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Stress and Open-Office Noise

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Forty female clerical workers were randomly assigned to a control condition or to 3-hr exposure to low-intensity noise designed to simulate typical open-office noise levels. The simulated open-office noise elevated workers' urinary epinephrine levels, but not their norepinephrine or cortisol levels, and it produced behavioral aftereffects (fewer attempts at unsolvable puzzles) indicative of motivational deficits. Participants were also less likely to make ergonomic, postural adjustments in their computer work station while working under noisy, relative to quiet, conditions. Postural invariance is a risk factor for musculoskeletal disorder. Although participants in the noise condition perceived their work setting as significantly noisier than those working under quiet conditions did, the groups did not differ in perceived stress. Potential health consequences of long-term exposure to low-intensity office noise are discussed.

Research on the nonauditory (i.e., annoyance, physiological, performance, motivational) effects of noise has been concentrated on high-intensity, ambient sources, primarily on airport-impacted communities and occupational exposure or on loud, acute sources in laboratory experiments. Cardiovascular responses to acute noise rapidly habituate unless the individual is engaged in highly demanding tasks (Carter & Beh, 1989) or is noise sensitive (Stansfeld & Shine, 1993). Fewer studies have examined short-term neuroendocrine reactions to noise, but these data also suggest rapid habituation unless task demands are high (Tafalla & Evans, 1997). The large literature on occupational noise exposure and cardiovascular outcomes is so badly designed that no definitive conclusions have been possible (Evans, 2000; Thompson, 1993). Common methodological problems have included poor or nonexistent control groups, inadequate estimates of noise exposure, confoundings between noise levels and job type, and unreliable measures of blood pressure (Evans, 2000). Better designed studies of children chronically exposed to airport noise, including one prospective study (Evans, Bullinger, & Hygge, 1998), have indicated modest elevations in resting blood pressure (see Evans & Lepore, 1993, for a review). The Evans et al. (1998) prospective study also found elevated, overnight urinary catecholamines but no concomitant shifts in cortisol.

A large number of experimental and field studies have demonstrated that exposure to uncontrollable noise leads to poststressor (aftereffect) deficits in task performance (Cohen, 1980). One aftereffect index, task persistence, was used in a series of experiments by Glass and Singer (1972). They found that when individuals were exposed to uncontrollable noise, they were less likely to persist on challenging puzzles following noise exposure. These effects, which have been replicated in many studies of noise both in the lab and in the field, are generally considered indicative of diminished task motivation related to learned helplessness (Cohen, 1980; Cohen, Evans, Stokols, & Krantz, 1986; Evans, 2000). One of the major reasons for this explanation is the reliable finding that manipulations of perceived control over the noise stimulus largely ameliorate the aftereffects of noise. Furthermore, other indices of helplessness (e.g., giving up instrumental responding when effective behavioral options are available) show parallel noise deficits. These other measures of helplessness are also sensitive to manipulations of perceived control (Cohen et al., 1986; Evans, 2000; Evans & Lepore, 1993).

Researchers know much less, however, about the consequences of low-intensity noise exposure as is commonly found in office settings. The focus on high-intensity sound levels in noise research has led to the neglect of attention to potentially injurious effects of varying sound content. Noise is among the most prevalent annoyance sources in offices (Becker, 1981; Sundstrom, 1986). In a longitudinal study of office workers who relocated, Sundstrom, Town, Rice, Osborn, and Brill (1994) demonstrated that relative to workers who experienced no change or reductions in noise, the subset of workers who experienced more office noise after relocating experienced greater disturbance from noise, were less satisfied with their new work environment, and had the lowest levels of overall job satisfaction. Both self- and supervisor-rated job performance, however, did not change. The apparent absence of noise-related productivity deficits parallels results from many lab and field studies. Unless high information-processing demands are placed on individuals (e.g., monitoring multiple signals), noise has little or no effects on task performance (Broadbent, 1971; Hygge, 1997; Smith & Jones, 1992).

Low-intensity noise may be capable of producing performance deficits when information-processing demands are high. Irrelevant speech, in comparison with nonspeech-related stimuli at normal conversational volume, disrupts memory when load is high (Jones & Morris, 1992). Loewen and Suedfeld (1992) found that representative, open-office noise of low intensity interfered with complex but not with simple task performance. Complex task performance was assessed with a standardized index of cognitive complexity that measures the level of differentiation and integra-

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tion when a participant is asked to write about a novel topic. Simple performance was a visual search task. College students in Loewen and Suedfeld's (1992) study also expressed more negative mood on a standardized index and reported greater levels of disturbance and stress relative to participants in the quiet, comparison condition.

The present study builds on the work of Loewen and Suedfeld (1992) by examining physiological measures and performance aftereffects indicative of motivation in addition to self-report indices of stress under low-intensity, open-office noise. Another important extension of the present study is the use of experienced clerical workers rather than college students and a longer exposure period (3 hr vs. 30 min). Given Loewen and Suedfeld's findings with the same noise stimulus as we used in the present study, in addition to trends in the literature reviewed above, we hypothesize that low-level office noise is perceived as stressful, leads to post-stressor aftereffects indicative of diminished motivation, and elevates psychophysiological stress. Because manuscript typing at a relaxed pace is a simple task, we expect no noise impacts on typing performance.

In addition to self-report, psychophysiology, and aftereffect measures, we were interested in exploring another potential health impact of occupational noise exposure. Occupational stress appears, in concert with poor posture and repetitive use, to increase musculoskeletal disorders. Both field studies (Houtman, Bongers, Smulders, & Kompier, 1994) and laboratory experiments (Lundberg et al., 1994) suggest a link between occupational stress and musculoskeletal problems. The mechanism believed to account for these relations is elevated muscle tension induced by the mental strain accompanying occupational stressor exposure (Melin & Lundberg, 1997).

Another mechanism that might also link job stress to musculoskeletal disorder is static muscle load, or postural invariance. Researchers have long known that static muscle load and lack of postural adjustment heighten muscle strain (Putz-Anderson, 1988). We reason that because stress leads to a narrowing of attention to dominant stimuli (Broadbent, 1971) and a predominance of reflexive, habitual action patterns (Janis, 1982), perhaps under noise, workers might be less likely to make adjustments in work-station furniture. The possible contribution of occupational stressors such as noise to diminished use of ergonomic features in the work environment is an intriguing but as yet unstudied topic. Thus, in addition to increases in self-report, psychophysiological, and aftereffect indices of stress, we also explore whether workplace furniture adjustments during typical office work are affected by low-intensity noise exposure.

Method

Participants

Forty experienced female clerical workers (M = 36.50 years old) were randomly assigned to the noise or quiet-office condition. Participants responded to advertisements in local news media and were paid $150 for their participation. The study was described as a research project on computer work-station equipment. Most participants worked as secretaries (88%), administrative assistants (7%), or data analysts (5%). All used a computer for word processing at least 3 hr/day. All were in good health and had normal hearing, and none had been diagnosed or treated for musculoskeletal problems.

We restricted the sample to women for three reasons. Most clerical workers are women. Second, nearly all respondents to our advertisements were women. Third, there may be gender differences in physiological responses to stressors (Stoney, Davis, & Matthews, 1987).

Procedures

We conducted two 3-hr experimental sessions at the same time of day for each participant. Session 1 consisted of 3 hr of clerical work, and Session 2 consisted of 3-hr resting baseline session. The resting baseline session occurred 1–3 days later (session lag had no effects on the data). During the resting session, participants sat in a comfortable chair and read. Both sessions occurred in the Cornell Human Factors Laboratory with well-controlled climatic and illumination conditions.

For the experimental session, participants worked on clerical tasks under quiet or simulated-noise conditions. Simulated open-office noise, representative of typical conditions, was played continuously over loudspeakers so that average levels were 55 dBA, with peaks up to 65 dBA. The noise consisted of conversation segments, typing sounds, ringing phones, and drawers being opened and closed. The noise was the same representative, open-office noise stimulus developed by Loewen and Suedfeld (1992). Under the no-noise condition, the average, ambient sound intensity in the laboratory was 40 dBA.

The participants' primary task was to type into the computer a manuscript of unfamiliar content (aviation safety). We instructed the clerical workers to work at a normal, relaxed pace and explicitly told them that we were not monitoring performance. Rather, we told them that our interest was in the effects of computer work-station furniture on worker satisfaction and health. We informed them that we would measure their opinions and the physiological responses that had been shown to be sensitive to different work environment conditions. In the noise condition, we also told participants that they would hear low-level sounds designed to simulate a realistic open-office plan. We instructed them to focus on their task and just ignore the noise. In the quiet, comparison group, nothing was said about sound during the tasks. We informed all participants that during their work on the manuscript, they would periodically be interrupted with realistic tasks (i.e., prepare a poster, cut and paste layout sheets, alphabetize and paste up a list of names and addresses, complete an expense report). We informed the participants that these tasks were included to simulate the variety of tasks clerical workers typically perform on their jobs. Materials for the tasks were in a file cabinet, placed next to the computer work station and a nearby work table. The tasks required the participants to get up from their chairs. Interruptions occurred every 25 min throughout the 3-hr work period. Participants were also asked to take a drink of water at each interruption.

Similarly, every 25 min during the resting baseline, we reminded participants to drink some water. We informed them that drinking water was necessary so that we could collect their urine at the end of the session to test it for physiological changes that have been shown to be sensitive to work environment conditions.

Dependent Measures

Immediately before and after each session (experimental, resting baseline), the participants were asked to void all urine. The postsession urine was collected in a specimen container with a preservative (sodium metabisulfite) for subsequent neuroendocrine analysis. The use of a double-void procedure ensures that the neuroendocrine measures reflect activity only during the experimental period. Extensive research for over 3 decades at the Karolinska Institute, where Gary W. Evans trained, indicates more reliable and valid baseline estimates that use the double-void experimental procedure when the baseline period occurs after the experiment, so that participants can be assured that no further experimental sessions are pending (Frankenhaeuser, 1986; Lundberg, 1984). Postexperiment baselines are also recommended for other physiological parameters (Krantz & Falconer, 1995).

Epinephrine and norepinephrine were assayed with high performance liquid chromatography with electrochemical detection (Riggin & Kissinger, 1977), and cortisol was assayed with a radioimmune assay (Baxter Travenol Diagnostics, 1987). Immediately following collection, total urine volume was measured and duplicate 10-ml samples were randomly drawn. The pH of the catecholamine samples was acidified (pH = 3) with hydrochloric acid to further inhibit oxidation, and then the four samples were placed into ultralow freezing (−80°C) until the assays were performed.

Throughout the 3-hr work period, a trained observer unobtrusively monitored each participant and recorded every 10 min whether the participant adjusted one of eight work-station features (chair, document holder, monitor, keyboard, whiteboard, adjacent work table, footrest, movable file cabinet). The occurrence, not the amount of adjustment, was recorded. Interrater reliability for the two trained workers was perfect ($k = 1.0$). The observers were not informed of the hypothesis that noise leads to less equipment adjustment.

We evaluated typing performance by the total number of words typed per minute and by the percentage of errors (total errors/total number of words).

Immediately following the clerical task, participants indicated how noisy the setting was on a 5-point semantic differential scale ranging from 1 (*quiet*) to 5 (*noisy*) and indicated their level of perceived stress on a seven-item (bothered, worried, relaxed, frustrated, unhappy, contented, tense), 4-point rating scale ranging from 1 (*not at all*) to 4 (*very*, $\alpha = .86$). This was followed by the Glass and Singer (1972) aftereffect measure. Four different piles of geometric line drawings were placed in front of the participant. She was instructed to trace over the lines without crossing over any line twice and without lifting her pencil. For each attempt, the participant was requested to take a new puzzle from the pile. She was instructed to work on each puzzle until either it was solved or she felt she could not solve it. At that point, she was to move on to a new pile of puzzles. Once the participant had moved on to a new pile, she was not allowed to go back and work on a previous pile of puzzles. Participants were given up to 20 min to complete the four puzzles. Although the participants did not know it, the first and third puzzle were unsolvable. The number of attempts on the first and third puzzles constitutes the index of motivation.

Results

Manipulation Check and Simple Task Performance

Participants in the office-noise condition perceived the environment as significantly noisier ($M = 1.81$) than did those in the quiet condition ($M = 1.13$), $t(38) = 2.90$, $p < .01$. Typing performance was unaffected by noise ($M = 1.1\%$ error) relative to the quiet group ($M = 2.4\%$ error), $t(38) < 1.0$. Typing speed was also unaffected by noise (quiet: $M = 39.10$ wpm; noise: $M = 40.56$ wpm), $t(38) < 1.0$.

Stress

Table 1 depicts several indices of stress, including urinary neuroendocrine hormones, perceived stress, and the Glass and Singer (1972) aftereffect index. As is apparent in the table, although participants did not report feeling greater stress at the end of the 3-hr work session, both epinephrine and the aftereffects index indicated elevated stress.

Work-Station Adjustments

Participants in the noise condition were significantly less likely to adjust their work station ($M = 4.20$), in comparison with those working under quiet conditions ($M = 8.40$), $t(38) = 5.91$, $p < .001$. Looking at individual components of the work station, we note that participants made significantly fewer adjustments on

Table 1
Multimethodological Indicators of Stress

Stress index	Noise	Quiet	$t(38)$
Epinephrine (ng/min)	5.61 [4.67]	3.90 [4.71]	1.79*
Norepinephrine (ng/min)	3.90 [28.41]	2.59 [29.43]	<1.0
Cortisol (μg/min)	0.04 [0.03]	−0.03 [0.08]	<1.0
Perceived stress	1.72	1.88	<1.0
Aftereffects	11.50	19.10	4.75***

Note. Urinary neuroendocrine measures are difference scores, with the mean 3-hr resting baseline subtracted from the mean 3-hr experimental session. As we expected, given random assignment, resting baseline readings (shown in brackets) were all equivalent between the noise and quiet conditions. Perceived stress was rated on a scale ranging from 1 (*not at all*) to 4 (*very*). Aftereffects were measured as the number of attempts made on unsolvable puzzles.
* $p < .05$. *** $p < .001$.

chairs, foot rests, whiteboards, and document holders under the noisy conditions. Descriptive statistics and zero-order correlations for the various dependent variables are depicted in Table 2.

Discussion

The primary aim of this study is to investigate whether typical, low-intensity office noise can cause stress among experienced clerical workers. Prior research on the stressful effects of noise has focused on high-intensity noise levels. In general, the pattern of results herein resembles those found in prior experimental and field studies of high-intensity noise. Realistic, open-office noise has modest adverse effects on physiological stress, particularly on epinephrine, which is the most reliable neuroendocrine index of stress (Baum & Grunberg, 1995; Grunberg & Singer, 1990). Norepinephrine levels are more reactive to physical exertion, and cortisol levels are more sensitive to psychological distress (Lundberg, 1984).

Physical exertion can increase catecholamine levels, but the absence of norepinephrine differences, which are the most sensitive index of exertion (Baum & Grunberg, 1995; Lundberg, 1984), indicates that the epinephrine noise results are not due to differences in movement or physical activity between the noise and quiet groups. We did not measure the amount of overall movement, but the task constraints generally provided little opportunity for variation in movement other than equipment adjustments, which, as shown, were lower for the noise group.

Aftereffects indicative of diminished motivation (Cohen, 1980; Cohen et al., 1986; Evans, 2000; Glass & Singer, 1972) also appear sensitive to low-intensity office noise. It is interesting to note that Rotton, Olszewski, Charleston, and Soler (1978) found that the inclusion of speech augmented the negative affects of conglomerate noise on aftereffects relative to a quiet comparison group. These motivational findings are important conceptually and for policy. Conceptually, our data fit with interpretations in the literature (Cohen, 1980; Cohen et al., 1986; Glass & Singer, 1972) that the uncontrollability of sound rather than its intensity is what makes it stressful. Even low-intensity sound levels, simulating typical open-office noise, can induce performance aftereffects indicative of diminished task motivation. In terms of practice, these results are important, because if worker motivation is lower under open-office noise because of its uncontrollability, use of

Table 2
Descriptive Statistics and Zero-Order Correlation Matrix

Dependent measure	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. Perceived noise	1.47	1.17	—	.02	.30*	.24	−.01	.00	.15	.24	−.13
2. Perceived stress	1.80	0.47		—	−.08	.02	.30*	−.10	.08	.24	−.27
3. Epinephrine Δ score	4.76	5.57			—	.50**	−.23	−.12	.30*	−.02	−.33*
4. Norepinephrine Δ score	3.25	2.71				—	.07	.11	.05	.04	−.11
5. Cortisol Δ score	0.01	0.16					—	.10	−.25	.34*	−.26
6. Aftereffects	15.30	8.46						—	−.23	.00	−.12
7. Ergonomic adjustments	6.30	2.15							—	−.02	−.10
8. % error	1.90	0.89								—	−.46**
9. Words per minute	39.33	14.84									—

* $p < .05$; ** $p < .01$.

various design options (e.g., availability of quiet, enclosed rooms when concentration is desired) or technological interventions (e.g., sound-masking devices under the control of the user) might help alleviate the harmful effects of open-office noise on workers. To properly test these ideas, researchers could repeat this experiment including a noise-with-perceived-control condition, analogous to the Glass and Singer (1972) paradigm.

As in most studies of high-intensity noise (Broadbent, 1971; Hygge, 1997; Smith & Jones, 1992), low-level office noise also did not affect concurrent task performance. More complex tasks that strain information-processing capabilities, such as tasks with multiple cues, appear necessary to capture concurrent noise effects on performance. The pattern of correlations in Table 2 is consistent with prior work (Tafalla & Evans, 1997) indicating that maintenance of simple task performance under stressors like noise nonetheless requires effort that is manifested in psychophysiological activation.

Although we expected to, we did not find differences in perceived stress as a function of noise exposure. Loewen and Suedfeld (1992), using the same noise stimulus at the same volume, did find negative effects on perceived stress, although with a different outcome measure and over a much shorter period of exposure. The present null self-report results could reflect the common experience of habituation in annoyance to noise found in many settings (Evans & Tafalla, 1987; Kryter, 1994). Three aspects of the present study increase the likelihood that habituation may have occurred. First, we used experienced workers as participants rather than college undergraduates. Second, the length of exposure (3 hr) was substantially longer than the typical duration (10–30 min) used in laboratory experiments. Third, we used realistic, low-intensity noise recorded from actual offices. This post hoc habituation explanation warrants further scientific scrutiny, particularly in light of common reliance on annoyance as an indicator of problems with noise.

This is not the first study to find disassociated physiological, performance, and self-report indices of stress (see Table 2; Cohen, Kessler, & Gordon, 1995). We need to be cautious in assuming that just because people fail to report that environmental conditions are negative, no adverse impacts have occurred. Simply asking employees whether various physical and psychosocial conditions of work are suitable may mask adverse effects. Similarly, the apparent lack of occupational stress effects on productivity (i.e., manuscript typing in the present case) should not be equated with having no stressor impacts. Multimethodological probes are important to more adequately capture the full array of occupational and environmental stressor impacts.

Besides contributing the finding that low-intensity office noise can produce physiological and motivational indices of stress, the present study sheds some light on a potentially important and new health risk for noise exposure. Experienced clerical workers performing realistic office tasks under typical, low-level open-office noise are substantially less likely (by 50%) to adjust ergonomic work-station features that allow postural variability while working.

The observers were aware of the background noise, so it is possible that observer bias could account for some of this effect. We believe this is unlikely for two reasons. First, observers were not informed that work-station adjustments were expected to be noise sensitive. The observers were instructed to observe work-station adjustments because we wanted to determine how much workers actually used various ergonomic options available in the work station. Second, when queried after the experiment about why we were observing adjustments, neither observer mentioned the link to noise; instead they repeated back what they had been originally told about use of ergonomic options.

To our knowledge, the effect of noise, or occupational stressors more generally, on workplace adjustment is a new finding. Such effects, should they prove robust, provide a possible additional mechanism for explaining links between occupational stress exposure and musculoskeletal disorders. To date, this body of research has focused on elevated muscle tension as the principal underlying, explanatory mechanism (Melin & Lundberg, 1997). Occupational stress from various sources, including noise, could contribute to musculoskeletal disorders as well by suppressing use of adjustable ergonomic features in the immediate work environment. This finding needs to be replicated with a more heterogeneous sample (e.g., men, nonclerical workers) and should examine more intense (e.g., industrial) noise sources.

In addition to the possible musculoskeletal health impacts of chronic noise exposure, the results of this study indicate other potential health effects from chronic low-level noise exposure. Chronically elevated epinephrine is a risk factor for heart disease (McEwen, 1998). Nearly all research on noise has focused on sound intensity or loudness (Kryter, 1994). More research is called for on low-intensity sounds, particularly on those experienced as annoying, such as irrelevant speech (Jones & Morris, 1992). In a U.S. national survey of office workers, the most prevalent complaint about working conditions was disturbance from noise (Harris, 1978). The tendency to dismiss negative effects of office noise because levels do not exceed National Institute for Occupational Safety and Health hearing-protection thresholds or because indicators of productivity are unaffected may be shortsighted. Chronic exposure to noise, even low-intensity noise, may have the potential to cause health problems. Moreover, reliance on workers' self-reports of job stress or overall satisfaction may prove insensitive for monitoring some of the negative effects of the physical work environment on health and well-being. Habituation to noise and other suboptimal working conditions readily occurs in self-report data, especially if workers feel that little or nothing will be done in response to their complaints.

In conclusion, 3-hr exposure to simulated low-intensity open-office noise elevated urinary epinephrine levels, lowered postnoise-exposure task performance indicative of depressed motivation, and reduced use of ergonomic work-furniture features designed to provide opportunities for postural adjustments during work. Although there was physiological, motivational, and observational evidence of elevated stress from low-intensity noise exposure, workers' self-reports and a simple index of productivity did not reveal greater stress under low-intensity noise conditions.

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