



Open-plan offices: Task performance and mental workload

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ARTICLE INFO

Article history:

Available online 24 September 2008

Keywords:

Open-plan office
Irrelevant speech
Focused attention
Workplace design
Noise

ABSTRACT

Open-plan offices are equipped with barriers such as panels and bookshelves to induce the perception of a private workspace. Despite perceived privacy, irrelevant speech contributes to mental workload, poor performance, stress, and fatigue. Certain dispositional variables related to sustained attention might exacerbate the effects of speech-related noise. This study used a $3 \times 3 \times 2$ mixed factor design to determine the effects of two forms of irrelevant speech and individual differences on performance of a real-world verbal task and mental workload. The Expanded Tellegen Absorption Scale (ETAS) based upon Tellegen and Atkinson's scale was used to assess individual differences in focused attention. The NASA Task Load Index was administered to assess mental workload. Main effects of noise were found on performance and mental workload. Irrelevant speech appeared to increase false alarms and completion rates. Workload ratings were higher in the irrelevant speech conditions. Other differences found were among High and Low Task and Imaginative Absorbers, as measured by the ETAS. Recommendations to reduce the impact of irrelevant speech and future research suggestions are provided.

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1. Introduction

Research in cognition and cognitive ergonomics has highlighted the need to understand work cultures in work environments requiring the use of computer-based technologies and computer-mediated work (Hollnagel, 1997; Hutchins, 1995; Jordan & Henderson, 1995). Despite increases in computing budgets for corporations, the expected productivity increases have fallen far behind, averaging 2% per year. Likewise, the \$100 billion in annual expenditures on information technology in the form of hardware, software, and computer services, including staff support, have not led to the expected corporate productivity increases (Nickerson, 1995; Tornatzky & Fleischer, 1990).

This research aimed to understand operator cognition in knowledge work environments by replicating an open-plan design. Open-plan offices have been identified as problematic due to interference from background noise. Performance decrements have been associated with ambient noise, speech, and visual distractions (see Danielssen, 2008; Evans & Johnson, 2000; Roelofsen, 2008; Schlittmeier & Hellbrück, 2008). Two specific phenomena were examined. First, irrelevant (ambient) speech, a situational condition common to many workplace environments, was examined to determine effects on task performance. Second, the ability to focus attention, an individual difference, was examined as a possible

moderator of the relationship between threat reactions, cognition, and verbal task performance.

1.1. Barriers introduced by open-plan offices

The open-plan office design exposes operators to situational factors while engaging in knowledge work. This context was modeled in the laboratory in an attempt to produce a 'scaled world' phenomenon to gather data of interest to the research questions (Ehret, Gray, & Kirschenbaum, 2000). Open-plan designs will refer to offices with individual workstations placed within an open space; sometimes divided by panels, but also including conventional shared offices with several workers in an office space. When introduced, open office plans were presumed to provide an environment that would increase work efficiency and facilitate communication, while reducing construction and equipment costs. Although physical cost has proven to be lower than the more complex designs requiring separate offices, the predictions of increased efficiency and better communication have yet to be fulfilled. The lack of positive outcomes for workers and productivity may very well negate the savings introduced by a less expensive physical design. Noise is one factor that may undermine the expected efficiency and productivity gains.

Noise in open-plan offices and performance under these conditions received much research attention since the early 1970s. Green (1993) reviewed 94 studies conducted from 1965 to 1985 to assess performance on primary and secondary tasks. From the meta-analysis, ten external task factors were identified, but only

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four were found to have significant effects on performance of office-type tasks. They were feedback, carbon monoxide, noise, and temperature. The present study examined noise introduced by unattended/irrelevant speech to determine performance effects on a computer-editing task. Green's study isolated noise as a powerful external contributor to performance problems.

Several studies have found evidence that open-plan offices are related to decreased job satisfaction, reduced motivation, and lower perceived privacy (Mital, McGlothlin, & Faard, 1992; Oldham & Brass, 1979; Young & Berry, 1979; Zalesny & Farace, 1987). Other studies examining subjective reports of employees in open-plan offices have identified irrelevant speech as a factor linked to negative perceptions of the workplace, lower productivity, and stress (Becker, Bield, Gaylin, & Sayer, 1983; Kupritz, 1998; Nemecek & Grandjean, 1973; Rivlin & Weinstein, 1984; Sundstrom, Town, Rice, Osborn, & Brill, 1994). In many of these studies, participants consistently identified speech as more intrusive than other types of noise such as copiers, telephones ringing, and traffic noises.

Additional studies have focused on health and well-being and "annoyance" reports. Workers in open-plan offices have reported that conditions are stressful and further examinations of these environments have found some support for a relationship between open-plan designs and fatigue, irritation, generalized distress, and health complaints, i.e. headaches and respiratory infections (Hedge, 1984; Klitzman & Stelman, 1989). Similarly, several studies have identified irrelevant speech in open-plan offices as the main sources of irritation reported by office workers (Sundstrom et al., 1994; Young & Berry, 1979). An interesting study conducted by Flynn et al. (1996) examined prescription-filling task performance by pharmacists in uncontrollable noise conditions (office machine noises) and controllable noise conditions (conversations in the work area). Pharmacists' prescription-filling performance (accuracy, speed) was better when office machine noise was present than when conversations were occurring in the task environment. This study examined performance in a realistic environment, but due to the research design, was unable to partial out the precise characteristics of the task and speech that disrupt performance.

1.2. Relevant cognitive theories

A few studies have been conducted to address the specific types of tasks and the characteristics of speech that may negatively impact performance in open-plan environments. Two theories could be used to explain effects of irrelevant speech center; these are Salame and Baddeley's (1989) *Irrelevant Speech Effect* and Jones' (1993) *Changing-state Hypothesis*. The Irrelevant Speech Effect is a phenomenon that has been used to explain the activity of working memory. The effect suggests that the disruptions occurring in memory and verbal tasks in the presence of speech only occur if the speech is meaningful and similar to the stimuli presented in the tasks. The Changing-state Hypothesis suggests that it is not the meaning of speech, but the variations in the rhythm of speech that account for performance decrements by blocking the performer's ability to habituate, and therefore, ignore the noise. According to Jones (1993), meaning does not disrupt performance. Any irrelevant sound that mimics the varying rhythm of speech will disrupt cognitive processing. These two assertions are in direct contrast to one another and parallel the early and late selection models of attention (Keele, 1973; Treisman, 1969). The Irrelevant Speech Effect asserts that disruptions will occur in the late filter process, while the Changing-state Hypothesis implies that disruption occurs at the early selection stage, before meaning is processed. Evidence supporting either of the two explanations is still not conclusive.

Several studies provide some support for the Irrelevant Speech Effect. For instance, Baddeley's (1986) research on irrelevant speech

and memory found support for the tendency of irrelevant speech to interfere with working memory. Baddeley proposed that the disruption actually occurs when phonemic stimuli from both the irrelevant speech source and the written words in a verbal task are both converted to phonological codes, within the articulatory loop of working memory. Resource overlap occurs at this point and leads to performance degradation. This resource overlap is also supported by Multiple Resource Theory (Navon & Gopher, 1979; Wickens, 1984).

A later study by Salame and Baddeley (1987) used irrelevant speech to determine the degree of interference of noise with short-term memory. Comparing performance under irrelevant speech, pink noise (steady streams of Arabic text), and a control (quiet) condition as well as an articulatory suppression trial (participants repeated the words 'blah-blah' while performing the verbal task). Salame and Baddeley found significantly more performance decrement in the irrelevant speech condition than in either the quiet condition or the irrelevant noise conditions. Also, performance decrement was greatest in the articulatory suppression (blah-blah) condition, compared to silent trials. This study provided support for the mechanism behind the intrusion of task performance occurring with irrelevant speech. A study by Maher and von Hippel (2005) showed that individuals in actual open-plan offices who exhibited stronger inhibitory abilities (as measured by a pre-task Stroop test) performed significantly better on a reading task than those with lower scores.

Smith (1989) reviewed the effects of noise on performance. Despite an extensive review, Smith concluded that noise effects are still not clear, and that beyond intensity issues, researchers need to analyze the questions of what type of noise at what intensity affects which type of task performance. Smith's studies in the eighties also provided critical elements to the development of hypotheses identifying the role of speech, as opposed to non-speech-related noise (i.e. white or pink noise), in disrupting task performance and the nature of the disruptions occurring in working memory.

Loewen and Suedfeld (1992) found that unmasked office noise consisting of speech, ringing phones, and copier noises disrupted performance more than masked noise and resulted in higher subjective ratings of distraction. Martin, Wogalter, and Forlano (1988) conducted a series of studies to investigate the effects of irrelevant speech on reading comprehension. Significantly poorer performance occurred in the continuous speech and randomly arranged speech conditions than performance in the quiet condition. A fourth experiment confirmed the hypothesis that irrelevant speech masked phonological activity necessary for reading and comprehension.

It is possible that verbal processing activity may impair an operator's ability to monitor and respond to other stimuli. In open office designs, individuals are typically engaged in verbal tasks, but must also attend to surrounding sounds to respond selectively when necessary. The fact that the task itself may lead to distortion of background noise is an additional reason why open office designs do not provide an optimal work environment. Although the present study does not address interference in the direction of task-to-noise, this possibility is a logical extension. The task-to-noise interference phenomenon demonstrates the extent to which graphemic and phonemic processing overlap.

The previous studies collectively provide an explanation of the disruptive nature of irrelevant speech as being related to the meaningfulness of the irrelevant speech. But, closer examination of these studies revealed some findings that do not specifically differentiate meaningful speech from other types of speech. For example, Loewen and Suedfeld (1992) study used noise not only containing speech, but also phone, copier, and keyboard sounds. The disruption in performance cannot be attributed to the presence of speech alone. Likewise, one of Martin et al. (1988) experiments

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