Noise in the School Environment
Memory and Annoyance

Doctoral Thesis
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Abstract

Objectives. The general objectives of this dissertation were to examine the effects of acute exposure to meaningful irrelevant speech and road traffic noise on memory performance, and to explore annoyance responses to noise exposure in the school environment for pupils and teachers in different age groups.

Methods. The thesis comprises seven papers, representing different methodological approaches: experiments, survey studies and interviews. In the experiments, reported in Papers I-V, 288 pupils and teachers participated in the age groups, 13-14 years (n=96), 18-20 years (n=96), 35-45 years (n=48) and 55-65 years (n=48). The subjects were randomly assigned to one of three conditions: (a) meaningful irrelevant speech, (b) road traffic noise, and (c) silence. The equivalent sound level in the noise conditions was set to 66 dB(A). A test battery reflecting episodic and semantic memory were used. The survey studies, reported in Paper VI and VII, included 207 pupils (M=13.5) and 166 teachers (M=45.9). Two separate questionnaires mainly comprising items about annoyance, noise sensitivity and stress symptoms were administered. Paper VI presents results of focus group interviews (n=16) treating the main topics: disturbing sounds, emotions, ongoing activity, and suggestions concerning future changes.

Results. The overall findings showed that both noise sources affected episodic and semantic memory to the same degree for all age groups. The results indicated that the similarity of semantic content between noise and the task at hand was not the only suitable explanation model, since a non-speech noise impaired memory as much as speech. Results also indicated that attention effects did not mediate the obtained noise effects and that the noise effects did not differ between age groups. Therefore, it seemed unlikely that different memory and attentional capacities stood out as explanatory factors of the memory effects. Since performances of both episodic and semantic memory tasks were impaired, the explanation based on level of access to long-term memory was also ruled out. However, the episodic memory task, reading comprehension, stood out to be most impaired by noise, suggesting that complexity of the task to perform was of importance. For reading comprehension there was also a different noise pattern obtained. Participants performance was in this task, more impaired by meaningful irrelevant speech than by road traffic noise. This effect indicated that meaningful irrelevant speech might reduce the available cognitive resources necessary for learning the text. The annoyance models derived from the survey studies indicated that sensitivity acted as a mediator between hearing status and annoyance, with stress symptoms as an outcome. Whether annoyance arises or not was also determined by control and predictability of the noise. In the interviews a different annoyance pattern was found, in that stress symptoms appeared to be a determinant of annoyance. To be involved, respected, take own responsibility and respect others were suggestions on how to change the environment to become more silent.

Conclusions. For both pupils and teachers acute exposure to meaningful irrelevant speech and road traffic noise influenced both the achieving and providing of knowledge. A common annoyance pattern was also found for pupils and teachers, where individual and situational factors were of importance. To achieve a more silent school environment in the future, the pupils pointed out that the interaction between themselves and their teachers was of importance.

Key words: Noise, meaningful irrelevant speech, road traffic noise, memory, age groups, school environment, pupils, teachers
Foreword

Between the present covers there is one doctoral thesis with two authors. This unusual arrangement deserves a comment and a clarification.

When we hit upon the idea of this research project our intention was that the studies would conclude with two doctoral theses, one focused on pupils and one focused on teachers. The work continued in that direction in the beginning of our doctoral education. Part of our education was to have a dialogue with a reference group that comprised mainly teachers and school politicians, and also to present the project at different meetings concerning school environment issues. On a number of these occasions we were encouraged to bring all the studies together in one thesis to provide a holistic view of unwanted sounds in schools. This would serve as a knowledge base that would benefit the actors in this environment. Their recommendations provoked thoughts about how to continue our work. Should we follow the academic tradition, which advocates a more individualistic way of working, or should we follow a recommendation made in the public’s interest, which required a more co-operative approach? After many discussions, we decided on the latter alternative. On the journey to the final product there have been doubts about this decision, from us as well as from other researchers. Nevertheless, we are now close to the end of our education and we think that we made the right decision, as this choice not only met the public interest, but also led us to develop our abilities to work independently as well as co-operatively, both important for a good researcher.

As a consequence of this way of working, we both designed and conducted the first and the second study. After that we continued the project in different directions, with one of us – Eva – studying pupils and one of us – Ingela – studying teachers. To fulfil the requirements for an individual assessment of doctoral candidates, well-defined responsibility chains for the different parts of the present thesis must be stated. For the empirical papers that the thesis is based upon, we are responsible in the order that we appear as authors. For the chapters in the present thesis, Introduction, Methodological Overview and the chapter General Discussion, we share the responsibility equally. The same procedure stands for Paper I.
List of publications

The present doctoral dissertation is based on the following seven papers:


IV Boman, E., Enmarker, I., & Hygge, S. Strength of noise effects on memory as a function of noise source and age. Manuscript submitted for publication.


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*Tomas*  

*Leif*

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*Ida, My and Thea*  

*Vendela, Helena and Isac*

*For*  

*Just being*

*Mars 2004*  

*Eva Boman*  

*Mars 2004*  

*Ingela Enmarker*
Neme solus satis sapi
No man alone can know enough

(Titus Maccius Plautus, 254-184 f. Kr)
A dedication to

Ida, My and Thea

Vendela and Helena
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Paper I: The effects of road traffic noise and meaningful irrelevant speech on different memory systems

Paper II: The effects of noise and gender on pupils’ episodic and semantic memory

Paper III: The effects of meaningful irrelevant speech and road traffic noise on teachers’ attention, episodic and semantic memory

Paper IV: Strength of noise effects on memory as a function of noise source and age

Paper V: Structural equation models of memory performance across noise and age

Paper VI: Factors affecting pupils’ noise annoyance in schools: The building and testing of models

Paper VII: Pupils’ and teachers’ response structures of noise annoyance

GENERAL DISCUSSION

Effects of Acute Noise Exposure
Perceived Noise Exposure in the School Environment
Practical Implications and Future Challenges

REFERENCES
INTRODUCTION

The school is the most prominent place for learning in modern society. In this environment, pupils and teachers work together to achieve and provide knowledge in a social and educational interplay. In Sweden, the responsibility for the schools was transferred in 1991 from the national to the local government. This change, together with the new curriculum (Swedish Ministry of Science and Education, 1994), implied that schools individually could determine their own profile and use different pedagogical methods. These commitments promoted a development of more individually based teaching. However, in parallel with this positive development of ideas, media points out a depressing side in the school of today, with problems in maintaining discipline, worse performance in basic subjects, and teachers leaving their profession. In addition decrease in economic resources has led to more pupils in each class, a degraded working environment for both pupils and teachers, and increase stress and sick-leave (Give the power to the teachers, 2002; Increasing sick-leave among teachers, 2003).

In this complex environment, noise is often an additional hinder to learning and working. The problem is not only high sound levels. It follows from the simplest and most common definition of noise as unwanted sounds (WHO, 1980) that also weak sounds, speech and music can be seen as a part of the noise problem in schools.

Our intention with the present thesis was to extend the knowledge of noise in schools and the focus thus has been on an actual working environment. To fulfil this intention, we arranged the studies so that several aspects of the problem were elucidated. To throw light on all the actors in the classroom situation, we studied pupils in different age groups from upper regular school as well as their teachers. We also wanted to examine the effects of acute noise exposure on memory performance, so we exposed participants to meaningful irrelevant speech and road traffic noise while they performed memory tasks in a laboratory setting. In addition to that, the experience of noise in their own school environment was also examined with questionnaires and interviews. Thus, we used different methodological approaches - experiments, survey studies and interviews – to examine the effects of different noise sources relevant in the school setting, one indoor - meaningful irrelevant speech – and one outdoor –
road traffic noise. To get an idea about how to make the school environment quieter, the pupils’ suggestions concerning this issue were also explored. Altogether, this set of studies broadens the psychological perspective concerning noise in the school environment.

The sound level in an occupied classroom can vary in the range 40-70 dB(A)\(^1\) (Berg, Blair & Benson, 1996; Lundquist, 2003; Markides, 1986; Pekkarinen & Viljainen, 1991), but noise levels as high as 75 to 85 dB(A) have been reported (Finitzo, 1988). However, the Swedish National Board of Occupational Safety and Health (1992) has recommended that the equivalent sound level during a working day should not exceed 40 dB(A) in a room used for teaching and activities demanding concentration and/or undisturbed communication. It is therefore important to examine how the actual sound environment affects cognitive functions and how different noise sources contribute to these effects. In addition, it is important to find out new ways to reduce noise and thereby provide better learning and working conditions.

In Lundquist, Holmberg and Landström’s (2000) study, the pupils rated chatter as one of the most annoying types of noise in the school environment. Tesarz and Kjellberg’s (1998) obtained similar results in a survey on teachers’ experiences of noise problems. That is, the teachers perceived irrelevant speech and its interference with their work as the most serious noise problem. Thus, irrelevant speech seems to be the most disturbing indoor noise in Swedish schools. However, outside schools, road traffic noise is a major source of complaint (cf. Ouis, 2001; Vos, 1992), and it has also been shown to affect pupils’ learning (Hygge, 1997, 2003).

Memory is essential for achieving and providing knowledge. Two memory systems were of special interest in our research: episodic memory, the initial acquisition and the subsequent remembering of new information, and semantic memory, the representation of facts, concepts, words and their meaning (Tulving, 1993). Therefore, the first main objective of the present thesis was to examine the effects of acute exposure to meaningful irrelevant

\(^1\) dB(A) is the most commonly used frequency weighted measure of sound level. The frequency weighting (A) means differential sensitivity to different sound frequencies, reflecting the sensitivity in the human ear by suppressing low and high frequencies. To get an idea of the mean sound level across time the measurement is also often reported in equivalent sound level, \(L_{eq}\).
speech and road traffic noise on memory performances for pupils and teachers in different age groups. A better understanding of these effects is of great interest from both theoretical and practical points of view.

It is also important to take a comprehensive view of the noise problem and therefore to include the patterning of subjective responses to noise for both pupils and teachers. The second main objective was thus to explore the influence of noise exposure in the school environment and to take part in pupils and teachers experiences of noise annoyance.

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**Noise and Memory**

**Meaningful Irrelevant Speech and Memory**

Meaningful irrelevant speech is defined as speech that contains meaning but is irrelevant for the task at hand. The effects of this speech are especially important to study, since speech is a dominant type of noise in schools (Lundquist *et al.*, 2000, Tesarz & Kjellberg, 1998). This type of noise has consistently been found to impair memory processes (e.g., Jones, 1990; Jones, Miles & Page, 1990; Martin, Wogalter & Forlano, 1988; Oswald, Tremblay & Jones, 2000; Tremblay, Nicholls, Alford & Jones, 2000). Most studies examining the effects of irrelevant speech on memory concern working memory. The results from these studies show that both meaningful and meaningless speech may impair memory performance, particularly in tasks with a serial component (Ellermeier & Zimmer, 1997; Tremblay *et al.*, 2000). However, meaningful speech is more disruptive than meaningless speech for reading comprehension and proof reading (Smith, 1989).
Road Traffic Noise and Memory

Road traffic noise is the most prevalent outdoor noise source (Bendtsen, Ellebjerg Larsen, & Mikkelsen, 2000; Ouis, 2001; Vos, 1992), and its effect on memory has received less attention than the effects of irrelevant speech. Hygge (1997, 2003) conducted noise experiments in ordinary classrooms where road traffic noise was presented to the children at 66 dBA $L_{eq}$ and 55 dBA $L_{eq}$ during text reading. It was found that road traffic noise had a strong effect on the pupils’ performance on recalling the text, and a smaller, but significant effect on recognition. Thus, the few studies completed to date have found that road traffic noise may have detrimental effects on children’s reading comprehension.

Theoretical Models of Noise and Memory

The effects of irrelevant speech on memory have been given two main theoretical interpretations. One relates the interference to the similarity of processes of seriation (Beaman & Jones, 1998; Macken, Tremblay, Afford & Jones, 1999), while the other emphasises the similarity of content between the noise and the item to be remembered (Martin et al., 1988; Salamé & Baddeley, 1982). The former view suggests that the disruption is a result of a conflict based on interference between two concurrent processes of seriation. That is, the order of information in the sequence of auditory events interferes with the process of ordering within the rehearsal set (Macken, et al., 1999). Accordingly, Jones and co-workers presented the changing-state hypothesis, which assumes that the disruption of memory is due to changes between the noise components rather than from the nature of the sound itself (see also Tremblay et al., 2000). Research has shown that when lists of words or consonants should be retrieved in serial order, tone presented with higher frequency differences lead to more error compared to tones presented with small frequency differences. This implies that when frequency changes are held constant, non-speech stimuli, such as road traffic noise, should impair recall as much as speech stimuli.
The alternative interpretation of the disruptive effect of irrelevant speech on memory is the similarity of content hypothesis, which emphasizes both the effect of meaningfulness of the irrelevant speech as well as the semantic similarity of the speech and the material to be remembered (Jones, 1999). The latter suggestion implies that when two concurrent semantic processes take place at the same time, the cognitive resources decrease (cf. Knez & Hygge, 2002). For the similarity of content hypothesis, the results are more scarce and divergent (Banbury & Berry, 1998; Martin et al., 1988; Oswald, et al., 2000) compared to the substantial body of research on the similarities of seriation (cf. Tremblay et al., 2000). Martin et al. (1988) investigated whether the detrimental effects of unattended speech that had been obtained in short-term memory tasks would be found in reading comprehension. They used different texts with following multiple-choice and cued recall questions. Their main finding was that the detrimental effect of different auditory background noise was due to the semantic content of the noise rather than the phonological characteristics. Oswald et al.'s. (2000) findings were in the same direction when examining the disruption by irrelevant speech of different levels of sentence comprehension. The meaningful irrelevant speech was a recording of the early evening news and the meaningless speech was the same recording played in reverse. The results showed that both noise sources disrupted the comprehensive aspect of the tasks, but the effect of meaningful speech was significantly greater.

Besides these two theoretical interpretations concerning irrelevant speech, the complexity of the task at hand must also be taken into account when considering noise effects on memory (Cohen, Evans, Stokols & Krantz, 1986). Cohen et al. (1986) offered a model which implies that three factors reduce task efficiency during noise exposure: task performance is impaired when the number of inputs one must attend to increases, when speed of the input increases, and when signal predictability is reduced. In other words, they meant that noise increases demands on the limited capacity of attention and information processing, thereby reducing the information processing resources available for the memory task. This reduced capacity should disrupt a complex task more than a simpler one. To follow this reasoning, exposure to noise, taking place during work with a cognitive task may be seen as a kind of divided attention situation, since multiple stimuli are presented simultaneously and may draw attention from the task to the noise. However, performance may also be impaired.
when one is able to keep attention on the task, since the effort required not to be distracted by the noise reduces the resources available for the memory task.

**Memory Systems**

A theoretically fruitful way to analyse noise effects on cognition would be to start from an accepted cognitive theory. The theory of memory systems by Tulving (1993, 2001) is such a candidate. Tulving (1993) separated five interacting systems in memory: procedural memory, perceptual representation system (PRS), semantic memory, primary memory and episodic memory. The procedural memory is a motoric system, independent of any cognition; it stores information about all kind of movements and provides a blueprint for future actions. The other four are cognitive systems. The perceptual representation system (PRS) facilitates the perception of the same or similar object on another occasion. This memory system is assumed to be involved in perceptual priming, that is, when experience-based changes manifest themselves as enhancement in the perceptual identification of objects. Semantic memory is concerned with the structured representation of facts and general knowledge. It is an impersonal memory system with no reference to the time, place and context where the knowledge was acquired. Primary memory is the immediate memory (also called working memory; Baddeley, 1990). This system registers information in a highly accessible form for a short period of time after the input. Episodic memory is event-based and enables individuals to remember previous personal experiences, that is, memories associated with personal events in subjective time.

According to Tulving's (1993, 2001) serial parallel-independent (SPI) model, there is a relation among PRS, semantic and episodic memory. The central idea is that these systems are process-specific, which means that encoding of information proceeds serially, with the PRS at the lowest level and episodic memory at the highest processing level, whereas storage is parallel, and that retrieval from the system is independent of each other. To be more specific, when encoding episodic information the process starts with an activation of PRS, thereafter the information is transmitted to the next highest level, semantic memory, and finally reaches
the episodic memory. To follow the parallel storage assumption, information about the perceptual features of the input are stored in the perceptual system, semantic information is stored in the semantic system, and finally information about the involvement of the self is stored in the episodic system. Further, the third process in the SPI model, retrieval, is assumed to take place independently between the systems, meaning that retrieving information only involves one memory system.

Tulving’s (1993) classification allowed us to make a distinction between the memory systems based on type of information: “to remember” (episodic memory) or “to know” (semantic memory), essential memory functions in promoting learning.

**Noise Effects on Episodic Memory**

The characteristics of episodic memory are personal experiences and objects, people and events that have been experienced at particular times and places. When recalling this particular episode, the remembering process consists of a conscious retrieval. In other words, this memory system includes a distinct time differentiation between encoding and retrieval. Therefore, the encoding and retrieval phases have to be separated to distinguish noise effects on the two phases.

Studies have demonstrated that memory performance declines when attention is divided at the time of encoding relative to conditions of full attention (Anderson, Craik & Neveh-Benjamin, 1998), and that divided attention during encoding has a larger detrimental effect than it does during retrieval (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Craik, Naveh-Benjamin, Ishaik, & Anderson, 2000; Mulligan, 1998). In line with Craik, *et al.* (2000), the emphasis in noise research has been on impairment due to noise at the encoding stage (Jones, 1990). Since noise effects on episodic memory depend on the elaborating processes during encoding, the encoding and retrieval phases were separated in the experiments in the present thesis and retrieval was performed in silence for all subjects.

Different memory tests provide more or less efficient retrieval cues and it is of interest to test the importance of these differences for the noise effects. Recognition tasks seem to
involve a kind of matching process (Haist, Shimamura & Squire, 1992), and thus should give the best retrieval cues. In cued recall, hints are given that may stimulate recall of memories, that is, memories that cannot be spontaneously recalled may be activated by appropriate cues (Haist et al., 1992). Free recall means that no cues are presented and thus should require more effective processing compared to recognition (Craik & McDowd, 1987). Noise has been shown to have strong effects on recall and smaller or non-significant effects for recognition in episodic memory (Enmarker & Hygge, 2000; Hygge, 1997, 2003; Knez & Hygge, 2002). So the presence of environmental support, such as good retrieval cues, may alleviate the effects of noise.

Another form of memory support is the involvement of a motoric component in episodic memory. That is, enactment of the phrases to be remembered when encoding verbal episodic phrases has been shown to improve the memory trace and thus give better retrieval (Engelkamp, 1995; Nilsson et al., 1997). Noise research has not addressed this particular issue, but it might be assumed that enacted sentences would withstand noise exposure to a higher degree than the sentences without enactment.

Since there is evidence that face recognition is unique compared to identification of other episodic materials (Coin & Tiberghien, 1997; Eimer, 2000; Farah, Wilson, Drain & Tanaka, 1998; Hancock, Bruce, & Burton, 2000), it is also of interest to examine noise effects on this non-verbal episodic memory material. It is uncertain in what way face recognition is special, but it is obvious that the recognition of faces is of utmost importance for social interplay. Since there are no studies reported on noise effects on face recognition, it is also of theoretical value to compare noise effects on verbal and non-verbal materials. Therefore, we included encoding of faces during noise exposure in our experiments.

One of the characteristics of episodic memory is that retrieval of the memory material is processed in a conscious way (Tulving, 1993). The encoding, however, could be intentional or incidental, which means that the material could be processed with or without any conscious processing. When examining the distinction between intentional and incidental learning, Craik and Lockhart (1972) assumed that incidental encoding sometimes could be superior to intentional encoding. They postulated that the operations carried out on the material, not the intention to learn, determine retention. When exposed to noise the attentional resources are
assumed to be reduced (Cohen et al., 1986), which leads to priority being given to cues central to the task at hand (Smith, 1989). In line with this, some results show that noise influences incidental learning negatively (Hockey & Hamilton, 1970; Smith, 1985). However, the hypothetically greater vulnerability to noise of resource demanding processes (see PRS; Tulving, 1993) leads to the opposite prediction. Put in other words, incidental learning does not demand any conscious processing during encoding, and thus should not be impaired by noise. On the other hand, noise would impair the controlled encoding process, the intention to learn.

Ageing is supposed to decrease the attentional resources (Craik, 2000) and divided attention situations should be particularly sensitive to ageing (Allen, Groth, Weber & Madden, 1993). This reasoning is supported by the general finding that when attention is divided, young adults’ performance resembles that of older adults working under full attention conditions (Anderson et al., 1998; Craik, 2000). Further, there are age decrements demonstrated for episodic memory, where the decline in cross-sectional data seems to appear as early as around the age of 20. Results from longitudinal studies on the other hand have not found age deficits until later in life (Tulving & Schacter, 1990; Nilsson, 2003; Nilsson et al., 1997). Concerning gender, most research has been on adults showing that, independently of age, females outperform males in verbal episodic memory materials (Herlitz, Airaksinen & Nordström, 1999; Herlitz, Nilsson & Bäckman, 1997; Nyberg, Habib & Herlitz, 2000). This leads to the prediction that performance is least impaired by noise in the ages 18-20 years and the sensitivity increases below and above that age. A further prediction is that episodic memory would be affected by noise to a higher degree in males than in females.

Noise Effects on Semantic Memory

The semantic memory contains structured general knowledge, such as concepts, words and their meanings. It is impersonal, which means that it is not tied to the time or place when the information was learned (Tulving, 1993). The foundation of semantic memory consists of concepts which are organised in different schemata. To use a schema, the stimuli first has to
be categorised, a process that proceeds on the basis of earlier stored information in long-term memory (Arai, 2001). Since the structure of semantic knowledge cannot be derived from any particular episode, the only possibility to study noise effects on this memory system is during retrieval, which is supposed to include more automatic access compared to retrieval from episodic memory (cf. Nyberg, Bäckman, Erngrund, Olofsson & Nilsson, 1996; Roediger & McDermott, 1993). This implies that less attentional resources are required when retrieving semantic information compared to remembering episodic information.

One of the abilities that reflect the general knowledge contained in semantic memory is word fluency. Word fluency tests can be constructed to measure different aspects in the retrieval process of “knowing”. They can reflect a lexical process (Solso, 1995), like an encyclopaedia search. They can also involve speed of recall (Eysenck, 1975; Nilsson et al., 1997) and be constructed to measure a search in a particular cluster (cf. Bousfield, 1953), that is, a search for words in a certain category. Another ability in semantic memory is word comprehension (Nilsson et al., 1997), the understanding of the meaning of concepts.

Performance of semantic memory tasks peaks at a higher age level than the performance of episodic memory tasks (Nilsson et al., 1997). Sometimes best performance is seen at ages as high as around 60 years, but age seems to be of less importance than education for this kind of task (Nilsson, 2003). There does not seem to be any general female advantage for semantic memory, although some reports show that women are better at verbal fluency (Herlitz et al., 1997).

Since no studies were found that explicitly focused on noise effects on the ability to access different aspects of semantic memory (cf. Eysenck, 1975; Smith, 1985), we had no empirical findings to rely on developing hypotheses referent to classroom situation. The reasoning so far concerning episodic and semantic memory might imply that semantic memory tasks should be more resistant to noise effects than episodic memory tasks, and that the older group should have more stored knowledge than the younger ones. Nevertheless, it was uncertain whether noise would impair this memory system and whether the teachers could withstand noise effects better than the younger groups.
Memory Performance Assessments

The test battery in the present experiments was composed to assess noise effects on episodic and semantic memory, with several distinctions. The episodic memory tests were defined in terms of a study phase during noise exposure where certain information was given, and a phase in silence in which this information was retrieved with different retrieval cues. The test battery included a comparison between noise effects on sentences encoded with and without enactment. For this task the participants were tested with free and cued recall questions, which made it possible to analyse the depth of elaboration during encoding. To assess this elaboration process, a distinction between cued recall and recognition was made for reading comprehension. Noise effects on recognition for verbal vs. non-verbal (family names and faces) episodic memory material, as well as between incidental (first names) and intentional (family names) learning were also tested.

We also examined noise effects on semantic memory with two different tasks, word fluency with speed requirements and word comprehension. The former task encompassed a lexical process and a search in a certain category. The latter task involved a test of synonyms.

Noise Annoyance

The subjective response to noise that most often has been measured is annoyance (see e.g., Stansfeld, Haines, Burr, Berry & Lercher, 2000). Annoyance stands for rather unspecific reactions, associated with disturbance, irritation, discomfort, distress, frustration and general feeling of unpleasantness (Job, 1988, 1996, 1999). When studying noise annoyance most research has focused on the influence of transportation noise, such as aircraft and road-traffic noise with high sound levels (Fidell, Barber & Schultz, 1991). The findings from these studies show a positive correlation between annoyance and sound level. The relation is, however, less obvious at moderate sound levels (Kjellberg et al., 1996; Landström, Kjellberg, Tesarz, &
Åkerlund, 1995; Lundquist et al., 2000), one reason being that other sound properties, such as fluctuations, than have shown to be of greater importance (see also Guski, 1999).

Whether annoyance arises or not is not only determined by sound characteristics, but depends primarily on situational and individual factors. Guski (1997, 1999) conceptualised annoyance as a situation in which the sound and the persons' intended activities are incompatible. This definition suggests that the annoyance response will depend on the ongoing activity. Another situational factor of importance is the possibility to control the noise, either by the individual or by others (Glass & Singer, 1972; Stallen, 1999), with high self-control leading to less annoyance (Kjellberg et al., 1996). Predictability is a characteristic related to control and refers to whether the noise is expected or not (Glass & Singer, 1972; Cohen, 1978), where predictable compared to unpredictable noise offers a greater possibility to prepare for the stressor and is less annoying for the individual.

The subjective responses of noise annoyance also depend on individual characteristics; the same noise source could elicit widely different responses in different persons. An individual characteristic of great importance is noise sensitivity, which is a broad term that is not explicitly defined. Individuals who regard themselves as more sensitive than others are more likely to show stronger annoyance responses (Kjellberg et al., 1996; Stansfeld, Sharp, Gallacher & Babish, 1993). The general finding is that the annoyance reaction is not related to age. Studies of age differences among adults however, have sometimes found a relationship between age, perceived hearing status and sensitivity to noise, with sensitivity increasing with age (Weinstein, 1978; Stansfeld, 1992; Kjellberg et al., 1996). However, young persons might lack well-developed coping repertoires and thus have less flexibility in coping with noise exposures compared to adults (Cohen et al., 1986). So even though the annoyance reaction is not related to age, the response pattern on annoyance and its associated characteristic may differ for pupils and teachers.
Annoyance Assessment

Since annoyance is a broadly defined concept, we used two different approaches, quantitative survey studies and a qualitative interview study, to develop and assess conceptual models of how different factors mediate and moderate the annoyance reaction in the school environment. The survey studies encompassed questions that measured situational and individual factors as well as sound properties. The interview study was designed to elucidate annoyance through questions about students' feelings about noise and their experiences of how noise interfered with their ongoing activity.

The pupils in the survey and interview study were also asked about their views concerning how to make the school environment more silent in the future.
Research Questions

Two main issues were addressed in the present thesis: to examine the effects of acute exposure to meaningful irrelevant speech and road traffic noise on memory performance, and to explore annoyance responses to noise exposure in the school environment for pupils and teachers in different age groups. Specifically, we addressed the following general questions:

(a) What is the influence of acute exposure by meaningful irrelevant speech and road traffic noise for pupils and teachers in different age groups in performance on episodic and semantic memory tasks?

(b) What is the influence of noise exposure for pupils and teachers in different age groups on the strength and nature of the noise annoyance pattering?

Besides these two main issues, it was also of special interest to find out new ways to alter the school environment so that it could become more silent, leading to the last research question:

(c) How could the sound environment in schools be improved?
METHODOLOGICAL OVERVIEW

Because the same strategy or research design could not be applied for all research questions in the present thesis both experimental and non-experimental studies were designed.

In order to examine acute noise effects and to try out the design and the dependent measures, the first study employed was an experimental study with students. To broaden the range of information about noise in the school environment, focus group interviews were conducted in connection with this first study. After this initial phase, we continued the research project examining the effects of acute noise with experimental studies and the influence of noise in their own school environment with survey studies in pupils and teachers (see Figure 1). The choice of dependent and independent variables was discussed in a reference group including teachers, school politicians, health-inspectors and headmasters. Established before designing the studies, this group was also valuable in the recruitment of schools and participants and in ensuring face validate, through judgement of the data as reasonable or not (see e.g. Patton, 1990).
Figure 1. Overview of the studies included in the project and their corresponding papers.

The Experimental Studies

The main objective in the three experimental studies (see Figure 1, Studies 1, 3 and 4) was to examine the effects of meaningful irrelevant speech and road-traffic noise on different memory tasks. Different age groups participated in the three experiments, which were close to identical in all other respects.

Basic design and procedure. In Study 1, 96 male and female students aged from 18 to 20 years participated. This age range was chosen to make comparisons with school children and teachers in future replications. The same number of subjects, but aged 13-14 years, took part in Study 3. Finally, 96 teachers aged 35-45 and 55-65 years participated in Study 4. In all three experiments the subjects were randomly assigned to one of three groups: (a) meaningful irrelevant speech, (b) road traffic noise, and (c) silence. The equivalent sound level (L_{eq}) in the noise conditions was set to 66 dB(A) 2 m in front of the loudspeakers. The dominant
frequency range of the road traffic noise (100-300 Hz) was lower than that of the meaningful irrelevant speech (500-1500 Hz). The sound level in the silent control group was 38 dB(A) $L_{eq}$. The experiments were run in a climate chamber (4 x 6 m) with controlled air temperature (21°C) and light level (900 lx). Two to four subjects were present in the experimental room at the same time, but worked on the tasks individually. Altogether, the experimental session lasted approximately two hours and the noise exposure for one hour. All sessions were run in the afternoon. At the outset, the subjects were informed that the study was about memory and noise. They were told that they would be given separate instructions and time limits ahead of each task. See Table 1 for the order of tasks and time limits. The only difference between the three experimental groups was the noise condition during the first part of the experiment.
Table 1. Chronological Order of Dependent Measures and Time Limits for Each Task

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Dependent Measure</th>
<th>Block</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Self-reported affect</td>
<td>Block 1</td>
<td>5</td>
</tr>
</tbody>
</table>
|          | **Part 1** Encoding and retrieval in silence or during exposure to either irrelevant speech or traffic noise (three groups)**
| 2)       | Attention, search and memory task (SMT)                               | Block 1 | 6       |
| 3)       | Reading a text                                                         |       | 15      |
| 4)       | Face and name encoding<sub>a</sub>                                      |       | 2.5     |
| 5)       | Word fluency<sub>a</sub>                                                |       | 3       |
| 6)       | Word comprehension<sub>a</sub>                                          |       | 7       |
| 7)       | Word stem completion<sub>a</sub>                                        |       | 6       |
| 8)       | Sentences with and without enactment<sub>a</sub>                       |       | 4.5     |
| 9)       | Attention, search and memory task (SMT)                               | Block 2 | 6       |
|          | **Part 2** Retrieval in silence (same condition for all subjects)**
| 10)      | Self-reported affect                                                   | Block 2 | 5       |
| 11, 12)  | Free and cued recall of sentences encoded<sub>a</sub> with and without enactment |       | 10      |
| 13)      | Recognition test of faces and first and family names<sub>a</sub>        |       | 12      |
| 14)      | Cued recall of sentences<sub>a</sub>                                   |       | 4.5     |
| 15)      | Test of recall and recognition of text                                |       | 10      |
| 16)      | Self-reported affect                                                   | Block 3 | 5       |

*Note.* The subscript <sub>a</sub> indicates that the test and the time limits were adapted from the Betula project (Nilsson et al., 1997). In Study 3 and 4 the test number 7 was excluded and test number 16 included. In Study 1 test number 15 was separated into two parts.
The Survey Studies

The main aim in Studies 5 and 6 was to elucidate the relationship of pupils and teachers’ annoyance to noise in schools by using modified questionnaires from Kjellberg et al.’s (1996) study of non-physical noise characteristics at different workplace settings with sound levels below 85 dB(A).

Basic design and procedure. In Study 5, 207 pupils 13 to 14 years old (n=104 boys and n=103 girls, M=13.5) participated. Study 6 included 166 teachers (n= 61 males and n=105 females, range 21-65 years, M=45.9 years). The participants studied or worked in different schools situated in a medium-sized city in Sweden. The schools were judged to be equal in outdoor noise levels, that is ~55 dB(A) (cf. moderate sound levels according to WHO, 1980).

Two separate questionnaires were modified from Kjellberg et al. (1996), one for the pupils and one for the teachers. Some of the questions were identical for both groups and some were specific to one group alone. The identical questions reflected annoyance, noise sensitivity, hearing status, stress symptoms, control and predictability. The questions were rated on Likert-scales, with four to six alternatives. The overall general self-rated annoyance question was made on a 10 cm graphic rating scale on which the two poles and five other points were labelled verbally (Landström et al., 1995). In addition demographic questions, that is, position (pupils and teachers) gender and age were included.

The specific questions for the pupils concerned their interest in the given school subject and their perception about noise conditions during homework. Further, there were also two open-ended questions, one about during which lessons noise was perceived as most disturbing and one about how to achieve a quieter school environment in the future. For the teachers, the specific questions were mainly about the conditions in their workplace, such as comfort, social support and physical pollution.

The questionnaires were administered in groups for pupils and individually for teachers. The participants were informed, both in writing and verbally, that their participation was the voluntary and that they could terminate whenever they wanted (Bell, Green, Fisher & Baum, 2000). The response rate was 90 percent for the pupils and 78 percent for the teachers. No reminder was given.
The Focus Group Interviews

The main aims in this exploratory study were twofold: to describe experiences concerning disturbing sounds in the school environment of today and to get a point of view about future changes due to noise in this environment.

Basic design and procedure. A total of 16 male and female students, aged 18 to 20, participated in Study 2. This age group was chosen since they could both inform about their experiences at the present time and were in a position to view their schooldays in retrospect. Moreover, they also were assumed to be able to communicate descriptions and suggestions about how to make the school environment more silent in the future. The informants were assigned to one of four interview sessions, with four informants in each group. The small small group size affords more opportunity to share ideas compared to larger groups. This sampling procedure, bringing together a small group of students with similar educational background, provides favourable conditions for fruitful discussion of the topic at hand (Kreuger, 1994).

Sessions were held in a permissive environment and, the informants knew each other. The same moderator (I.E.) and assistant (E.B.) conducted all interviews. The assistant took written notes. Each interview lasted for approximately one hour. With the permission of the informants, all discussions were tape-recorded.

A general interview schedule was used. The issues covered, in the interview schedule included the informants' experiences of their school environment and views about possible changes in this environment concerning noise. The main questions were developed and composed by the authors to elucidate experiences concerning (a) perceptions of disturbing sounds; (b) the influence on emotions; (c) ongoing activity, and finally; (d) suggestions concerning future changes. The schedule was used as a flexible discussion guide rather than a structured protocol. Beside the main questions in the schedule there were also probes with follow-up questions for each topic. Each group interview started up with a short account of the purpose of the study, followed by one of the main questions (Kreuger, 1994; Patton, 1990).
Participants and Recruitment Procedure

The students in Study 1 were recruited from two local upper high-schools, from the social or natural science programmes. The headmasters were first contacted by phone and given information about the research project. Permissions were obtained and announcements were sent out to the classes involved. In all, about 400 students were asked and from them about 150 students were interested in participating. We contacted the students over the phone to make an appointment. Those who accepted were randomly assigned to one of the experimental conditions. In all 96 students, aged 18-20, participated in the experiment and received payment.

From the students that participated in Study 1, four groups with four informants’ in each were chosen to participate in focus group interviews after the experimental session. In advance we had decided that the two groups should be mixed, while the two others should be homogenous concerning gender. Another criterion for group selection was that the informants should know each other well. These groups provided the data material for Study 2.

For Study 3, one upper level regular school, with 101 pupils aged 13-14 years, was chosen. In all, 89 pupils from that school participated in the experiment. The dropouts were mainly due to sick leave the day when their classmates participated. Thus, seven pupils were randomly selected from another school to fill the groups. Information about the study was given to the headmasters and the teachers, and with their co-operation agreements about a time-schedule and payments to the classes were made. A letter was also distributed to the parents with information about the study and with a return slip to fill in with their consent. All parents gave their consent.

The pupils in the survey study (Study 5) were recruited from two different schools. To a great extent, the same procedure as for Study 3 was followed. However, parental consent was not sought. In all, 230 pupils studied at the schools. The questionnaire was group administrated and they were informed, both in writing and verbally about informed consent. A total of 207 pupils, aged 13-14, participated and the reasons for affiliation were basically the same as in the former study.
The recruitment of the teachers from six upper level regular schools in Studies 4 and 6 started with a presentation of the studies at their weekly staff briefing. Together with the delivery of a questionnaire, the next step was to inform in writing, that participation was voluntary and that the answers would be treated confidentially. In return, for completing the questionnaire, they were offered an audiotometry test. The questionnaire was supposed to be returned at time of this test. In all, 214 teachers received the questionnaire and 166 completed the form. The dropouts were mainly due to time limits. Those teachers that were in the actual age groups, 35-45 and 55-65 years, for the experimental study also received a return slip with times to participate in the experiment. If they agreed to take part in the experiment, this return slip was filled in with suitable times and brought to the hearing test. An appointment was then made by phone. To fill the groups in the experimental study, five teachers with similar educational level from other schools also participated. In the experimental study, each participant received a payment.

Assessing Data Quantitatively

To assess the main and interactive effects of noise and age on memory, analyses of variance (Software SPSS 11.5 for Windows) were performed. The type I error level was set to .05.

To describe the structure of annoyance and the key factors related to it, structural equation modelling was used. According to Jöreskog & Sörbom (1993), there are three possible ways to substantiate causal inferences. The first is to conduct an experiment in which the independent variable is controlled or manipulated. The second is to employ a longitudinal design. A third possibility is to generate a theory or model, including forming latent variables, for how the main dependent variable is generated, and test this model against observed data. This approach was used in the present studies by taking the participants answers to form a model (see Paper VI) or analyse the answers from a theoretical model (see Paper VII). Since the chi-square fit statistic depends on sample size, the RMSEA fit index is a better alternative to choose, and were reported in the papers. Browne and Cudeck (1993) suggested that
RMSEA-values of less than .05 indicate a good fit and that values up to .08 represent a reasonable fit.

In both the experiments and in the survey studies, descriptive statistics were used to describe and synthesise the data.

Assessing Data Qualitatively

The analysis in the interviews was started from grounded theory (Strauss & Corbin, 1990). This method involves analyses of the interview material until statements could be categorised and interpreted as concepts, themes or patterns of concepts. The purpose of the grounded theory is to generate models or theories from empirical data; that is, the development of theory should be based on the interviews. As far as it is possible, the analysis will be abstracted until maturation is found. The method of grounded theory allows the concepts and patterns to emerge instead of pressing the material into already existing theories or structures of concepts.

After each group discussion, tapes were fully transcribed. The analyses of the present data continued parallel with the data collection. In this way, the probes became more developed and provided a maturation in the material. The first step was to identify codes that described the substance in the statements. This open coding made the data comprehensible; the core contents in the statements were given names. To ensure validity, the transcription and identification of codes was done independently by the two authors. Subsequently, the authors constituted patterns of the phenomena in the informants' experience of noise according to the two milieus, the one of today and of the future changes. The second step was to reduce the patterns into overall categories. This was done between each interview by comparisons between the codes, patterns and categories. Finally, according to the informants' suggestions about future changes, the categories were abstracted into theoretical concepts.
Validity Aspects

The studies included in the project allowed different degrees of control of the research situation. A major aspect of control is validity of the measurements and of other aspects of the methodology. The validity of the measurement concerns the relation between what is actually measured and what are intended to be measured. Together with the other aspects of the methodology the validity of the measures determine internal and external validity of the study. The internal validity has to do with whether it is possible to conclude about the questions posed in the study. The critical question most often is whether it can be concluded that the independent variable caused the observed effects. The external validity refers to the degree to which conclusions can be generalised to other persons and situations (Liebert & Langenbach-Liebert, 1995).

The first threat to validity that will be discussed and analysed is testing effects, which means the effect of already having taken a test upon one's performance when taking it again (Liebert & Langenbach-Liebert, 1995). In the experimental studies, there were two dependent measures that were administrated in different blocks, that is self-reported affect and the search and memory task that measured attention (SMT) (see Table 1). The advantages of this procedure were the possibility to measure main effects of noise, the influence of noise across time and finally it allowed testing of whether the effects of noise on memory were mediated by affect and/or by attention. On the other hand, the advantages of those within-subject tasks might be spoiled by the transfer effect. Perceived affect was rated on Likert-scales in five steps. In all there were 48 items organised into 8 unipolar scales, tapping combinations of perceived high and low activation, pleasantness and unpleasantness. In the attention task (Smith & Miles, 1987), the subjects were presented lines of random letters with five target letters at the beginning of each line. The task was to memorise the given target set, search through the given line only once, and to mark all targets found. From our point of view, the transfer effect is a minor problem for those two tasks, though the instruction for the affect
measure was to rate the momentary feelings, not in retrospect. Moreover, the SMT measurement is known for not showing much of a learning effect (Smith & Miles, 1987). To further minimise any learning effect, we reversed the pages for SMT, which resulted in new lines for the subjects at taking the test the second time. Further, there were also several memory tasks between the two test occasions for both tasks.

*Instrument decay* is a validity threat that refers to any change in the characteristics of the measurement procedure over time (Liebert & Langenbach-Liebert, 1995, p. 262). Basically, the threat against instrumentation decay in the present studies was the role of the experimenter in the experimental situation. To avoid this threat, we had written instructions that were followed literally by the experimenter. Secondly, the experimental conditions were assigned so that they appeared equally often across time, which also prevented the bias of the experimenter's role.

Another threat against validity is *selection bias*, any systematic difference between comparison groups other than experiencing the treatment of interest (Liebert & Langenbach-Liebert, 1995, p. 266). The most important step, to avoid selection bias, is randomisation of subjects to different experimental conditions, which was performed in the present studies. Besides, we also assured that the groups were homogenous within each study, in terms of education level and age.

The last validity problem that will be discussed in relation to internal validity, is *diffusion*, which means the spread of treatment effect from treated to untreated groups (Liebert & Langenbach-Liebert, 1995, p. 261). The studies included one dependent measure that was especially sensitive for a kind of diffusion, that is, face and name recognition (see Table 1), developed for testing intentional and incidental learning (Nilsson et al., 1997). This test was computerised and adapted to group presentation. There were 16 colour-pictures of faces of 10 years old children. Together with the picture made-up, but common, first and family names were presented. The subjects were instructed that they later would be tested for recognition of faces and just family names, but in addition to that, and without having been so instructed at encoding, they were also given a recognition test for the first names. In order to prevent diffusion, the subjects were requested not to talk about any test, and particularly not the incidental test, to coming participants, that is, classmates and colleagues.
The purpose of a survey study is to describe relationship among variables in the population. To do so, a classic correlational design includes a large representative sample of the population of interest, which means that the focus is on generalisation. In other words, the demographic makeup in the sample should be similar to that of the population, and the sample size must be sufficient large to cover the full range of variance on all variables (Brink & Wood, 1989; Weiten, 2001). The most critical validity aspect, sample selection, will first be discussed and analysed. In the present studies both genders were represented in the samples, and age groups in the range between 13 to 14 vs. 21-65 years. Moreover, the participants studied or worked in different schools situated in a medium-sized city in Sweden. In addition, the response rate was high for both pupils and teachers. The requirement of a representative sample is so to say fulfilled, since the sample constituted a miniature of the population in interest, that is, pupils and teachers in compulsory school-environments. The second criterion that was taken into consideration is sample size. Two of the factors that determine the required size of the sample are the number of variables that are included in the analyses and the data analysis technique that will be used. There were 207 pupils and 166 teachers included in the sample. To find the structure of the pupils and teachers experiences, LISREL analyses were performed for each group. There are different opinions about the sample size that is required to conduct those analyses. A sample size of about 200 is adequate for small or medium size models (Tabachnick & Fidell, 1996).

According to the reasoning about observed and latent variables, a second validity aspect to analyse critically in correlation studies is the measuring tool, that is the questions posed in the surveys. Since the value of a correlational study is directly related to the accurate measurements of the variables, the questionnaire must be reliable and valid. That is, the measurement of each variable must produce a representation of the "true" value of the trait being measured. A measurement tool that was tested for reliability and validity on adults was used in the present study (Kjellberg et al., 1996). To test the comprehension of the questions a pre-test was performed for the pupils. Besides, factor analyses were conducted to test the idea that the items actually formed the expected latent variables. To avoid that the participants rated all questions in an equal manner, the questionnaires consisted of different label alternatives. The settings were different for the pupils and the teachers. The pupils filled in the
questionnaire in a group setting where the investigator controlled that they worked individually, while the teachers filled in the questionnaire individually and without that control. Therefore, we have no complete control over the reply situation.

One advantage of an exploratory design lies in the closeness between the investigator and the subject. On the other hand, this closeness also constitutes a risk against credibility, namely that the researcher becomes so involved with the subjects, that difficulties in separating own experiences from the subjects' experiences appear in the interpretation (Sandelowski, 1986). This threat against credibility, termed going native, was safe guarded in our study by also using an assisting moderator that took notes in each interview. This procedure reduced the risk of the moderator becoming too close to the subjects. Further, an interview schedule was followed, and the interview setting only lasted for approximately one hour and took place in a surrounding that was equal for all groups, which also contributed to minimise the risk of going native.

The following two threats against validity is about fittingness, that is external validity. The purpose in exploratory studies is to describe "a slice from the real world". Therefore, subjects that can elucidate the phenomena of interest clearly and in depth were selected. Although, particular problems arise in this sampling procedure since subjects who act as informants often are the most articulate, accessible members of their group. This elite bias, brings about a result with low fittingness, that is, the general audience do not perceive the finding as meaningful and applicable in terms of their own experiences (Sandelowski, 1986). In our interview study the subjects were randomly selected from a larger sample that took part in an experimental study (see Study 1). Therefore, we did not know in advance if the selected informants had a special capacity of verbalisation or not.

A third threat against validity is holistic fallacy, which occur when the researcher make data look more patterned or regular than they are (Sandelowski, 1986). Strategies to avoid this threat is to examine whether a concordance exists concerning the interpretation of the interviews between different interpreters, and also other researchers in the same area. To ensure fittingness these both steps were taken in our study. First of all, the reading of the transcriptions and the identifying of codes in the data were done independently by the two of us. Secondly, the findings were then scrutinised by a researcher from the same research field,
as well as one from another research area. Further, a qualitative study is also valid when people, the participants as well as people in general, recognise themselves in the description of the phenomena (Wedin & Sandell, 1995). Parts of that requirement were fulfilled, as the findings were presented for teachers, who confirmed that the statements could be valid for students in general. However, a weakness in our study from this point of view, is that the findings were not presented for the informants that took part in the interviews. In the interview study we tried to control for these factors, even though all threats against fittingness may not be taken into consideration sufficiently.

In conclusion, the experimental studies are the only studies in the project "Unwanted sounds in the school environment", that can prove a cause-effect relationship. We had control over the assignment of subjects to the conditions as well as over the independent and dependent variables. Therefore, we can confidently rely on the cause-effect inferences. The correlational studies do not have the same control possibilities as experimental studies, but on the other hand, they are performed in a more naturalistic setting and rely on participants’ reports of their own perceptions and experiences. In our studies we assumed that the participants had that ability and therefore, we think it is possible to generalise our findings from our sample to the population of interest, that is, pupils and teachers in the chosen age groups.

OVERVIEW OF PAPERS

This dissertation comprises six empirical studies, which have resulted in seven papers (see Figure 1). The overall aim in the first three papers was to examine the effects of acute exposure of meaningful irrelevant speech and road traffic noise on episodic and semantic memory. Paper I emanates from the first data collection with students aged 18 to 20 years. In that paper priming (PRS) and context dependency were also examined. These dependent measures were excluded in the following two studies, which dealt with pupils (Paper II) and
Overview of Papers

teachers (Paper III), while two independent variables were added, gender respectively age. In paper IV, all age groups were brought together examining the strength of the effects of noise and age on memory. The last paper with experimental data was paper V, where the relations of age and noise on episodic and semantic memory tasks were presented with structural equation modelling.

Paper VI and VII focus on noise exposure in their own school environment. The basic aim was to assess conceptual models of how different factors mediate and moderate the annoyance reaction. The first of these two papers comprised data from the interviews and the survey study with pupils. Another aim in this paper was to elucidate the pupils’ suggestions concerning how to change the sound environment in schools. In paper VII, an annoyance model was tested with both pupils and teachers.
Paper I

The effects of road traffic noise and meaningful irrelevant speech on different memory systems

The purpose of Paper I was to investigate the influence of meaningful irrelevant speech and road traffic noise on attention, episodic and semantic memory, priming (PRS) and context dependency in students aged 18-20 years. To cover the memory domain a test battery was modified and developed by using representative tasks from the Betula project (Nilsson et al., 1997). The tests were adjusted to fit into experimental group settings, during noise exposure, and also to fit different age groups. From Carter (1982) and our own research (cf. Hygge, 2003), we revised and developed a text about a fictitious ancient culture. In order to prevent the participants from using their possible knowledge, imaginary words and names replaced real ones (cf. Lehto, 1996).

Memory performance was assessed by using three episodic memory tasks (reading comprehension, sentences with and without enactment, face and name recognition), two semantic memory tests (word fluency, word comprehension) and one priming task (word stem completion). Attention was measured by using a search and memory task (Smith & Miles, 1987). Self-reports on affect and activation were also taken (Knez & Hygge, 2001). These tasks were presented twice during the experimental setting (see Table 1). Besides, self-ratings concerning health, hearing, motivation for schoolwork and grades in Swedish, English and mathematics were asked about after the experimental setting. The participants also filled out a form about perceived effort, degree of difficulty and distraction during the experiment. The context dependency of reading comprehension was examined by splitting the cued recall and recognition of the text in two separate questionnaires, one retrieved in silence and the other in road traffic noise. The questionnaires were designed to cover equal parts of the four-paged text.

The noise effects found for episodic memory were restricted to cued recall of the text, with the same magnitude of impairing from both noise sources. From the context-dependency research (Godden & Baddeley, 1975; Tulving & Thompson, 1973) it was expected that the
cued recall of the text should be better in the group that had road traffic noise presented both during encoding and retrieval, but this hypothesis was not supported. Notable is that all groups did improve during retrieval in road traffic noise, and thus one explanation could be that the two questionnaires used were not equally in difficulty and not counterbalanced.

Word fluency in semantic memory was tested with three different tasks: generating words, five-letter words and professions in certain letters, all within the same time limits. Main effects of noise and gender were found for generating professions, with both noise sources impairing to the same degree and females performing better compared to males. No significant noise effects were found on the two other word fluency tests, or on word comprehension.

The perceptual representation system priming (PRS), was measured by a presentation with word stems from the earlier presented word comprehension test, and the participants were asked to write the first word the came to mind. In line with the prediction, no noise effects were found on this task.

There is a reasonable consensus (Cohen et al., 1986), that the cognitive effects of noise partly are the result of changed information processing strategies leading to faster processing of information, at the expense of the flexibility and efficiency of cognitive resources. In line with this, Hockey (1984) assumed that a speed-to-accuracy (SATO) effect would occur during noise exposure, with increased speed, but less accuracy. This hypothesis was confirmed in both noise conditions when data were collapsed across blocks. No mediating effects of attention or the self-reported states were found on the memory tasks.

To summarise, the noise effects found indicates that performance on complex episodic memory tasks and retrieval from semantic memory that involves a more cognitively controlled process are vulnerable to noise. In this paper, the noise effects found on attention, episodic and semantic memory were interpreted from the changing-state theory (Jones, et al., 1999; Jones, Madden & Miles, 1992; Tremblay et al., 2000) since no differential effects of traffic noise and speech were obtained. The road traffic noise was interpreted as fluctuating enough to make it as disturbing for retrieval as the irrelevant speech.
Paper II

The effects of noise and gender on pupils’ episodic and semantic memory

The aim of Paper II was to extend the noise effects found in Paper I to younger persons, and to evaluate whether the noise effect was the same for girls and boys. This study included pupils in the age of 13-14 years. Since Hygge (2003) found noise effects on cued recall of reading comprehension when he conducted ten noise experiments with a total of 1358 pupils in that age range, the main reason for this choice of age group was empirical driven. Another reason was that the age group would be able to perform the dependent measures used in Hygge, Boman and Enmarker (2003), so noise effects on different age groups could be compared.

Basically the same tests as in Hygge et al. (2003), were used (see Table 1). The main differences were that noise effects on PRS and context dependency were not examined. The reason for that choice was that for students, aged 18-20 years, the result indicated a floor effect on the word stem completion test. Further reasons for excluding was that PRS is a stable memory system (Tulving, 1993) and that no noise effects was found in Hygge et al. (2003). To get a more reliable test on reading comprehension separate questionnaires were not used for the cued recall and recognition of the text. Thus, noise effect on context dependency was not further examined. The word comprehension test contained four alternatives, instead of five as in Hygge et al. (2003), and words that were more adjusted to the chosen age group. Since there were a large number of successive tests, the effects of fatigue could be a problem, and therefore an additional self-reported affect measurement was included.

The chosen age group has not yet reached their peak performance in episodic memory (Tulving, 1993) and divided attention during encoding reduces performance considerably (Anderson, et al., 1998; Craik et al., 1996). Therefore, it was predicted that noise would impair all verbal episodic memory tasks. It was also predicted that the impairment should be more pronounced for recall than for recognition (Craik & McDowd, 1987; Haist et al., 1992) and that traffic noise should have less effects than meaningful irrelevant speech, which was supposed to tax limited resources for parallel processing (Martin et al., 1988; Oswald et al.,
2000). Finally, it was predicted that girls would take advantage of their higher episodic memory capacity (cf. Herlitz et al., 1999; Herlitz et al., 1997; Nyberg et al., 2000), and that their performance would not be affected to the same degree as for boys’ during noise exposure.

The only noise effects found, on episodic memory were that meaningful irrelevant speech impaired recognition and cued recall of the text. This result gives further support to the notion than meaningful irrelevant speech is particularly disturbing for reading comprehension (Martin et al., 1988; Oswald et al., 2000), but stands in contrast to Hygge’s (2003) classroom experiments where the road traffic noise affected reading comprehension. The study also showed significant gender differences in that girls outperformed boys in several episodic and semantic memory materials, but these differences did not interact with noise.

It has been shown that divided attention during retrieval causes very little reduction in memory performance (Anderson, et al., 1998; Craik et al., 1996; Craik et al., 2000; Mulligan, 1998). In addition, the subjects performing the semantic memory tasks are not required to think back to a study event, which may imply that retrieving information from this memory system is more automatic access compared to episodic memory (cf. Nyberg, et al., 1996; Roediger & McDermott, 1993). On the other hand, it is unclear whether the present age group had reached this automatic activation of semantic information (Schneider & Pressley, 1989). Therefore, predictions of noise effects on this memory system were left open. It was found that meaningful irrelevant speech impaired the pupils’ word comprehension. For the present age group, it could be reasonable to speculate that this semantic task involved a more cognitively controlled process than an implicit semantic memory task (cf. Nyberg et al., 1996) and therefore is more susceptible to a divided attention situation.

The obtained noise effects on episodic and semantic memory were not mediated by attention. It seems possible that meaningful irrelevant speech taxed limited resources for parallel processing for this age group, apparent in complex memory tasks, which demands more elaborate and controlled processing, either during encoding or in retrieval. In this paper the noise effects found were therefore interpreted from the similarity of content hypothesis (see also Macken et al., 1999).
Paper III

The effects of meaningful irrelevant speech and road traffic noise on teachers’
attention, episodic and semantic memory

The aim of paper III was to further examine meaningful irrelevant speech and road
traffic noise on attention, episodic and semantic memory in teachers aged 35-45 and 55-65
years, and also to examine whether the noise effects were age-dependent within this group.

For both theoretical and practical reasons it was of special interest to include the older
teachers in the study and to examine whether it was possible for them to retain their cognitive
capacity during noise exposure. For future comparisons the intention was also to make a
certain age distance to the students aged 18-20 years. Further, since several of the dependent
measures were adopted from the Betula project (Nilsson et al., 1997), the chosen age groups
made it possible to make selective age group comparisons between the studies.

Before attending the experiment a pure-tone audiometry hearing test was conducted,
either in the teachers’ own working environment or in our laboratory. At the outset the sound
levels in the room was psychoacoustic controlled by two subjects with well-known stable
audiogrammes. Studies have shown that the deterioration of the hearing threshold level
accentuates at an age above 50 years (Brant & Fozard, 1990; Johansson & Arlinger, 2002). In
line with this, the pure-tone audiometry, as well as the subjective perception of their hearing
was poorer for the older than the younger teachers.

Memory performance was assessed using the same tests as in Hygge et al. 2003 (see
Table 1). As in Boman’s study (in press), however, word stem completion test and context
dependency were excluded for the teachers, and an additional self-reported affect
measurement (Knez & Hygge, 2001) was included at the end of the experiment.

As for the students in Hygge et al. (2003), cued recall of reading comprehension in
episodic memory for the teachers was significantly impaired to the same magnitude by
meaningful irrelevant speech and road traffic noise. When the students were included in the
analyses a main effect of age appeared, where the students outperformed the teachers. This
result is in line with earlier cross-sectional studies that show a peak performance in episodic
memory around the age of 20 years (see Nilsson et al., 1997). In contrast to the students’ results, but in line with the prediction, only the meaningful irrelevant speech impaired the teachers’ recognition performance in the text reading test. The result supported the hypothesis that recognition should be less impaired by noise than cued recall. Contrary to expectation, however, there were no noise effects on the other episodic memory tests.

Providing knowledge is one of the most prominent features in teaching, therefore, noise effects on semantic memory were of great importance to examine. Performance on two of the word fluency tasks was impaired: to generate words by meaningful irrelevant speech, and to generate professions by road traffic noise. The different noise pattern is hard to explain. To fluently retrieve professions probably requires an involvement of a more controlled process than to retrieve just words, that is, it demands a more conscious recollection. The impairments of road traffic noise on generating professions and cued recall of the text were therefore discussed in the light of task complexity (Cohen et al., 1986) and automatic vs. controlled processes (Anderson et al., 1998). That is, it could be assumed that tasks that require a high degree of information processing either during encoding or during retrieval, where few cues are given, are more vulnerable to the acoustic variation in noise for adults (cf. Tremblay et al., 2000).

Both meaningful irrelevant speech and road traffic noise affected the students’ attention in Hygge et al. (2003). It was assumed in this study that a SATO-effect also would appear and to a higher extent for the older teachers. However, there was no SATO-effect. Neither were there any predicted interactions between noise and age on the memory tasks. When examining age differences in divided attention tests, decrements usually are shown first after the age of 60 years (Allen et al., 1993). The mean age for the oldest group in the present study was 58.4 years. So, even if the age groups were chosen on the basis of the age differences for memory systems found in the Betula-project, the difference between the two groups was probably not large enough.

The mediation analyses indicated that attention, objective or subjective hearing, affect or annoyance did not mediate the effects of noise on memory. This implies that there might be some kind of direct connection between meaningful irrelevant speech and road traffic noise and the affected memory tasks in episodic and semantic memory for these age groups.
Paper IV

Strength of noise effects on memory as a function of noise source and age

The aim of Paper IV was to examine the strength of noise and age on memory, and whether the age differences interacted with noise on memory. In this way age peaks of performance of episodic and semantic memory tasks could be identified, as well as whether these memory peaks were remained unaffected by noise exposure. The data from the three separate experimental studies (Boman, in press; Enmarker, in press; Hygge et al., 2003) were analysed together, which meant that the analyses were based on 288 participants. A total of 18 different dependent measures that covered a spectrum of attention, episodic and semantic memory were analysed.

It was expected that both noise sources would impair episodic and semantic memory. However, for the semantic memory tasks the noise effects were expected not to be of the same strength as for the episodic memory tasks. Further, main effects of age were expected in that episodic memory would be best for the group aged 18-20 years and for semantic memory the age group 55-65 years was expected to perform the best (Nilsson et al., 1997; Nilsson, 2003). The performances of both types of tasks were expected to be worst for the youngest group. For attention no main effects of age were expected. A further prediction was that noise and age would interact as a result of noise effects being weaker the better the capacity to perform the task. This meant that the group 18-20 years was expected to be least impaired in episodic memory tasks and the oldest age group would withstand noise effects to the highest degree in semantic memory tasks. The youngest group was expected to be most impaired by noise in both types of tasks. For attention no explicit predictions were made on the noise effects or any interaction with age.

The results showed noise effects for several dependent measures, both when taken alone and aggregated according to the nature of the material to be memorised. As predicted, the performance of episodic memory tasks was affected to a higher degree than semantic memory
tasks. The strongest noise effect found was for performance on cued recall of reading comprehension. When cued recall and recognition were aggregated there was a differentiation between the noise conditions in that meaningful irrelevant speech was more devastating for memory compared to road traffic noise. For the other noise effects found, the noise conditions did not differ.

The analyses also revealed main effects of age where the cued recall part of reading comprehension was the single most age sensitive test among the episodic memory tasks. In line with prediction (cf. Nilsson, 2003) the best performance was found in the age group 18-20 years. Contrary to predictions the age group 55-65 years did not show higher means than the second oldest group, 35-45 years, in semantic memory tasks. However, these two groups outperformed the students, 18-20 years, who in turn outperformed the youngest group.

Our primarily concern was the interaction between noise and age on memory processes. Contrary to predictions the result of the overall pattern did not show any interactions, thus, the younger pupils were not more negatively affected than the older groups by the noise.

The main findings in this paper were that, independently of age, both meaningful irrelevant speech and road traffic noise affected episodic and semantic memory performance, and that the performance of a complex episodic task, reading comprehension, was more impaired by speech than by road traffic noise. This result is in line with earlier findings (cf. Knez & Hylge, 2002) that when two concurrent semantic processes take place at the same time, the cognitive resources decreases.

**Paper V**

*Structural equation models of memory performance across noise and age*

From Boman et al.'s. (submitted) study it was concluded that the age groups differed in their performances of the memory tasks, but that there were no overall interactions between noise and age. Our next issue of interest was therefore to find out whether episodic and
semantic memory performance structure was invariant across age groups and noise exposure. The first step was to analyse whether semantic and episodic memory formed distinct latent variables (cf. Nyberg, 1994, 2003). The outcome of the structural equation model testing provided a support for the subdivision of memory into episodic and semantic memory. However, the best model found showed that episodic memory in turn was subdivided into three latent variables reflecting reading comprehension of text, sentences encoding with and without enactment, and memory for faces and names (see Figure 2).

Figure 2. Conceptual diagram of the five latent variables with their constituent items.
This subdivision might reflect task complexity as well as that there are different functions within the episodic memory.

To test whether the obtained well-fit model was valid across age groups, the next step was to make a multimodel analysis to test whether the same model fit well in all four age groups. The testing showed a worse model fit, but when excluding the youngest pupils, 13-14 years old, a better fit was obtained. However, when this age group was split up according to their performance for the cued recall of the text in high and low performers there was a good resemblance between the high performers and the students in the age group 18-20 years. This finding might suggest that the lack of coherence in the youngest group is a matter of them being in a transitional state in cognitive development (cf. Schneider & Pressley, 1989).

Still the issue to examine whether the obtained memory performance structure would be remain unaffected by noise exposure. If it would be unaffected, this would be an argument for inferring that noise effect would not be the result of changes of the allocation of cognitive capacities when the task is performed in noise, but rather on how efficiently a given allocation works. Although the analyses of variance had shown that there were reliable effects of noise (Boman et al., submitted) the same model described well the performance structure in all noise conditions, that is, the subdivision of episodic memory into three different variables remained.

The results have important implications for us, since they validated our interpretation of the memory tasks as reflecting the same memory functions in all noise conditions. This also indicates that there is no changed allocation of information processing resources or any strategy shifts when the task is performed in noise.

The results also pointed out that the obtained structural model cannot be generalised to the youngest group of children with less capacity to perform the memory tasks. They also indicate that consideration must be taken to the complexity of the task when examining noise effects on episodic and semantic memory.
Paper VI

Factors affecting pupils’ noise annoyance in schools: The building and testing of models

Paper VI comprises the results from two studies, the focus group interview study and the survey study with pupils. The main objectives were to find conceptual models of how different factors mediated and moderated the noise annoyance reaction in the school environment and to get the pupils’ views about what can be done to improve the sound environment in school. To get answers on those main issues, the studies were designed and analysed with different theoretical approaches, qualitative focus group interviews with students in the age of 18-20 and a quantitative survey study including pupils in the age 13-14 years.

In the survey study a modified questionnaire from Kjellberg et al. (1996) with Likert-scale items that dealt with factors supposed to be of importance for the perception of annoyance in the school environment were used. Besides, the questionnaire also comprised three open-ended questions, to elucidate disturbing noise sources during an ordinary school day and during which lesson noise was perceived as most disturbing. Finally, the last question concerned the pupils’ suggestions about how to achieve a quieter school environment.

An interview schedule with four main questions focused on the students experience of disturbing sounds, the influence on emotions, ongoing activity, and their suggestions concerning future changes were asked. However, the schedule was employed as flexible guide rather than a structured protocol, and probes with follow-up questions were also used.

In both studies, sounds generated by other people, such as chatter in the classroom and sounds from the corridor, was perceived as the most disturbing sound in the school environment. Lesson in mathematics was pointed out as most sensitive to noise interference.

Annoyance models were tested with structural equation models (Jöreskog & Sörbom, 1993) on data from the survey study. In the annoyance model derived from the survey study, general sensitivity and adaptation led to a higher degree of annoyance, which in turn caused stress symptoms. All coefficients in this causal chain were significant. The pupils’ perceptions
of annoyance was also dependent on in which degree they could predict the noise and their interest in school subject. Their perception of stress symptoms was dependent on the noise conditions in their dwelling. Although, the moderators predictability, subject and dwelling did not show significant path coefficients in the model testing, they significantly improved the fit of the model (see Figure 3).

![Annoyance Model Diagram](attachment:image.png)

*Figure 3. The annoyance model from the survey study.*

The interviews were analysed with a starting point in grounded theory (Strauss & Corbin, 1990), since the intention was to catch the core of the informants' opinions by abstracting the identified categories into an annoyance model. The conceptual annoyance model developed from the interviews is shown in Figure 4. The annoyance response pattern found from the two studies emphasised different aspects as important for annoyance. The main differences between the two models, is that the interviews pointed out a serial arrangement where stress symptoms acted as mediator to annoyance, which was split up into distraction and disturbance. Another difference between the two models is that the teachers’ role was emphasised as important for whether annoyance would arise or not.
Figure 4. The annoyance model from the interviews.
In both studies many ideas and suggestions emerged about how the school environment could become more silent in the future. The younger pupils gave suggestions concerning school-policy measures, such as shorter lessons, smaller classes and more teacher resources in the class. Further, they believed that pedagogical methods such as more computer-aided teaching could provide more silent lessons. Both age groups also pointed out preventive measures, as better air quality and soundproofing to provide a more silent indoor milieu. However, the pupils emphasised the interaction between pupils and teachers as the most important aspect to achieve a more silent school environment. This aspect consisted of being involved, respected, own responsibility and respecting others.

**Paper VII**

_Pupils' and teachers' response structures of noise annoyance_

In paper VII, the first aim was to examine differences and similarities of pupils' and teachers' reactions to noise. Modified questionnaires from Kjellberg et al. (1996) were used also here, but only questions that were identical for both groups, which concluded in analyses of questionnaires from 207 pupils and 166 teachers.

As in Boman and Enmarker, (2004) the result showed that the teachers also judged noise generated from humans activity as the most disturbing. When comparing pupils' and teachers' ratings on items reflecting disturbance and distraction, and on the factors of importance for these reactions, the overall pattern of answers showed that teachers perceived themselves as more sensitive to noise than the pupils did. The only exception was that the pupils became more irritated and perceived themselves as having less self-control over noise compared to the teachers.

From these findings it can be concluded that there are mean differences between the groups on almost all responses. Does this result imply that the response structures of annoyance are dissimilar too, or is it possible to find a common annoyance model valid for
both pupils and teachers? The next issue was therefore to test a conceptual model of the
erelations between annoyance, and the factors of importance for the perception of annoyance in
the school environment. The starting point was a conceptual annoyance model, constructed
from the findings in Boman and Enmarker (2004), and from other empirical results (e.g.
Kjellberg, et al., 1996) (see Figure 5).

Figure 5. A conceptual model of noise annoyance in the school environment.

The first step in the model testing was to perform a factor analysis. From this analysis,
distraction and disturbance formed one new latent variable, labelled annoyance. Thus, the
conceptual model was slightly modified and included 24 of the items into six latent factors.

To find similarities and dissimilarities, the next step was to test the model separately for
pupils and teachers. For neither group did the moderating factor control show any significant
correlation with annoyance, and nor did predictability for pupils. However, when omitting
these variables, the refined models yielded a poorer fit. When finally both samples were
included to test the conceptual model, the control factor was still not correlated to annoyance,
but yet of importance for pupils’ and teachers’ annoyance structure (see Figure 6).
Figure 6. Structural equation model for pupils' and teachers' responses including all mediating and moderating variables.

Taken together, despite mean differences in ratings on the items the result showed that the annoyance structure was of the same nature for pupils and teachers. This supports earlier findings that the annoyance reaction is not related to age (Kjellberg et al., 1996; Stansfeld et al., 2000; Ouis, 2001).

GENERAL DISCUSSION

The main focus in the present thesis was the influence of acute exposure to meaningful irrelevant speech and road traffic noise on episodic and semantic memory tasks for pupils and teachers in different age groups. Other central issues were to examine the influence of noise exposure in the school environment and how the sound environment in schools could be improved.
Effects of Acute Noise Exposure

When attaining knowledge, episodic memory has a central function. The elaboration of new information at encoding is dependent on the particular learning situation, such as the complexity of the task and the environmental interference, but also on the individual's attentional resources and memory ability. Noise was therefore expected to interfere more with episodic memory the more information processing resources required by the task and less resources available for it. The predictions for the episodic memory system were thus based on the assumptions that the amount of resources required in the retrieval process would be affected by (a) how well the information had been encoded, and (b) available retrieval cues. The quality of encoding was also expected to be affected by the (c) total amount of available resources and (d) how large resources that could be allocated to the task, as a result of competing for resources.

Semantic memory is central in providing knowledge. It is assumed that the retrieval occurs with direct assess to memory, thus in a more automatic and less resource demanding way than in the episodic memory. Compared to episodic memory, tasks reflecting semantic memory were therefore expected to withstand noise exposure to a higher degree.

Another central issue in the present thesis was to examine the importance of the semantic content in noise and the performed task. It was expected that meaningful irrelevant speech would impair memory in a higher degree than road traffic noise, due to its semantic content.

To sum up, an overall main finding in the present thesis was that noise affected both episodic and semantic memory. Further, meaningful irrelevant speech and road traffic noise was found to impair the memory tasks in an equal manner. This result might support the changing-state hypothesis (cf. Tremblay et al., 2000), rather than the similarity of content hypothesis (Martin et al., 1988; Oswald, et al., 2000), since a non-speech stimulus impaired memory as much as speech. However, in the reading comprehension task cued recall was more impaired by meaningful irrelevant speech than by road traffic noise. This result is in line with previous studies (Knez & Hygge, 2002; Martin et al., 1988; Oswald, et al., 2000),
showing that comprehension of a text is particularly vulnerable to noise with meaningful semantic content.

What accounts for these noise effects? Do they depend on memory or attentional capacity? Despite age effects in all memory tasks, which indicate capacity differences, no interactions were found between age and noise. Neither did attentional effects as measured by the Search and Memory task seem to mediate the obtained noise effects. Therefore, it seems unlikely that the different memory and attentional capacities stands out as explanatory factors. To be critical, our choice of attention measure might not be the optimal way to test divided attention and distraction effects, since it has a character a selective attention task. Noise effects were also found in semantic memory, and an explanation based on the level of access to the information base could therefore also be ruled out. Nevertheless, our data give some support for the hypothesis that, independently of age, performance of a more complex and resource-demanding task, such as reading comprehension in episodic memory, is more vulnerable to noise than performance of an easier one, such as encoding three-word sentences. Presumably this is an effect of the more complex task being more vulnerable to the reduction imposed by the noise of the information processing resources available for the task (cf. Cohen et al., 1986). The findings might also suggest that noise disturbs the serial processing for novelty complex episodic information, so that it never becomes integrated into the episodic memory system (cf. Tulving’s 1993, 2001).

To directly test whether the groups had identical underlying performance structures, a set of structural equation models were tested. This modelling supported the subdivision into episodic and semantic memory (Nilsson et al., 1997; Nyberg et al., 2003) for all age groups. However, episodic memory was in turn subdivided into three different latent variables reflecting text comprehension, sentences encoded with and without enactment, and encoding of faces and names. The age group 13-14 years deviated from this overall picture, which might reflect that many children in this age group yet have not attained cognitive maturation.

Thus, it can be concluded that acute exposure of meaningful irrelevant speech and road traffic noise influence both the achieving and providing of knowledge independently of age and of retrieval cues.
Perceived Noise Exposure in the School Environment

From the laboratory experiments we now know more about how pupils, students and teachers cognitively reacted to irrelevant speech and traffic noise, but how do they perceive noise in their own working environment? When considering this issue annoyance is a central theoretical concept (Guski, 1997, 1999). However, annoyance is in turn dependent on several ambient factors. Thus, it was of special interest to find out the annoyance patterning for the actors in the school environment.

Two methodological approaches, interviews and questionnaires, were used to evaluate the annoyance patterning. At first we wanted to find out which noise sources that were perceived as bothersome in the school environment. Irrelevant speech in the classroom as well as that coming from the outside stood out to be the most annoying sound (cf. Lundquist, 2003; Lundquist et al., 2000). Thus, the most disturbing sound derives from humans and the interplay them between.

The model testing started with a set up from the interviews indicating a serial arrangement in which stress symptoms and distraction mediated between chatter and disturbance. The degree of distraction was dependent on the task at hand and their interest in the subject. They also described that the methods used by the teacher and the teachers' authority was important for their performance during noise or to prevent the onset of irrelevant speech. In the best model generated from the responses from the pupils, general sensitivity and adaptation led to a higher degree of annoyance, which in turn caused stress symptoms. Thus, the two models suggested different models for the prediction of the reaction to noise exposure in the school environment. One of the basic differences between the two models was whether stress symptoms acted as an outcome or a determinant of annoyance. This dissimilarity may be due to that the informants in the interviews associated the feeling of stress to a specific situation while the questions in the survey study were formulated to reflect stress reactions over a longer period (cf. Guski, 1999).

From the models found and from previous research (Kjellberg et al., 1996), a conceptual model was then tested to find an annoyance model that was valid for both pupils and teachers. From previous empirical findings annoyance was divided into disturbance and
distraction (cf. Job, 1996; Kjellberg et al., 1996; Stallen, 1999). However, the best model found that fitted both groups did not support this division.

Taken together, the found models of how different factors mediate and moderate the annoyance reaction of noise exposure in the school environment show that whether annoyance arises or not is determined by individual and situational factors. The model testing emphasised that individuals who regard themselves as more sensitive than others are more likely to show stronger annoyance responses (cf. Kjellberg et al., 1996; Stansfeld et al., 1993). Even though the relationship between the situational factors, control and predictability, and annoyance was weak, these moderating factors were of importance for the annoyance response structure, which implies that the concept of annoyance is complex in its nature (cf. Guski, 1997, 1999; Passchier-Vermeer & Passchier, 2000).

The experimental studies in the present thesis used just one dependent measure to establish the relation between annoyance and cognitive performance. For future research the annoyance models found indicate that this is not optimal to capture this relationship.

Practical Implications and Future Challenges

The results in this thesis imply that remembering and knowing, abilities central to achieve and provide knowledge in the schools, work better in a more silent environment, but how should this environment be improved?

In the questionnaire for the pupils and in the interviews this aspect was addressed and in both studies and they had many ideas and suggestions how to achieve a more silent school environment. In both studies preventive measures as soundproofing and better air quality was pointed out. In the survey study, the pupils expressed their own responsibility by less talking, while a pattern that appeared particularly clear in the analysis of the interviews was the interaction between pupils and the teacher, consisting of being involved and respected, and to take own responsibility and to respect others. When improving the sound environment in school all these aspects must be taken into account and thus technical aspects are not the only factors to consider.
The main findings of the present thesis indicate that irrelevant speech is annoying and that it affects the process to achieve and provide knowledge for all actors in the school environment. However, an improvement of this condition seems far away since the current trend in the Swedish school policy points towards financial set backs, and thus the intention towards smaller classes and more teacher resources are hard to fulfil. Nevertheless, if the individual is assumed to be an active subject and not a passive object the results from this thesis show that there are still methods to conduct for improvements. The curriculum (Swedish Ministry of Science and Education, 1994) for Swedish schools emphasises the student’s influence and own activity in the construction and shaping of the school environment. According to the participants’ statements this intention is not fulfilled concerning unwanted sounds in schools. The reason for this shortcoming may be the lack of suitable models to solve environmental problems. Focus groups allow the participants the opportunity to both give and gain data, a method that facilitates a dynamic dialogue process (Wood-Charlesworth & Rodell, 1997), where the aspects of being involved, respected, own responsibility and respecting others benefits. The knowledge about the annoyance models and the noise effects obtained on episodic and semantic memory could therefore stimulate a democratic dialogue which could lead to an active participation in all the stages of the local work of change.
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