Open-Plan Office Designs: An Examination of Unattended Speech, Performance, and Focused Attention

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ABSTRACT

This study modeled the open-plan office environment by introducing background speech (a common workplace noise) at moderate decibel levels and measuring performance on a computer editing task. Also assessed was whether focussed attention moderates the effects of background speech on task performance. Editing accuracy was significantly higher under quiet compared to continuous background speech conditions. Results also showed that participants scoring higher on focused attention using the Tellegen Absorption Scale (Tellegen & Atkinsson, 1974) were more accurate detectors of certain types of errors and edited more lines of text than low absorbers. Implications for open-plan office design, selection of personnel, technology deployment in non-optimal environments, and the importance of focused attention are discussed.

INTRODUCTION

The implementation of technologies in workplaces is a relatively unexplored area of human factors (Nickerson, 1995). The physical environment can introduce factors that undermine usability of acquired technology. For example, office environments commonly expose the operator to environmental factors that can intrude upon their ability to successfully use the technology. One environmental factor which may intrude upon the operator's ability to perform a task is noise. Noise in the workplace can take the form of unwanted sounds such as telephones ringing, conversations, and office machines such as copiers or printers.

Various approaches have been used to investigate the effects of noise on task performance. Previous research indicates that noise is a more intrusive variable in office environments than other factors, such as temperature or lighting (Green, 1993; Young & Berry, 1979; Nemecek & Grandjean, 1973; Rivlin & Weinstein, 1984; Broadbent, 1979; Smith, 1989; Martin, Wogalter, & Forlano, 1988). It is also well supported that unattended speech can be a disrupter of performance. Broadbent (1979) suggested that even moderate levels of certain types of noise can disrupt cognitive performance. Martin, Wogalter, and Forlano (1988) found that background speech impaired reading comprehension by interfering with inner speech (articulatory loop). Noise and cognitive task demands are characteristics describing many open-plan offices.

The open-plan office is a workspace design placing several workers in a shared space operating various types of equipment (e.g., computers, copiers, phones) at the same time. The open-plan has been accepted as an inexpensive alternative to separate closed offices and is believed to facilitate communication and collaboration. Many plans separate work spaces by using panels, but irrelevant speech and equipment noises can still be heard, albeit at somewhat lower levels. Many office tasks require complex cognitive operations such as linguistic processing, pattern recognition, and decision making. These operations frequently co-occur with extraneous machine noise and speech. These irrelevant sounds may introduce attentional and processing demands that could degrade the operator's ability to meet immediate task demands.

Problems with open plan offices have been examined in previous studies; many have used a quasi-experimental approach or only examined subjective evaluations. Sundstrom, Town, Rice, Osborn, and Brill (1994) found that telephones ringing, face-to-face conversations, and phone conversations are the most disturbing noises reported by open plan office workers and this noise reduced environmental and job satisfaction. Young and Berry (1979) determined that speech was perceived as the most undesirable type of noise by office workers engaged in tasks requiring complex processing. Becker, Gield, Gaylin, and Sayer (1983) examined community colleges that utilized open- and private-plan designs. Faculty in open-plan offices reported greater work impairment and reduced ability to effectively interact with students than faculty in private-plan offices. Students were also surveyed and reported dissatisfaction with open-plan offices, finding them particularly intrusive when trying to consult with faculty (Becker et al., 1983). Rivlin and Weinsten (1984) found that elementary school students in open-space schools do not perform as well as those in schools with separate classrooms with solid, floor-to-ceiling walls. In addition, they found that teachers were dissatisfied with open-space classrooms and believed that the design challenged their ability to deliver quality instruction.

Problems with open plan offices also extend to physical and mental health. Klitzman and Stellman (1989) identified noise as a predictor of satisfaction, fatigue, irritation, and distress. Hedge (1984) found that employees in open plan offices were more likely to experience health problems such as upper-respiratory tract infections, frequent headaches, fatigue, strain, and nausea. Thus the open plan office appears to have several environmental problems that could impair operator performance and well-being. The purpose of the present study was to determine the effects of speech-related noise on cognitive task performance. The environment common to open plan offices was modeled and participants performed activities similar to those required in modern office workplaces. In the present experiment, a computer-based editing task was used.

An additional consideration is the extent to which factors *within* the operator might play a role in the interaction of the environment and the task. Some people may be better able to concentrate on the task in noise than others. The Tellegen Absorption Scale (Tellegen & Atkinsson, 1974) was selected as a paper and pencil measure of focused attention. Tellegen and Atkinsson (1974) developed a 71-item scale which identified 11 factors related to attention. Two factors, reality and fantasy absorption, appear to reflect focused attention. Reality absorption reflects a tendency to become strongly focused upon an event in the external environment to the exclusion of all other events. Fantasy absorption involves a tendency to allocate so much attention to internal processing that fantasy activity becomes vivid and almost realistic. Crawford, Brown, and Moon (1993), using a series of Gestalt tasks, found strong relationships between reality and fantasy absorption, and focused attention. Figure-ground relationships could be more easily detected by individuals with higher absorption measures. Focused attention also appears to be related to situation awareness which is defined as "adaptive, externally-directed consciousness" (Smith & Hancock, 1995, p. 138). This research considers the individual's attention to task relevant stimuli, and the degree to which they can appropriately allocate attentional resources while excluding non-relevant stimuli. Persons capable of regulating attention in a manner which allows efficient processing of critical system characteristics are desirable as operators.

A study conducted by Jackson and Wogalter (1997) found that participants who performed an editing task under quiet conditions gave significantly higher task difficulty ratings than participants exposed to discontinuous background speech (one-side of a two-sided conversation). In addition, although not significant, participants exposed to a two-sided conversation perceived the editing task as slightly more difficult than quiet and slightly less difficult than a one-sided conversation (discontinuous speech). These results provided a rationale for the hypotheses tested in this study.

This experiment used two unattended speech conditions, continuous and discontinuous, and a no-speech (control) condition. An editing task was also used to explore the effects of background speech on task performance. It was hypothesized that background speech would degrade performance compared to quiet and, specifically, that discontinuous speech (analogous to a one-sided telephone conversation) would be more disruptive than continuous speech. Discontinuous speech is unpredictable, disjointed noise which might disrupt the listener's ability to adapt to the noise through habituation. Thus, chronic dishabituation might disrupt attentional focus and undermine information processing. Conversely, discontinuous speech could be more easily blocked than continuous speech because of its lack of meaning to the listener and consequently, may not be as disruptive as a meaningful continuous conversation. Discontinuous speech also comprises less total noise than continuous speech, which could make it less disruptive. It was also hypothesized that differences in the propensity to focus attention would moderate the speech-performance relationship.

METHOD

Participants

Forty-eight undergraduates, ranging in age from 18 to 27 (M = 19.68, SD = 2.19) participated for credit in undergraduate psychology courses. The sample consisted of 19 females and 29 males.

Materials and Equipment

The Tellegen Absorption Scale (Tellegen & Atkinsson, 1974) was used to assess the degree to which participants focused their attention on selected targets. The scale measure also reflects the direction of attentional focus (internal processing or external environment).

A Sharp portable cassette stereo system was used to reproduce the speech stimuli. Two recordings were developed for the continuous and discontinuous speech conditions. The speech recordings were presented through open air speakers. The continuous speech condition consisted of a two-way conversation. An attempt was made to reduce inflection changes, however, the recorded conversation followed the natural flow of a conversational exchange. The one-way (discontinuous) speech condition was made by blocking the sound of one speaker and producing two separate recordings each consisting of only one person from the two way conversation. This condition simulated a phone conversation. The speech conditions were delivered at a decibel level of 75 dB (A).

Procedure

Individuals participated in single sessions (between subjects design), and randomly assigned to one of three conditions, the quiet condition, continuous speech condition or discontinuous speech condition. In the discontinuous speech condition, half of the participants heard one person from the two-sided conversation, while the other half heard the other person from the two-sided conversation. In the continuous condition, participants heard both persons. The Tellegen Absorption Scale was completed at the beginning of the session. The editing task was performed in a sound proof chamber. The stereo system was located eight feet behind the participant who was seated at a computer terminal. Participants were given instructions to perform the task as accurately as possible and were provided with a practice session consisting of a paragraph that was edited in the presence of the experimenter, who provided feedback (under quiet conditions) regarding the types of errors to be detected.

A computer displayed the document to be edited. The computer software allowed the operator to use only three keys, two directional keys to move horizontally or vertically, and the spacebar, which was used to mark an error. Operators could not move backward in the document and they could not move back to a previous line. The directional keys could be operated with the dominant hand only. The other keys were covered and the mouse was removed.

There were three types of errors in the document; homonyms, misspelled words and spoilers. Spoilers were illogical words that were placed in a sentence, for example, "...a tendency to overestimate the time spent in highly valued was activities." The spoiler in the sentence is the word "was." Spoilers were used by Jorna (1991) to force contextual processing. Both homonyms and spoilers require the processing of context, which is more difficult than simply identifying misspelled words. Once participants indicated their understanding of the task, the experimental session began. Those participants assigned to noise conditions were told that they would hear speech in the background and they were told to ignore it. All participants were told they would have 10 minutes to perform the task.

At the end of the session, participants were debriefed and dismissed.

Performance was measured by examining general proofreading accuracy (including specific accuracy which was a proportion of the number of errors correctly identified out of all errors marked), completion rates (number of lines completed), and accuracy of detecting the different types of errors (homonym, spoiler, and misspelled word detection rates).

Because of missing values for one participant, the data analyses for absorption were based on a total of 47 participants. The absorption scores ranged from 2 to 20. A median split was used to divide participants, based on their scores on the Tellegen Absorption Scale, into high- and low- absorbers. The split resulted in 24 high absorbers ($M = 17.29$, $SD = 2.39$) and 23 low absorbers ($M = 10.26$, $SD = 2.82$).

RESULTS

ANOVAs were used to examine the performance measures with noise and absorption as independent variables.

An ANOVA showed a significant main effect for noise condition on specific accuracy scores, $F(2, 46) = 2.53$, $p < .05$. Paired comparisons of the means indicated significant differences between the quiet condition ($M = .86$) and the continuous speech condition ($M = .78$). Participants in the quiet condition were significantly more accurate detectors of errors than participants in the continuous speech condition. The mean for the discontinuous speech condition was .85. No other significant effects were found among the noise conditions.

Significant main effects were found for absorption on two performance measures, completion rates, $F(1, 46) = 4.49$, $p < .05$) and homonym detection rates, $F(1, 46) = 4.93$, $p < .05$). The High absorbers edited significantly more lines of document ($M = .49$) than low absorbers ($M = .43$). High absorbers were more accurate detectors of homonyms ($M = .88$) than low absorbers ($M = .78$).

Absorption tended to have an effect on overall accuracy, although it failed to reach the conventional level of significance, $F(1, 46) = 3.43$, $p = .07$. High absorbers were more accurate overall ($M = .46$) compared to low absorbers ($M = .39$).

DISCUSSION

Participants in the quiet condition performed better than participants in the continuous speech condition on the specific accuracy measure. According to Martin et al. (1988), continuous speech competes with information gained from reading that is held in the phonological store. This competition for resources undermined performance in the continuous speech condition. The discontinuous speech condition failed to show any significant effects in this experiment; it was intermediate between the other two conditions. Discontinuous speech has less meaning and lower overall noise compared to continuous speech and this might make it less intrusive to the operator.

Earlier findings in a study conducted by Jackson and Wogalter (1997) found that operators rated discontinuous speech conditions higher than quiet or continuous speech conditions. This study failed to show the same pattern. Although there are a number of possible reasons for the apparent conflicting results, this may be another example of a mismatch between subjective judgements and actual performance.

Although the noise conditions did not yield significant differences, its effects deserve further consideration using larger sampling sizes and longer exposure time. In an effort to enhance internal validity, the recorded speech was controlled in order to reduce excessive speech characteristics such as emotional inflections or unusual pauses. In addition, a topic (insurance) was deliberately chosen to prevent any negative or unusual reactions by the participants to the content of the conversations. It is possible that the controlled nature of the conversations masked any effects because they were easier to ignore. Future research should use a wider range of representative background speech that has content that is reflected in real-world open-plan offices.

According to Jorna (1991), homonym detection is more difficult than misspelling error detection. It is at this higher difficulty level that the focused attention variable, absorption, relates to performance under noise conditions. The advantages of focused attention were observed in the speed at which participants performed the task. High absorbers seemed to demonstrate less of a speed-accuracy trade-off than low absorbers. The ability to focus attention may account for the higher speed and accuracy of the high absorbers.

Although environmental or system redesign would be the ultimate solution to open-office problems, it is frequently not feasible under financial/budget constraints. Nevertheless, minor changes to the environment or to the user interface could assist operators to focus their attention and enhance performance quality. A possible human factors solution might involve the use of masking white noise. Another approach would be to use ear plugs or better sound proofing in open-plan offices. An understanding of individual differences would assist in identifying other dispositional factors which might reduce the negative impact of noise on performance. Focused attention skill, like other types of attention, is a changeable and adaptable individual difference. Gopher (1992) found that changes in attentional skill could occur with training and that improved attentional skills were transferable to other tasks. Reisberg (1997) suggests that attention can be seen as an "achievement" in either dividing one's processing resources (divided attention) or adequately avoiding distraction (focused attention). Thus, operators who had lower absorption scores might be trained to focus and sustain attention in non-optimal environments in order to achieve a sufficient level of productivity. If training is not possible, scales such as the Tellegen Absorption Scale may serve as a personnel selection tool for jobs requiring complex cognitive operations under "speech" noise conditions.

Finally, this study points out the need to consider the contribution of environmental factors such as ambient speech in human-technology systems. The goal is to have human-technology interfaces that are not only usable in optimal settings, but are also usable in less optimal environmental conditions.

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