Children's perceptions of classroom noise: self-reported data from clinical and non-clinical populations

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INTRODUCTION

The many possible adverse effects of classroom noise on a student include reduced ability to consistently hear the teacher's voice, and reduced capacity to attend to and remember longer and more complex utterances. These effects may be magnified for a student with an auditory processing disorder (APD). A diagnosis of APD implies that the student has less ability than his/her age peers to successfully resolve auditory input. This may arise because of perceptual deficits, however cognitive deficits related to language competency, attention and working memory may also undermine a student's ability to make optimum use of auditory input. APD is typically described in terms of numerous observed deficits (signs) in affected children, such as markedly poor listening skills, poor comprehension of speech and need for repetition, slow responses when spoken to, distracted or 'dreamy' behavior and frequently misunderstanding or forgetting oral instructions. These difficulties usually become more apparent in noisier and more reverberant listening environments such as classrooms and shopping centers.

The complaint behavior (symptoms) of children with APD has received little attention. There is a general assumption that all children with APD are bothered by noise, to a greater or lesser extent. If this is the case, are their complaints uni-dimensional or do affected children express other symptoms in a multi-dimensional way? Further, do these complaints assist in distinguishing children with APD from children without APD or differentiate sub-types of APD? The aim of this poster is to present the complaint behavior of children referred to a specialist APD clinic based on their reported perception of how they experience listening and learning in their classroom.

METHOD

Sample: We report the results of qualitative data elicited from 265 consecutive children, age 7-17 years (mean age: 10.02 yrs; SD: 2.3 yrs), seen in one of the APD Clinic of Flinders University from 2004 to 2010. All children completed a 4-test AP test battery (2 dichotic tests and 2 tests of short term auditory memory) and were diagnosed with an APD if their results on 2 or more of the 4 tests fell below normal limits (> 2 SDs below age mean). 162 of the 265 referred children met criterion for APD (110 of the 179 boys [61.5%] and 52 of the 86 girls [60.5%]). At the end of the test battery, as a standard part of the clinical assessment, all children participated in a semi-structured interview (8-9 standard questions) with the audiologist.

Data collection: We report the children's responses to the following 4 questions related to classroom noise and to a visual analogue scale (VAS) activity called "the noise ruler." (Preliminary opening question to the interview: "How do you find hearing and listening in your classroom?)

Q. 1 “Tell me about noise in your classroom.”
Q. 2 “Does the noise affect you?/How does the noise affect you?”
Q. 3 “Would you like your class to be quieter?”
Q. 4 (If Yes to Q. 3), “Why would that be better for you?”
The noise ruler, hand-drawn at the time and explained to the child, was then presented. The VAS was verbally and visually labeled 0 at one end, “silent”, and 10 at the other end, “extremely noisy.” First, a child was asked to mark the line at/around the noise level at which he/she *perceives* the class to be *most* of the time (m) and then in the same way to indicate where he/she would *prefer* the classroom noise level (p) to be, again most of the time. After each response the child was asked to express a numerical value between 0 and 10 for each noise level marked. See examples.

RESULTS

“Noise Ruler”: Children with APD perceived classroom noise to be louder than the referred children who did not meet the diagnostic criterion [non-APD children] (mean VAS levels 7.00 vs 6.64). This difference did not achieve statistical significance ($p = 0.21$). Children with APD also would prefer classroom noise levels to be lower than non-APD children ($p=0.028$) and the difference between the perceived and preferred levels was also significantly different for the two groups, $p = 0.021$ (unpaired t-tests). There were strong correlations with age for measures of both perceived and preferred noise levels with younger children perceiving classroom noise to be significantly louder ($p<0.001$) and preferring lower noise levels to older children ($p<0.001$, Pearson correlation)

We examined the relationship between the diagnostic outcome “severity” scores (non-APD = 4 and APD = 6-10) for 234 children with complete test data and noise ruler scores. Correlations of VAS results with severity were significant for both the *perceived* noise level ($p = 0.043$, 1 tailed) and for *preferred* noise level (inverse correlations, $p = 0.011$, 1 tailed, Pearson correlation).
Interview questions: Twenty four percent (24.2%) of children voiced no concerns about classroom noise or any noise specific effects. The remainder volunteered concerns about noise that were *post hoc* aggregated in the following four domains:

1) Physical effects, e.g. headaches, ears hurting (15.5% of children)
2) Mental effects, e.g. annoyance, distraction, frustration, arousal and anger (28.7% of children)
3) Inability to concentrate and/or work optimally (41.9% of children)
4) Inability to hear and/or listen well (42.7% of children)

The non-APD children were significantly more likely to express no concern about noise than the children with APD ($p = 0.007$, Fisher’s exact test, 2 tailed). When compared for specific noise effects the APD and non-APD groups showed no statistically significant differences with respect to self-reported physical effects of noise ($p = 0.60$), mental effects of noise ($p = 0.40$) or inability to concentrate and work in classroom noise ($p=0.124$). However, children with APD were much more likely than non-APD children to report difficulties hearing and/or listening in class ($p = 0.007$).

Comparison with results for non-referred school age children

Kilcoyne (2004) assessed 125 children (64 girls and 61 boys) age 7.7 yrs to 11.3 yrs (mean 9.8 yrs, SD 0.9 yrs) in 5 schools in metropolitan Adelaide using a VAS and a semi-structured interview to ascertain the perceptions of classroom noise in a sample of non-referred children. Children with known hearing impairment or current middle ear problems were excluded from the sample. The study method was as described above. The VAS results for this sample showed a significant difference between the children's perceptions of classroom noise *most* of the time (mean: 5.90, SD = 1.95) and preferred level of classroom noise most of the time (mean: 2.81, SD = 1.84) ($p<0.001$). The VAS responses were independent of gender, age and year level.

The non-referred children and the non-APD children differed significantly on the *perceived* level of classroom noise on the VAS ($p=0.01$), however, there was no significant difference for this measure between the children with APD and the non-APD group ($p=0.215$). In contrast, the non-referred children and the non-APD children did not differ in terms of their VAS responses for *preferred* noise levels ($p=0.80$), but, as reported above, the non-APD children differed significantly from the children with APD on the *preferred* noise level ($p=0.028$, unpaired *t*-test).

CONCLUSIONS

1. The referred children, those with APD as well as the non-APD children, perceived classroom noise as significantly louder on a VAS than the non-referred children. Younger referred children, irrespective of diagnosis, expressed more problems with classroom noise than older children using the VAS.

   This finding lends support to a broadly based, non-restrictive referral policy for AP assessment. The referred children differ significantly from non-referred peers with respect to their perceptions of classroom noise and its effects. Clinical assessment which includes an interview allows the child to articulate his/her problems, thereby enhancing understanding of the child's difficulties and stimulating better targeted classroom management.

2. The children with APD differed significantly from the non-APD children on 2 of 3 measures using the VAS and for self-reported difficulties hearing and listening in classroom noise.

   These findings suggest that children with APD are especially vulnerable to noise effects. Further investigation of this interaction may help to elucidate the nature of APD, which remains elusive. Experiments with good ecological validity conducted outside of the clinic may complement psychoacoustic studies of noise effects.

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Metrology of subjective reaction to noise through performance evaluation

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ABSTRACT

It's well known that sound and noise have influence on humans, in terms of enjoyment, annoyance or damage. It's particularly interesting to quantify the influence of auditory stimuli when a subject is carrying out an activity that may require attention and accuracy.

We designed and carried out an experiment with the purpose of judging the performance of subjects engaged in a visual task, by comparing two different environmental conditions: silence and noise.

This experiment, set up in semi-anechoic room, involved 25 subjects of both sexes and aged between 22 and 75.

Data analysis has been conducted in order to 1) highlight any variation in the subject's performance accuracy in the presence of disturbing noise and 2) investigate the influence of the noise on reaction time. These results were also compared with information collected by a questionnaire.

INTRODUCTION

The attempt to determine, quantify and measure the effects of external stimuli in humans requires the synergy of both scientific and humanities fields and a consequent interpretive synthesis that transcends the boundaries of the search field of metrology as commonly understood.

In 2006 the European Commission gave emphasis to this issue with the establishment of an international research project characterized by a strong interdisciplinary approach that has taken the name of Measuring the Impossible Network, in the context of the New Emerging Sciences and Technologies (NEST) and with the aim to extend metrology in innovative research fields. The measure of subjectivity is one of the objectives sought by the Soft-Metrology, defined as "the set of techniques and models that allow objective quantification of the properties determined by the perception in the domain of all five senses". The ambitious project to measure the impossible, namely to quantify, through methods typical of the measurement science, the phenomena identified as subjective, is expected to define quantitatively variables such as, for example, satisfaction, usability, comfort, and many others.

In a nutshell, we need to identify and interpret the objective changes that occur in humans as a result of certain sensory stimuli. The main question that we try to answer may be as follows: if the stimulus is a sensory input metrologically quantifiable (a sound, a flash of light, a roughness...) which output can be measured once filtered through the senses and interpretation of the subject?

According to the tools and analytical models currently available, we can identify three main types of output, which we define as: 1) opinion, 2) physiological response, and 3) performance.

The opinion of a subject about an object or an event related to the sensation caused by them can be investigated through appropriately designed questionnaires. A series of questions related to a scale submitted to a sufficiently large panel, can provide meaningful answers for understand how a given phenomenon is perceived.

Another way to investigate the subjective response to a stimulus is to identify some physiological parameters of organs that can be monitored and measured. For example, indicators of cognitive load, attention, or stress are the pupil diameter, heart rate and skin conductivity. Over the last decade, the neuroscientific disciplines have given great importance to the techniques of functional magnetic resonance imaging to monitor brain activity.

The third and final output of the interaction between humans and the world that we intend to quantify is the performance. This is assessed by measuring changes in the attitudes of the subject to perform a specific task, such as reaction time to a stimulus or accuracy in performing a given action.

We believe that the integrated analysis of these three main outputs allow to obtain "objective" information, both quantitative and qualitative, about the "subjective" response at a specific sensory stimulus.

Since this integrated approach to the problem of human perception is strongly multidimensional, a multidisciplinary perspective to the problem is highly desirable. The tools offered by Metrology - in addition to define and quantify measurands accurately allow us to study the appropriate method to correlate the results obtained and identify the reliability margins of different interpretations.

OUR EXPERIMENT

Given the general conditions described in the introduction, we decided to set up an experiment designed to investigate the influence of environmental disturbances on the performance of individuals engaged in a simple visual task. It's well known how sounds and noises generate a feedback in the human feelings in terms of enjoyment, annoyance or harm. It becomes particularly interesting to evaluate the influence of sound stimuli, noise in our experiment, when a subject is intent on carrying out activities that may require attention and accuracy, like visual task.

Experiment set-up

The experiment, arranged in a semi-anechoic room, involved 25 subjects of both sexes and aged between 22 and 56 years. In Figure 1 we show a schematic representation of the experimental set-up. The person involved in the test was placed at a distance of 0.5 m from the computer monitor. A dodecahedric sound source generating a particular background noise was placed behind him.

As shown in the picture, the monitor was also flanked by two sources of glare, an incandescent light source and a LED one, because the influence of visual sources of disturbance was also investigated. Here, however, we will describe the trial investigating the influence of sound.

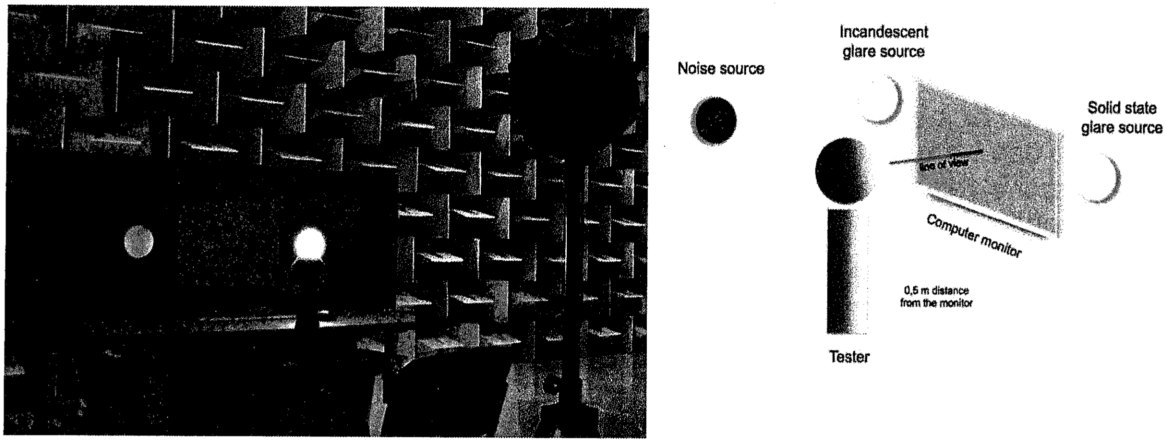

Figure 1: Experiment set-up picture and schematic representation

The test, conducted in darkness and divided into several sessions of about 5 minutes each, consisted in the identification, by each subject and with the click of a mouse, of small targets square shaped and of different contrast on the monitor, in a maximum time of 60 s. Subsequent to the identification, the subject was then asked to drag the identified targets in order to form a sequence ordered by contrast, decreasing the negative to the positive and growing, as exemplified in Figure 2.

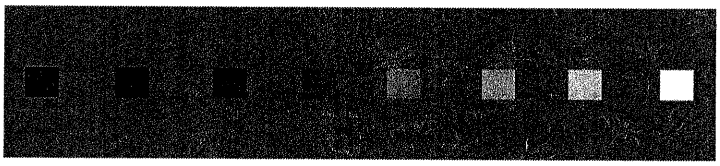

Figure 2: Correct target sequence ordered by contrast

This task (target detection and then ordering) was carried out either in silence or in the presence of noise. To each subject, at the end of the test, was then asked to provide a self-evaluation about their performance. Referring to the test conditions in which there was background noise compared to those carried out in silence, subjects were asked to express an opinion on what they thought had been the influence of this noise on their accuracy in performing the visual task assigned.

The subjects, following the pattern tree shown in Figure 3, could say whether they had received some influence and, if so, whether in terms of improvement or worsening, while also providing an information about this influence magnitude.

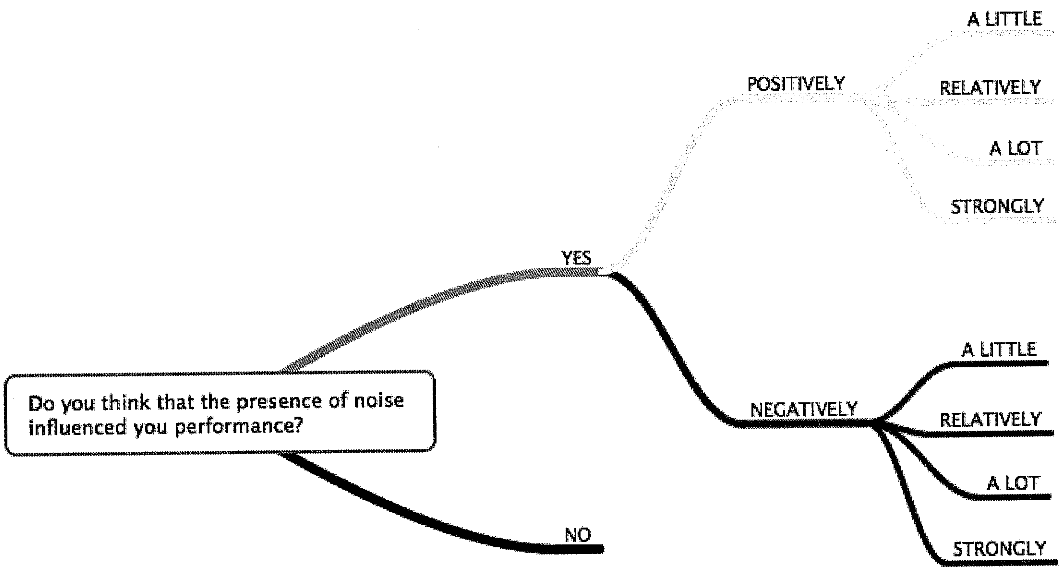

Figure 3: Questionnaire proposed to subjects at the end of the test

The stochastic noise

In the design phase of the experiment described here, in order to identify a noise that could highlight the best possible influence on humans, some preliminary tests have been conducted.

Some subjects have been asked to detect visual targets both in silence and in a noisy condition. We used a pink noise, a series of sounds with informational content (ambient noise, radio messages, phone rings, etc..) and a pink noise to which was added an artificial disturbance unrelated to the common experience, an infinitely ascending scale, i.e. the acoustic illusion of Shepard scale (Shepard 1964).

Based on a preliminary analysis of collected data a general tendency for subjects to improve their performance in the presence of background noise has been noticed. For this reason we decided to deepen the investigation.

However, it is known that the human brain is able to adapt quickly to a stress condition. It is possible that an auditory source of disturbance, with particular characteristics of predictability and monotonicity, after a short administration period, can be "masked" by the human ear and thus lose its influence.

Due to this, based on some recent studies (Ball 2010), it was decided to compose a noise that can be as refractory to this suppression as possible. One of the hypotheses suggested by Ball is that our brain is more adaptable to different types of noise for which it is able to "anticipate" their evolution. For example, a classical symphony "meets" the brain processes that can predict, within certain limits, the evolution of the melody. Ball argues that this is one of the main reasons why the contemporary music is very often considered unpleasant: our brain cannot predict its evolution, generating in the listener a kind of stress or discomfort.

For the proposed test a sound of stochastic nature has therefore been specially composed and generated, consisting of 100 frames of sinusoidal signals with frequencies between 10 Hz and 10 kHz, which turn on and off at random intervals with a minimum of 0.25 s. The overall sound pressure level was 78 dBA, so as to exceed the threshold of 60 dBA identified by Saeki et al. (2004) in their experiment that aimed to investigate the minimum sound level to obtain an influence in human.

Figure 4 shows the sound pressure level of stochastic noise used during the test. The decision to administer a sound like this was prompted by the desire to create disorder and confusion in the subject engaged in test, because of the highly variable and unpredictable nature of this sound that does not allow or minimize the masking effect.

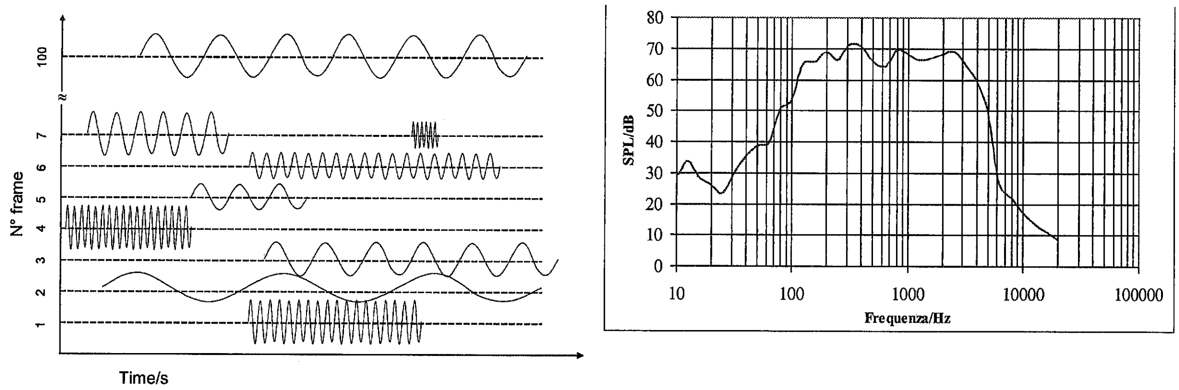

Figure 4: Schematic representation of stochastic noise and its sound pressure levels

MEASURAND IDENTIFICATION AND OBJECTIVES

In our experiment we considered the following measurands:

- Number of correct answers;
- Number of false positives;
- Time: 1) to conduct the entire test, 2) reaction to the first stimulus, and 3) between a target and identified the following;
- Number of errors in ordering targets by contrast;
- Correlation between self-evaluation (questionnaire) and performance.

Regarding the number of correct answers, we considered the percentage of targets identified in the first phase of testing. As mentioned above the targets presented were different in contrast and position. Was then monitored the threshold of contrast perception and therefore given the number of targets identified in the total submitted.

About the second measurand, we considered as "false positive" each click of the mouse that the subject did in a wrong position on the screen where no target was presented.

Time evaluation has been center of the analysis of data obtained from this test. Temporal variations between silence and noisy condition have been considered regarding: 1) the total time required to perform the task, 2) reaction to the first stimulus (i.e. the time between submission of the screen with target and the first click of the mouse made by the subject) and 3) the average time between a mouse click and the next one.

The penultimate parameter considered for the measurement of subject performance has been the accuracy degree with which the target ordering by contrast was made. In fact, although the ability to discern small differences in color - shades of gray in this case - is a visual property that is more or less influenced by ambient lighting conditions, the degree of precision with which the subject performs this operation is also the result of attention and concentration that may indeed be affected or not by the presence of sound noise.

The last measurand concerns the correlation between the self-evaluation that the subject provided by questionnaire at the end of the test compared to his performance evaluated according to the criteria previously described.

It therefore intends to improve the performance increase in positive responses as well as the decrease of false positives, the shortening of reaction time and the average time between a response and then the other as precisely the sort of carrying stimuli. Upon the occurrence of the opposite conditions of course we mean that the performance has worsened. We refer to the last section of this paper for a specific study on future developments of this approach.

FIRST DATA ANALYSIS AND RESULTS

For the results analysis a preliminary investigation about the influence of subject ages on the parameters chosen was carried out and it was therefore decided to divide the sample into two groups (Group I: aged between 20 and 30, Group II: between 35 and 55).

Regarding the first measurand (total number of targets identified) we made a comparison between the experimental sessions took in silence and in the presence of noise. In this case the group of subjects was considered as a whole and, as shown in the histogram shown in Figure 5, in the presence of noise there is an increase of 35 % in the number of targets identified.

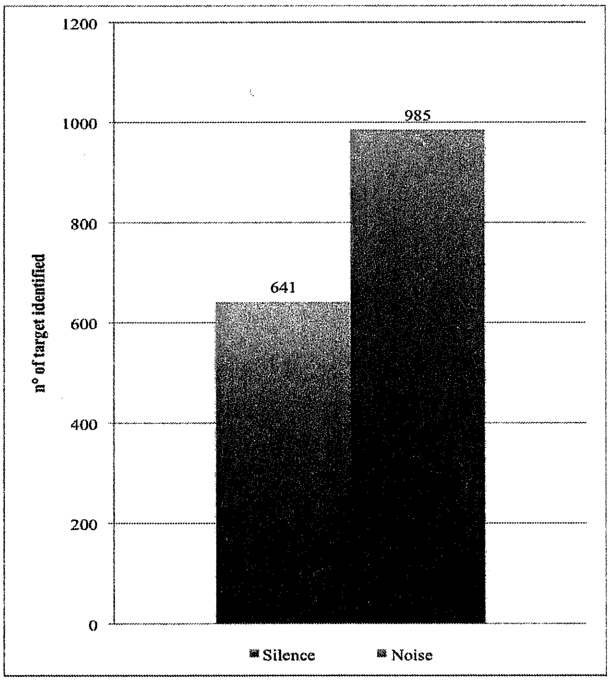

Figure 5: Total number of identified targets in the two different environmental conditions

Regarding the number of false positives and the duration of the entire test, there was no significant difference between the two experimental conditions (silence and noise). On the contrary, interesting results have been obtained for the other two time parameters.

Considering the distinctions of subjects by age, which in this case is significant, we note that the reaction time to the first stimulus, and the average time between the selection of a target and the subsequent, decrease with the addition of noise.

As shown in Figure 6, was in fact registered a decrease of 25 % for group I and 43 % for group II, in the reaction time to the first stimulus at the transition from silence to noisy condition. Similarly (Figure 7) a decrease of 13 % for both groups was noted regarding the average time between the selection of a target and the next one.

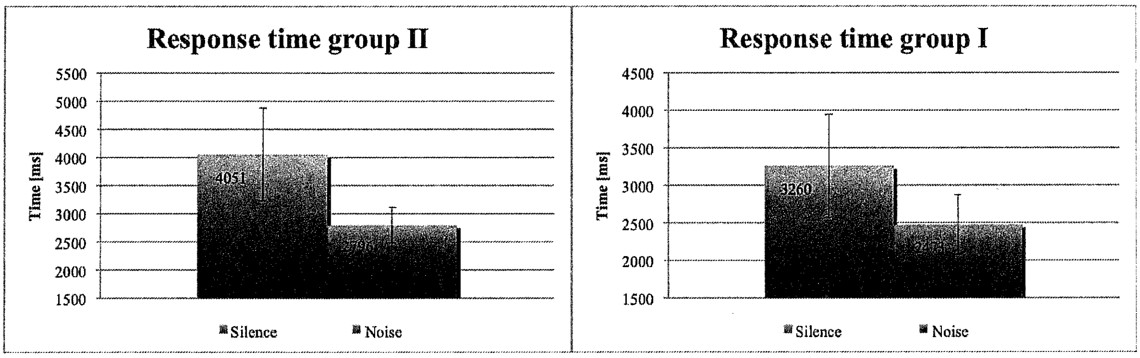

Figure 6: Comparison between response time in silence and in noisy condition for the two subjects group (group I: age between 20 and 30; group II: age between 35 and 55)

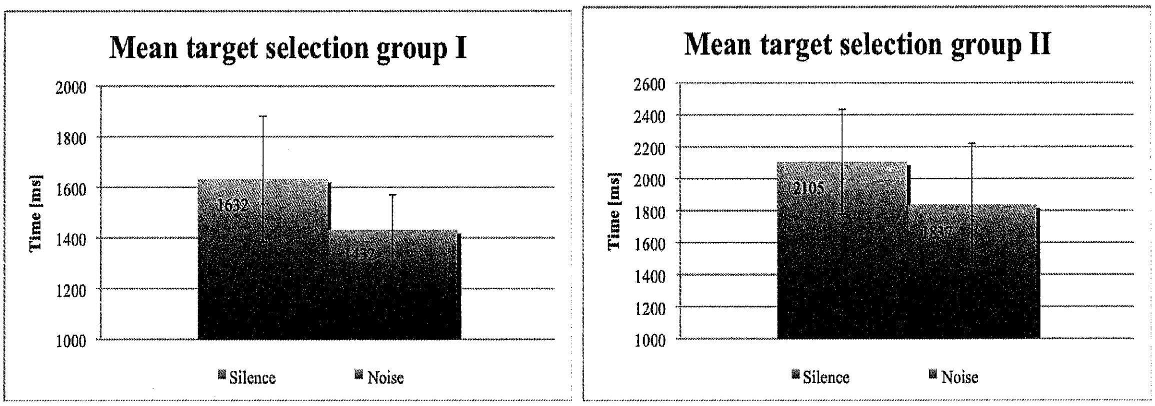

Figure 7: Comparison between mean target selection time in silence and noisy condition for the two subjects group (group I: age between 20 an 30; group II: age between 35 and 55)

The final consideration about the data analysis concerns the evaluation of the accuracy with which each person has ordered the target by contrast. In this case a significant difference in subjects performance between the two environmental conditions, was noted for at least half of the testers, such as highlighting that the presence of noise actually influences the development of this task, for someone positively and for others negatively.

We then wanted to correlate this result with subjective data about performance self provided by the person in the questionnaire with the intent to verify a match. The chart presented in figure 8 shows, for each subject, if the performance has worsened or improved in the transition from silence to noise, together with the same information obtained by self-evaluation (questionnaire).

This comparison show that about 20 % of the subjects provided self-assessment of their performance is consistent with the measured data. The remaining sample showed peculiarities in certain situations would be dealt with case by case basis. Some people in fact have underestimated the influence of noise on their performance and others gave an opinion opposite to the observed reality. For the realization of this plot was used only the information concerning the parameter relating to the correctness of sort of targets. We think it is interesting to investigate this issue by including other results that are unified in a single index, can be directly correlated with the self-assessment and provide more precise information regarding the effectiveness of this technique in this context.

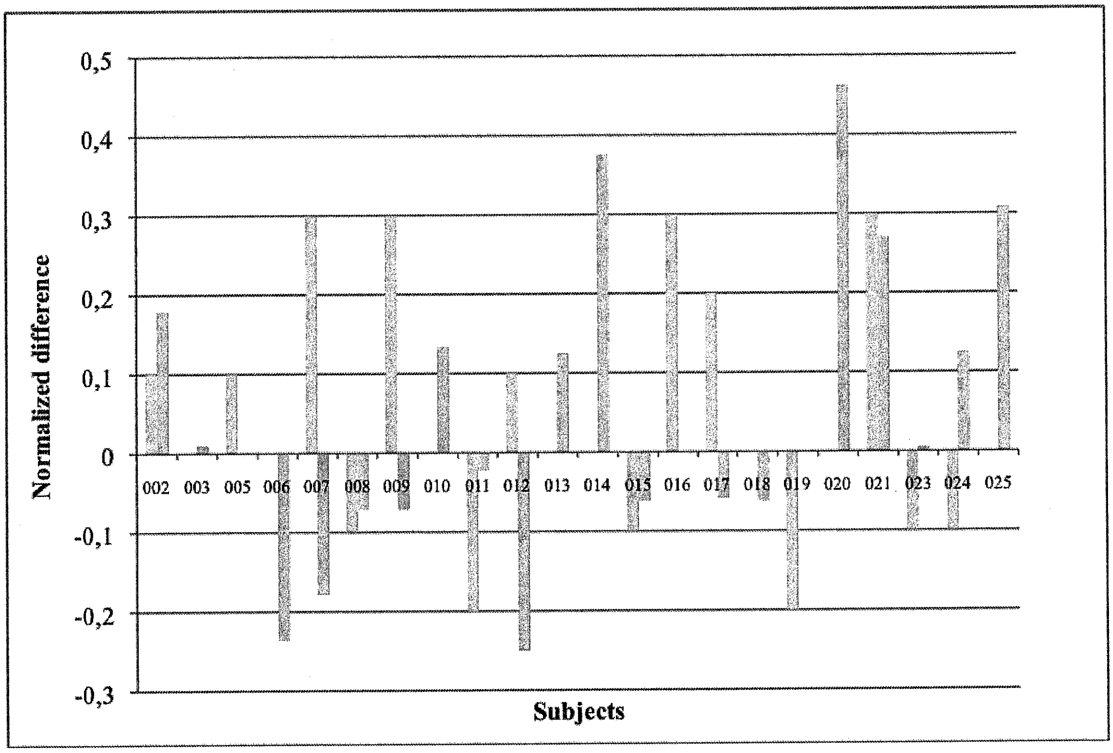

Figure 8: Correlation for each subject between self-evaluation (yellow columns) and performance (green columns)

CONCLUSIONS

Through the use of metrology tools, the intent of our work is to investigate the different techniques of quantification of subjective response to stimuli, in order to provide useful information for the optimal method of investigation in various fields of human perception. In the case of this experimental research, future development will be to establish a "performance index" that takes into a suitably weighted account, all the parameters identified as significant for defining the characteristics of a human performance. As for the aspects strictly related to auditory perception, we will instead investigate the influence of different nature and level of noise.

The ultimate goal is to provide new tools to soft metrology to be used in various fields, from experimental psychology to the design of effective human-machine interfaces, or the characterization in terms of subjective evaluation of objects, materials and environments.

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