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The Hearing Conservation Paradigm and the Experienced Effects of Occupational Noise Exposure

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Summary

The high prevalence of over-exposure to industrial noise is examined by means of an analysis of the paradigm of hearing conservation in noise and the characteristics of industrial workers' perceptions of the effects of noise. After considering the historical context and documents that have inspired the hearing conservation paradigm, the underlying implicit postulates and their influence on programs concerning industrial noise are examined. It is then demonstrated how the hearing conservation paradigm operates as a black box, allowing only the risk of compensable hearing loss as input and personal protection, audiometric surveillance and experts' reports on compensation claims as output. The absence of controversy around the paradigm itself is explained by the lack of awareness of the consequences of noise exposure and the fact that such consequences are not viewed as being serious. Alternative paradigms are proposed to improve the acoustic environment in industry.

Sommaire

La forte prévalence des sur-expositions au bruit en milieu industriel est examinée par le biais d'une analyse du paradigme de la préservation de l'audition dans le bruit et des caractéristiques de la perception des effets du bruit par les personnes qui travaillent en industrie. En s'appuyant sur le contexte historique et sur les écrits qui ont donné naissance au paradigme de la préservation de l'audition, les différents postulats implicites qui le sous-tendent sont examinées en montrant leur impact sur les interventions concernant le bruit industriel. Ainsi, il est démontré que la préservation de l'audition opère comme une boîte noire dont le seul intrant admissible est le risque de perte auditive indemnisable et les extrants sont la protection individuelle, la surveillance audiométrique et les expertises de réclamations. L'absence de controverse autour du paradigme lui-même est expliqué par le fait que les conséquences de l'exposition professionnelle au bruit ne sont pas connues et ne sont pas ressenties comme étant importantes. D'autres paradigmes sont proposés en vue d'assainir l'environnement sonore industriel.

1. Introduction

Noise in the workplace has been known to cause hearing impairment for more than a century [1].Yet, fifteen years ago, approximately 60 % of the total industrial workforce in the U.S.A. was known to be exposed to sound levels capable of causing damage to hearing [2]. The situation has not improved since then [3-4] despite the fact that hearing conservation programs have been instated in a large majority of industrial workplaces. Noise appears to be the most common environmental aggressor in industry [5]. A survey conducted in heavy industry across the province of Québec has shown that 56% of the workforce was exposed to daily levels of over 85 dBA-8h; in comparision, the second most prevalent environmental aggressor, ergonomic constraints, involved only 12% of the workforce. Despite the high prevalence of over-exposure, noise control is in very low demand in industry.

This was the unanimous conclusion of a seminar held recently at the Institut de recherche en santé et sécurité du travail du Québec (IRSST) where representatives of management and labor, researchers and consultants discussed research priorities in noise control [7]. Furthermore, in many workplaces affected by recent technological change, noise levels often increase with the introduction of more productive machinery [8].

In this paper, it is argued that this paradoxical situation stems from the influence of two inter-related factors: (1) the way in which the effects of occupational noise exposure have been addressed under the hearing conservation paradigm and (2) the way in which such effects are perceived and experienced by noise-exposed workers.

2. Hearing conservation: a scientific paradigm that has served to define and address the problem of industrial noise

2.1 The concepts of paradigm and black box

The concept of paradigm was introduced into the philosophy of science to account for the inevitable sharing

of a certain number of presuppositions among members of a given scientific community at a given time [9]. Such presuppositions spare the latter from endless verification prior to undertaking an investigation. This process is inevitable if investigations are to be undertaken. It may, nonetheless, be enlightening to go back to the underlying presuppositions to understand how a particular demonstration of evidence is bound to a specific social context.

Parallel to this general view, the concept of black box was introduced to account for the other end of the process of constructing scientific proofs. Once a controversy is settled in favor of a given paradigm, the proposition becomes a "fact" accepted by everyone in the field [10-11]. Let us take an example: evidence of damage to hearing from occupational noise exposure can be obtained by means of an audiogram. Such a fact operates as a black box in the sense that it is referred to without any authorship and any reference to the historical or experimental context that informed its acceptance by the scientific community; it is taken for granted as being part of the nature of things by anyone involved in the field of occupational hearing loss. In order to clarify the presuppositions behind such facts, one must retrace the history of the controversies that took place before such propositions became accepted. In other words, in order to open a black box, one has to go back to the history of its construction.

In the following paragraphs, hearing conservation (HC) is examined as a black box that has served to define and address the problem of industrial noise in a particular way. Its underlying presuppositions are examined after a brief historical account of its emergence. This is followed by a short analysis of the way HC operates as a black box with predefined input and output that exclude a certain number of issues and govern the way industrial noise exposure is addressed.

2.2 Historical construction of the HC black box

Hearing loss due to prolonged exposure to industrial noise is an occupational disease that does not prevent its victims from continuing to work in the harmful industrial environment. Consistent with the fact that it did not involve wage loss, it was considered by scientists as unproblematic. A case in point is the noncommital conclusion of the following review, published in 1950, of more than 40 field studies showing a relationship between hearing loss and the working environment: "Apparently, continued repeated exposures over extended periods (years) may result in a partial but permanent deafness" [12]. The nature of the relationship changed from one of mere possibility to established fact when court rulings entitled workers to monetary compensation for partial loss of hearing even though the impairment did not prevent them from working.

A ruling was handed down on a test case for the first time in 1948 by the New York Workers' Compensation Board, and upheld by the Supreme Court of New York [13, p.64]. Another case was filed in 1951 in Wisconsin by a worker from the Ladish Forge Company, and the foundry paid the first claimant without challenge from the employer's insurance company. Strong opposition from the employer came when over 100 additional claims were filed [14]. Facing a barrage of claims, the Wisconsin Industrial Commission decided to hear a test case in an appeal. The Commission ruled that the claimant, Albert Wocjik, who was employed by Green Bay Drop Forge, was subject to compensation without suffering wage loss. This decision was overturned in an appeal to the County Circuit Court. The Commission appealed the latter decision, but in the meantime, all claims for hearing loss compensation were blocked. In 1953, the State Supreme Court upheld the original Industrial Commission ruling.

To prepare for a regulation on permanent hearing loss, the Commission appointed an Advisory Committee chaired by Meyer Fox, an otologist acting as medical consultant for Ladish Forge and the Liberty Mutual Insurance Co., a local workmen's compensation insurer. Three other otolaryngologists were involved, together with the chairman of the Wisconsin Industrial Commission, a former vice-president of the Employers Mutual Insurance [14]. Before a bill was passed in 1955, which reinstated the admissibility of claims for hearing loss, the employers represented strong arguments to the Advisory Committee, claiming that compensation would involve billions of dollars if the Commission ruled in the same way as in the first test case, and that such a ruling would lead manufacturers to move to other states. The labour movement did not raise strong objections to such contentions, nor did they voice the possibility of conflict of interest on the part of members of the Advisory Committee. The schedule proposed by Meyer Fox and his advisory committee was adopted by law, and later served as a reference for all other states and countries where occupational hearing loss became eligible for compensation. The schedule involved an intricate set of procedures that considerably limited a worker's chances of filing a claim; one of these was to require a 6-month leave of absence from noisy work in order to be eligible for a claim, ostensibly to allow for complete recovery from temporary hearing loss due to occupational noise exposure. In most instance, this meant that only unemployed or retired employees were able to file a claim.

This compensation schedule gave rise to the paradigm that later defined the problems raised by occupational noise exposure and defined their solutions accordingly. In other words, prior to the first successful claims, occupational noise exposure was a non-issue. But it then became a problem for employers and their insurers, who called for scientific and professional intervention:

> "As employers and insurance carriers were confronted with these claims, they became more conscious of the occupational hearing loss problem. Research studies indicated that as many as 25 per cent of applicants for industrial jobs had some loss of hearing. In some states, fears began to be expressed that the flood of hearing loss claims might be ruinous to insurance carriers who did not collect premiums against this kind of liability. This

> situation is further complicated by the fact that the worker's hearing loss may be due only in part to occupational exposure. In many cases, there are no records by which causal relationships can be established as between present employment, past employment, and non-occupational causes..." [13, p. 685].

This type of scientific and professional intervention, that was initially sustained by Meyer Fox and three other otologists, rapidly drew in a larger circle of experts, namely the American Academy of Ophthalmology and Otolaryngology (AAOO), which in 1957 published a set of practical guidelines paradoxically labelled "Guide for Hearing Conservation in Noise" [15]. This included the defintion of hearing loss arbitrarily set by Meyer Fox. The AAOO later convinced the American Medical Association to revise its medico-legal definition of hearing loss in keeping line with the Wisconsin compensation schedule [13, p. 689]. The hearing conservation in noise approach rapidly became a black box for which input and ouptput was constantly refined, without any basic questioning of the paradigm it put forward. Since that time, it has dominated almost all scientific analysis of and professional or institutional intervention on the effects of occupational noise exposure.

Hearing conservation in noise has been designed to limit access to compensation to a minimum. It appears to have achieved its goal, considering the small number of individuals who actually benefit from compensation, compared to the very large population exposed to noise levels that have been shown to be damaging. For example, it is estimated that approximately four percent of the total number of noise-exposed retirees have benefited from a compensation in the USA [3, p. 7]. The degree of success in limiting access to compensation have inevitably varied from one country to another and, within countries, from one state or province to another. However, the object of the present analysis is not to review compensation statistics for occupational hearing loss across national administrations, but rather, to characterize how the HC black box has contributed to maintain high proportions of industrial workers being exposed to noise.

2.3 Opening the HC black box: making its underlying presuppositions explicit

The HC paradigm involves unquestioned presuppositions which in most cases are never stated explicitly. In the present analysis, five of these presuppositions hereafter called postulates and their major corollaries, listed in Table 1, are drawn from passages in the "Guide for Hearing Conservation in Noise" published by the AAOO [15; Note: The 1969 version has been used as source of reference in this paper, knowing that it had a major influence on the national regulations concerning occupational noise exposure].

Table 1. The basic preconceptions of the hearing conservation in noise paradigm formulted in terms of postulates (P.) and corollaries (C.).

P. A: Occupational noise exposure poses a health problem as long as it is proved to cause 'compensable hearing losses'
C. A1: Loss of hearing sensitivity is of no consequence until it reaches the specified compensable level.
C. A2: The only effect of noise on hearing is loss of sensitivity and its only consequence in the course of a lifetime is a loss of ability to understand speech.
C. A3: There are no environmental factors in the workplace other than noise that can adversely affect hearing.
C. A4: There are many non-occupational factors responsible for hearing loss among noise-exposed workers.
C. A5: Ear-nose-and-throat surgeons are the HCN experts.

P. B: Noise is there to stay

P. C: Some individuals are excessively susceptible to noise-induced hearing loss.
C. C1: The risk factors of NHIL are a) the level of exposure, b) the length of time an employee is exposed to noise and c) individual susceptibility to noise-induced hearing loss.
C. C2: The susceptible individuals need to be identified.

P. D: Hearing protective devices can always be an effective and adequate means to prevent compensable hearing los

P. E: Periodic hearing tests warrant prevention of hearing loss
C. E1: Early detection of hearing loss by means of audiometric monitoring leads to prevention.
C. E2: Audiometric monitoring can effectively detect changes in the hearing sensitivity of noise-exposed individuals before any hearing disability occurs.

Postulate A. Occupational noise exposure poses a health problem as long as it is proved to cause 'compensable hearing losses'

> "By risk we mean the percentage of persons who, because of noise-exposure, may be expected to develop a significant hearing handicap during their life"[15, p. 15]. "Hearing impairment (handicap) is defined as more than 26 dB ISO for the average hearing level at 500, 1000, and 2000 Hz "[15, p22].

The definitions quoted above have many implications that may be termed implicit corollaries.

Corollary A1: Loss of hearing sensitivity is of no consequence until it reaches the specified compensable level.

Scientists have decided that a certain sensory capacity is superfluous. This position has since been refined in technical discussions on what is "acceptable hearing loss" [16]. It is noteworthy that, even in the narrow context of compensation for occupational diseases, the concept of

an acceptable impairment is unusual in compensation schedules with respect to other diseases. The early proponents of the HC paradigm have persisted in asserting that even with a loss of 25 decibels averaged over 500, 1000 and 2000 Hz, "the large majority of listeners notice no disadvantage" [17]. Such expert assertions were made without empirical support [18]. This line of argument maintained by scientific authorities created the impression that someone with noise-induced hearing loss is only handicapped when the degree of deafness is equivalent to total loss of hearing [19], a very unlikely event. Since a compensable hearing loss, as defined above, refers to difficulties in hearing faint speech, no serious difficulties are implied and, and their is then no need for rehabilitative help. The HC paradigm has thwarted the development of rehabilitation programs specifically designed for people affected by occupational hearing loss, despite the fact that such loss is one of the most prevalent irreversible occupational diseases [20].

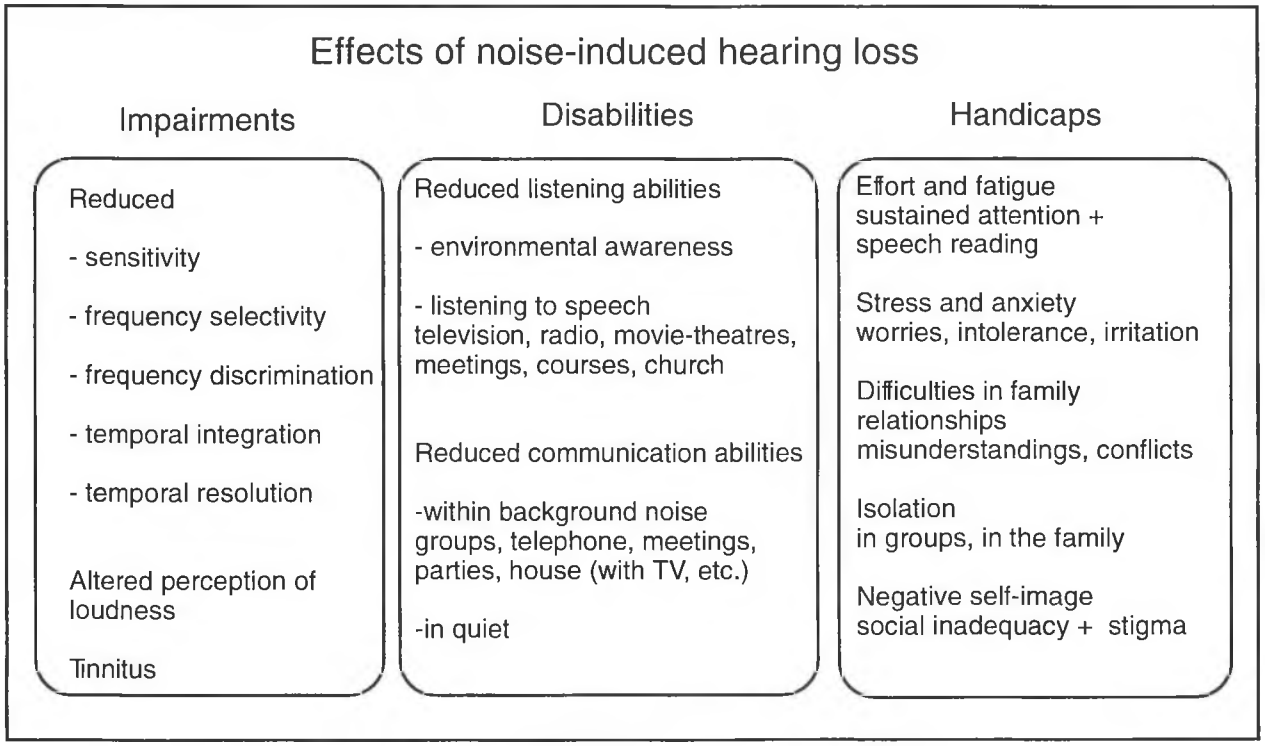

Figure 1. Classification of the various effects of noise-induced hearing loss.

Corollary A2: The only effect of noise on hearing is the loss of sensitivity, and the only consequence in the course of a lifetime is a loss of ability to understand speech.

That the effects of noise exposure are being reduced to a loss of hearing sensitivity becomes obvious when one considers the various effects of noise-induced hearing loss, as summarized in Figure 1. Impairments refer to abnormal hearing function as characterized more than 30 years ago by psychoacousticians. Disabilities refer to the hearing difficulties experienced by people suffering occupational hearing loss as reported in questionnaire surveys and interviews [20]. It can be seen that a reduced ability to communicate in quiet is only one of the many difficulties involved. Actually, this problem is reported less often by such people; the problem of understanding speech with competing background noise is much more prominent. Handicaps correspond to the psychological and social disadvantages resulting from impairment and disability. The list in Figure 1 provides only a very brief summary of the complex descriptions given by affected workers and their spouses in the context of couple and group interviews. The temporary hearing loss resulting from day-to-day noise exposure at work causes the same type of effects as permanent loss, and is experienced daily. It is nevertheless excluded from the HC paradigm; since it is reversible, it is considered not unharmful. This means that the daily experience of altered hearing ability in the hours following a workday is not seen as causing consistent difficulty and handicap.

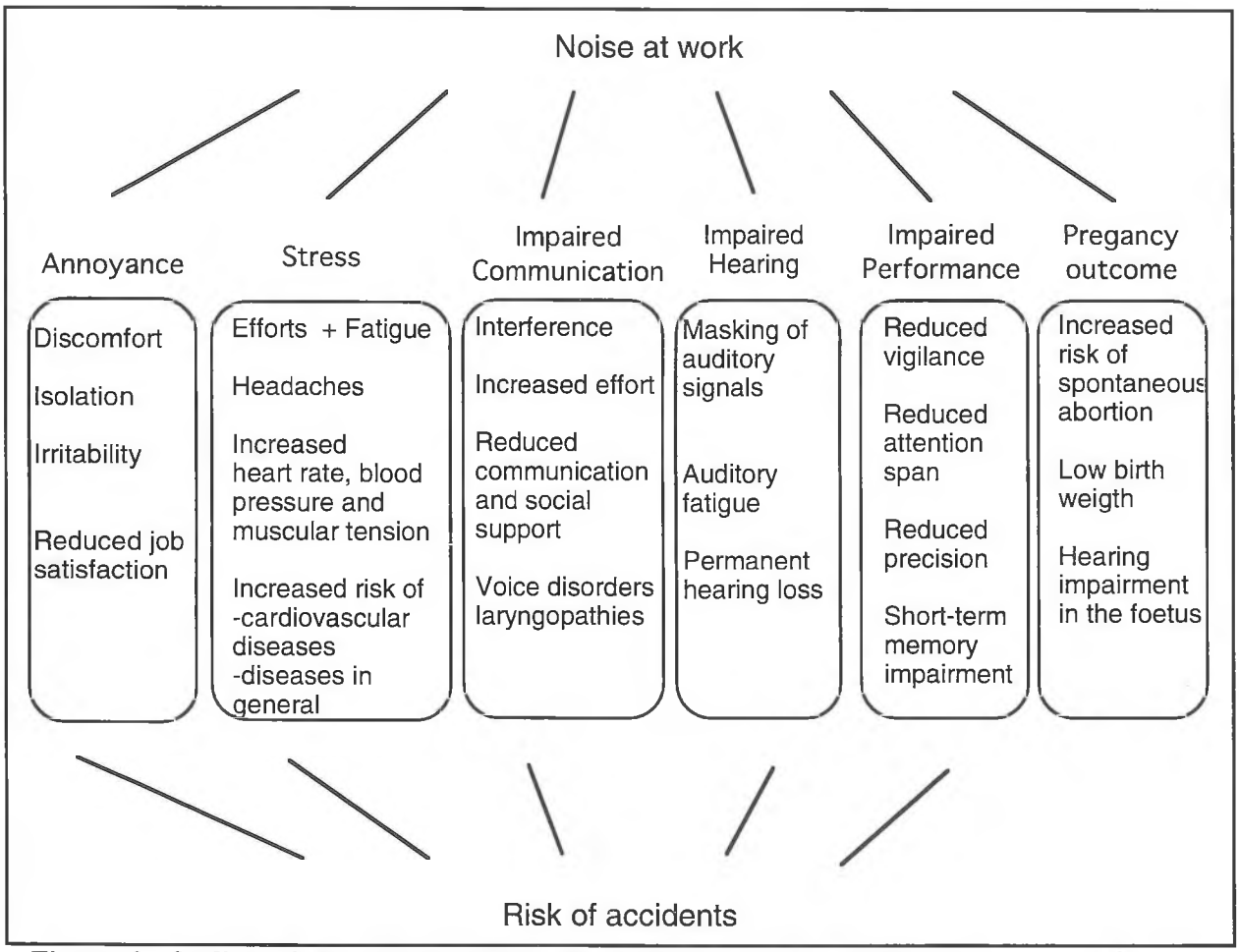

Figure 2. Outline of the various effects of occupational noise exposure.

The definition of the problem in the HC paradigm further reduces all possible effects of occupational noise exposure to its effect strictly on hearing. This oversimplification is illustrated by the brief summary of documented effects of noise [21-28] given in Figure 2. These other effects were ignored as being related to attitude, and therefore insignificant, or as not being subject to systematic and controlled measurement, or as being a mere question of habituation:

> "The annoyance caused by noise is largely a psychological response" [29].
>
> "The behavioral effects [of noise] are quite nebulous and virtually impossible to measure" [30].
>
> "Fortunately, the magnitude of these physiological responses wears off rapidly with repetition of the noise exposure"[29].
>
> "Much has been said and written concerning the effects of noise upon the behavior of man. Some of the purported effects include nervousness, fatigue, inefficiency, sterility and even death. In no case, however, is there any valid evidence to support any of these claims. As a matter of fact, previous evidence refutes any such claims except in the case of extremely loud noises such as those produced by after-burning jet engines" [31].

Otologists have taken on the role of defining the health problems that can be experienced by noise-exposed people, a common practice in the medical profession [32]. Doing so within the HC paradigm implies that the scientist cuts himself off from the experience of being exposed to and affected by noise at work, thus considering only the objective quantifiable description of an altered physical condition resulting from this experience. Treating people's health as an object by reducing it to the form of its measurement makes it possible to control those concerned [33]. It denies most of the effects of noise exposure and invalidates workers' perception of the potential harmfulness of their environment.

As health problems due to noise are reduced to audiometric records, they become computable, mobile and combinable [11, p.227] in a way that makes them manageable. HC is thus headed essentially towards management of the loss of hearing sensitivity among industrial workers.

Corollary A3: There are no environmental factors in the workplace other than noise that can adversely affect hearing.

The definition of risk stated under Postulate A refers strictly to noise exposure. This again represents a simplification that disqualifies any other environmental

factor from being hazardous to the auditory system. It has had the effect of discouraging any attempt to systematically investigate such factors and consider them within the framework of regulation of the working environment. Except for whole-body and hand-arm vibration, data on the effects of other toxicants to hearing, such as toxic gases, heavy metals, organic solvants, repiratory irritants and climatic conditions, have been collected outside the framework of occupational exposure [34]. Evidence of the potentialization of noise by vibration exposure has never been considered in the adoption of exposure limits to noise. More disturbing is the fact that, when these various factors are involved in the causation of hearing loss among industrial workers, compensation is denied because their hearing loss is judged as not being typical of the effects of noise [35]. Obviously, the possibility of interaction between the effect of noise and other environmental factors is ignored as well, and hearing conservation programs in industry do not consider other occupational exposure conditions aside from noise.

Corollary A4: There are many non-occupational factors responsible for hearing loss among noise-exposed workers.

Once the health problem is defined within a compensation scheme, its occurrence is necessarily judged within an individual diagnostic perspective with the aim of retrospectively establishing its cause. The line of argument on hearing loss among industrial workers has thus been persistently governed by the supremacy of non-occupational factors. In 1955, a representative of employer insurance carriers expressed the view that still governs hearing conservationists:

> "Although no definite standards have been established, the report of the New York Committee of Consultants implies that levels above 90 decibels may be found to be harmful to certain individuals. If such a standard is adopted, it could result in holding industry responsible for hearing losses which are incurred only in part on the job. There are many sources off the job to which both industrial workers and the general population are regularly exposed where the levels are in excess of 90 decibels. For example, published reports have shown that heavy city street traffic at 95 decibels, the noise of a subway train passing a station at 100 decibels and an automobile horn or blaring radio at 120 decibels" [36].

The same argument was maintained in 1990 as the result of a symposium sponsored by the USA National Institute of Health on occupational noise-induced hearing loss [37]. Emphasis was put on such sources of noise as kitchen appliances, domestic lawn mowers, etc., as a serious threat to hearing. This gives the impression that workplace noise is not a serious problem [19]. Despite the fact that extra-occupational noise exposure has not yet been demonstrated as a significant source of hearing loss among industrial workers [35,38], it is commonly invoked as a camouflage for excessive occupational noise.

Another non-occupational factor invoked is the normal aging process of the auditory system called presbycusis. The practice of adjusting the audiometric measurements was instated in the original compensation schemes, thus substracting the portion attributed to presbycusis from the total hearing loss measured. Apart from the complex technical issues involved regarding the validity of these corrections, this procedure obviously ignores the fact that the amount of hearing loss due to noise can dramatically exacerbate the effect of the inevitable loss of hearing due to aging. In other words, the hearing disability in everyday life is related to the total loss of hearing sensitivity, not to that part that could be attributed to noise exposure alone; an older industrial worker is thus at a serious disadvantage compared to people with presbycusis alone, or to a younger worker only affected by noise.

More generally, results of periodic hearing tests performed on noise-exposed workers by hearing conservationists are interpreted as showing only medical and nonoccupational noise exposure effects [e.g. ref. 39]. The persistent background belief is that occupational hearing loss is the exception not the rule in noisy industrial settings.

Consistent with corollaries A3 and A4, ear physiolgists have systematically investigated the possible interaction between noise exposure and the consumption of various drugs [40], ignoring the possible interaction with the chemicals of the working environment that can affect the hearing of industrial workers. Thus, people who are medically treated with drugs that can be toxic to the ear are identified as unfit to work in noisy industrial environments.

Corollary A5: Ear-nose-and-throat surgeons are the HC experts.

This corollary stems implicitly from the necessity, in a hearing sensitivity management program, of attributing abnormalities to the proper causes. It is further justified by the physicians' appropriation of responsibility for people's health:

> "The conservation of any human function is primarily a medical responsibility. Hearing conservation is no exception. Prevention, diagnosis and treatment of hearing loss; validation and approval of audiometric records; and the final assessment of measurements of hearing are medical responsibilities. Any hearing conservation program without medical supervision must be considered inadequate" [15, p.12].

Indeed, the otologists have the solution to the problem that they have defined in medico-legal terms and for which they provide the means of management. Seen in a broader context, it is paradoxical that surgeons, who have no technical knowledge or skills in noise control and industrial processes, are the accepted rational authority and the most legitimate spokesmen for the problem of excessive noise in the workplace. As explained below, the otologists rapidly recruited many allies among different scientific and professional specialties in order to have them adopting the HC paradigm.

Postulate B. Noise is there to stay

Although most publications on HC since 1975 are titled "hearing conservation", omitting "in noise" in qualifying their approach, they still convey the presupposition that hearing must be conserved despite the presence of excessive noise. The rationale explicit in the original texts is that it is most often technically impossible or economically unfeasible to reduce noise in the workplace; in more recent publications, noise control is merely a possibility, in constrast to the more accessible alternative of a hearing conservation program [41, p.4; 42, pp.1-8]. Noise control is sometimes included as a component of hearing conservation; but, then, it is stated as a possibility, the management of hearing being a necessity.

Noise control engineering has grown very significantly as a science and technology over the last 30 years. While debating the feasibility of reducing the permissible exposure limit to noise, the U.S. occupational health and safety administation (OSHA) commissioned a study on the issue of noise control feasibility in industry. The report, published in 1974 [43], showed convincingly that noise control solutions were available for a very large majority of job-sites across the manufacturing industry. More recently, experts in noise control engineering have clearly stated that the available technology is not implemented because of a lack of demand [7;44].

HC promoters further invoke the constraints associated with economical feasibility of noise control. "Achievability', "practicability", "economic viability" are argued for any occupational health issue [45]. Noise, however, is never considered as such, given the value-laden postulate that industry cannot support the cost of making the sound environment acceptable and safe. This implies a societal choice, made by scientists and professionals without any explicit and public debate. The influence of values on scientific practice in general is increasingly being acknowledged [46]. In the case of HC, contextual values not only have a degree of influence, they can be said to actually govern this field.

The values in question imply that it is not possible for an industrialized society to afford various goods and services without deafening a significant segment of the workers who produce and maintain such goods. The issue of weighing the value of workers' health, safety and lives in relation to economic demands is in itself objectionable, as shown by the U.S. Supreme Court ruling concerning pneumoconiosis in the textile industry [47, p.304]. In the case of occupational hearing loss, it has not even been discussed [49]. It was settled without ever being raised in a debate, thus subjecting men and women to the machine, a legacy of the industrial revolution. In the ongoing second industrial revolution, examples of increased noise levels in the workplace abound given the faster operations of more productive machinery which relies on more powerful technologies [8]. Hearing conservation programs are introduced as soon as new plants or new departments in existing plants are opened. Once it is assumed that noise is there to stay, "hearing conservation in noise" is not a contradiction in terms.

Postulate C. Some individuals are excessively susceptible to noise-induced hearing loss

> "It is clearly not feasible in many situations to try to eliminate the possibility of causing any noise-induced hearing loss in any individual. People vary too much in their susceptibility to noise and to other factors" [15, p.23].

Another version of this postulate is as follows:

> "No noise-exposure limit can be set to protect everyone. This is not possible, let alone reasonable: there is too much individual variation in susceptibility to noise-induced hearing loss" [30].

An artificial discontinuity is created in the distribution of the effect of noise on hearing sensitivity. The results from cross-sectional studies of hearing loss among industrial workers all showed that, for a given noise dose, there is indeed a wide variation of responses, the distribution of which is accounted for by a single statistical function [49]. By creating an artificial category, such as the so-called "susceptible individuals", the HC proponents open the door to differential treatment for a subgroup presumably corresponding to the extreme end of the statistical distribution. This special treatment is made explicit in the following two corollaries.

Corollary C1: "The risk factors of NIHL are a) the level of exposure, b) the length of time an employee is exposed to noise and c) individual susceptibility to noise-induced hearing loss" [13, p.1] (NIHL: noise-induced hearing loss).

Individual differences in the response to noise, defined in two mutually exclusive categories of susceptibility and non-susceptibility, is assimilated with exposure descriptors. This makes it possible to define an acceptable level of risk, namely, a level of exposure to noise that creates a risk of hearing loss only among the so-called susceptible individuals:

> "In most discussions of proposed criteria it is generally agreed that 80 dBA is completely acceptable, with no clear risk at all, while 95 dBA is usually the highest that is considered as possibly acceptable. This equivalent sound level A approaches a 30 % risk at 35 years. Actually 90 dBA has been the most frequent choice, but usually with the recognition that personal protection and also careful monitoring of hearing for telltale losses of sensitivity beginning at 4000 Hz should also be employed" [17;50].

Knowing that 90 dBA impairs shouted speech at a distance of one meter, one can imagine how annoying and constraining is such an "acceptable" exposure level. The introduction of the concept of acceptable risk within this outlook has laid the foundation for the first legal limit to occupational exposure to noise ever to be passed: that is, the Walsh-Healy Act in the USA in 1969 [51], which has

inspired most national regulations later adopted by industrialized countries. It was explicitly acknowledged that limiting daily exposure to 90 dBA-8h would protect only 80 to 85 percent of the population against a compensable hearing loss after a lifetime of work. In doing so, it justified the need for procedures to assist in the management of the so-called susceptible individuals.

Corollary C2: The susceptible individuals need to be identified.

The scientific literature in the fields of auditory perception, audiology and ear physiology abound with accounts of attempts to identify a predictor of susceptibility to noise-induced hearing loss. This concern has inspired many investigations of the potential relationship between sensitivity to noise-induced hearing loss and sensitivity to auditory fatigue [52-54], eye color [55], race and gender [56], cigarette smoking [57], noise regimens that could induce increased resistance of the ear [58], etc. None of these attempts has yet been successful, and audiometric monitoring, that is, periodic hearing tests with noise-exposed workers, has served as the measure of susceptibility, as explained below.

Once an individual is classified as excessively susceptible by a physician, there is no other choice given but find another job that does not involve noise exposure. It is the individual, not the noise, that is considered the problem.

Such a hearing sensitivity management approach to industrial noise opens the door to further distinctions between subgroups of individuals:

> "The percentage of an industrial population potentially compensable for hearing loss caused by on-the-job noise exposure is strongly dependent on the race and sex characteristics of the population" [56, p.565].

It has been claimed by these authors that women are less sensitive than men, and black people less sensitive than white people, to hearing loss due to occupational noise exposure. This implies that employers who wish to limit compensation costs for noise-induced hearing loss could recruit the workers to be assigned to the noisiest worksites from specific subgroups of the population defined in terms of race and sex.

Postulate D. Hearing protective devices can always be an effective and adequate means to prevent compensable hearing loss

Once it is assumed that noise is there to stay, the effectiveness of palliative means for preventing hearing loss must then be unquestionable:

> "Hearing loss varies with the type of exposure and its degree of intermittency, the individual exposed, the total duration of exposure, and the degree of consistency of use of ear protection" [29].

The use of hearing protectors is prescribed with little if any consideration given to the working conditions in which they are supposed to be used. The protector is an icon with a cult following; it needs to be respected. If, for instance, a worker modifies it for more comfort, he or she is labelled an "offending employee" which is said to "abuse" the protector [59-60], as if a transgression had been committed.

Actually, thought and practice concerning the use of hearing protectors has evolved over the past 35 years. Because the very act of trying to motivate employees to wear protectors could result in an increase of claims for compensation [8, p.38], there was originaly little insistence on their use despite their recognized status as a privileged means of preventing noise-induced hearing loss. This is demonstrated by the fact that, prior to the eighties, many surveys of occupational hearing loss (in the absence of hearing protection) were being conducted in different industrialized countries. Because of the increasing number of compensation claims [13, p.4-6], insistence on their use by the hearing conservation professionals increased markedly in the late seventies. Consideration of the potential obstacles to their use was rare [61]. More recently, the insistence on the necessity of wearing them is demonstrated in motivation programs that use the results of hearing tests as proof of the damaging power of noise exposure [62]. In this context, the difficulties arising with the use of protectors are acknowledged but considered as always surmountable. Such difficulties are examined without reference to actual and concrete work situations. Hence, hearing conservationists have not analysed the type of constraints that arise in specific industries.

Such constraints certainly exist [63]. For example, in underground mines, it can take more than half-an-hour to reach the nearest facility for washing one's hands before inserting earplugs. In foundries, the use of a hard-hat, eyeglasses, masks, and thick gloves is common for a number of job-sites; there is a problem of compatibility between this protective equipment and the use of earmuffs, particularly in high temperature areas. On production lines in the manufacturing industry, the rapid pace of repetitive gestures does not allow the workers to take the time required for proper placement and periodic re-placement of hearing protectors. Drivers of heavy and very noisy vehicles are not allowed by the road traffic regulations to wear any device that can impair sound detection. Such examples are not discussed in the HC literature; any mention of incompatibility between work requirements and the use of hearing protectors is being excluded.

Furthermore, discomfort, the most salient feature of the experience of wearing hearing protectors, is practically ignored. Feelings of isolation, insecurity and annoyance have been documented in studies of the psychosocial effects of hearing loss artificially created by the use of hearing protectors [64]; and these observations are ignored by the hearing conservation literature. The discomfort from the inevitable pressure within the ear canal or around the ear has been studied recently within laboratory conditions. But one may well question the validity of jugdements made by paid subjects who are asked to passively wear different protectors for a few seconds [65] or a few minutes [64] as predictive of the experience of real life conditions in which people have to wear them for hours and communicate verbally, localize auditory signals, etc.

Field studies of their effectiveness have consistently shown that protection is low and highly variable, so much so that it is not possible to warrant a given amount of protection for an individual wearer [4;69]. As a matter of fact, results of hearing tests conducted on workers who had been wearing protectors for the extent of their working lives indicate that they had sustained various degrees of hearing loss [67-68]. It is worth mentioning that such data were not analysed as an assessment of the success of hearing conservation programs, but rather as a comparison between the long term effectiveness of different types of hearing protectors. As it is postulated that hearing protective devices can always be an effective means of preventing compensable hearing loss, the measured ineffectiveness is attributed to intermittent use of the protectors, thus implicitly blaming the victims. The HC paradigm demands that hearing protective devices be adequate means of prevention of hearing loss. The users are at fault, not the devices. Workers' doubts as to the effectiveness or the safety of protectors are made inadmissible if not illegal:

> "Strict enforcement of the hearing protective device program is essential, and such enforcement should include a four-step procedure: a) verbal warning; b) written warning; c) brief suspension (no pay); and, finally, d) termination" [69].

The use of hearing protectors has been made a condition of employment in some plants [70]. According to compensation rules in some states of the U.S., failure to wear hearing protectors may result in reduction of the compensation award [71]. The idea of failure of the personal protective equipment is simply inadmissable to the hearing conservationists.

Postulate E. Periodic hearing tests warrant prevention of hearing loss

> "The measurement of hearing ability is the most important part of a hearing conservation program" [15, p.28].

Knowing that a test has never prevented a disease, this statement is paradoxical unless it is understood within the context of protection of employers against successful compensation claims, as some employers have actually acknowledged [72]. In fact, pre-employment and periodic examinations have been instated for this very purpose as soon as occupational diseases became compensable, that is, shortly after the first world war [73-74]. Audiometry was recommended to employers by insurers as soon as noise-induced hearing loss was formally compensable:

> "From these facts it is easy to visualize the tremendous number of these people who become eligible for compensation for hearing loss without suffering any job-connected impairment if employed by industry. A possible solution to this problem, as far as workers employed in the future are concerned, is found in the proposed new Wisconsin legislation to which reference had been made; namely, a provision that if the employer can show, through pre-employment audiometric record, that a hearing loss existed at the time of employment of the worker, he shall not be responsible for the loss which existed at that time" [36, p.344].

This proposal was further extended to periodic hearing tests within the "Guide for Hearing Conservation in Noise" as an implicit, and at times, explicit as marketing arguments for hearing conservation programs offered to the employers:

> "Historically, the market for hearing conservation services in industry is stimulated by the threat of workers compensation claims from occupationaly induced hearing loss and from federal or state regulations mandating programs to protect workers. These continue to be the moving forces behind management's consideration in developing and maintaining industrial hearing conservation programs. American business is now motivated to implement appropriate hearing conservation programs to minimize potential liabilities and protect the bottom line profits" [75, p.246].

Actually, audiometric monitoring is the corner stone of the HC paradigm, which is essentially a hearing sensitivity management protocol for industrial workers. It is formally justified by Postulates A,B and C mentioned earlier:

> "Ideally it would be desirable to reduce all existing noise doses below some acceptable value. Practically, however, noise reduction sufficient to properly protect the working population will not occur in the near future; therefore, adequate hearing test programs are essential" [56, p.551].

Audiometric monitoring further legitimizes the use of hearing protective devices despite uncertainty about their effectiveness. It also legitimizes having hearing specialists act as experts on the problem of industrial noise. It individualizes the problem of occupational hearing loss, making the worker responsible for his/her hearing loss, as it serves as evidence that the worker is not making proper use of a hearing protector or is in the "more susceptible" category. For those workers not yet showing signs of compensable losses, the results of periodic hearing tests are used to (falsely) reassure them about the potential risk of hearing damage [72, p.5].

The practice of testing hearing is in itself a means to structure the problem of occupational noise exposure within the context of hearing sensitivity management, by defining it as a loss of hearing resulting from inadequate protection or individual susceptibility. The expression "management of hearing" has been used explicitly in a Japanese paper about compensation for hearing loss [76]. But, in the usual scientific argument, audiometric monitoring is advocated as a means of secondary prevention, that is, of early detection of hearing damage in order for proper preventive measures to be implemented. Such a contention, analysed below as a corollary of Postulate E, appears to serve to camouflage the practice of hearing sensitivity management.

Corollary E.1: Early detection of hearing loss by means of audiometric monitoring leads to prevention.

> "Periodic hearing tests are conducted to identify changes in hearing level so as protective follow-up measures can be initiated before hearing loss progresses" [77].

This quotation from the recent amendment of the US federal regulation of occupational noise exposure has made audiometric monitoring part of the legal obligations of employers in noisy industries.

In more than thirty years of periodic hearing tests in the workplace, not a single documented case of noise control has been motivated by the results of such tests. In fact, apart from reassurances that the test result is "normal", there are three possible outcomes of audiometric examinations: a) workers are referred to a specialist, in which case a diagnosis is given to the employer and treatment for ear disease may be offered to the worker [78]; b) personal protection is recommended, with possible review of the fitting and placement procedure, encouraging careful and continuous use of protective devices [72, p.3]; or c) job reassignment [79]. The latter is infrequent as it is often impractical and potentially a source of economic disadvantage to the workers. But job reassignment appears nevertheless to be used in some instances. Results from a cross-sectional audiometric survey in a large steel mill where a hearing conservation program had been implemented showed that the department comprising the highest proportion of workers affected by noise-induced hearing loss was the yard, an area where the noise level was generally lower than inside the plant [80]. This was consistent with the practice of assigning hearing impaired workers to this area before their hearing loss reached a level that would have made them eligible for compensation.

Athough audiometric monitoring is formally justified as the ultimate measure of success of a hearing conservation program, a claim that has not been empirically validated [81-82], it rather appears to be a tool to collect information on the hearing status and auditory history of noise-exposed workers in order to oppose counter-arguments to compensation claims for occupational hearing loss. Many workers have reported to the present author that they had never heard about the results of their periodic hearing tests until they filed a claim for compensation [79]; at this point, the employers used the test records as evidence against the claim of the occupational origin of the hearing loss. Poor test results obtained since the earlier years of employment in the plant were used to argue that the hearing loss of the claimant was not related to the current job.

The contention that audiometric monitoring serves as a camouflage for the practice of hearing sensitivity management is further subtantiated by an analysis of the second corollary of Postulate E.

Corollary E2: Audiometric monitoring can effectively detect changes in the hearing sensitivity of noise-exposed individuals before any hearing disability occurs.

The concept of secondary prevention implies that appropriate action is taken when early signs of the presence of disease are detected. This presupposes that the health surveillance procedure is sensitive enough to detect signs of illness before any serious damage occurs. In the context of occupational hearing loss, this would mean that periodic audiometric tests can actually detect slight changes in hearing sensitivity before the listening and communication ability of noise-exposed workers becomes reduced. It also implies that the testing procedure is subjected to rigorous quality control. Actually, studies of fairly large samples of hearing test facilities in industry, from Europe as well as from the U.S.A., have shown that the great majority of these facilities did not meet the most basic requirements for a valid test [83-84]. This clearly indicates that early detection of noise-induced hearing loss is not the focus of industrial audiometry.

Even under well controlled testing conditions, the sensitivity of audiometric monitoring has been seriously challenged by the results of the most extensive and rigorous population study of noise-induced hearing loss ever conducted. This study, conducted in Great Britain was co-authored by an otologist, W. Burns, and an engineer, D.W. Robinson. It was commissioned by the Ministry of Pensions and National Insurance in 1961 for the purpose of examining the problems underlying the assessment of noise as an industrial hazard, particularly with regard to compensation. It is generally agreed among epidemiologists that a prospective study is the most powerful procedure for demonstrating a relationship between a given factor and the occurrence of a particular disease. Accordingly, this study was designed to describe the progression of noise-induced hearing loss over time among a highly selected group of industrial workers showing no signs of ear disease and having no prior record of noise exposure. The recruitment of such individuals proved to be rather difficult:

> "...the serial study ran into problems more severe than we had envisaged. One of these was the scientifically extraneous difficulty of locating enough cases of persons with little or no previous noise exposure" [85, p.21].

But the most significant finding is the actual failure to describe the progression of noise-induced hearing loss over time:

> "A second and more deep-seated problem exists, however, and would have beset our endeavours no matter how successful our quest for unexposed subjects might have been. This is the influence of random errors in the audiometry which all but swamp the noise-induced part of the threshold shifts. Even with the safeguards of precision equipment and impeccable control of the testing, these errors must be regarded as ineradicable in the practice of pure-tone audiometry as it is today... It is necessary to draw from our data some rather disquieting conclusions about the significance of apparent hearing level changes in annual serial audiometry such as might be administered routinely in industrial hearing conservation schemes. This is perhaps the most important lesson to be learnt from this part of our

investigation even though it is rather discouraging in character"[85, p.21].

In view of such a failure, the authors modified their study design to collect cross-sectional data on groups of workers with different lengths of service in noisy occupations. Their findings became the major reference to describe the dose-response relationship between noise exposure and loss of hearing sensitivity. Viewed from within the HC paradigm, the consistent practice of overlooking the most significant finging of this most frequently cited study (i.e. the failure of audiometry) is not paradoxical if one considers this paradigm as the foundation of a pratice that serves to restrict the cost of reducing noise in the workplace.

To acknowledge such a failure would be to abandon the myth of the omnipotence of scientific and technical knowledge [86]. In line with this interpretation, W. Burns and D. Robinson have continued to support audiometric surveillance as a means of preventing noise-induced hearing loss [87]. Moreover, for the numerous proponents of HC, acknowledging this failure precisely means opening the black box of HC and questioning the very foundations of its legitimacy. A cultural amnesia [88] has systematically served to protect the socially legitimate image of science entwined with the HC paradigm.

Other attempts to introduce the notion of failure of audiometric monitoring have been overlooked by the HC literature. In 1979, a paper was published in a widely-circulated journal of occupational medecine, which showed that, Burns and Robinson's cross-sectional data could actually lead to the same conclusion as the prospective study, as to the inability of audiometric monitoring to detect significant changes in hearing sensitivity due to noise [89].

Not only was it ignored as a critical analysis of HC, it was used as a reference (together with the only other study questioning the validity of audiometric monitoring that was published in scientific journals [81]) to support the recommendation in favour of health surveillance of noise-exposed workers, in the context of general guidelines issued by Health and Welfare Canada and published in the Canadian Journal of Public Health [90]. This procedure not only obscured the existence of disagreements among scientists, it subtly overturned the argument challenging the validity of audiometric monitoring.

In 1985, a committee of the International Standardization Organization (ISO) adopted a draft of a standard that provided a generalized dose-response relationship between occupational noise exposure and loss of hearing sensitivity. This was the synthesis of the results of previously published cross-sectional studies using a new mathematical model that was based on a number of agreed upon postulates. The consensus among the international experts on this document later allowed ISO to publish it as an international standard [91]. This provided the present author with new material for evaluating the sensitivity of periodic hearing tests for detecting changes in hearing levels among noise-exposed workers [92]. The mathematical model described in the ISO document was computerized, and the annual rate of change of hearing threshold levels was determined for different exposure levels and durations. The results were compared with the margin of error of audiometry in controlled laboratory conditions and in field testing conditions as found in hearing conservation programs. A change greater than the margin of error was defined as a significant threshold shift (STS). As expected, the annual rate of change in hearing sensitivity turned out to be always smaller than the conventional values of STS, showing once more that the likelihood of measuring a noise-induced hearing loss in its early stages is extremely small. In order to have a more concrete picture of this finding, a simulated example was presented of an industrial population with a typical range of noise exposure levels, ages, and lengths of service. The deduced likelihood of detecting a true STS was less than one in 1000, in the case of workers subjected to annual hearing tests performed in the best conditions. The conclusion was then drawn that such tests are incapable of detecting a noise-induced STS at an early stage.

HC proponents have recently proposed a procedure, in the form of a draft American national standard, for assessing the effectiveness of hearing conservation programs using audiometric monitoring data [93]. Implicitly acknowledging the impossibility of relying on an index of non-decrease in measured hearing sensitivity over time, this procedure is based on an index of statistical variability: that is, on the degree of both improvement (which is bound to be the result of measurement errors if permanent hearing loss is considered) and decline in the measured hearing sensitivity. The postulate behind this index is that a limited variability in audiometric records reflects an absence of both temporary and permanent effects of noise on hearing with the population subjected to periodic audiometric testing. It is assumed that the validity of monitoring audiometry as a procedure of secondary prevention of occupational hearing loss cannot be assessed as such. Furthermore, this procedure is founded on a tautological definition of what is an effective HC program whereby audiometric variability is to be compared with so-called control data that has been adopted "because several years of personal experience with their HCP and on-site observations indicated that the quality of HPD fitting and utilization in these programs was sufficiently strict to make them useful in control comparisons" [93, p. 11] (HCP: hearing conservation programs; HPD: hearing protective device).

2.4 The HC black box in action: input, output and exclusions

The noxiousness of occupational noise exposure became a fact as a result of a medico-legal controversy (Parag. 2.1). The nature of the solution to the problem (hearing conservation) thus created bore the stamp of the medico-legal context, whereby the risk of compensable hearing loss resulting from occupational noise exposure became the input for the HC black box.

Once the ground was set around audiometry, other manifestations of the effects of noise exposure were excluded as discussed under corollary A2. For instance, when educators in day-care centers for young children

complained about stress and poor communication conditions because of excessive noise in their work environment, occupational health and safety inspectors assessed their situation as not noisy; sound levels were below the permissible level adopted for prevention of compensable hearing loss [94]. The same happened with physical education teachers complaining about sound environments in gymnasia that were inappropriate for verbal communication [95]. The inspectors' dismissal of such complaints as invalid echoes the early HC proponents' dismissal of the effects of noise on health except for hearing loss.

The output is also essentially restricted to activities that help prevent compensable hearing loss: personal protection programs, audiometric monitoring, and experts' reports on compensation claims. The focus is not on the sources of noise in the workplace (Postulate B), but on individuals' compliance with the personal protection program and on individuals' history of ear disease and extra-occupational noise exposure. Controversies have emerged over the effectiveness of personal protection, the way audiometric surveillance has been conducted, and claims adjudication, that is, within the boudaries set by the HC black box but not over the practice HC as such. One particularly disturbing exclusion from HC output is the need to adapt the workplace to accommodate those workers who have proven to have sustained compensable hearing loss. Amplified telephone receivers are very rarely found even in factories where a significant portion of the workforce has actually been compensated for occupational hearing loss. Sound warning signals are not adjusted to the residual hearing capacities of hearing-impaired workers. Meetings are held without proper speech amplification or acoustic listening devices. Problems created in the workplace by hearing impairment [96] do not appear to be an issue even when hundreds of audiograms are performed every year in noisy industrial settings to detect such impairment.

The psychosocial consequences of hearing loss are simply denied by some HC experts [17]. Others consider these effects as a matter of fact but with marginal significance. This is illustrated by the fact that, in a book recently published on occupational hearing loss by well known american experts in this field, over 350 pages are devoted to the diagnosis of the disease (that is, to expert opinion on claims), and only half of a page on its effects on family and social life [41]. Workers affected by occupational hearing loss are not perceived as people who need specific rehabilitation services by HC proponents.

2.5 Expansion of the HC black box

The HC black box has emerged in an attempt to limit compensation claims costs relative to hearing loss, with the claims subjected to the expert opinion of the otologists. As a professional group, the latter were involved in the original construction of the paradigm, and rapidly recruited allies in many areas of scientific research, a variety of professions, various governmental institutions and diverse commercial endeavours.

Among the scientists, we find not only ear physiologists and pathologists as well as psychoacousticians, as mentioned above, but also acousticians in general. The Acoustical Society of America, in its bi-annual scientific convention, systematically holds specialized sessions on 'hearing conservation'. There is also an annual meeting of the National Hearing Conservation Association in the US.

Engineers and physicists have been involved in the development of protective devices and hearing sensitivity measuring equipment. Many health professionals besides otologists also share the HC view and practice, despite some inevitable competition. They include occupational physicians and nurses, audiologists and industrial hygienists. Recruitment of these health professionals was probably facilitated due to the fact that HC opened a field of intervention, noisy industrial settings, to specialists with no specific competence in noise reduction. It is not surprising that, without such competence, these professionals "have little choice but to accept as 'reality' the existing noise situation, and hence the propriety of 'conserving hearing' within that noise" [97, p.108]. Within the claims process, there are also lawyers involved, making alliances with one or the other professions listed above.

Governmental institutions have readily adopted the HC paradigm. Most of the occupational health and safety administrations have shaped the regulations of occupational noise exposure around this paradigm [77]. This is clearly the case for the US federal regulation as it is for many European regulations. The European noise directive adopted in 1986 heavily relies on hearing protection and audiometric monitoring [98]. Hence, occupational health and safety inspectors become involved in implementing HC in industry, backed by the mandate afforded by the state laws. Their intervention is further supported by various local or national institutions that are involved in occupational health. For instance, the US National Institute for Occupational Safety and Health (NIOSH), which is basically a research institute, has recently issued a practical guide for hearing conservation [99]. The NIOSH had previously prepared, with the Association of Schools of Public Health, a national strategy for the prevention of noise-induced hearing loss that was based firmly on HC [100]. The Canadian Departement of Health and Welfare sponsored a federal-provincial committee to prepare a model regulation of occupational noise exposure [101] which, as it turned out, relied essentially on the HC paradigm. This then served as a basis for the Canadian Standards Association to adopt a series of standards on various aspects of the practice of HC [102-103].

Commercial institutions have flourished within the HC network. They include manufacturers of hearing test equipment and protective devices, private consultants who offer integrated package-deals for hearing conservation, and insurance carriers who provide support to employers in thwarting claims for occupational hearing loss.

This whole network shares a common perspective - the HC paradigm outlined above- and a common goal of minimizing claims costs associated with occupational hearing loss. It has a common stake in serving the industry

by acting in ways that help limit the cost of noisy environment. All such intervention involving the legitimacy of scientific knowledge appears to be necessary to render the very high noise levels in the workplace acceptable over time. Because so many scientists, professionals and institutions share the same perspective, devoid of any trace of ownership and of the original circumstances that gave rise to it, it defined reality. Disputing HC's definition of the reality of occupational noise exposure implies challenging the view by all those who participate in the operation and expansion of this black box.

3. The effects of occupational noise exposure as experienced by industrial workers

The paradoxical concept of conservation of a function despite the presence of a deleterious environmental agent is unique to HC. Expressions such as "respiratory function conservation in dust", "attention maintenance in organic solvents", "renal function conservation in lead", "balance conservation on vibrating structures", are not found in the occupational health literature. Although personal protection and biological monitoring are advocated for these and many other toxic agents, the rationale for them does not reach the same level of conceptualization as for HC. This raises the question of the reasons for the widespread acceptance of HC (despite the contradiction that is inherent in the original concept).

The HC paradigm emerged as a response to the threat of compensation claim costs associated with occupational hearing loss. It became the frame of reference for any problem related to occupational noise exposure. This dismissal may provide a clue in explaining the widespread adoption of the HC paradigm and of the absence of controversy.

On the one hand, of all the effects of noise exposure on health, hearing loss is the only one involving a measurable alteration of a bodily function that can obviously be attributed to this specific environmental agent. As mentioned above, annoyance, stress, impaired communication or other types of performance impairment are viewed by scientists and the medical profession as inconvenience factors rather than health and safety problems per se. On the part of the exposed people, such effects are reported to be felt as inevitable drawbacks associated with the working environment, to which one must adapt [100].

On the other hand, hearing loss as such is not perceived as a serious threat to health by those at risk [20;104;105]. The physical damage is invisible. Hearing impairment due to noise develops very insidiously and its repercussions in everyday life are ambiguous. Its most characteristic manifestation is the result of a loss of frequency selectivity. This means ambiguous hearing behavior, in which the affected person's hearing capacity varies with the prevailing acoustic conditions. In addition, the major effects of OHL are experienced outside the workplace, that is, within family interactions, and these are not interpreted as a direct consequence of noise exposure and of hearing loss. Most of the time, such effects are are not discussed with co-workers.

At a later stage in the development of partial deafness, the stigmatization of deafness is such that anyone who shows signs of deafness risks being socially discredited. The implication is then that the more the workers are affected by OHL, the more they have a negative image of themselves. As a result, they are reluctant to endorse such a negative self-image and hence to acknowledge signs of hearing impairment [20]. This leads them to attribute their listening and communication difficulties to other causes, and adopt a passive attitude towards them.

When hearing difficulties are so obvious that they can no longer be denied or minimized, the affected workers try to conceal them [104]. This inevitably involves not only social withdrawal but also exclusion by others as a result of the image provided to their co-workers and significant others. The people around do not perceive the lack of communication as the result of a hearing problem. They are not solicited to help and they are not informed about the kind of behavior that might help [105]. Moreover, the lack of compassion resulting from concealment of the difficulties is such that the co-workers do not realize the offensiveness of their jokes about signs of hearing impairment. This feeds the stigmatization process with all its negative consequences.

Concealment of the effects of occupational hearing loss by those who are seriously affected underplays the risk of noise-induced hearing loss. In a group in which many people have been identified as having hearing impairment and have themselves reported some degree of hearing difficulty, a relatively small number of workers are identified by their unimpaired co-workers as being hearing impaired [105]. Furthermore, the latter's condition is often attributed to age rather than noise. In other words, if one asks workers in noisy plants about the likelihood of developing a hearing impairment because of noise exposure, the answer would most probably be, "minimal". People tend to say: "*it won't happen to me*".

Concealment of the effects of occupational hearing loss also makes it more difficult for those who are still unaffected to realize the impact of this condition in everyday life. This factor combines with occupational hearing loss sufferers' reluctance to acknowledge hearing difficulties to reinforce the misperception that hearing loss is an anomaly that is inconsequential. This is the case even in plants where the people had been subjected to mass audiometric screening and had their results explained [105]; one has to conclude that the audiogram is not a convincing means to raise awareness of the severity of the effects of occupational hearing loss, as was explicitly mentioned in group discussion among noise exposed workers. Misperception of its effects considerably delays workers' awareness. It is only when people have to ask others to repeat themselves very often that they realize they have a serious hearing impairment [106].

It is obvious, in this context, that the hearing impaired workers do not seek to convince union officials,

occupational health practicioners and employers of the need to reduce noise.

The strength of the HC approach to industrial noise is thus enhanced by the absence of complaints or disputes on the part of exposed workers and their representatives. As mentioned above, disputes have occurred within the boundaries set by the HC black box, that is, over acceptable levels of hearing loss, acceptable exposure levels of noise, adequate hearing protection, and valid hearing tests. Still, these have been rather few and uncompelling. For instance, the labour movement did not challenge the definition of compensable hearing loss when it was subjected to the first compensation schedule in 1954; nor did it object to the selection of a management-oriented committee of otologists [14, p.689].

4. Conclusion

Based on the above analysis of the HC black box and the way in which occupational noise exposure is perceived and experienced, one has to conclude that very high noise levels in industrial workplaces will continue to be the rule, rather than the exception, for many years if not decades to come. Scientists and occupational health practitioners can only help improve the acoustic work environment if they recognize the ways in which the postulates behind the prevailing conception justify high noise levels in the workplace, and if they adopt new paradigms to address this longstanding problem.

As explained in section 3, concealment, reluctance to acknowledge and misperception of the effects all converge to make it difficult for noise-exposed workers to know the manifestations and consequences of occupational hearing loss. This results in their viewing hearing loss as inoffensive. A health problem associated with a perceived low level of risk and low level of impact on everyday life is not felt as a threat by those at risk. Hence, the need for prevention is not felt by most workers exposed to noise, and by their employers, unless a suitable campaign is organized to raise awareness of the extent and the severity of the consequences.

The most convincing people for raising awareness would certainly be the workers who are currently affected by OHL and bear witness to its effects. This presupposes that such workers be able to disclose their condition, and such disclosing in turn requires support, to alleviate the effects of stigmatization. In other words, rehabilitation [107] may well be the first step towards prevention [20;105].

A complementary perspective can be developed whereby noise is considered a source risk for accidents, ineffective communication and work dissatisfaction. An ecological approach has been proposed keeping in line with this perspective, in which the compatibility between auditory demands and capacities are systematically examined [108]. Within this framework, improvements in the acoustic environment are governed not so much by regulatory exposure limits but rather by the characteristics of human capacities for sound detection, discrimination, identification and localization, and by speech communication needs. This would be compatible with an ergonomic approach to auditory activities in the workplace as well as with so-called total quality management programs that include working conditions.

Where management is already open to the possibility of acknowledging the devastating consequences of over-exposure to noise, a direct approach to the problem is in order: i.e., one that explicitly focuses on noise as the target of an intervention program. Worksafe Australia has developed such a program, 'Noise management at work', with a clear focus on management issues [109]. The form and content of the program is based on (a) consultation with employers, workers and government agencies, (b) market research with key workplace groups and (c) a field trial in small factories. Industry is thereby provided with practical material for tackling the longstanding problem of noise.

When combined with the noise management approach, the international machine noise declaration system [110] can be an effective tool to reshape the industrial sound environment in the long term. Once machine manufacturers have to consider noise as a formal design constraint, quieter equipment will become increasingly available. However, availability does not in itself imply a demand. Motivation will come from increased awareness of the highly undesirable consequences of noise exposure.

The problem of industrial noise is certainly not an easy one to solve. But there is no need to wait another century for scientific research on its deleterious effects before taking steps to improve the industrial sound environment.

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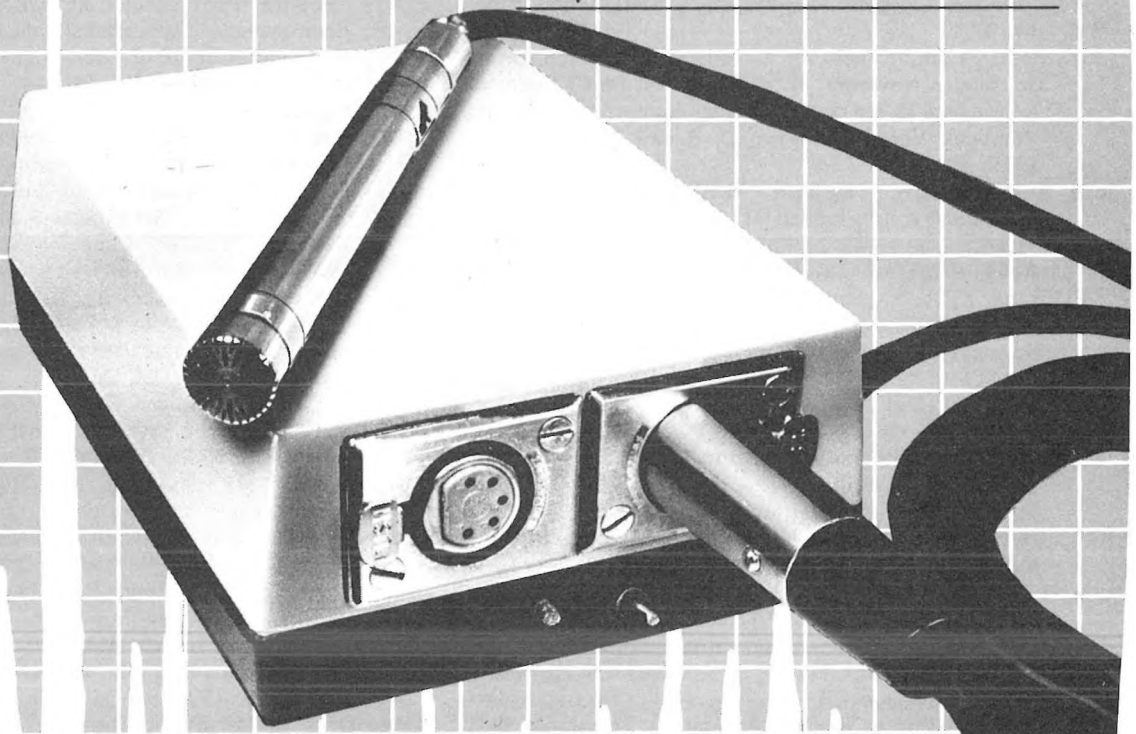

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