Effects of noise, job characteristics and stress on mental health and accidents, injuries and cognitive failures at work

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INTRODUCTION

This paper addresses two key topics in noise research. The first is whether effects of noise are specific or reflect other correlated attributes. In the workplace noise exposure is often associated with other negative factors such as exposure to dangerous machinery or having to perform demanding tasks. If one finds associations between noise levels and outcomes such as accidents and injuries one needs to ask whether it is the noise per se that leads to such effects or whether other job characteristics associated with noise exposure underlying the association with accidents and injuries.

The second issue examined here is the explanation of non-auditory effects of noise. It has often been the case that noise effects have been explained in terms of an increase in stress (Babisch 2000). However, recent studies suggest that environmental noise exposure does not lead to reliable effects on key outcomes of the stress process (stress hormones – Maass & Basner 2006; immune parameters – Prasher 2010; and mental health – van Kamp et al. 2007). Research has not addressed the issue of whether occupational noise exposure influences both perceived stress and mental health outcomes. If noise exposure influences these measures then one needs to examine whether such effects reflect associations with other psychosocial stressors or are independent effects of noise. This was investigated here and the present study also examined effects of noise on cognitive failures, injuries and accidents at work. This was done by conducting secondary analyses of a large community sample. The aim was to determine whether noise influences the stress process (independently of other occupational factors) and whether effects of noise on accidents, injuries and cognitive failures were due to noise or correlated attributes. The next section reviews research on noise and safety at work.

Smith (1990) reviewed studies of the effects of noise on accidents. Cross-sectional studies have produced conflicting results, with some showing a greater accident rate in high noise areas (e.g. Kerr 1950; Cohen 1974) but others (e.g. Lees 1980) reporting no effect of noise. All of these early studies suffer from the problem that noise exposure was confounded with other uncontrolled factors. Intervention studies (e.g. Cohen 1976) suggest that reduction of noise exposure does lead to lower accident rates. However, these results can be interpreted in other ways (e.g. changes in morale) and a reduction in injuries was seen in both workers who used hearing protectors regularly and those who did not. Another major problem in this area is the definition of an accident. In some studies it is likely that an accident refers to an injuring requiring medical attention whereas in others the injuries are likely to have been more minor. There is a need, therefore, to examine associations between noise exposure and both accidents and minor injuries. Many everyday errors (failures of attention, memory or action) do not lead to accidents. However, in certain contexts human error is a major cause of accidents and it is important to determine where noise exposure influences the occurrence of cognitive failures. Smith and

Stansfeld (1986) compared self-reports of everyday errors given by people who lived in a high aircraft noise area with those given by people in a quieter area The results showed that the high noise group reported a greater frequency of everyday errors. It is now important to determine whether such associations are also observed in the workplace, and whether they reflect noise or other correlated job characteristics.

Smith (2003) found that perceptions of noise exposure were related to reports of accidents. minor injuries and cognitive failures. Clear dose-response effects were observed and this suggests that some causal relationship were present. Analyses were carried out to determine whether the associations between noise exposure and the outcomes reflected noise or other correlated job characteristics. The results suggested that the association between noise and accidents largely reflected other correlated job characteristics. In contrast to this, controlling for other factors and excluding those exposed to other physical agents did not remove the effects of noise exposure on minor injuries or cognitive failures. The effect of noise on minor injuries was greater at higher perceived intensities. However. the effect on cognitive failures was more apparent in those who perceived that background noise disturbed their concentration. As this last measure of noise exposure implies a functional deficit it is not too surprising that it should be associated with another measure of cognitive problems. The question measured not only exposure to noise but also sensitivity to its effects which may make it more useful than general questions about exposure. The present paper extends the above research by including a greater number of psychosocial characteristics in the analyses. Smith, McNamara and Wellens (2003) found that the physical working environment (of which noise exposure formed a part) was significantly associated with safety at work even when psychosocial factors were covaried. In contrast, the physical working environment was no longer associated with stress and mental health when psychosocial factors (job demands, control, support and effort-reward imbalance) were included in the analyses. The present investigation re-examined this issue with the focus being on perceptions of noise exposure and a model of stress outlined below.

Many models of stress (see Mark & Smith 2008) share the following features. First, they consider job characteristics that are perceived as negative (e.g. demands – Karasek 1979; high extrinsic effort – Siegrist 1996) or as positive (e.g. social support, control or reward). Perceived stress is seen as an imbalance between demands and control/support (Karasek 1979) or effort-reward imbalance (Siegrist 1996). Negative mental health changes (increases in anxiety and depression) then often result. In order to assess whether noise influences the stress process on needs to look at associations between noise and stress and mental health. One then needs to determine whether these effects reflect other psychosocial stressors or whether there are independent effects of noise on stress which could underlie many of the non-auditory effects of noise on health.

METHOD

The present paper reports a secondary analysis of a database formed by combining the Bristol Stress and Health at Work study and the Cardiff Health and Safety at Work study. Details of the database are given in Smith et al. (2003) and Smith (2000, 2001). This database contained information on perceptions of noise exposure at work, job characteristics, accidents, injuries and cognitive failures, and stress, anxiety

and depression. In addition, it contained information about possible confounders that need to be controlled in such analyses (e.g. demographics and health-related behavior).

Ethical approval

The Bristol Stress and Health at Work study was carried out with the approval of the local regional ethical committee. The Cardiff Health and Safety at Work was approved by the Cardiff University School of Psychology Ethics Committee. It was also scrutinized by the Local Research Ethics Committee, which deemed that formal ethical approval was not necessary.

Measurement of perceptions of noise exposure at work

Perceived noise exposure was measured by two questions. One asked how frequently they were exposed to noise which led to a ringing in the ears. The second asked about exposure to noise that disturbed concentration. A 4-point scale (from 'Never' to 'Often') was used to respond to the questions.

Measurement of accidents, injuries and cognitive failures at work

Frequency of accidents that required medical attention was recorded (number in last 12 months) and the frequency of minor injuries (not requiring medical attention from another person e.g. cuts and bruises) and cognitive failures were rated using a 5-point scale ('not at all' to 'very frequently').

Measurement of stress, anxiety and depression

Stress at work was measured using a 5-point scale from 'Not at all' to 'Extremely stressed' (Smith 2001). Anxiety and depression were measured using the Hospital Anxiety and Depression Scale (Zigmond & Snaith 1983).

Psychosocial stressors

The 21-item version of the Effort-Reward Imbalance Questionnaire (ERI, Siegrist 1996) was as used in the Whitehall II Study (Kuper et al. 2002). Three subscales measured intrinsic effort (internal motivations e.g. "overcommitment" to work) extrinsic effort (external pressures) and internal reward (adequate rewards). Participants respond on a four-point likert scale indicating to what extent (if experienced) they find the suggested work situations distressing. A 27-item version of the Job Content Questionnaire (JCQ: Karasek et al. 1998) was used. Four subscales measured job demands (workload, time pressure); decision authority (control over decisions); skill discretion (opportunity to use skills); and levels of social support. Participants responded as to how often they experienced the suggested situations at work on a four point likert-scale.

Control variables

The following variables were also included in the regressions to control for other factors: age, gender, income, educational level, social class based on occupation, full/part-time employment, negative affectivity and working hours.

Sample

Details of the sample are given in Smith (2003). In summary there were 6,512 workers (43.4 % male), with 71 % living in the Cardiff area and 29 % in the Bristol area. About a quarter of the sample had manual jobs.

In the following analyses noise exposure was recoded as (1) High noise exposure: those who were never exposed to deafening noise versus those who were; (2) Distracting noise: those who were never exposed to deafening noise versus those who were. In further analyses those who were exposed to noise that led to ringing in the ears were excluded from analyses of distracting noise.

RESULTS

Effects of noise on accidents

Table 1 shows that exposure to noise that led to ringing in the ears was associated with more accidents ($p<0.0001$), more frequent injuries ($p<0.0001$) and more cognitive failures ($p<0.0001$). These effects were also significant for exposure to distracting noise (Table 2). These effects remained significant when psychosocial stressors were covaried.

Table 1: High intensity noise, accidents, injuries and cognitive failures.

	Low noise	High noise
% having accident	7.4 %	16.5 %
% frequent injuries	9.1 %	26.2 %
% frequent cognitive failures	11.2 %	17.3 %

Table 2: Distracting noise, accidents, injuries and cognitive failures.

	Low Distraction	High Distraction
% having accident	7.1 %	8.3 %
% frequent injuries	7.8 %	13.8 %
% frequent cognitive failures	10.0 %	16.0 %

Effects of noise on stress and mental health

Table 3 shows that exposure to noise that led to ringing in the ears was associated with greater stress ($p<0.0001$), anxiety ($p<0.0001$) and depression ($p<0.0001$). These effects were also significant for exposure to distracting noise (Table 2 – all p-values <0.0001). These effects were no longer significant when psychosocial stressors were covaried. Perceived stress was most strongly influenced by job demands and extrinsic effort. Mental health was most strongly influenced by intrinsic effort.

Table 3: High intensity noise, stress and mental health problems.

	Low noise	High noise
% at least moderate stress	18.8 %	25.0 %
% high anxiety	29.2 %	41.1 %
% high depression	8.5 %	15.4 %

Table 4: Distracting noise, stress and mental health problems.

	Low Distraction	High Distraction
% at least moderate stress	16.2 %	28.6 %
% high anxiety	27.0 %	38.3 %
% high depression	7.5 %	13.0 %

DISCUSSION

The present results confirm that occupational noise exposure is associated with an increased risk of accidents and injuries. This effect is observed with both intense noise and lower intensity noise that causes distraction. For both noise exposures there was an association with an increased frequency of cognitive failures. It is plausible to suggest that this effect of noise on human error underlies that seen for accidents and injuries. One must now consider the underlying mechanism for this effect. The effect was still significant when psychosocial stressors were covaried. Furthermore, associations between noise exposure and stress, anxiety and depression were no longer significant when Karasek (1979) and Siegrist (1996) dimensions were included in the analyses. This suggests that noise plays little part in stress and mental health problems of workers and that it may be unwise to interpret effects, such as the effects of accidents, injuries and cognitive failures, in terms of a stress mechanism.

One must now ask what other mechanisms could underlie the effects of noise found here. One type of effect that has been put forward to account for effects of noise on attention is "over-arousal" (Broadbent 1971). Attention is best at moderate levels of arousal because the person can select relevant cues from irrelevant ones. As arousal increases the person becomes too selective and misses relevant information as well. An alternative view is that accidents reflect the masking of information or interference with internal speech (Poulton 1977). This "auditory" effect of noise may be important in explaining other health effects of noise (see below).

One could argue that an explanation based on over-arousal is very similar to one based on noise increasing stress. Stress is now usually defined in terms of "Demands exceeding the ability to cope" and noise could add to this by creating and additional burden that has to be dealt with. This type of effect is important in terms of explanations based on noise using up processing resources. However, the present results show that the effects of noise are clearly different from those of psychosocial stressors such as job demands or effort-reward imbalance.

Smith (2010) has argued that we need more research on noise and health. Part of his argument is that we need better models of underlying mechanisms. It is likely that noise influences health and cognitive function through many different mechanisms (see the above account of accidents). These are likely to be a combination of auditory effects and subsequent non-auditory consequences. For example, chronic effects of noise have been demonstrated in children tested in quiet (Stansfeld et al. 2005) and these may actually reflect interference with speech perception (Hartley et al. 2000) which may lead to reduced cognitive functioning (Deary 1995). The outcome of long term exposure to noise may be a reduction in intelligence. Recent research (Gottfredson & Deary 2004) has shown that reduced intelligence is one of the biggest risk factors for long term health problems and mortality. The mechanism underlying this could be an increase in bio-markers that reflect the metabolic syndrome (Batty et al. 2008). This theory now needs to be tested by first demonstrating that noise im-

pairs auditory perception and that this underlies the poorer reading comprehension found in children in noisy schools. Long-term follow up of those living in a noisy environment also needs to be done in order to examine whether these people are at greater risk of developing the metabolic syndrome.

The present paper has presented evidence suggesting that past and current approaches to the effects of noise on health and safety need to be modified in order to provide a greater understanding of the area that will be of relevance to policy and practice. It is also important to use new methods to address the old question of what are the effects of noise on health. For example, it is important to examine the effects of noise on gene expression as this may give a strong indication of future health effects. Similarly, noise and cognitive functioning can now be studied using a variety of brain imaging methods that can provide plausible mechanisms for observed behavioral effects. These new approaches must be combined with different methods of measuring noise exposure. Individual differences in noise sensitivity need to be refined to separate general biases in perception and response from those which are specific to noise. Noise exposure is usually combined with exposure to other risk factors (e.g. traffic noise is combined with air pollution). Future research must not only control for other factors but investigate the combined effects of noise and other agents.

In summary, previous research on the effects of noise on health has often been interpreted in terms of a stress model. Reviews of recent studies suggest that environmental noise exposure does not lead to reliable effects on key outcomes of the stress process (stress hormones, immune parameters and mental health). The present study examined whether occupational noise exposure influenced the stress process (measured by perceived stress and mental health) and whether this reflected noise per se or the psychosocial environment. The results showed that the effects of noise on stress and mental health were due to correlated attributes (job demands, effort-reward imbalance). In contrast, both intense noise and distracting noise were associated with more frequent accidents, injuries and cognitive failures, an effect that remained even when psychosocial factors are covaried. Possible mechanisms underlying these effects are discussed and it is argued that future research must elucidate the underlying mechanisms of established effects and use new methodologies to address non-auditory effects of noise.

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Disruption of cognitive performance by sound: differentiating two forms of auditory distraction

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INTRODUCTION

Attentional selectivity—the capacity to focus on task-relevant events and ignore effectively task-irrelevant events—is a core feature of all efficient information processing. In order to be maximally efficient, attention must be flexible so that it can be responsive to unexpected and potentially significant events outside the focus of attention. Flexibility is achieved by having a degree of processing of events that are at any one time outside the attentional focus. This is only achieved at some cost, however, both from the need to monitor events but also because such events have the potential to wrest attention away from task-relevant processing even when they are not in fact of interest or importance. Attentional control—which is essentially about mapping of events in the world onto one of a range of possible actions—cannot be completely efficient. Indeed, in the auditory modality there is evidence that all auditory information is processed in an obligatory fashion, making behavior particularly liable to distraction by sound.

A range of findings reviewed here suggest that this obligatory processing of sound can lead to two distinct forms of auditory distraction. The first—*competition-for-action*—occurs when the results of obligatory sound processing are similar to those of the focal task. The second—*interruption-of-action*—takes place when an unexpected sound draws attention away from the focal activity. In this paper, we focus on reviewing four lines of recent evidence that suggest that the two forms of distraction are distinct, namely: i) that the two forms act additively; as well as differences in the expression of each according to ii) the type of focal task; iii) the attentional load involved in stimulus-encoding; and iv) whether the focal information is being taken in or whether it is being acted-upon. We first provide an overview of each form of distraction.

COMPETITION-FOR-ACTION

A great deal of the laboratory research on auditory distraction over the last 30 years or so has focused on the particular vulnerability of how we remember sequences. This is a basic and ubiquitous mental function that underpins language and thought. The typical paradigm involves presenting a list of usually visually-presented items (e.g. digits, words, or letters), slowly, one-by-one on a screen and requiring that they be remembered in the order in which they were presented. Sometimes, sound is presented that is irrelevant to the task and which the person is told to ignore. Despite its irrelevance, the sound disrupts serial recall appreciably compared to a quiet control condition (up to 30-50 % disruption for sound such as narrative speech; e.g. Colle & Welsh 1976; Salamé & Baddeley 1982; Jones et al. 1990; for further discussion of the psychometric characteristics of the effect, see Ellermeier & Zimmer 1997).