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# Individuals Utilization Behavior While Using Critical Healthcare Systems (Medical Ventilator)

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***Abstract:*** Ergonomics and human factors play an important role in interaction design. Poor usability design of critical safety systems can easily lead to human error. While inspecting the critical systems, there are vital factors that have to be considered, such as demographic, organizational, interface design, and task factors. This study has inspected the influence of different demographic factors (age, gender, and education) on the medical ventilator system's usability. The primary purpose is to seek the difference in task completion time, reflection time, and the number of touches during the interaction, considering different demographic factors. As well as to seek the difference in perceived task workload index. To test the study hypothesis, the Hamilton-c6 ventilator prototype was developed. The experiments were conducted on 54 participants, including physicians and nurses, in a controlled environment from different public-private sector hospitals in Pakistan. Descriptive statistics and ANOVA were used to assess the study objectives. The results suggest significant differences between male vs. female and physician's vs. nurses groups while interacting with safety-critical systems. However, the difference between young and older adults was not significant. These findings have substantial implications for the effective user-centric design of safety-critical systems.

***Keywords:*** Critical Healthcare Systems, Demographic Factors, Age, Gender, Educational Background, Usability Study, NASA-TLX.

## 1 Introduction

Optimizing the way of information deliverance via interaction is essential for dealing with the patient in emergencies. The medical industry has several machines, which are highly critical in their usage. The negligence of human factors such as age and Gender in user interface design results in the rise of some occupational diseases such as user frustration, personal stress, and man-made errors.

In the health care industry, there is a notable development in the HCI context. The primary purpose of computers in health care is to improve medical diagnostics' precision, efficiency, and easiness. A well-designed and highly usable device are needed to provide useful and safe clinical care for patients and device users. There is a need to design an interface that comprises different demographic factors, such as age, gender, and educational background of the person using the device.

Interfaces that adapt to individual users' preferences have earned significant ratings in terms of aesthetics, feel, and long-term usage [1]. In particular, inefficient interface usability affects people of older age due to changes in visual acuity [2]. Age is likely to influence the familiarity with technology

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and users' skill level. In the human factor study, the consensus has been that male and female users have markedly different preferences [3]. Current systems are linked to increased probabilities of errors because of poor usability, information overload, and other unintended consequences. By explicitly designing interfaces considering demographics along with other usability issues in mind, we can improve the user experience. A limited number of research has investigated how different demographics can provide a deeper understanding of GUI design perceptions and how they can affect the different design and research processes, specifically in a critical care environment. This study was conducted on the HAMILTON-C6 mechanical ventilator's simulated version to address this gap.

## 2 Literature Review

Development in HCI has shifted to reveal the difference between age and gender-related effects on ergonomics and design [3]. A detailed review of the literature shows that limited studies have investigated the influence of different demographic factors while using GUI specifically for critical healthcare systems. Several studies have investigated the utilization behavior of users between Gender, age, and other demographic groups and revealed the significance of these variables.

As far as Gender is concerned, Beckwith argued that both men and women process the information differently [2]. Another study also reveals that female users prefer interfaces with fewer graphics and less clutter than male users [4]. Cyr and Bonanni also highlighted gender-based preferences in terms of navigation design, information design, visual design, and satisfaction [5]. The difference in aesthetic perception in gender groups was also notable [6]. The literature also highlighted that each user's behavior and attitude might vary according to personnel demographics [7].

Along with gender, aging is a strong factor in interaction design. Previous studies have shown that aging negatively correlates with the ability to use, reaction time, movements, and motor skills [8]. On average, Older adults take double the time compared to younger adults in computer interaction, but their accuracy is two times higher [9]. Another study [10] reveals that gender-specific movement biases emphasize accuracy for females and speed for males. Katre et al. evaluated the usability of a touchscreen ventilator. Mainly, he suggests some heuristics against different user interface aspects [11]. Liu et al. presented the ventilator machine's novel circular display prototype [12]. Khairat et al. studied the relationship between physicians' efficiency, performance, satisfaction, perceived workload, and usability of electronic health records [8]. The females perform efficiently along with higher satisfaction and perceived usability. In contrast, males present a higher perceived workload, stress, and frustration. The detailed literature review indicates a strong need to consider the design of critical health care systems against different demographics. This study will be a useful catalyst for a user-centered and personalized design of healthcare systems.

## 3 Materials and Methods

The study design is exploratory as it explores the individual's usage behavior against the user's demographics. The purposive sampling technique was used for data collection. The experiments were conducted in a controlled environment (one by one) to seek individual differences. The prototype of a well-designed medical ventilator (Hamilton-C6) was developed in “sublime text” to conduct experiments with three pre-decided tasks (start ventilation, change settings, and change mode). The experience in the "start ventilation" task was interpreted as the experience with an unseen interface. In the "change setting" task, there were some hidden options and some values to recall, and it was comparatively a memory-loaded task. Participants gradually became acquainted with the user interface, so the experience in the 'change mode' task was more familiar. The behavior in this task was interpreted as interaction with familiar interfaces.

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The simulation was carried out on a 19-inch touchscreen-based all-in-one PC with an Atom processor, 4GB Ram, and NVIDIA graphic card. Written informed consent was obtained from the participants before the experiment. Instructions for each task were also presented in paper format and verbally to each participant to overcome unnecessary memory load. This study covers two dimensions, i.e., performance measures and subjective measures. Different demographic factors (age, gender, and education) were considered dependent variables. Task completion time, reflection time, and touches count against all three tasks, along with the perceived workload index, were selected as study variables.

Different government and private sector hospitals in Pakistan were targeted to perform experiments during the COVID period. The experiments were conducted with physicians in Intensive Care Units during job hours. The staff nurses were also included, as the ventilation machines usage was part of their job. The targeted audience and environment were specifically selected, so the participants unconsciously considered the criticality of the systems. The sample distribution of data by age has two classes, i.e., the participants having ages ≤ 29 labeled as young adults were 21 (38.89%) while 33 (61.11%) participants were older adults or had aged ≥ 30. Similarly, out of 54 participants, 20 were male (37.04%), and 34 were female (62.96%). Whereas data by education includes physicians and nurses; out of 54 participants, 21 (38.89%) participants were nurses, while 33 (61.11%) participants were physicians. During the study, no physical or psychological harm was inflicted on the participants. Confidentiality was maintained, participants were debriefed regarding the study's aim, and their right to withdraw from participation was granted.

## 4 Results and Discussion

A descriptive statistical analysis and a well-known technique, One Way ANOVA, were used to examine whether there is any statistically significant difference between different demographic groups (age, gender, educational background) regarding the study variables (task completion time, reflection time, number of touches, and workload index) or not.

### 4.1 Analysis of Difference between Gender Groups

According to the proposed hypothesis H1, males and females behave differently while interacting with the critical healthcare systems. The result of ANOVA on task completion time within gender groups revealed a significant difference in the "change mode" task *($p<0.001$)*. We can interpret these findings differently that males' and females' efficiency is significantly different while interacting with familiar interfaces. If we look for the result of reflection time within the gender group, it reveals a significant difference in the "start ventilator and change mode" task *($p=0.014$, $p=0.001$)*. These findings can be interpreted as the reflection time is significantly different for males and females in the acquainted and familiar interfaces. However, in memory-loaded tasks, this variable has no significant difference. Additionally, the result of ANOVA on data of the total number of touches within the gender group revealed a significant difference in the "change mode" task *($p= 0.012$)*. The total number of touches can be seen as significantly different in acquainted interfaces. In addition, according to the proposed hypothesis H4, males and females perceived different workloads while interacting with the safety-critical systems. The ANOVA result on workload index data within gender groups revealed no significance. However, the detailed review of results reveals that males' perceived workload index is slightly higher than females.

### 4.2 Analysis of Differences between Age Groups

According to the proposed hypothesis H2, young adults and older adults behave differently while interacting with the critical healthcare systems. The result of ANOVA for task completion time within

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age groups revealed no significant difference in any task *(p=0.33, p=0.68, and p=0.24),* respectively. Moreover, reflection time within age groups revealed a significant difference in the "change mode" task *(p=0.03)*. We observe that for the tasks on familiar interfaces, the reflection time of this group is significantly different. Moreover, for memory-loaded tasks such as "change setting," the total number of touches within this variable recorded a significant difference *(p=0.04)*. According to the proposed hypothesis H5, young and older adults perceived different workloads while interacting with the critical healthcare systems. The result of ANOVA on data of NASA-TLX within age groups revealed no significant difference. However, the detailed review reveals that young adults' perceived workload index is slightly higher than older adults.

### 4.3 Analysis of Differences between Physicians and Nurses

According to the proposed hypothesis h3, physicians and nurses behave differently while interacting with critical healthcare systems. The result of ANOVA on task completion, reflection time, and number of touches within educational groups recorded no significant difference in any task *(p=0.91, p=0.14, and p=0.17), (p=0.26, p=0.26, and p=0.24), and (p=0.09, p=0.23, and p=0.07)* respectively. However, the descriptive statistics reveal that the nurses perform slightly better on acquaint interfaces than physicians. In contrast, the physician performed better than nurses in memory-loaded tasks. Furthermore, the results show that the total number of touches is recorded slightly fewer in nurses. In addition to that, according to the proposed hypothesis H6, physicians and nurses perceived different workloads while interacting with the critical health systems. The result of ANOVA within educational groups revealed a *0.05* level significance. Moreover, the detailed review reveals that nurses' perceived workload and performance are significantly higher than physicians.

### 4.4 Discussion

This is the first study that explores the individual's behavioral differences specifically for any critical healthcare machine usage. Study data offers a broader understanding of individuals' behavior towards critical healthcare systems by simulating a well-designed and highly usable ventilator machine and a multi-dimensional perceived workload assessment tool.

Study report profound demographic differences in critical healthcare machine usage and perceptions. In contrast to females, the task completion time of males' on the familiar interfaces is significantly higher. However, it is observed that the gender group has no significant difference in memory-loaded tasks. The females' total number of touches can be seen as significantly fewer in familiar interfaces; however, it makes no difference in new interfaces or memory-loaded tasks. The results support previous findings that males' perceived workload index is slightly higher than females [8]. We observe that for the tasks on the familiar interfaces, the reflection time of older adults was significantly higher. But in memory-loaded tasks, it was slightly lower than younger adults. Additionally, the older adults recorded significantly lower mistakes in memory-loaded tasks. The study's findings support the previous findings that older adults take more time to complete a task. However, the accuracy was recorded better than in younger adults [13]. Besides, findings also reveal that young adults' perceived workload index is slightly higher than older adults. A possible explanation for the observed difference could be their experience. The older adults were calm, less frustrated, and satisfied with their performance. Furthermore, the study reveals that nurses' efficiency is slightly better on acquaint interfaces than physicians. Potential explanations for this could be that nurses are more encountered with the ventilator. In contrast, the physicians performed better in memory-loaded tasks, which demanded some domain knowledge. The results show that the total number of touches was recorded slightly fewer in nurses than physicians. The results also reveal that nurses' perceived workload index and performance are significantly higher than physicians. Although the differences in efficiency were

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recorded as slightly significant in some variables, we note that even a small amount of time and number of touches saved per task may be clinically significant, especially when dealing with critical healthcare systems. The limitations include a single machine, which reduces the generalizability of results. There's a strong need to explore scientific roots for observed behavioral differences. Multiple other demographic and design factors demand the researcher's attention and must be explored. Researchers highlighted that a sample size of 5-15 participants uncovered about 85 to 97 percent of usability issues. Specifically for critical healthcare systems inspection, our results' sample size (N = 54) adds credibility.

## 5 Conclusion

This study inspected the influence of different demographic factors (age, gender, and education) on critical healthcare systems usage. The focus of the study was to check whether there is a statistical difference between groups in *task completion time, reflection time, number of touches, and perceived workload*. The findings of this study reveal significant differences in different groups. The findings of this study have substantial implications for the effective user-centric design of critical healthcare systems or could help for a personalized user experience.

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