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Effects of noise type, noise intensity, and illumination intensity on reading performance

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ABSTRACT

This study empirically investigated the effects of noise type, noise intensity, and illumination intensity on reading performance. Three levels of noise types: factory noise, classical music, and pop with lyrics; three levels of noise intensity: 45 dBA, 65 dBA, and 85 dBA; and three levels of illumination intensity: 200 lx, 600 lx, and 1000 lx were tested. Results indicated that all three independent variables had significant effects on reading performance. Reading performance for classical music was significantly greater than that for pop with lyrics and factory noise. For noise intensity, 45 dBA resulted in the best reading performance, followed by 65 dBA, and 85 dBA. For illumination intensity, 600 lx resulted in the best reading performance, followed by 1000 lx and 200 lx. The interaction effects of noise type × illumination intensity were statistically significant. In conclusion, reading performance was best with classical music, low noise intensity, and normal illumination intensity conditions.

1. Introduction

Human computer interactions have increased greatly due to the wide availability of high-speed Internet access and the growing popularity of web browsing. Therefore, visual display terminals (VDT) have become indispensable in offices over the past few decades. Generally, the working performance of VDT workers in an office is affected by ambient noise and illumination conditions [1–3]. However, study concern with interaction effect of ambient noise and illumination is rare. Therefore, there is need to empirically investigate the effects of noise type, noise intensity, and illumination intensity on reading performance.

1.1. Noise type and noise intensity

Basner et al. [4] proposed that noise is pervasive in everyday life and can cause both auditory and non-auditory effects. They also pointed out that observational and experimental studies have shown that noise exposure leads to disruption of sleep, annoyance, increased cardiovascular disease, and impairs cognitive performance. Some studies [2,5–8] indicated that noise reduces task performance, while others [9,10] indicated that noise has no effect or even increases tasks performance.

Morrison et al. [5] investigated the correlation between noise and nursing stress, and concluded that noise is potentially a significant contributor to higher heart rates and tachycardia among nurses. Jahncke et al. [6] investigated cognitive, emotional, and physiological effects of noise conditions during work in a simulated open-plan office. Results indicated that the participants remembered fewer words, rated themselves as more tired, and were less motivated to work in high noise conditions compared to low noise conditions. Trimmel et al. [7] investigated the effects of low intensity noise on cognitive learning. Data indicate remarkable cognitive of low intensity background noise. Results showed impairments of reproduction (cognitive) under noise conditions. Clark et al. [8] showed that noise exposure might impair reading comprehension and increase noise annoyance. Lin [2] indicated that noise intensity has significant effects on reading performance. Reading performance was better at 30 dBA than at 60 and 90 dBA. Reading performance was better at 500 lx and 30 dBA than at 800 lx and 90 dBA.

In general, studies have concluded that high noise intensity impairs task performance because high noise intensity increases the overall workload associated with a given task and can, thus, potentially affect visual performance [9]. In addition, auditory distraction is indeed no exception when it comes to working memory

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and comprehension of written materials [11]. In contrast, Helton et al. [10] indicated that vigilant performance under noise conditions was significantly better than under quiet conditions. Furthermore, they indicated that the presence of noise increases self-reported task-engagement and improves performance.

Parsons [9] concluded that the effects of noise on non-auditory task performance have been inconclusive. Despite the inconsistent results of noise effects on psychological response, overall, most previous studies have concluded that noise impairs auditory task. However, effects of noise on other modalities (e.g., visual, olfactory, and tactile) are rare. Furthermore, Konkani and Oakley [12] indicated that no studies have quantified any relation between ambient noise and task performance. Therefore, the effects of noise (types and intensity) on reading performance remain to be studied.

1.2. Illumination intensity

Illumination intensity is an important factor in VDT workstation design and significantly affects visual performance [13–15]. Furthermore, illumination intensity might vary greatly when working with a TFT-LCD (notebook computer screen).

Luckiesh and Moss [13] indicated that at least 100 foot-candles (about 1076 lx) are desirable for reading under usual conditions. In contrast, Tinker [14] pointed out that speed reading increased from 5 to 25 foot-candles, but not for greater than 25 foot-candles; and Lin [15] indicated participants had better reading performance at 600 lx than at 1000 lx. Therefore, there is a need to further examine the effects of illumination intensity on reading performance.

1.3. Interaction effects

Huang et al. [16] carried out a controlled field survey to investigate the acceptable ranges of noise and illumination for indoor environmental quality. They indicated that participants feel more comfortable with illumination intensity above 300 lx and noise intensity below 49.6 dB. They also indicated that participants are less sensitive to illuminance changes. Bhattacharya et al. [17] indicated that the interaction between noise and illumination has a significant effect on visual performance. Lin [2] investigated the effects of the interaction between noise intensity and illumination intensity on short-term and long-term visual tasks. Results showed that the interaction between noise intensity and illumination intensity does not significantly affect short-term visual performance. In contrast, the interaction of noise intensity and illumination intensity had significant effects on reading performance. In short, the interaction between these two factors might have a significant effect on long-term visual performance. Therefore, it is important to empirically evaluate the interaction effects of noise types, noise intensity, and illumination intensity on reading performance.

2. Method

2.1. Experimental design

The experiments in this study primary evaluated three independent variables: noise type, noise intensity, and illumination intensity.

Three levels of noise types were tested: factory noise, classical music, and pop with lyrics. The factory noise used here was a recording from a bolt factory in Tainan. The classical music was Bach's Orchestral Suites no.1 and 2 which was played by Stuttgart Chamber Orchestra. The pops included recent top 10 billboard Chinese songs in Taiwan. The present time of the sound files are about 1 h. The noise was broadcast by two loudspeakers with maximal power output 1000 W, and the speakers located about 1.5 m behind the participants.

The present experiment employed three levels of noise intensity: 45 dBA (low level noise intensity and below the satisfactory level of 49.6 dBA (Leq) from Huang et al. [16]), 65 dBA (normal level noise intensity), and 85 dBA (high level noise intensity equal to the NIOSH [18] recommended limit and below the permissible exposure limits at workplaces in Taiwan).

Three levels of illumination intensity were tested: 200 lx (low level office illumination, and lower than the comfort level of 300 lx from Huang et al. [16]), 600 lx (normal level office illumination; [14]), and 1000 lx (high level office illumination; [13]). Extreme levels of illumination intensity, i.e., 50 lx or 10,000 lx, were not used because they are not practical for office environment settings, although considering those levels might also lead to significant findings.

The present study employed gray as the text and background color to prevent chromatic aberration [19]. The luminance of background was 40 cd/m^2 and the luminance of text was 5 cd/m^2. Therefore, the luminance contrast value was 8:1 [20] and the polarity was positive [21].

2.2. Participants

Ten female students from Kun-Shan University (they are all native Chinese speakers) majoring in Business Administration were enrolled as participants (age range = 19–22 years, M age = 20.3, SD = 0.95). All participants had at least 0.8 (20/25 visual acuity) corrected visual acuity or better and normal color vision (an Ishihara Color Vision test was performed). To maintain work motivation, participants were paid NT$120 per hour, plus an extra NT$5 for each correct answer on the comprehension test.

2.3. Apparatus

An ASUS TFT-LCD display (19 in.) monitor with a 485-mm diagonal screen provided an active viewing area of 412 mm horizontally and 256 mm vertically. The pixel resolution was 1024 horizontally and 768 vertically, and the center-to-center pixel spacing was about 0.4 and 0.33 mm, respectively. The screen images were refreshed at a rate of 72 Hz. The maximal luminance contrast ratio value and maximal luminance of the TFT-LCD were about 200 and 300 cd/m^2, respectively. The screen surface was coated with SiO_2 polarizer to reduce glare and reflection.

The used fluorescent lamp was 40 W FL40D/38 which was purchased from Taiwan Light Co. (Taiwan). The illumination intensity was measured using a TES-1330 digital lux meter purchased from TES Electronic Co. (Taiwan) and the noise intensity was measured using a NM102 noise meter purchased from Noise Meters Co. Ltd. (UK). A Topcon SS-3 Screenscope was used to test the visual acuity of the participants. The experiment was held in a soundproof and light-obstructed room. A Topcon SS-3 Screenscope and standard Pseudo-Isochromatic charts were employed to test the visual acuity and the color vision of the participants, respectively.

2.4. Workplace condition

Fig. 1 shows the experimental workplace configuration. The TFT-LCD was positioned on a table 70 cm in height [22–24]. The inclination angle of the TFT-LCD screen was 105° [24,25] with respect to the vertical axis. A chinrest restrained each participant's head at 25 cm above the table and maintained their viewing distance at 60 cm during the experiment. There was no glare on the TFT-LCD screen.