspects of invisible physical and mental loads, which are task complexity, management requirements, and pressure of resources (see Fig. 1).

Another extremely important load is the physical load. For CT scan technicians, there is a considerable amount of physical load during the operation of the machine. Nonetheless, there are many tasks performed by the technicians where the physical load is unavoidable. Such tasks are the framework of this study. For instance, it is a customary practice in Saudi Arabia that CT technicians help the bedridden patient transfer to the CT table. Literature has demonstrated the effect of overload on radiologists on many fronts. Various studies have explored the risk factors associated with excessive loads [12] [13] [14]. Bruni et al. [15] noted that considerable discrepancies in interpretation are demonstrated in the late shift for radiologists as opposed to the starting shift. It is critically important to explore and identify the effect of the invisible load on

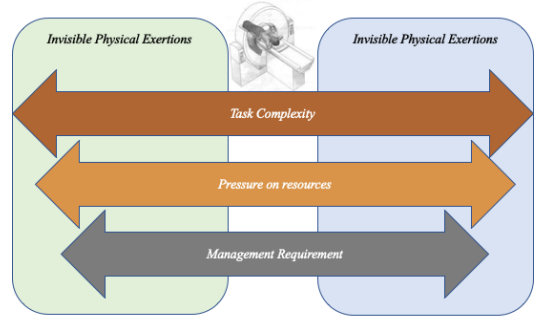


Fig. 1: A conceptual framework of the physical and mental exertion sources

radiologists so that researchers and practitioners can propose reduction procedures.

III. METHOD

For this research, the authors developed a survey questionnaire that measures invisible exertion while operating the CT. Such exertions can be unintended and come from the inner work environment.

1) *Participants*: The population of the study comprises CT scan technicians who operate the machine on a daily basis and who are geographically located in Saudi Arabia. One vital variable dimension that must be distinguished is the work sector. In Saudi Arabia, the healthcare sector is divided into two categories. That is a public and private sector. It is essential to distinguish these two groups within the demographic characteristics. In total, 57 technicians participated in this study. The participants are all CT scan technicians who, at the time of the study, were working in Saudi Arabia in either the public or private sector. Participants were invited to the study by either online questionnaire link or by a telephone call. See Table 1 for more details of the demographic characteristics.

TABLE I: Participant Demographic Characteristics

Variable		Total Percentage
Gender	Male	50.90%
	Female	49.10%
	Total	100%
Age	20-29	77.20%
	30-39	15.80%
	40-49	3.50%
	50+	3.50%
	Total	100%
Educational level	Diploma	3.50%
	Bachelor	86.00%
	Master	10.50%
Total		100%
Years of Radiology Experience	0-3 years	68.40%
	4-7 years	8.80%
	8-11 years	10.50%
	12+	12.30%
	Total	
WorkingSector	Public Sector	87.70%
	Private Sector	12.30%
Total		100%

2) *Survey method:* After evaluating the causes of invisible physical and mental exertion, a field visit was conducted to King Saudi Medical City (KSMC) to gather and observe technician exertion. Due to the excessive particularity of the measured variables, a questionnaire was developed to suit the special particularity. The questionnaire was sent to technicians across Saudi Arabia, asking them to respond to six statements regarding their views on physical and mental activities while operating a CT. Three statements represent physical exertion (PRQ), and the other three represent mental exertion (MRQ). The statements were as follows:

1) PRQ1: I have helped to transfer a bedridden patient from the hospital bed to the radiology table,

2) PRQ2: It is my duty to prepare the examination room for receiving the next patient,

3) PRQ3: It is my duty to prepare for contrast media administration as needed,

4) MRQ1: I think that I work in an understaffed environment,

5) MRQ2: I think that the department needs more CT scan machines,

6) MRQ3: I think that management targets are unreasonable (not in alignment with existing resources).

In addition, open-ended questions were added after each statement as optional commentary feedback. A self-rating questionnaire was created based on a five-point Likert scale.

IV. RESULTS

A. Invisible Physical Exertions

Invisible physical exertion is presented clearly in Fig. 2. The research statements demonstrate the invisible physical exertion through the activities that are required to operate a CT from three dimensions, which are PRQ1-PRQ3, as stated above. For transferring the bedridden patient to the CT table, 29 (50.9%) technicians responded with “always.” “Usually” constituted 17 (29.8%) responses. “Sometimes” constituted 10 (17.5%) responses, whereas “never” constituted only 1 (1.8%) response. For preparing the examination room for the next patient, 43 (75.4%) responded with “always.” “Usually” constituted 10 (17.5%) responses. “Sometimes” constituted 4 (7%) responses. For preparing and administering the contrast media, 38 (66.7%) responded with “always.” “Usually” constituted 13 (22.8%) responses. “Sometimes” constituted 4 (7%) responses. “Rarely” and “never” constituted 1 (1.8%) response.

B. Invisible Mental Exertions

Invisible mental exertion is presented clearly in Fig. 3. The research questions demonstrate the invisible mental exertion through activities required to operate a CT from three dimensions, which are MRQ1-MRQ3, as stated above. For working in an understaffed environment, 14 (24.6%) technicians responded with “strongly agree.” “Agree” constituted 19 (33.3%) responses. “Neutral” constituted 20 (35.1%) responses. “Disagree” constituted 4 (7%) responses. For suitability of the number of CT machines, 22 (38.6%) techni-

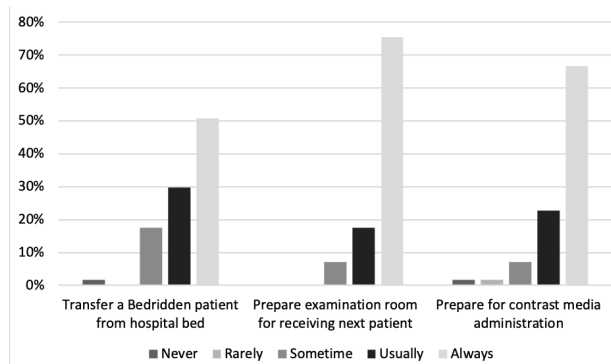


Fig. 2: Physical exertion responses

cians responded with “strongly agree.” “Agree” constituted 18 (31.6%) responses. “Neutral” constituted 7 (12.3%) responses. “Disagree” constituted 8 (14%) responses. “Strongly disagree” constituted 2 (3.5%) responses. For management alignment with existing resources, 14 (24.6%) technicians responded with “strongly agree.” “Agree” constituted 19 (33.3%) responses. “Neutral” constituted 14 (24.6%) responses. “Disagree” constituted 10 (17.5%) responses.

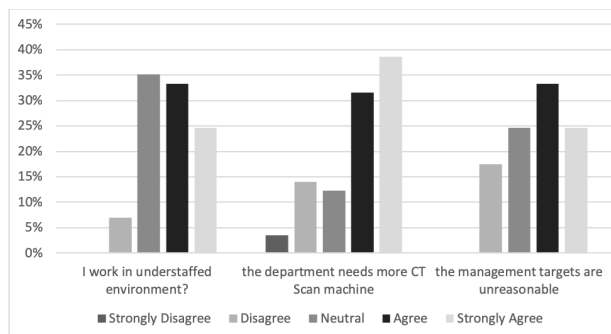


Fig. 3: Mental exertion responses

C. Demographic Characteristics: Physical and Mental

1) *Gender:* Figure 4 shows the proportion of difference between male and female respondents. For the physical exertion statement in PRQ1, 62.1% of male technicians indicated that they always contribute physically by transferring the bedridden patient to the CT table, in contrast to only 39.3% of female technicians. Interestingly, 3.6% of female technicians stated that they never helped or contributed to transferring the bedridden patients to the CT table. In response to PRQ2, 89.7% of male technicians indicated that they have always prepared the exam room for the next patient, as opposed to 60.7% of female technicians. In response to PRQ3, 79.3% of male technicians indicated that they always prepared the contrast media for the next patient, in contrast to 53.6% of female technicians. Interestingly, 7.2% of female technicians responded with “never” or “rarely.”

In response to mental exertion statements, in MRQ1, 34.5% of male technicians indicated that they work in an understaffed

environment, as opposed to only 14.3% of female technicians. In response to MRQ2, 48.3% of male technicians indicated that the department needs more CT scanners to accommodate the patient overload, compared to 28.6% of female technicians. In response to MRQ3, 27.6% of male technicians indicated that management targets are not aligned with existing resources, compared with 21.4% of female technicians.

2) *Age*: Age is a fundamental factor in determining physical and mental exertion. Figure 5 shows the proportion of difference between age groups from 20 to 29, 30 to 39, 40 to 49, and over 50. In response to the physical exertion statement in PRQ1, 43.2% of the 20 to 29 age group indicated they always contribute physically to transferring the bedridden patients to the CT table. Similarly, 66.7% of the 30 to 39 age group indicated that they always contribute physically, whereas all of the 40 to 49 and over 50 age groups indicated that they always contribute physically. In response to PRQ2, 75% of the 20 to 29 age group responded with “always” for preparing the examination room for the next patient, compared to 66.7% of the 30 to 39 age group. Both the 40 to 49 and over 50 age groups stated that they always prepare the examination room for the next patient. In response to PRQ3, 63.6% of the 20 to 29 age group reported that they prepare and administrate the media contrast for the next patient, compared to 77.8% of the 30 to 39 age group, 50% of the 40 to 49 age group, and 100% of the over 50 age group.

In response to the statements regarding mental exertion, in MRQ1, 20.5% of the 20 to 29 age group strongly agree that they work in an understaffed environment in comparison with 33.3% of the 30 to 39 age group, 50% of the 40 to 49 age group, and 50% of the over 50 age group. In response to MRQ2, 38.6% of the 20 to 29 age group reported that they strongly agree that they work in the Radiology Department with fewer CT scans in operation, in contrast to 33.3% of the 30 to 39 age group and 50% of both the 40 to 49 and over 50 age groups. In response to MRQ3, 20.5% of the 20 to 29 age group reported that the management targets are not aligned with the existing resources, in comparison to 33.3% of the 30 to 39 age group and 50% of both the 40 to 49 and over 50 age groups.

3) *Years of radiology experience*: Years of experience is a dominant factor in determining the invisible physical and mental exertion. Figure 6 shows the proportion of difference between 0 to 3 years, 4 to 7 years, 8 to 11 years, and more than 12 years. In response to the physical exertion statement in PRQ1, 46.2% of those with 0 to 3 years of experience reported that they always contribute physically to transferring bedridden patients to the CT table, in comparison to 20% of those with 4 to 7 years of experience, 66.7% of those with 8 to 11 years of experience, and 85.7% of those with more than 12 years of experience. In response to PRQ2, 74.4% of those with 0 to 3 years of experience reported that they always prepare the examination room for the next patient, in contrast to 80% of those with 4 to 7 years of experience, 66.7% of those with 8 to 11 years of experience, and 85.7% of those with more than 12 years of experience. In response to PRQ3,

61.5% of those with 0 to 3 years of experience reported that they prepare and administrate the media contrast for the next patient, in comparison to 80% of those with 4 to 7 years of experience, 66.7% of those 8 to 11 years of experience, and 85.7% of those with more than 12 years of experience.

In response to the mental exertion statement in MRQ1, 17.9% of those with 0 to 3 years of experience reported that they strongly agreed that they work in an understaffed environment in contrast to 40% of those with 4 to 7 years of experience, 33.3% of those with 8 to 11 years of experience, and 42.9% of those with more than 12 years of experience. In response to MRQ2, 41% of those with 0 to 3 years of experience reported that they strongly agree that they work in a Radiology Department with fewer CT scans in operation, compared to 20% of those with 4 to 7 years of experience, 50% of those with 8 to 11 years of experience, and 28.6% of those with more than 12 years of experience. In response to MRQ3, 23.1% of those with 0 to 3 years of experience reported that the management targets are not aligned with existing resources, in contrast to 33.3% of those with 8 to 11 years of experience and 42.9% of those with more than 12 years of experience.

V. CONCLUSION

Generally, the findings suggest that there is indeed invisible physical and mental exertion associated with the operation of CT scans. Regarding the agreement rate in response to the physical statement in PRQ1, 80.7% of radiologists confirmed that they commonly transfer bedridden patients to the CT table. Therefore, manufacturers should pay extra attention when designing the machine because meeting the technical requirements is not enough for delivering a suitable machine that meets all work environment requirements. It is fundamentally ideal if the manufacturing standards cover customization that meets the lowest end-user specifications. Fundamentally, patients are the core reason for the existence of the machine. Therefore, empowerment of the patient’s current condition during the exam is highly sought after by many patients, especially during the movement of bedridden patients from and to the CT table. The current CT scan machine on the market lacks the basic habilitation capability that is needed to empower those who are bedridden. The agreement rate in response to the physical statement in PRQ2 indicates that 93% of radiologists confirmed that they frequently prepare the examination room for each patient. Moreover, the agreement rate in response to the physical exertion statement in PRQ3, 89.5% of the radiologists confirmed that they frequently prepare and administrate the contrast media to patients. The findings imply that invisible physical exertion occurs more than invisible mental exertion. The agreement is 57.9% for the mental exertion statement in MRQ1, 70.2% for MRQ2, and 57.9% for MRQ3. Two-thirds of radiologists agree with the mental exertion statement. Nonetheless, they almost consensually agree with the invisible physical exertion general statements. As future work, the authors intend to propose a human-centered system engineering model to integrate usability and exertions at the very beginning of the design flow.

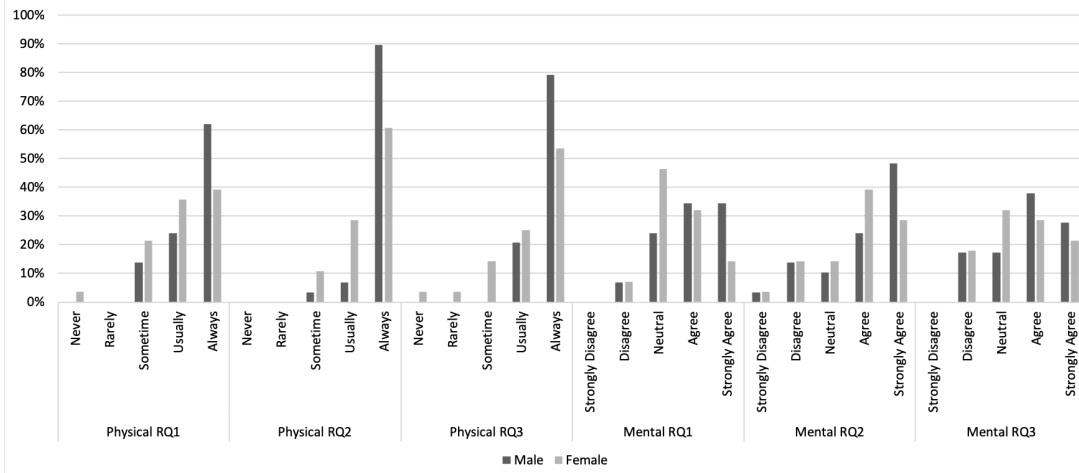


Fig. 4: Physical and mental exertion respond based on gender

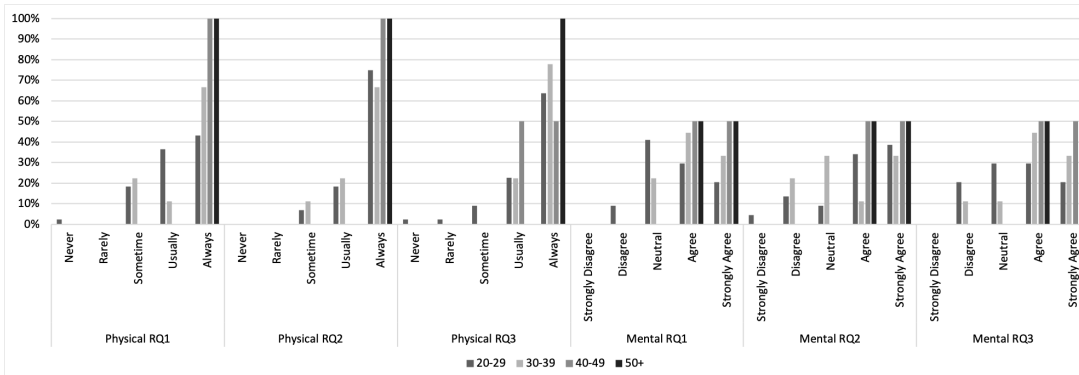


Fig. 5: Physical and mental exertion response based on age

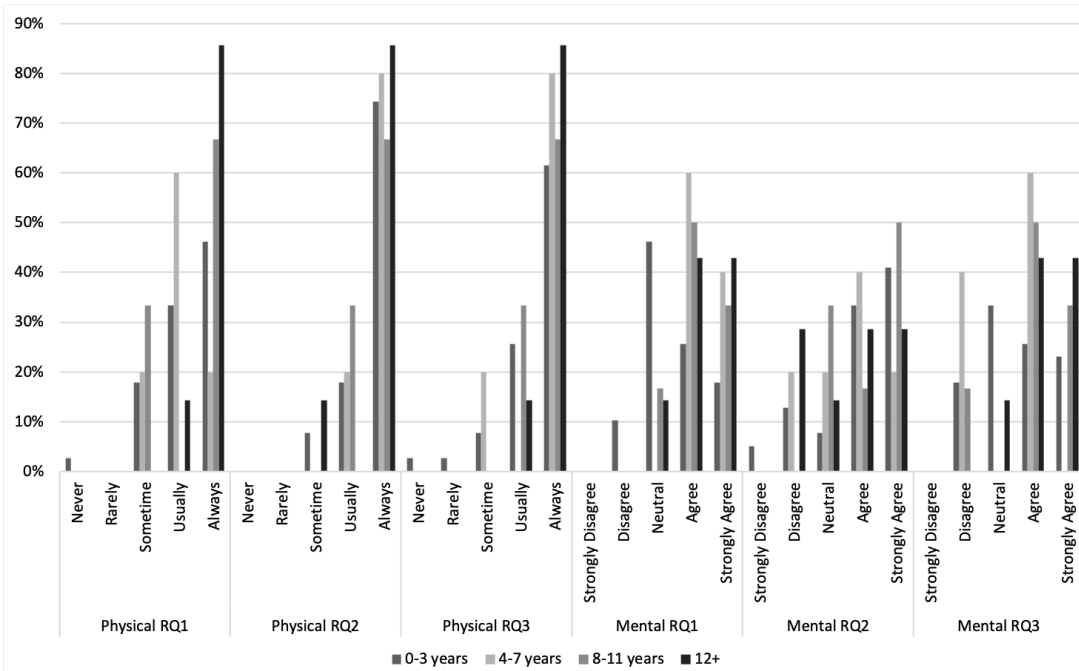


Fig. 6: Physical and mental exertion response based on years of experience

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