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A Study on the Effects of Human Age, Type of Computer and Noise on Operators' Performance of a Data Entry Task

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*The effects of human age, type of computer, and noise on computer operators' performance of a data entry task were investigated. Twenty male subjects aged 10–55 were assigned into 4 age groups each consisting of 5 persons. They performed the task for 15 min on desktop and laptop computers in a sitting posture under varying levels of noise. The mean number of characters entered per minute (MNCEPM) was statistically analyzed. Operators in the 16–25 age group achieved the highest rate of data entry at each level of noise investigated. Operators performed better on desktop than on laptop computers. Their performance decreased when noise level increased from 82 to 92 dB(*A*), but it improved at 102 dB(*A*). The effects of age and noise were statistically significant. However, the effects of the type of computer, the interactions between age and type of computer, age and noise level, and type of computer and noise were not found to be statistically significant.*

equivalent noise level   age   visual display units   data entry task performance

1. INTRODUCTION

The number of older people in the population has been growing and will continue to increase in the next decades [1]. By 2030 the percentage of people aged 65+ will be ~24% in Europe and ~12% in Asia and Latin America and the fastest growing cohort within this subgroup will be people over 75 [1]. Currently, in the USA ~44.5 million people are over the age of 75; by 2050 they will number almost 50 million and similar changes are occurring worldwide [1]. At the same time that the population is aging, technology is rapidly being integrated into most aspects of life and changing the nature of work, the form and scope of personal communication, education, and health care delivery. Some form of computer technology is commonplace in most environments including the home. Many routine activities such as banking, information retrieval, bill paying, and shopping increasingly involve the use of computers. It is highly likely that older people will need to interact with some form of computer technology to carry out routine activities. Aging causes decline in the abilities to sense, process information, and respond to stimuli [2], with such declines accelerating after individuals reach their mid-forties [3]. Aging also causes decline in the ability to make fast movements with precision. In the context of interaction with computers, this decline is more pronounced in typing and mouse manipulation

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speeds. These declines can negatively affect older users' ability to perform computer-related tasks and, thus, older people show poorer performance with these devices compared to younger people. Older people take longer and make more errors in computer-based work [4, 5], and show less speed and make more slip errors in using input devices [6].

Although the effects of noise on human performance have long been studied by human factors researchers, some recent articles have sought to clarify the sometimes conflicting viewpoints [7]. Tasks involving seriation are found to be vulnerable to exposure to irrelevant sound [8]. The effects of noise enhanced or degraded inspection task performance [9]. Random and intermittent noise was shown to contribute to performance decrements for an easy task [9]. A single source noise enhanced performance on a more difficult task [9]. Low-frequency noise negatively influenced performance on two tasks sensitive to reduced attention and on a proof-reading task [10]. Noise was also found to have a significantly negative effect on the performance of a readability task in a mobile driving environment [11]. Noise significantly affected human performance of a data entry task [12]. However, several other studies have shown no effect of noise on human psychomotor performance [13, 14]. More work has to be carried out to be specific about the noise effects.

With regard to the use of computers with different design, there is a trend to replace desktop with laptop computers. However, laptop computers may not be suitable for prolonged use because of their smaller size and lack of a separate keyboard and screen position adjustment. Unlike in desktop computers, laptop screens are usually fixed to the keyboard with a hinge. This allows for the angle of viewing to be adjusted but does not allow independent adjustment of screen and keyboard distance and height. Given these physical constraints, it was assumed that the user would be required to compromise their typing posture either by increased neck flexion to see a lower screen or by increased shoulder and elbow flexion to reach a higher keyboard. Prior research has suggested that increased neck and shoulder flexion increases the biomechanical load on surrounding structures, leading to discomfort and possibly the development of musculoskeletal disorders [15]. It was reported that an increase in shoulder flexion from 0º to 45º resulted in an increase in shoulder discomfort. Increase in head tilt and neck flexion was also found during text typing on a laptop computer, compared to using a desktop computer [16]. Therefore, if laptop use is associated with increased neck and shoulder flexion, the replacement of desktop computers with laptops may lead to an increased incidence of pain and pathology in computer users. Additional laptop computer features that raise concerns include other keyboard design characteristics (reduced key size and/or spacing, increased thickness), permanent attachment of keyboard and display, and pointing device design (lack of alternative integrated devices and device locations [17]). Each of these features can be cause for concern, because of their potential to increase biomechanical strain in the user and hinder performance.

Although many studies have identified age-related differences in the use of computer-related appliances and the Internet [18, 19, 20], it appears from the literature surveyed that the effect of aging has not attracted due consideration in research in the area of human–computer interaction (HCI), particularly under the impact of noise-induced stress.

Keeping this in view, the present study was designed to investigate the effects of human age, type of computer, and noise on the operators' performance of a data entry task when the task was performed by operators in a sitting posture on desktop and laptop computers under varying levels of noise. The following hypotheses were structured:

1. Age has a significant effect on operators' performance of a data entry task.
2. The type of computer (desktop or laptop) has a significant effect on operators' performance of a data entry task.
3. The varying levels of noise significantly affect operators' performance of a data entry task.

4. Interaction between age and noise significantly affects operators' performance of a data entry task.
5. Interaction between age and type of computer significantly affects operators' performance of a data entry task.
6. Interaction between type of computer and noise has a significant effect on operators' performance of a data entry task.
7. Interaction between age, type of computer, and noise has a significant effect on operators' performance of a data entry task.

2. METHOD

2.1. Subjects

Twenty male subjects aged 10–55 participated in this study. They were assigned to four age groups each consisting of 5 subjects. The age of the subjects in groups 1, 2, 3, and 4 were 13.6 ± *SD* 3.2 (10–15) years, 20.4 ± 2.6 (16–25) years, 32.2 ± 1.8, (26–40) years and 48.8 ± 4.5 (41–55) years, respectively. All subjects were familiar with computer operation with the exception of age group 1; therefore, they were specially trained enough to get familiarized with the task assigned to them in this study. None of the subjects had any previous history of neuromuscular disorder.

2.2. Experimental Setup

Experiments were conducted in a simulated environmental chamber 4.9 × 4.6 × 2.9 m^3. The temperature in the chamber was maintained at 25 ± 2 ºC. When closed, the chamber was acoustically sealed from the outside environment. The level of illumination throughout the experimental session was maintained at 340 lx in accordance with International Labour Office's (ILO) recommendations [21] and was monitored with a TES 1330 digital light meter (TES EE, Taiwan). The contrast ratio of the screen was 4:1 and was maintained throughout the experiment as recommended by ILO. Screen luminance was 310 cd/m^2; the positions of the keyboard monitor and documents were the same throughout the experimental session. The distance from the screen to the subjects' eyes was kept at 500 mm and that from the centre of the screen to the ground was 910 mm [22]. An audiocassette recorder (Keltron, India) was used to play and replay pre-recorded noise. A GA-214 sound level meter (Castle Group of Industries, UK) was used to measure and monitor the noise level. A call bell was used to signal the beginning and the end of the experimental task. In addition, a digital watch to indicate the length of the experimental task (15 min), a Siva SM 1428 desktop computer (Sterling Computers, India) and an Armada 1350 laptop computer (Compaq, USA) were also used in the study. The angle of the screen of both computers was kept at 110º, this being the most comfortable viewing position as suggested by the subjects. The text given to the subjects was in French written in 12-pt regular Times New Roman, double-spaced. It was printed on a high-quality white paper sheet that remained fixed in a document holder throughout the experimental sessions. The sheet contained words which the subjects did not understand so as to minimize the difference between the subjects, whose level of proficiency in English was difficult to control.

2.3. Experimental Procedure

The following steps were taken before the actual experiment:

- the subjects were briefed about the objectives of the experiment;
- they were given instructions for the experimental task;
- they received sufficient training that familiarized them with the task.

After a subject sat down in the chamber, the following steps were taken in both the training and experimental sessions:

- the sheet that contained the printed text in French was presented to the subject;
- the bell was triggered to signal the beginning of the experimental session;
- the subjects performed the data entry task for 15 min and task performance was measured in terms of mean number of characters entered per minute (MNCEPM);

- the bell was triggered to signal the end of the data entry task.

The experiments were conducted under varying levels of noise. The selected equivalent levels of noise, L_{eq}, were 82, 92, and 102 dB(A) and they were played in a random order during the experimental sessions. When the task was performed, the level of noise was kept at a pre-specified value, the level being constantly monitored by manipulating the volume of the audiocassette player as measured near the subject's ear. A 20-min rest period was provided before the next set of experiments.

2.4. Noise Levels

A pilot study was carried out to determine the different levels of equivalent noise to which operators were subjected when working on computers in different work environments. For this purpose, sound levels at New Delhi Railway Reservation Office, Aashram Chowk (one of the busiest road-crossings of New Delhi), and the National Thermal Power Corporation (NTPC), Badarpur, in New Delhi, India, were recorded for 15 min on a Sony (Japan) audiocassette. These situations represented noise levels in office, traffic, and factory environments, respectively. The equivalent noise levels, L_{eq}, in those locations were 82, 92, and 102 dB(A), respectively.

2.5. Statistical Analysis

A 4 (human age) × 2 (type of computer) × 3 (level of noise) analysis of variance (ANOVA) with repeated measures on the last two factors was used to determine the effects of the parameters under investigation. Age and noise levels (L_{eq} of 82, 92, and 100 dB(A)) constituted the independent variables. Human performance, measured in MNCEPM, of the data entry task was the dependent variable. If the effect of noise emerged to be significant, a test for comparison among treatment means would be undertaken to establish which means differed from one another. The variation of task performance (MNCEPM) with the variation of noise level (L_{eq}) for both desktop and laptop computers was also studied. The analyses were related to eight conditions of the experiment:

- condition I when subjects of age group 1 (10–15 years old) entered data on a desktop computer at various noise levels;
- condition II when subjects of age group 2 (16–25 years old) entered data on a desktop computer at various noise levels;
- condition III when subjects of age group 3 (26–40 years old) entered data on a desktop computer at various noise levels;
- condition IV when subjects of age group 4 (41–55 years old) entered data on a desktop computer at various noise levels;
- condition V when subjects of age group 1 entered data on a laptop computer at various noise levels;
- condition VI when subjects of age group 2 entered data on a laptop computer at various noise levels;
- condition VII when subjects of group 3 entered data on a laptop computer at various noise levels;
- condition VIII when subjects of age group 4 entered data on a laptop computer at various noise levels.

The comparison among treatment means for the eight conditions was conducted with Newman–Keuls test [23].

3. RESULTS

Table 1 presents performance (expressed in MNCEPM) of subjects belonging to the consecutive age groups at various noise levels. As the level of noise increased from 82 to 92 dB(A), the subjects of all age groups entered fewer characters in the stipulated time. However, MNCEPM increased with a further increase in noise level. The results also revealed that at each level of noise, the subjects entered more data on the desktop than on the laptop and performance of the subjects in age group 2 was better than of those in the other groups. It should be noted that these results were obtained for an experimental study in which subjects performed data entry task for 15 min on desktop and laptop computers at 82, 92, and 102 dB(*A*) noise levels.

ANOVA indicated that the individual effects of age and noise were statistically significant (Table 2). However, the individual effects of the type of computer and the interaction between age and the type of computer, the type of computer and noise level, age and noise level, and also the second order interaction (age × type of computer × level of noise) were all found to be statistically nonsignificant. Table 3 shows the post hoc comparison of the mean MNCEPM values obtained at various noise levels under the eight experimental conditions. Figures 1–2 show the data entry task performance of operators of different ages on desktop and laptop computers at three different noise levels.

TABLE 1. Character Entry Rate at Different Noise Levels

	Character Entry Rate					
	Desktop			Laptop		
Age Group (years)	N_1	N_2	N_3	N_1	N_2	N_3
1 (10–15)	24.80	20.20	27.60	25.40	17.80	28.20
SD	5.40	6.18	5.41	6.31	3.83	4.15
2 (16–25)	32.00	28.20	36.00	31.20	27.80	33.80
SD	7.17	3.49	9.43	9.26	7.12	10.85
3 (26–40)	27.20	22.80	29.60	25.60	21.60	30.40
SD	2.95	5.59	3.44	2.30	3.91	4.16
4 (41–55)	18.00	15.80	22.20	18.80	20.20	21.60
SD	5.83	3.49	6.98	9.42	7.63	11.01

Notes. N_1 = 82 dB(*A*), N_2 = 92 dB(*A*), N_3 = 102 dB(*A*).

TABLE 2. Results of Analysis of Variance of the Character Entry Rate on a Desktop and a Laptop Computer at Varying Levels of Noise

Source of Variation	*df*	*MS*	*F*	*p*
Between subjects	19	276.14	1.48	.2163
Age	3	753.57	4.04	.0257
Subject within groups (error I)	16	186.62	1.00	.5000
Within subjects	100	22.68	1.49	.1843
Type of computer	1	0.84	0.06	.8096
Age × type of computer	3	10.32	0.68	.5770
Type of computer × subject within group (error II)	16	15.24	1.00	.5000
Noise	2	472.91	23.02	.0001
Age × noise	6	17.24	0.84	.5485
Noise × subject within group (error III)	32	20.54	1.00	.5000
Type of computer × noise	2	0.55	0.08	.9233
Age × type of computer × noise	6	9.98	1.42	.2376
Type of computer × noise × subjects within group (error IV)	32	7.01	1.00	.5000

TABLE 3. Results of a Comparison of the Character Entry Rate at Various Levels of Noise in 4 Experimental Conditions with the Newman–Keuls Test

Conditions	Significant Difference Between	Nonsignificant Difference Between
I	N_3 and N_2	N_3 and N_1 N_2 and N_1
II	—	N_2 and N_1 N_3 and N_2 N_3 and N_1
III	N_3 and N_2	N_2 and N_1 N_3 and N_1
IV	N_3 and N_1 N_3 and N_2	N_2 and N_1
V	N_2 and N_1 N_3 and N_2	N_3 and N_1
VI	—	N_2 and N_1 N_3 and N_2 N_3 and N_1
VII	N_2 and N_1 N_3 and N_2 N_3 and N_1	—
VIII	—	N_2 and N_1 N_3 and N_2 N_3 and N_1

Notes. Conditions I—10–15-year-olds enter data on a desktop at various noise levels; II—16–25-year-olds enter data on a desktop at various noise levels; III—26–40-year-olds enter data on a desktop at various noise levels; IV—41–55-year-olds enter data on a desktop at various noise levels; V—10–15-year-olds enter data on a laptop at various noise levels; VI—16–25-year-olds enter data on a laptop at various noise levels; VII—26–40-year-olds enter data on a laptop at various noise levels; VIII—41–55-year-olds enter data on a laptop at various noise levels. Noise levels N_1 = 82 dB(*A*), N_2 = 92 dB(*A*), N_3 = 102 dB(*A*).

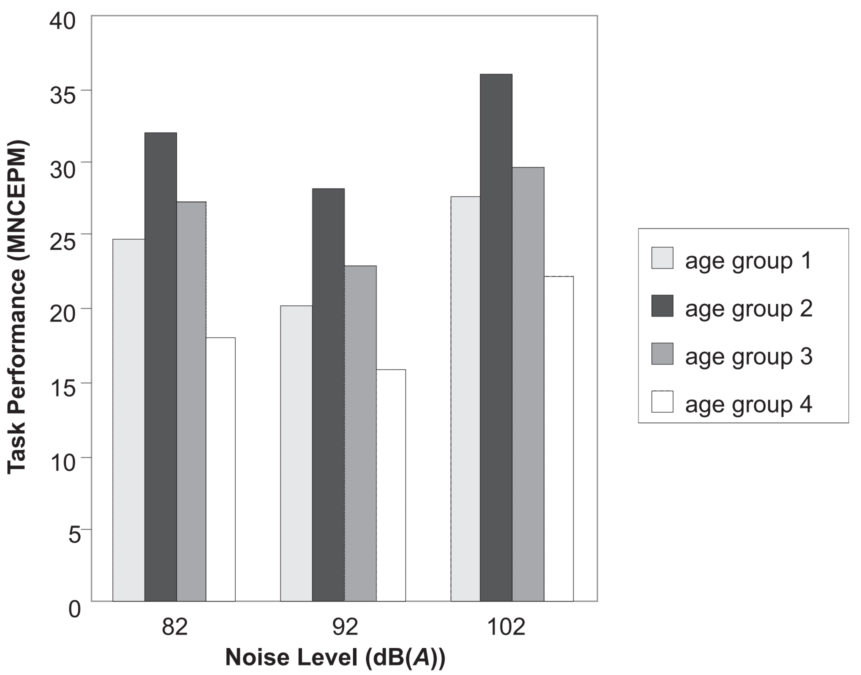

Figure 1. Data entry task performance of operators of different ages on a desktop computer at 3 levels of noise. *Notes.* MNCEPM—mean number of characters entered per minute. Age group 1: 10–15 years; age group 2: 16–25 years; age group 3: 26–40 years; age group 4: 41–55 years.

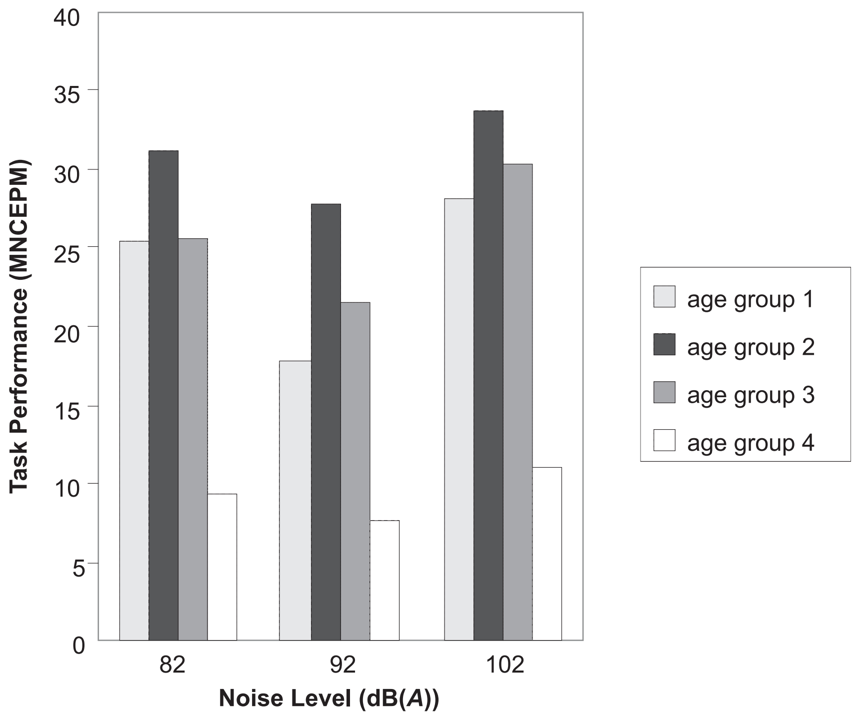

Figure 2. Data entry task performance of operators of different ages on a laptop computer at 3 levels of noise. *Notes.* MNCEPM—mean number of characters entered per minute. Age group 1: 10–15 years; age group 2: 16–25 years; age group 3: 26–40 years; age group 4: 41–55 years.

4. DISCUSSION

The hypotheses listed in section 1 were tested with ANOVA and it was found that the first and third hypotheses were valid, whereas the second and the last four were not. From the literature reviewed it appeared that either no or very few studies had been conducted in the past to study the effect of age on a data entry task performance in the HCI environment under the impact of noise. However**,** findings pertaining to studies on a similar topic, undertaken in the past, supported the present findings. Lindberg, Nasanen, and Muller's studies on the speed at which users of various age groups could find a specific computer icon from a group of others showed that search performance slowed down with age [24]. Wright, Bartram, Rogers, et al. found a major loss in accuracy and speed when users of old age entered text via a touch-screen keyboard on commercial handheld computers [25]. Khan, Mallick, Khan, et al. found a significant effect of age on the performance of a readability task in a mobile driving environment [26].

Another major finding of the present study pertains to the noise level that emerged to have a significant effect on human performance. The performance deteriorated with increase in noise intensity to a certain level but improved with further increase. This observation could be explained by arousal models [27] which predict increased activation due to increased levels of noise and, therefore, perceived arousal improves attention, memory and problem solving performance. This finding is supported by several studies. Vigilance performance in noise conditions was found to be significantly better than in the conditions [28]. Speed of cognitive task performance, which requires attention, was found to increase in noise [29]. This may be because lower levels of noise hinder performance; as the level of noise increases, it becomes even more difficult to carry out tasks. To accomplish them in a disturbing environment a person applies greater concentration and extra efforts and, consequently, performance improves.

5. CONCLUSIONS

This paper presented a study on the effects of human age, type of computer and noise on operators' performance of a data entry task. Twenty male subjects aged 10–55 years performed a data entry task for 15 min on desktop and laptop computers at three different noise levels, i.e., 82, 92, and 102 dB(*A*). On the basis of the results of the study, the following conclusions are drawn:

- Computer operators of age group 2 (16–25 years old) achieved the highest rate of data entry as compared to operators of other age groups.
- The type of computer does not have a significant effect on data entry performance.
- Noise is a highly significant factor in human performance pertaining to the data entry task carried out in a HCI environment. Within the range considered in this study, human performance deteriorated with an increase in noise intensity to a certain level and it improved when this level was exceeded.
- The interaction between human age and noise is statistically nonsignificant.
- The interaction between human age and type of computer is statistically nonsignificant for the data entry task in this study.
- The interaction between type of computer and noise does not have a significant effect on the operators' performance of a data entry task.
- The interaction between human age, type of computer and noise is statistically nonsignificant for the data entry task in the present study.

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