ENVIRONMENTAL NOISE AND HEALTH:
AN INTEGRATED RESEARCH PERSPECTIVE

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INTRODUCTION

Environmental noise is an ubiquitous encounter in the human life of industrialized nations. In Europe, 26% of the population is currently exposed to noise levels above 65 dB(A) (WHO 1995), while WHO guidelines set an upper limit of 55 dB(A) in residential areas. Moreover, the noise exposure situation seems to be worsening when compared with the 15% exposed to levels above 65 dB(A) in the early eighties.

In spite of significant efforts over the past two decades, a clear causal link between community noise and health could not be established (Cohen and Weinstein 1981; Dejoy 1984; Kristensen 1989; Taylor and Wilkins 1986; Thompson 1993; Kryter 1994). While measurable effects of environmental noise on several facets of human functioning have been demonstrated, ambiguity about what constitutes an adverse health effect has forced responsible agencies to issue conservative statements. The following statement from a recent WHO-report exemplifies this conservatism:

"The main negative effects of such noise on people are disturbances of communication, rest and sleep, and general annoyance. Over long periods of time these effects have a detrimental influence on wellbeing and perceived quality of life" (WHO 1995).

While this summary neglects some important findings of social science research, it identifies the lack of reliable evidence of long-term health consequences of environmental noise. Earlier studies with claims of airport noise-related birth abnormalities and increased mortality rates did not withstand critical scientific analysis (Frerichs 1980). More recent reviews have also questioned a causal association between community noise and psychiatric symptoms (Stansfeld 1992) or cardiovascular effects (Thompson 1993). The reason for these more cautious and critical reviews are methodological shortcomings and the prima facie inconsistencies of available results. The lack of sufficient longitudinal information is still the most serious

Considering the increasing proportion of exposed people and the limitations of the epidemiologic method to detect small associations, the remaining uncertainty introduces a considerable risk for misjudgement of the true public health importance of environmental noise exposure. This situation requires a serious effort of the research community involved.

While the methodological and analytical problems have been discussed extensively, conceptual issues of research designs commonly employed in extraauditory health effects studies have received surprisingly less attention (Cohen et al. 1986; Lercher 1994). This may be related to the great variety of employed research strategies (from animal and human experiments to population surveys) and the considerable diversity of the various disciplines (from physics to sociology).

The aim of this paper is to review the most important conceptual approaches and to discuss their potentials and limitations. Selected examples from the literature will be used to support the view that some of the inconsistencies of earlier studies may have their origin in conceptual deficiencies. The present research perspective is developed from a multidisciplinary viewpoint. The review begins with the most fundamental and most common model in use.

THE GENERAL STRESS MODEL

Numerous experimental and clinical studies have repeatedly shown that environmental noise exposure activates the central nervous system and can trigger a host of changes in various subsystems of the human body identical to a typical stress response (Westman and Walters 1981; Cohen et al. 1986).

The conceptualization of noise as a stressor (noise-stress reaction-adverse health effect) was transferred to field investigations and based on Selye's (1956) assumptions that:
1) there is a uniform physiological stress reaction;
2) there is a finite amount of physical energy that can be invested; and
3) the process of adaptation to the stressor is itself costly.

It was further hypothesized that several types of health effects may occur under certain specified conditions. The most critical were:
1) when exposure is chronic;
2) when exposure interferes with daily activities; and
3) when people feel annoyed by the experienced exposure.

Evaluation of this model through epidemiological studies seemed promising. This involved measurement of both the health status of various populations and their exposure to different levels of environmental noise.

The intensity of the noise exposure was generally measured as A-weighted mean sound pressure level and related statistically to the broad variety of possible outcomes according to the general stress model.

The early studies around Schiphol airport (Knipschild 1977a; 1977b) and the first Bonn road traffic study (von Eiff and Neus 1980) can be considered as typical examples of this type of research. With some minor refinements (statistical adjustment for several confounders), most of the best epidemiological evidence at present (Babisch et al. 1993a) is still based on this model, in part because funding agencies do not value research on underlying mechanism (Carter et al. 1993; Job 1993).

One major limitation of this biologically oriented approach is the emphasis on direct effects while adopting a black box attitude to the underlying causal mechanisms (Evans and Cohen 1987). A second difficulty arises from the lack of specification of the expected response set, and consequent uncertainty regarding response indices. Furthermore, the neglect of the large individual differences in human responses to stressors decreases the statistical power to detect true effects. A third limitation comes from the overemphasis on "hard" medical outcomes such as hypertension or myocardial infarction. This view automatically leads to a devaluation of "soft" responses such as depression or quality of social interaction, despite the legitimate status of the latter variables as health outcomes.

Challenged by the notoriously low explanatory power of the physical indices of noise exposure (McKennell 1963; Langdon 1976, 1987; Rohrmann 1984; Job 1988a, 1993), predominantly social scientists have tended to use a second, more differential approach, which will be called the individual or situational difference model (Fig. 1).

THE INDIVIDUAL OR SITUATIONAL DIFFERENCE MODEL

This research perspective acknowledges that human beings do not react uniformly to environmental challenges and are not passive respondents to environmental conditions. It changes the focus to the moderation of the noise-reaction process. New conceptual
Environmental noise and health

Situational Modifiers  Personal Modifiers

$k_1$  $k_2$  $...$  $k_i$

Environmental Noise  $\rightarrow$  Health Effects

Fig. 1. The individual-situational difference model (van Kamp 1990).

Table 1. Important personal and attitudinal moderating variables, their evidence and selected references.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rating</th>
<th>Reference (if unambiguous only first author is given)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locus of control</td>
<td>+?</td>
<td>Rotter 1966; Thomas 1982; Jones 1984; Pulles 1990; van Kamp 1990</td>
</tr>
<tr>
<td>Type A/B pattern</td>
<td>+?</td>
<td>Moch 1984; Di Nisi 1989; Melamed 1993; Nivison 1993</td>
</tr>
<tr>
<td>Non-complaining attitude</td>
<td>+?</td>
<td>Pulles 1990; Theorell 1990;</td>
</tr>
<tr>
<td>Misfeasance/Preventability</td>
<td>+</td>
<td>McKennell 1963; Borsky 1980; Jones 1984; Job 1988a; Fields 1993</td>
</tr>
<tr>
<td>Fear of danger/health effect</td>
<td>+</td>
<td>McKennell 1963; Tracor 1971; Borsky 1980; Rohrmann 1984; Fields 1993</td>
</tr>
<tr>
<td>Importance of attitude towards source</td>
<td>+</td>
<td>Cederlöf 1967; Rohrmann 1984; Job 1988a, 1993; Fields 1993</td>
</tr>
</tbody>
</table>

* mainly based on annoyance as reaction variable (may be different for other health outcomes; other groups)
+ sufficient evidence; +? contradictory evidence

developments (Helson 1964; Lazarus 1966; Rotter 1966; Barker 1968; Glass and Singer 1972; Averill 1973; Seligman 1975; Cohen 1978; Craik 1981) within general and environmental stress research ("arousal", "overload", "person-environment-fit", "environmental assessment", "adaptation level", "subjective appraisal", "perceived control", "learned helplessness", "behavior setting") have backed this endeavor and triggered the construction of adequate instruments capable of uncovering the unexplained variance believed to determine the noise-reaction relationship.

Within the individual and situational differences model, the three following types of approaches can be distinguished.

**Trait theorists**

Trait theorists searched for the importance of personal factors or characteristics (Table 1) and most of them demonstrated an increase in explained variance, usually limited to the noise-annoyance relationship. Nevertheless, the possibility that personal factors may be differentially influential on different health outcomes should be taken into account (Job 1993).

The large series of studies around London airport (Heathrow) may serve as an example for this type of research. McKennell (1963, 1973, 1980) was among the first to demonstrate the substantial impact of an individual's attitudes and beliefs on reported annoyance. Noise sensitivity, attitude to the noise source,
misfeasance, fear of aircraft crashing, and concern with health were identified as potent factors moderating the noise-annoyance relationship.

Later, psychiatric epidemiologists (Tarnopolsky et al. 1978; Tarnopolsky et al. 1980) have tried to disentangle the relationship between airport noise, annoyance, noise sensitivity, and mental health (Fig. 2). Their conclusion was that annoyance may not be a mediating variable between noise and psychological disorders, while noise sensitivity may be a vulnerability factor for noise effects on mental health. However, noise sensitivity is correlated also with other personality constructs shown in Table 1 (Broadbent 1972; Weinstein 1980; Thomas and Jones 1982; Jones and Davies 1984; Öhrström 1988). In pursuing this question further, Stansfeld (1985, 1992, 1993) has summarized as follows: "Noise sensitivity is related to several subcomponents of a pre-morbid personality (negative affectivity, neuroticism, affective reactivity, critical tendency), is predictive of psychiatric disorders, and is suggestive of being a moderator between noise and psychological morbidity." However, the link to other dispositional concepts (locus of control, Type A, learned helplessness) is still lacking. Furthermore, some of the variables mentioned in this section may interact with those in the next section.

**Situationists or environmentalists**

Within this group, Cohen and Spacapan (1984) distinguishes two main approaches. The first views noise as a possible determinant of interpersonal behavior and is outcome oriented.

Studies showing reduced helping behavior with greater noise provide the best support for noise as a determinant of interpersonal behavior. The seminal study of Appleyard and Lintell (1972) has shed light on the effects of noise on social interaction and the possible reduction of social networks which themselves are considered important mediators of health effects (Berkman and Syme 1979; House et al. 1988).

The second approach explores noise exposure in the larger physical, social, and cognitive environment and attempts to quantify the moderating effect of selected contextual factors. Many of such modifying variables have been identified (Table 2). These include the amount of interference with activities, home design and ownership, house depreciation, neighborhood satisfaction, and additional annoyance through vibrations/car exhaust. Clearly, there is some overlap among these factors. Furthermore, most variables measure how difficult it is to cope with the experienced noise exposure. Therefore, it is not surprising that the effect of changes in exposure is hard to predict because many other variables are involved and determine the perceived control of the exposed subject.

Another aspect, often neglected in prevention, considers the aesthetic/natural make up (Table 2) of the exposed site. Kastka and Hangartner (1986) have shown that rated traffic noise annoyance was significantly lower among residents whose streets were judged by independent raters as more appealing with respect to its visual appearance. The effect of the more pleasant appearance corresponded to a noise level of about 5 dB(A). This finding confirmed earlier analyses on the related issue of perceived neighbourhood quality and appearance (Aubree 1973; Langdon 1976).

Finally, there is evidence for substantial socio-cultural differences in reaction to noise. An earlier cross-cultural comparison of annoyance levels between an Italian and a Swedish city revealed an approximate 10 dB(A) difference in annoyance reactions for the same noise exposure (Jonsson et al. 1969). This again points to the importance of trait-environment-interactions.

**The interactionist perspective**

The interactionist perspective addresses the joint influence of all these factors in moderating the noise-health relationship.

As in the above approaches, annoyance, sleep disturbance, blood pressure, and subjective health complaints still dominate on the outcome side. However, typically refined indices of noise exposure are used. Statistical approaches are dominated by analysis of
Table 2. Important contextual moderating variables, their evidence and selected references.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rating*</th>
<th>Reference (if unambiguous only first author is given)</th>
</tr>
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<tbody>
<tr>
<td>Controllability/predictability/adaptability</td>
<td>+</td>
<td>Glass 1972; Graeven 1975; Lundberg 1978; Finke 1980; Rohrmann 1984; Cohen 1984; Job 1993</td>
</tr>
<tr>
<td>Non-noise impact (odour; vibrations)</td>
<td>+</td>
<td>Rohrmann 1984; Fields 1993; Dankittikul 1993; Lercher/Widmann 1993; Sato 1993</td>
</tr>
<tr>
<td>Home type and design/rooms facing noise source</td>
<td>+</td>
<td>MA 1974; Bradley 1979; Langdon 1987; Öhrström 1991,1993; Fields 1993</td>
</tr>
<tr>
<td>Change in noise environment</td>
<td>+</td>
<td>Griffiths 1986; Job 1988b; Raw 1990; Fields 1993</td>
</tr>
<tr>
<td>Home ownership</td>
<td>+?</td>
<td>Langdon 1987; Fields 1993; Lercher/Widmann 1993</td>
</tr>
<tr>
<td>Previous level of exposure</td>
<td>+?</td>
<td>Helson 1964; Wohlwill 1973; Cohen 1986</td>
</tr>
</tbody>
</table>

* mainly based on annoyance as reaction variable (may differ for other health outcomes; other populations)
+ sufficient overall evidence; +? insufficient/contradictory evidence

Fig. 3. The Gunn-Patterson noise stress reduction model (Gunn and Patterson 1975).

This model identifies the importance of an approach that views possible health outcomes in a combined perspective, including acoustical, social, environmental, situational, and personal variables, as represented first by the model of Gunn and Patterson (1975) (Fig. 3). After this model, dispositional and situational factors determine already the perception of the noise. Moreover, several steps and loops follow and may reinforce or diminish the original response. The major limitation of these models is the lack of an overarching theoretical perspective.
THE TRANSACTIONAL APPROACH

A promising approach emerges from a systematic transactional perspective, developed by Lazarus and his colleagues (Lazarus 1966, 1993; Lazarus and Cohen 1977; Lazarus and Folkman 1984). This model (Fig. 4) allows for mediation and moderation through psychological variables.

Here, appraisal describes the process through which a person evaluates the noise exposure with respect to personal significance (called primary appraisal). When the exposure is assessed as stressful, the next step is to evaluate the personal opportunities to deal with the burden (secondary appraisal). The noise-health relationship can be viewed as a continuous process of appraisals, coping efforts, and reappraisals.

In this perspective, coping refers to all the cognitive, behavioral, and emotional efforts to manage the specific demands emerging from the process of appraisal of the given noise exposure. This process is closed in a loop by a constant reappraisal process directed at changes in the experienced person-environment relationship. According to their reasoning (Lazarus and Cohen 1977), community noise exposure relates most closely to a group of environmental stressors classified as “daily hassles”. Unlike “cataclysmic phenomena” or “critical events”, “daily hassles” are described as more commonplace, circumscribed, and nonurgent and were believed not to require major adjustments. However, subsequent research has shown that adaptive responses and health effects associated with “daily hassles” are not necessarily smaller. Campell (1983) who recognized early the limitations of the “daily hassles-concept” has argued that chronic environmental stressors such as air and noise pollution or crowding should be viewed as a distinct class, namely “ambient stressors”. According to their analysis, “ambient stressors” are chronic, negatively valued, intractable, nonurgent, and perceivable. Although perceivable, they are not noticed all the time. Following Stokols (1979), this is a matter of “motivational salience.” This term refers to the extent to which the setting involved is of psychological importance to the exposed person, in contrast to “perceptual salience,” which is determined by objective features of the stimulus (e.g., loudness, pitch). Thus the salience of the environmental condition is an important mediator of the expected range of effects. Unfortunately, standard noise measurement techniques do not provide a true representation of the real physical characteristics of a given noise exposure situation. However, there is an urgent need for both reliable subjective and objective representations of the environmental exposure (Carp and Carp 1982; Kasl 1984). If only one exposure dimension is included in a study, interpretation and public health implementation will be extremely difficult. Therefore, more recent developments such as master scaled loudness judgments (Berglund et al. 1983) or other types of psychoacoustic analyses (Kuwano and Namba 1985; Zwicker 1982; Zwicker and Fastl 1986; Genuit 1988; Preis and Berglund 1994; Schulte-Fortkamp 1994) should be implemented in future epidemiological studies. The use of these techniques could improve scientific insight in the primary appraisal of noise.

The secondary appraisal is usually defined as evaluation of control possibilities, and perceived control appears indeed to be a useful paradigm (Glass and Singer 1972; Averill 1973; Evans and Cohen 1987; Steptoe and Appels 1989; Syme 1991). However, discrepant results with respect to the outcome have made clear that perceived control may not always be beneficial, especially when the “costs” are too high in order to keep the control perception alive (Stokols 1979; Lazarus 1993). Other reasons may be (Stokols 1979):

1) the appraisal was wrong or too short termed;
2) the exertion of control leads to social conflicts; and
3) there are methodological differences about the conception of perceived control.

An important personality construct in this context is “locus of control” (Table 1). Persons exhibiting internal “locus of control” are thought to believe that their own behavior determines the outcome, while people with external “locus of control” regard outcomes as not attributable to their own actions. For instance, in a Dutch study (Pulles et al. 1990), a higher score on internal “locus of control” was related to annoyance of people with external locus of control was reported, but there was no interaction with noise level.

Another personality construct which is of interest here is the Type A/B distinction (Table 1). It is known from numerous studies that Type A persons are constantly impelled by a sense of urgency and exhibit strong control needs. Therefore, they may be prone to slide into exhaustion when the stressor is difficult to cope with. A recent field study conducted by Melamed et al. (1993), found Type A behavior related to increases in diastolic blood pressure, heart rate reactivity, and tension when workers were exposed to noise above 80 dB(A). This suggests the importance of trait-environment interactions. However, the relevance...
Fig. 4. Lazarus' transactional stress model (Lazarus and Folkman 1984).

![Transactional Stress Model](image)

- **Stressor**
- **Primary Appraisal**
- **Secondary Appraisal**
- **Coping**
- **Adverse effect**
- **Person/Situation/Environment**

**Fig. 5. The moderating effect of coping style on systolic blood pressure.**

- **Initiative membership**
- **Complaints to authorities**
- **Sound proof windows**
- **Awareness of annoyance**
- **Optimistic attitude**
- **Window open during night**

![Coping Style and Blood Pressure](image)

- Mean difference in mmHg

- **95% CI**
- **Mean Difference**

**Environmental noise and health of this finding to environmental noise exposure remains untested.**

Additional complexity arises from variability in coping styles and its measurement. Lazarus (1966) parsimoniously distinguishes two basic styles: 1) Problem focused or "instrumental" coping includes cognitive and behavioral problem solving and decision making, information gathering, advice seeking, practical aids such as time management etc. 2) Emotion focused or "palliative" coping includes cognitive efforts that change the meaning of a situation without changing the environment, using techniques such as cognitive reframing, minimization, social comparisons, etc. Furthermore, it includes behavioral efforts to make oneself feel better; this may be exercise, relaxation, or social support, but also includes efforts to escape through the use of drugs, cigarettes, or alcohol.

Based on cluster analysis, Westbrook (1978) has identified six relatively independent coping styles: action, avoidance, seeking social support, optimism, fatalism, and seeking control over the situation.

In the above mentioned Dutch study, van Kamp (1990) has examined three basic coping styles (action directed, denial/avoidance, comforting cognitions) and their relationship within a slightly modified appraisal model of noise stress and coping.

Her analysis showed that all coping styles are significantly related to primary and secondary appraisal as well as to the level of experienced activation by the noise exposure. More specific results were obtained for the relationship between coping styles and subjective health outcomes; the problem-oriented style is negatively related and avoidance is positively related to the prevalence of health complaints. This pattern is followed consistently also across the health complaint subscales: somatic complaints, sleep complaints, and depression.

In an Austrian study on the effects of road traffic noise on blood pressure (Lercher and Kofler 1993), some efforts were spent to analyze the assumed effects of various coping styles (Fig. 5). Although it is obvious that the experienced noise exposure can be changed substantially by simply closing the window, the effects...
on health of such actions have rarely been evaluated. Our results showed some consistency with respect to a problem or situation-oriented coping style; the mean blood pressure for those practicing these styles is lower as well as for those with an optimistic attitude.

Both studies show that a systematic application of a transactional perspective may be useful and can improve non-auditory health effects research. Despite some advances, a broader framework may be more fruitful, because the concept of coping does overlap with both personality and context. Lazarus himself (1993) has criticized that coping has long been treated as belonging within the rubric of decision-making, overemphasizing cognitive processes.

Therefore, a conceptual framework is needed which guides efforts in non-auditory health effects research against biological and psychological biases towards an integrated research framework that systematically includes the ecological perspective.

THE CONTEXTUAL RESEARCH STRATEGY

A contextual research strategy and analysis may provide a such a theoretical and practical framework. Cohen et al. (1986) and Stokols (1987) have provided a first conceptual outline of contextual research. More recent applications of this approach to related subjects (commuting and crowding) have been described by Novaco et al. (1990, 1991), and Evans and Lepore (1992).

The central idea (Fig. 6) can be described by the term “embeddedness”. This notion means that a particular phenomenon of interest (e.g., the relationship between road traffic noise and depression) is systematically conceptualized as being embedded or surrounded by a set of events. The surrounding set of events is evaluated through four contextual dimensions (Stokols 1987).

The spatial, temporal, and socio-cultural scope

Possible situational, setting, or life domain moderators of the central question such as “all rooms noise exposed” or “exposed to noise at work” or “road visible” or “nice neighborhood” or “small flat” or “gardening as hobby” can be taken as examples for the spatial context. Temporal aspects may be represented by “duration of residence” or “duration of presence at home”. Socio-cultural moderators may include “education” or “intense social networks” or “windows are usually open during night”.

However, the ultimate goal of this evaluation is to identify the “effective context”, a subset of influential factors that best predicts the target phenomenon of interest. Modeling of the effective context may be facilitated by the other three principles or dimensions of the contextual research strategy.

Joint use of both objective and subjective representations

Joint use of both objective and subjective representations of the target and contextual variables is based on the empirically supported claim that objective and subjective indices may be complementary and/or corrective in explaining the target phenomenon and counterbalancing the relative strengths and weaknesses of both measurement approaches. Therefore, exposure misclassification is reduced and reliability is improved. Moreover, from another perspective, Kasl (1984) has mentioned already that one is also in a better position to interpret the results. For example, if the objective measure is confirmed as a risk factor for the outcome and the subjective measure is associated with both and the latter associations are stronger than the first, then we have a substantial suggestion of a disease effect of an environmental exposure, operating primarily through the intervening process of subjective perception or reaction. Distinctions of this kind are essential for the planning of public health interventions.

The use of partitive and composite indices of environmental stress

Partitive analyses view people and places as independent units and emphasize the interactive effects of environmental and personal attributes on various response criteria. Composite analyses treat people and places more closely interrelated within a common system. Therefore, composite indices summarize various structural or organizational properties of situations and settings. This can reduce the necessary number of variables in a statistical model considerably without loss of important information.

For instance, “Having a sleeping room not exposed to noise” can be considered as a typical composite term representing a person-place interaction (Table 2). This circumstance can increase the perceived control an exposed subject experiences by several means: 1) It reduces the amount of time the subject is exposed to noise: 2) it reduces the most critical exposure time where the organism is highly vulnerable to disturbances;
3) it provides a room to which the person can retire during day when she/he wants to relax. Thus, this composite variable represents an important transaction between the person, the built environment and time.

Results from an earlier survey conducted in Vienna (MA 1974) demonstrate the significant impact of such a composite variable ("sleeping room to the rear") on the noise-annoyance relationship (Fig. 7). At exposure levels of 60 dB(A), the respective proportions of highly annoyed are 5% vs. 25%. Recent studies (Öhrström 1991, 1993) have confirmed the importance of this variable also for other health outcomes than general annoyance.

Analysis of stress phenomena from both individual and aggregate levels

One noteworthy difference is the much higher noise-reaction correlations achieved in aggregated data. The decision to use individuals or groups as the unit of analysis clearly depends on the target phenomenon being analysed.

For instance, Job's (1988a) analysis of the individual correlations between noise, annoyance, attitude, and noise sensitivity from several studies has contributed much to the understanding of the interrelationship of these variables as did McKennell's (1978) earlier analysis of "patriotic feelings" towards Concorde overflights.
However, if you come to the conclusion that the relationship between a specific environmental condition and its health effect on a person may be mediated by the membership in a certain group (e.g., a village with certain cultural differences or a citizen initiative), you can learn more about the target relationships by comparing individual and aggregate levels of analysis that will remain unnoticed otherwise. For instance, in a five community study (Lercher and Widman 1993), both types of correlation were compared (Table 3). One community (Steinach) shows a significant change in its ranking; it ranks low (fourth place) on the individual correlation and moves to a higher ranking (second) if you consider group correlations, while the other communities keep their rankings on both levels of analysis. This can be taken as evidence of an important intersetting difference yet to be uncovered.

As a final example of how new insights can be gained through the systematic application of a contextually driven hypothesis, the Los Angeles airport study may serve as an example (Cohen et al. 1986). In this study, an attempt was made to re-examine the possible effects of home noise levels on children’s blood pressure at school (Table 4).

The data show overall higher blood pressure readings for children living in low-noise neighbourhoods. This initially surprising result may be interpreted in the framework of the adaptation level theory of Helson (1964); children residing in noisier areas may establish a higher adaptational level or tolerance at school and therefore exhibit lower arousal in noisy classrooms.

**CONCLUDING REMARKS**

Non-auditory health effects research must develop instruments that are capable of measuring what environmental noise really means to the people exposed in their specific social, psychological, and environmental context. A transactional model of stress, appraisal, and coping together with a contextual research strategy provides a useful conceptual framework to guide current and future research designs and analyses.

Combined effects with parallel exposures (e.g., road traffic noise and exhaust) must be included in an integrated framework for assessing effects. If this is not the case, research is not in compliance with the actual definition of environmental health “includes both the direct pathological effects ... and the effects (often indirect) on health and wellbeing of the broad physical, psychological, social and aesthetic environment, which includes housing, urban development, land use and transport.”

The recent update of the Environmental Health Criteria Document “Noise” (WHO 1996) provides the necessary scientific and practical information to comply with this perspective.

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