Summary

Occupant behaviour has been recognised as one of the key factors able to affect acoustic conditions of indoor and outdoor environments. In particular, high noise levels are mainly generated by occupants in densely occupied environments, such as classrooms, open-plan offices, hospitals and urban spaces, causing negative effects on annoyance, performance and occupant behaviour, as well as on health and well-being. Nowadays, international research community is aware of the key role of occupant behaviour, however the tendency to enclose active engagement of occupants in projects of acoustic improvements is still on a small scale, especially in indoor environments. This limitation is mainly caused by the great effort required by behavioural change interventions, owing to cultural factors, different preferences, priorities and habits.

In this context, a method based on external incentives to encourage more aware behaviours, such as lowering voice levels and changing the room for conversations, is applied in real environments. The key factor of this method is a noise monitoring system with lighting feedback that alternates colours from green, yellow and red according to the change of noise levels, namely SEM (Speech and Sound SEMaphore). It has been designed and patented at Politecnico di Torino in Applied Acoustics Group. An effective validation and impact evaluation of this device and method was still lacking. Therefore, the overall aims of the present PhD dissertation are: 1) to validate SEM device in a densely occupied environments; for this purpose, primary school classrooms and open-plan offices have been adopted as test bench; 2) to evaluate how occupants interact with SEM device and perceive the entire set of external incentives (i.e. paper-based communication, feedback on results provided by researcher, ICT-based solutions); 3) identify a roadmap for the adoption of such complete and qualified system in large-scale applications.

The core methodologies needed for addressing these goals are: 1) field monitoring campaigns to collect objective data; 2) subjective assessments through informal conversational, structured interviews and questionnaires; 3) prototyping and laboratory validation.

Field application of SEM devices was carried out in 13 classes of a primary school in Turin (Italy) over 3-scholastic years. In the last monitoring campaign, subjective data were also collected to gather information about the usefulness of the lighting feedback, moreover teachers' vocal behaviour was monitored using the portable vocal analyzer. The key findings of the long-term monitoring campaigns show that some independent variables, such as teacher, time-band, day of week and class are significant fixed factors that affect the background noise levels. Some degree of interactions emerge between the effect of these factors and the effect of the lighting feedback on the dependent variable ($L_{A90,mean}$), even if only one interaction between day of week and the lighting feedback is statistically significant. With respect to the analysis where these fixed factors were controlled, the activation of the lighting feedback led to a significant average decrease of 3.2 dB(A), 2.2 dB(A) and 3.3 dB(A) in the first, second and third monitoring campaigns, respectively, for a total of 51% pairs of independent lessons. These decreases emerge when the starting noise conditions are worse, i.e. the background noise levels are highest in the absence of the lighting feedback. In the other pairs of independent lessons (49%), background noise levels increase or do not significantly decrease in the presence of the lighting feedback. The average increase of $L_{A90,mean}$ values are about 1.6 dB, 1.9 dB and 2.5 dB in the first, second and third monitoring campaigns, respectively. However, these increases are lower compared to the decreases of background noise levels when the lighting feedback is switched on.

The prototyping activities and laboratory validation have covered a great part of the PhD research activities. The weakness and shortcomings of the original version of SEM prototype (Alpha prototype) and of existing devices were the key drivers in the development of the new prototype. Beta prototype aimed to be representative of a device ready for productization and large-scale applications.

A calibration by comparison was performed in order to make SEM Beta prototype able to measure reliable Sound Pressure Level according to a class 1 Sound Level Meter. The field validation in a real shared office show that Beta prototypes measure reliable decibel levels in the typical speech spectrum (125-2000 Hz), therefore a pilot study was performed in Finnish open-plan office as a starting point for proposing a methodology for future investigation.