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*«**ΑΚΟΟΛΟΓΙΑ & ΝΕΥΡΟΩΤΟΛΟΓΙΑ**»*

Διπλωματική Εργασία

«Συγκριτική μελέτη αντίληψης της μουσικής χροιάς σε άτομα με νευροαισθητήρια βαρηκοΐα και άτομα με φυσιολογική ακοή»

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Comparative study of Musical Timbre Perception in SNHL and NH

MSc Thesis

Dimitrios Pelekanos

-Thank you notes-

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-If you have knowledge, let others light their candle in it.

A candle loses nothing by lighting another candle-

Abbreviations Table

ANSI	American National Standards Institute
PCA	Principal Component Analysis
MDS	Multi-Dimensional Scaling
VAME	Verbal Attribute Magnitude Estimation
OHC	Outer Hair Cells
IHC	Inner Hair Cells
HL	Hearing Loss
NBN	Narrow Band Noise
SNHL	Sensory Neural Hearing Loss
NH	Normal Hearing
JND	Just Noticeable Differences
PTA	Pure Tone Audiometry
DPOAE	Distortion Product Otoacoustic Emissions
TEOAE	Transient Evoked Otoacoustic Emissions
OAE	Otoacoustic Emissions
TTS	Temporary Threshold Shift
DAC	Digital to Analogue Converter
PAF	Principal Axis Factoring
LTM	Luminance-Texture-Mass
MTV	Mass-Texture-Vision

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Abstract

Timbre has always been a complex multidimensional concept, especially in respect to the physical characteristics that describe it. Research has long tried to shed light on timbre dimensions, and timbre spaces that most accurately describe it. The most common study methodologies throughout history have been dissimilarity ratings and semantic attributions to sounds. However, varying methodology and results have cast confusion over the subject. Moreover, musical timbre perception, has been poorly studied. As this is a part of our greater study, following a series of previous research on the matter, at this point we tried to compare timbre perception in SNHL and NH subjects, by combining different timbral spaces and reaching conclusions for the principal perception factors of timbre in each group, correlating our results to their individual audiological characteristics. Our goal was to create a cross language model of timbre perception, based on previous semantic correlations between English and Greek speaking population, and finally reach in-depth conclusions on timbre perception in SNHL. Lastly, we wanted to study the effect of loudness, in NH and SNHL groups, in respect to timbre perception. 23 people took part in this particular study and were appointed into 4 groups, based on stimuli presentation level and hearing status.

The previous LTM model of sematic representation (Luminance-Texture-Mass), was strongly supported by our results, proposing a change for the Luminance factor to Vision, therefore suggesting the MTV model for the semantic representation of musical sounds, with Mass and Texture found to be the most robust factors. Loudness acted as a moderator of mean fluctuation, with a stronger effect on the SNHL groups, in agreement to previous research on timbre perception in HL. Our results suggest that Loudness and Timbre are at least two dynamically correlated entities, if not a single multidimensional unity, while they strongly also suggest perceptual changes between NH and SNHL groups.

Pure tone audiometry and Distortion product OAE levels, appeared to be the most sensitive measured for detecting perception shifts, strongly correlated with our two main factors, Mass and Texture, especially for frequencies around 1000Hz for low loudness levels, and extending result correlations to mid and high frequency ranges, when loudness presentation levels increased. Methodological changes to weighted coefficient computing were suggested, as well as the need for larger sample sizes. Finally, we conclude to report the need for discrimination between timbre perception and timbre identification, and point out the importance of the completion of this study.

Introduction

Everyday experience has shown us that listeners possess a remarkable ability to recognize, distinguish and discriminate complex sound sources, such as human voices, environmental sounds and musical instruments. (1) What makes this possible, is a series of sound characteristics and the way we perceive them.

In order to be able to understand how this is implemented, we would need to know that complex tones differ in 3 primary attributes, which are loudness, pitch and timbre. As we already understand, pitch and loudness of a given sound are correlated to a single physical parameter each, which in the case of pitch would be the fundamental frequency of a sound, whereas loudness depends on the total sound pressure level. Timbre, on the other hand, cannot rely on a single physical parameter and thus can only be conceived as a multidimensional attribute of sound. (2)

Timbre has been characterized as a misleadingly simple and vague word and that is due to its complexity. A simple single word is encompassing a series of complex auditory attributes and a plethora of musical and psychological issues. (3) But what exactly is timbre? In one of the most discussed definitions of timbre, ANSI in 1973 defines it as ‘ that attribute of auditory sensation in terms of which a subject can judge that two sounds similarly presented and having the same loudness, pitch and duration are dissimilar’ (4), a definition that has received a lot of criticism due to de description of what timbre is not, rather than what it actually is. Timbre certainly is a fundamental attribute of auditory perception (5) and therefore, it refers to something subjective in its nature. Formal definitions usually fail to describe such a multifarious word. If we contemplate about the other two attributes of sound, loudness and pitch , we would notice that each, may naively be semantically represented in a linear scale of two adjectives, soft to loud and low to high (6). Such simple measures could not apply for timbre.

Timbre

As timbre applies for all sounds including speech, it might be easier to understand that the speech equivalent of timbre, given the same loudness and pitch, is phoneme identification. In the psychoacoustical field, timbre in speech stands for particular, distinct phonemes and not some arbitrary point in timbre space. In music, timbre can only be conceived as a multidimensional continuum (7), with potential meaningfulness of any of its points. There is the frequency content due to harmonicity and inharmonicity of musical instruments and a spectral profile of the sound, conveyed to the listener by the individual spectral envelope of every instrument. (6) Due to limited frequency resolution of the human ear, a spectral composition vector can be easily reduced to a vector representing instantaneous acoustic power of critical bands (8) with apparent loss of information. The temporal envelope of an instrumental sound, including characteristics such as attack time, decay time and of course modulation of the steady state content determined by its modulation rate, has the ability to influence the perception of timbre to a great extent, that changes of any kind can make it susceptible to being unrecognizable. (9)

We know understand timbre to have two broad characteristics that contribute to the perception of music. A multitudinous set of continuously varying set of perceptual abilities, (for example attack sharpness, brightness, richness) discrete or categorical, and secondly some primary perceptual ways of recognition, identification and tracking over time of a sound source, (10–12). Given this information, timbre may be considered as a set of physical and perceptual characteristics, thus being both objective and subjective, and allowing for identification, classification and similarity or dissimilarity judgments of sounds.

Bearing that in mind, physical sound information derived by its spectral envelope and individual spectral components, can create an acoustic space of timbre retrieval, without making allowances for pitch and loudness. However physical and functional complexity of biological systems, makes the discovery of decoding schemes notably difficult. (13)

A better understanding of the physical attributes of timbre comes through the development of the Timbre Toolbox in 2011 available in the form of a Matlab toolbox (14). We now have a 54 set of audio descriptors, capturing spectral, temporal, Spectrotemporal and energetic properties of acoustic events. Temporal descriptors include attack, decay, temporal centroid, effective duration, and frequency and amplitude of the energy envelope modulation. Spectral shape descriptors include concepts like spectral centroid, spread, skewness, kurtosis, slope, rolloff, crest, factor and jaggedness. Spectrotemporal descriptors include spectral flux and energetic descriptors include harmonic and noise energy, as well as statistical properties of the energy envelope. Some of these descriptors are valid for single values for a given sound, whereas others represent time varying properties. Statistical measures of the latter, intend to depict central tendencies and variability. (14,15)

Timbre Research

Timbre research methods seem to be divided into roughly two broad categories; A category not based on human judgments, and on the other hand, the research implemented based on perceptual investigations of human subjects. The second category can be subdivided in some general types, which include psychoacoustical methods, methods of cognitive psychology and methods of ecological psychology. Approaches could also be based on neuroimaging applications. (13)

The most common methods used until now, psychoacoustical methods, imply the correlations between acoustics and perception, and is mostly carried out through semantically represented estimations in the form of mostly adjectives as sound perceptual descriptors, or similarity and dissimilarity ratings, followed by MDS techniques. Cognitive methods, suggest the use of previously integrated information compared to new stimuli information, as a way of cognitively processing sounds, a method mostly correlated to instrument identification. (13,16) The third approach deals with sound sources properties rather than signals properties alone, giving emphasis on source identification through source invariants, derived from physical properties as opposed to perceptually coded properties of sound signals. (13) These methods and properties, contribute to the creation of timbral spaces, which can be thought as a geometrical shape, whose purpose is to transmute the data derived from the ratings of those sounds equalized in terms of pitch, duration and loudness, to a mental representation of the stimuli, where the only difference among them is timbre, with that being achieved, by using dimension reduction techniques. These techniques include Principal Component Analysis (PCA) (17), Factor Analysis (18), Multidimensional Scaling (MDS) (7) and classification techniques such as Cluster Analysis (19,20).

There is a long history of research on timbre, mostly starting from the 19th century, when Von Helmholtz (5) investigated semantically represented perceptual attributes of musical timbre. Other researchers picked up on this work and during the 1970's, the semantically represented perceptual similarity of different instrument or polyphonic sounds, in the form of mostly descriptive adjectives, was studied, in order to create what has been already discussed above, perceptual timbral spaces. (7,17–19,21–25) The most widely applied methods for semantic descriptors of timbre are measures of dissimilarity (26) and a variation of this, the verbal attribute magnitude estimation (VAME) (19,27), which contrary to semantic differentiation where the measurements are based on opposing verbal attributes, examines attributes and their negations, all In compliance with the hypothesis that timbre can be adequately described with the use of semantic scales. (28)

In the highly cited work of Von Bismarck in 1974 (17), a semantic differential listening test of synthetic tones in German, was conducted in order to identify perceptual dimensions of timbre. The four dimensions that were identified were labelled as full-empty, dull-sharp, colorful-colorless and compact-diffused. In other studies, three to four semantic axes have been identified. Pratt and Doak's study in the English language, (29) featured the dimensions linked to luminance (bright-dull), temperature (warm-cold) and richness (rich-pure), in a three dimensional space interpretation of semantic representations of simple synthetic tone perceptuality. Dimensions associated with sight (gloomy-clear), texture (harsh-delicate), fullness (full-narrow) and hearing (noisy-rustle) were revealed in Stepanek's Czech and German study (30), while Moravec and Stepanek in 2003 (31) also determined four perceptual axes in Czech, related to sight/luminance (bright/clear-gloomy/dark), texture (hard/sharp-delicate/soft), width (wide-narrow) and temperature (hot-hearty). Four salient dimensions were reported through the work of Disley in 2006 (20), in English , who used string, brass, woodwind and percussive stimuli, labelled by the terms bright/thin/harsh, dull/warm/gentle, pure/percussive, nasal/metallic/wooden and evolving.

Timbre Research Complications

There is of course a number of inconsistencies observed among the aforementioned studies, potentially attributed to methodological factors, different stimuli, levels of music education and music background and last but not least, variety of languages used in the studies. Elaborating on this aspect, semantic dimensions of timbre have been found dependent on instrument type and pitch (30), pitch and timbre seem not to be perceived independently (32) and pitch differences in studies have been accounted for casting confusion over the function of instrument identification (33), although this may be disputable according to recent research results on timbre adaptation. (34) In a study conducted by Marozeau & de Cheveigne in 2007 (35) auditory brightness, as predicted by the spectral centroid, was affected by the fundamental frequency, also supported by Schubert and Wolfe through a semantic description listening test in 2006 (36). Further research on the fields of language semantic differences (37) intensify the previous arguments, suggesting that grammatical-morphological cross linguistic differences, have an applying effect over corresponding semantic descriptions. Lastly, factors such as differences in data acquisition and analysis approaches also contribute to result miscellany concerning semantic dimensions.

In 2012 and 2015,the work of Zacharakis, Pastiadis and Reiss in English and Greek (38,39), proposes a semantic three dimension labelling model based on Luminance (brilliant/sharp), Texture (smooth/round-rough/harsh) and Mass (thick/dense/rich/full), conducting a cross language study on timbre semantics and their acoustic correlates, in order to also investigate potential influences of language on timbre semantic descriptions, using a modified VAME method for the estimation. Results pointed to a common semantic space between the two languages, emerging from common conceptual properties, despite the differences in the use of individual descriptors, and justified further investigation for the universality of timbre semantics. An interesting result was also that same family instruments tend to occupy similar regions of perceptual space. The three largest categories for both linguistic groups were properties of source, temporal evolution and emotional terms, although temporal evolution is mostly suggested to be a part of future studies rather than properties of source and emotional terms. (38,40) However other research suggests that there is an overlap between timbre and emotion perception due to similarities emerging from the results that lead to their prediction, in respect to their acoustic features. (41–44) The spectral content components that were investigated were related according to previous research with a) energy distribution of harmonic partials b) noisiness, harmonic spectral flux and standard deviation of the harmonic spectral centroid c) spectral centroid variation and inharmonicity d) the logarithm of attack time and the temporal variation of the first nine harmonics -Mean coefficient of variation- (27) and e) Fundamental Frequency . The conclusion extrapolated was that, texture is affected by energy distribution of the harmonic partials, whilst inharmonicity and Spectral Centroid variation was positively correlated with Thickness and negatively with Brilliance and that the fundamental frequency (F_0) negatively affected Mass in the English population and positively affected Luminance for the Greek population, suggesting further research on these findings, linking this descriptive approach to pairwise dissimilarity tests and MDS analysis.(38)

Timbre Perception in Cochlear Hearing Loss

Cochlear Hearing Loss involves damage to Outer Hair cells (OHC), and Inner Hair Cells (IHC), with OHC more vulnerable to damage than IHCs. (45) The normal cochlea function greatly depends on Outer Hair Cell integrity, which acts as a compressive measure for incoming sounds, using a non-linear gain model, thus righteously referred to as a ‘’Cochlear Amplifier’’. (46,47) The compression ratio for mid-level sounds is approximately 5:1 whereas, in a damaged cochlea, loss of compression results in a 1:1 ratio, respectively. Another important implication of a dysfunctional cochlea regarding this matter, is loss of sensitivity to low level sounds. (48) Tuning curves of auditory filters on the Basilar Membrane become much broader, depending on the level of HL, and a great reduce of frequency selectivity is inevitable, resulting in a deteriorated ability to resolve or separate sounds of different frequencies. (48,49)

As timbre is a perceptive combination of spectral, temporal and loudness content of an auditory signal, one would suspect that changes attributes to Cochlear hearing loss, would have detrimental effects on the perception of timbre. Reduced frequency selectivity would affect spectral component analysis and would influence sound distinction (50–52), changes in long term spectral shapes or changes of the temporal envelope of sounds would have an effect on temporal perception (11), and loss of cochlear compression would suggest impaired intensity coding and temporal processing.

However, there are a lot of implicating factors on this subject. Frequency wise, some instrument’s spectral shapes are so different however, that even poor frequency resolution, would allow their discrimination, whereas other instruments that differ in more subtle ways would be more difficult to distinguish. In addition to that, other implications such as upward or downward spread of excitation, regarding dead cochlear regions, makes timbre perception even more complicated, resulting in either distorted like perceptive features, or compensating for the loss in their proportionate degree, depending on the listening situations. (53) Regarding temporal processing, certain measures seem affected by HL, such as forward masking and gap detection in Narrow band noise (NBN), when others such as modulation detection and gap detection in tones, often remain unaffected. There are also, of course inter correlations among the three dimensions. (48,53) Whilst theoretically, hearing impaired subjects would be predicted to have poorer frequency resolution, implying better temporal resolution, this is not always the actual case, and cannot be predicted by a simple single-filter model. This would probably be attributed to processing stages higher than the cochlea for all but the lowest frequencies. (48) Off frequency listening reliance seems to greatly escalate for hearing impaired subjects with dead cochlear regions and HL above 80dB, suggesting possible distortion, and could make research on timbre perception even more complicated. (54) To sum up with, there seem to be no predominant cues for the determination of timbre perception, as parts of sound are both redundant and substitutable by different parts with little loss. Listeners seem to make use of cues that lead to their best performance on each individual occasion, and sounds could be stored as both composites, prototypes and used in parallel, suggesting a perception that is versatile and compensable. Thus, although one cue alone can lead to identification, performance in enhanced when a combination of cues is attainable. (11)

Research of timbre perception in HL, however, is restricted. In 2007, Emiroglu and Kollmeier (55), trying to assess timbre discrimination in hearing impaired subjects with moderate Sensory Neural Hearing Loss (SNHL) and normal hearing (NH) listeners, used psychoacoustic measures of Just Noticeable Differences (JND) between three sets of two instruments presented diotically, where each set only varied on spectral cues, temporal cues or both and had the attack compound cut off. Timbre JND for subjects with steep hearing loss were found to be significantly higher than the NH listeners, and moreover, mean level and intensity seems to play a crucial part on timbre discrimination, in respect to the degree of HL. In 2009, Fitz, et al. (56) studied timbre perception and acoustic correlates in mild to moderate-severe Hearing loss subjects, in pairwise dissimilarity settings, consequently using MDS scaling. Consistent with Grey’s findings, spectral centroid correlated with brightness, was found to be a strong feature, as well as onset time, whereas spectral fluctuation was a weaker feature or of no particular significance. Sharpness was related to brightness, as a weighted centroid of loudness, and the number of audible harmonics, well correlated with the centroid, was also a significant feature, showing significant variation. To conclude with, listeners with HL seemed to be able to make discrimination judgments, and made use of the same timbral cues to NH listeners.

Although these studies do provide some insight on timbre perception in HL, the number of researches is limited, and the methodology used strongly varies between the studies. Moreover, even though they provide some information on the predominant cues used, they do not determine an in-depth cross dimensional perception of music sound, in a way that is correlated to specific aspects of hearing loss,nor suggest a strong model for this detection. Result variability across studies on timbre perception also can be attributed to variation on stimuli, analysis and is maybe pointing to a compensable model to timbre perception that must be further examined, especially in respect to Hearing Loss, thus more specific research is mandatory.

In accordance to previous research (38,39) , this research will try to compare timbre perception in SNHL and NH subjects, combining different timbral spaces and trying to find the most strong predicting features. We will further investigate the semantic dimensions that were suggested, to provide stronger results and try to inter-correlate timbre dimensions, timbral spaces and acoustic correlates of each group, and compare them, in order to reach more in-depth conclusions on timbre perception in SNHL. Moreover, we will attempt to shed light on the specific correlations between degrees and specific features of SNHL to the semantic space of timbre perception, all in an attempt to set the ground for establishing a potential robust cross language model for the determination of timbre perception in SNHL, in the future, taking into account the individual characteristics and medical history of each person.

This particular study will analyze semantic characteristics of each group and subgroup and determine its acoustic correlates, to the semantic timbre space, as a first part of the whole study described above.

Materials and Methods

The particular study is a clinical observational/non-experimental type of study, with correlational and differential outcome measures. Subject Recruitment was not blind or randomized, as subjects were chosen due to their particular audiologic profile.

People between the ages 18-60 took part in this study. The subject groups were dived in two categories; The Normal Hearing group (NH) which is the control group and the Sensory Neural Hearing Loss group (SNHL). For the purpose of being appointed to the NH group, each subject should be evaluated with Normal Hearing PTA results with no individual frequencies falling above the normal hearing range, in accordance with each subject's age, based on ISO7029, and exhibit normal Tympanogram (Type A) and Tympanic reflexes, in order to eliminate chances for middle ear pathology. The same measure applies for the SNHL group with the exception of the PTA results, which should indicate a mean hearing Loss <60dB HL. Exclusion Criteria included Conductive Hearing Loss, acute Hearing Loss, Meniere's disease, or other retrocochlear damage. Any other medical conditions that would obstruct the smooth conduction of the research procedures, was also excluded. Every subject provided us with an informed written Consent Declaration, following a fully detailed briefing and handed written explanation documents regarding the procedures, goals and potential dangers of this study, according to the WMA Declaration of Helsinki (Ethical Principles for Medical Research Involving Human subjects).

Procedure

Following the audiological evaluations, two different trials for the musical timbre evaluation occurred. After a preceding Loudness evaluation, a semantic determination followed by a differential comparing evaluation, took place.

Audiological exams

As part of the audiological evaluation, every subject's hearing state, was validated through a full audiological evaluation. That included a medical case history, initial otoscopy, Distortion product Otoacoustic emissions (DPOAE) and Transient evoked Otoacoustic emissions (TEOAE), Tympanograms and Ipsilateral Tympanic reflexes, and Pure tone Audiograms (PTA), for each subject.

Medical and case history, included a family history, previous or current medical conditions, perception of tinnitus and relevant otologic medical history. Other factors taken into account were noise exposure and use of ear protection, music training and active or inactive musician status.

Apart from cross validating our other exams, otoscopy was used to determine the existence of earwax, and where ear canal blockage was suspected, or a physical state that would interfere with our audiological results, ear wax suction removal took place.

DPOAEs were measured for the scale of 0.5 to 10 kHz while TEOAEs were measured at the range of 0.5 to5.5 kHz. After OAEs, subjects were evaluated with tympanograms and ipsilateral tympanic reflexes at 0.5, 1, 2 and 4 kHz.

When middle ear pathology and conductive HL were then ruled out, PTA thresholds were evaluated for each subject for the typical range of 125 Hz to 8 kHz, including in between frequencies, such as 3000 and 6000 Hz.

Timbre perception evaluation

The particular tasks were carried out through a specifically developed software, for the sole purpose of this particular study, by K. Pastiadis who was the scientific coordinator of the study, and Professor of Aristotle University of Thessaloniki, with the use of National instruments LabView software.

Loudness equalization

The first part of the study included a loudness equalization of the sounds, with the use of a loudness fader. Each subject listened to two sounds in a row, with the first remaining unchanged, and the second being one of the 23 used sounds. It was asked of every participant to adjust the fader to the point where, both sounds would seem to have the same loudness level for the end user. Following that, the person would validate his choice by pressing on the ‘’next pair’’ button, where he would listen another pair, using another of the 23 music instrument sounds that were used in the study. After the completion of this first phase, all sound stimuli had an adjusted presentation level for the particular user, so they would all have the same perceptual loudness level.

Semantic representation

For the second part, the listener was asked to attribute a grade, ranging from 0-10, to every semantic representation given for each sound, with 0 being the representation of ‘’not at all’’ and 10 representing ‘’very much’’, and the choice of attributing every integral number in between. The semantic representations used, based on previous research (38), were chosen to safely depict sufficient semantic coverage of the timbre elements. Every person heard through all of the sounds, and had the choice of unlimited repetition of the sound. There additionally was a given option of adopting two personally selected semantic characterizations, that every person could add, if only he felt that the semantic representations already given, were insufficient. For every sound, there was a validation button, in order to proceed to the next given sound. The semantic characteristics were presented in Greek, and are evident in all the tables found in the results sections.

Dissimilarity ratings

As part of the final evaluation, pairs of sound stimuli, presented in random order, were given to each subject (23x23). For every pair, the listener was asked to attribute a random value, to characterize the level of dissimilarity between the two sounds, with no specific numerical scale or scale end point given. Results were normalized, during our data analysis. The listener had the option for unlimited repetitions of the sound pairs and had to validate each choice with the press of the next pair button.

Subjects were free and urged to rest and continue at any given time, in order to prevent lack of concentration having effects on the results.

Stimuli and Apparatus

The study took place in Sound-isolated chambers in Hippokration University Hospital of Athens, using a laptop, while the sounds were presented through a V90-HPA Music Fidelity USB DAC (Digital to Analogue converter) device where an HDA-200 Sennheiser Overhead Earphone Headset, was connected. Electro acoustical gain had been adjusted with the use of a BK-4100 Head-Torso simulator, so that the free field level at the position of the listener, would not exceed 72 dBA (Leq), this way making sure that no Temporary Threshold shift (TTS) effects (57), or any other adverse audiological effects, would aggravate the listener, but also ensuring that sounds presented to the SNHL groups were well above Sensation Level. All 23 stimuli sounds were individual recordings of acoustic and synthetic music instrument sounds, with an approximate time length of 1 second and a frequency of 440Hz. (38).

For the purpose of studying loudness interference in timbre perception, some subjects participated two times, in two different loudness settings with a fixed measured stimuli loudness deviation of 30 dB HL, between tests.

OAEs, Tympanograms and Tympanic reflexes, were measured using the TITAN Interacoustics software, while for PTA thresholds were measured through the Affinity 2.0 AC440, with the use of the Audiometry Keyboard and TDH-39 Overhead Earphone Headset. All results were kept anonymously on the NOAH Link Hospital Databases.

Data Analysis

Epidemiological variables were collected and included age, sex, tinnitus occurrence, prior music training and extent of studies, as well as field of music occupation and group of instruments knowledge. Hearing protection, noise exposure, family history of SNHL, current medications and secondary medical reports, were also documented. Epidemiological variables such as age, sex and prior music training will be analysed, by means of descriptive statistics. Audiometry data were collected at a frequency range of 125Hz to 8kHz, with specific the specific points of 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 measured. DPOAE and TEOAE data included OAE levels, SNR measurements and OAE Detection per frequency examined. Ipsilateral Tympanic reflexes were arranged based on dB threshold of reflex emission.

For this first part of the study, semantic characteristics means will be determined for each group and subgroup. Following this, means for every semantic characteristic will be extracted for every particular subject. Subsequently, a Principal Axis Factoring will take place, which will determine the factor loading scores for every individual subject. An unweighted aggerate of their means will then be used and eventually correlated using Spearman correlation, with the audiological measurements for the groups and subgroups, and specifically PTA scores and DPOAE and TEOAE Levels, as a main focus point. Emphasis will be given on our two mainly compared groups of NH72 and SNHL72.

Results

A total of 24 people, participated in this part of the study, and 23 were appointed to one of the two groups, while one did not meet our inclusion criteria, due to bilateral Type B Tympanograms. 14 people were appointed to the NH group, and timbre perception stimuli loudness level was set at 42 dB HL.10 of them were reexamined at a +30dB stimuli level. 9 people were appointed to SNHL group, 4 of which were tested at a stimuli level of 42dB and 5 were tested at a +30dB level. Only one person that participated in the 42dB level sub group, was reexamined at the +30dB stimuli level, leaving us with 6people in the SNHL72 group. A total of 34 timbre perception trials, took place.

Age measurements follow a normal distribution as shown in Table 1.1, showing a mean age value of 36.26 years. All subject age values fell between the range of 28 to 42 years old (Table 2)

Table 1

Tests of Normality

	Kolmogorov-Smirnov^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Age	.133	23	.200*	.925	23	.086

Table 2

Descriptives

			Statistic	Std. Error
m Age	Mean		36.26	.914
	95% Confidence Interval for Mean	Lower Bound	34.37	
		Upper Bound	38.16	
	5% Trimmed Mean		36.40	
	Median		36.00	
	Variance		19.202	
	Std. Deviation		4.382	
	Minimum		28	
	Maximum		42	
	Range		14	
	Interquartile Range		7	
	Skewness		-.554	.481
	Kurtosis		-.746	.935

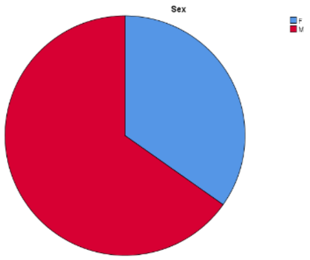


Figure 1

From the total of 23 participants, 8 subjects were Female and 15 were Male.

Reported Tinnitus Data were sorted into 4 categories.

No reported Tinnitus, Bilateral Tinnitus, Right Lateral Tinnitus and finally Left Lateral Tinnitus.

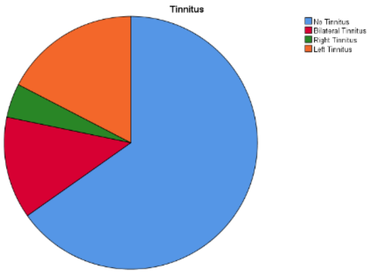


Figure 2

A 65.2% of the subjects reported no tinnitus, whilst a 17.4% reported left lateral tinnitus. 13% of the subjects reportedly had bilateral tinnitus and just a total of 4.3% reported having right lateral tinnitus, making this the most uncommon value among subjects.

Secondary Symptoms that were documented, included Unsteadiness and Dizziness, Migraines, Hypertension, Allergies, Abnormal Thyroid function and at specific cases Panic attacks. Current Medication for the reported symptoms, included benzodiazepines, antidepressants, T4, Corticosteroids and Antihistamines. Although use of psychotropic substances data, could be of potential use, those were not documented in this particular part of the study.

Prior music training was grouped into 3 main subgroups, one that did not report any prior music studies, and two subgroups divided by the level of education, marking the acquired degree in music fields as significant, and non-acquired music degrees as a positive marker to music studies. A 47.8% of the subjects had no previous music training, while a 26.1% reported non music studies and another 26.1% reported significant prior music studies, as shown in Figure 3.

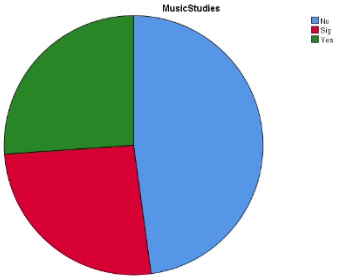


Figure 3

Amongst our subjects, the NH group, reported a family history of SNHL in just 21.4% whilst in our SNHL group family history was reported in a 44.4% of the cases.

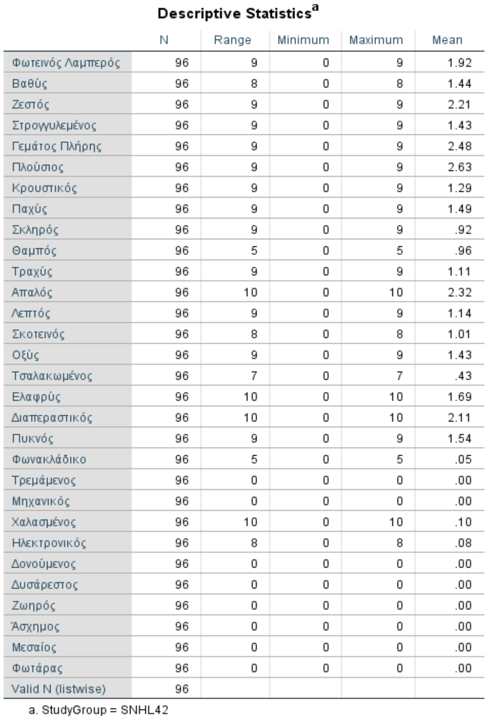
Of our 23 subjects in both groups,7 people, standing for a 30.4% of the cases examined, were never involved into music, with or without music training, whilst the majority of the subjects (16) were associated with music at some point, either by being a musician, a singer, a sound engineer or by multitasking amongst the aforementioned abilities.11 people had no prior music studies, and 12 subjects had previous music studies, with half of them reporting acquired degrees in music fields, leaving us with a 25% of subjects engaged to music at some point in their life with no music studies. At the same time, people who were not actively engaged into music reported using earplugs as a mean of hearing protection in just a 16.7% while all other non-active subjects, did not use any hearing protection. Sadly, amongst active musicians, a significant number still did not use any hearing protection, and if so, earplugs were again the most popular, while only 1 subject reported using both measures of protection, as shown in Table 3.

Hearing Protection[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	4	36.4	36.4	36.4
	Earplugs	4	36.4	36.4	72.7
	In Ear Monitors	2	18.2	18.2	90.9
	Both	1	9.1	9.1	100.0
	Total	11	100.0	100.0	

a. ActiveMusicStatus = Yes

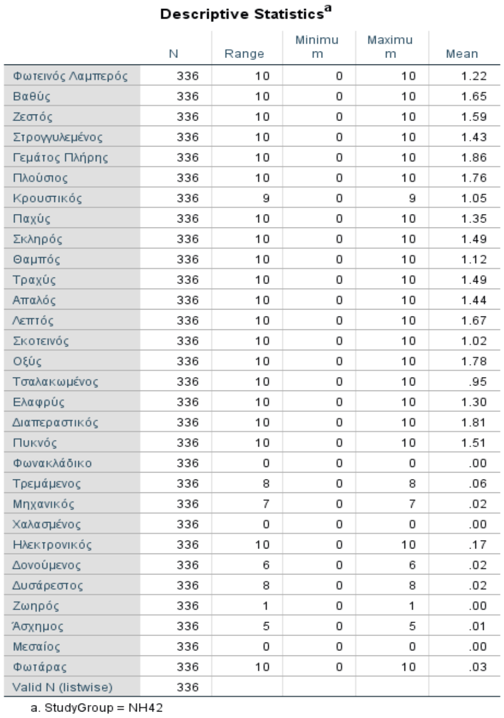
Means of every group and subgroup, for every individual semantic characteristic, were calculated in Tables 4-7 and depicted in Figures 4-7 in the form of error bar charts.



Descriptive Statistics[a]

	N	Range	Minimum	Maximum	Mean
Φωτεινός Λαμπερός	96	9	0	9	1.92
Βαθύς	96	8	0	8	1.44
Ζεστός	96	9	0	9	2.21
Στρογγυλεμένος	96	9	0	9	1.43
Γεμάτος Πλήρης	96	9	0	9	2.48
Πλούσιος	96	9	0	9	2.63
Κρουστικός	96	9	0	9	1.29
Παχύς	96	9	0	9	1.49
Σκληρός	96	9	0	9	.92
Θαμπός	96	5	0	5	.96
Τραχύς	96	9	0	9	1.11
Απαλός	96	10	0	10	2.32
Λεπτός	96	9	0	9	1.14
Σκοτεινός	96	8	0	8	1.01
Οξύς	96	9	0	9	1.43
Τσαλακωμένος	96	7	0	7	.43
Ελαφρύς	96	10	0	10	1.69
Διαπεραστικός	96	10	0	10	2.11
Πυκνός	96	9	0	9	1.54
Φωνακλάδικο	96	5	0	5	.05
Τρεμάμενος	96	0	0	0	.00
Μηχανικός	96	0	0	0	.00
Χαλασμένος	96	10	0	10	.10
Ηλεκτρονικός	96	8	0	8	.08
Δονούμενος	96	0	0	0	.00
Δυσάρεστος	96	0	0	0	.00
Ζωηρός	96	0	0	0	.00
Άσχημος	96	0	0	0	.00
Μεσαίος	96	0	0	0	.00
Φωτάρας	96	0	0	0	.00
Valid N (listwise)	96				

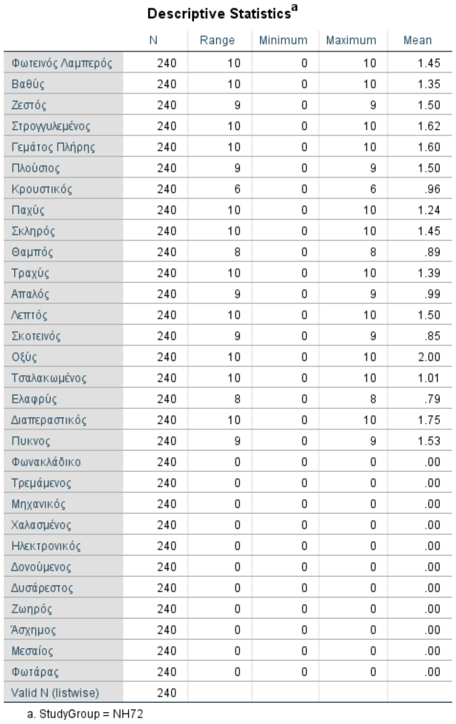
a. StudyGroup = SNHL42



Descriptive Statistics[a]

	N	Range	Minimum	Maximum	Mean
Φωτεινός Λαμπερός	336	10	0	10	1.22
Βαθύς	336	10	0	10	1.65
Ζεστός	336	10	0	10	1.59
Στρογγυλεμένος	336	10	0	10	1.43
Γεμάτος Πλήρης	336	10	0	10	1.86
Πλούσιος	336	10	0	10	1.76
Κρουστικός	336	9	0	9	1.05
Παχύς	336	10	0	10	1.35
Σκληρός	336	10	0	10	1.49
Θαμπός	336	10	0	10	1.12
Τραχύς	336	10	0	10	1.49
Απαλός	336	10	0	10	1.44
Λεπτός	336	10	0	10	1.67
Σκοτεινός	336	10	0	10	1.02
Οξύς	336	10	0	10	1.78
Τσαλακωμένος	336	10	0	10	.95
Ελαφρύς	336	10	0	10	1.30
Διαπεραστικός	336	10	0	10	1.81
Πυκνός	336	10	0	10	1.51
Φωνακλάδικο	336	0	0	0	.00
Τρεμάμενος	336	8	0	8	.06
Μηχανικός	336	7	0	7	.02
Χαλασμένος	336	0	0	0	.00
Ηλεκτρονικός	336	10	0	10	.17
Δονούμενος	336	6	0	6	.02
Δυσάρεστος	336	8	0	8	.02
Ζωηρός	336	1	0	1	.00
Άσχημος	336	5	0	5	.01
Μεσαίος	336	0	0	0	.00
Φωτάρας	336	10	0	10	.03
Valid N (listwise)	336				

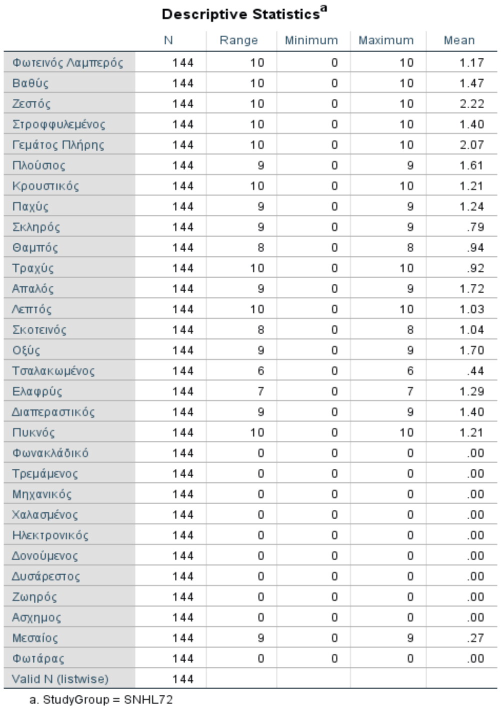
a. StudyGroup = NH42



Descriptive Statistics[a]

	N	Range	Minimum	Maximum	Mean
Φωτεινός Λαμπερός	240	10	0	10	1.45
Βαθύς	240	10	0	10	1.35
Ζεστός	240	9	0	9	1.50
Στρογγυλεμένος	240	10	0	10	1.62
Γεμάτος Πλήρης	240	10	0	10	1.60
Πλούσιος	240	9	0	9	1.50
Κρουστικός	240	6	0	6	.96
Παχύς	240	10	0	10	1.24
Σκληρός	240	10	0	10	1.45
Θαμπός	240	8	0	8	.89
Τραχύς	240	10	0	10	1.39
Απαλός	240	9	0	9	.99
Λεπτός	240	10	0	10	1.50
Σκοτεινός	240	9	0	9	.85
Οξύς	240	10	0	10	2.00
Τσαλακωμένος	240	10	0	10	1.01
Ελαφρύς	240	8	0	8	.79
Διαπεραστικός	240	10	0	10	1.75
Πυκνος	240	9	0	9	1.53
Φωνακλάδικο	240	0	0	0	.00
Τρεμάμενος	240	0	0	0	.00
Μηχανικός	240	0	0	0	.00
Χαλασμένος	240	0	0	0	.00
Ηλεκτρονικός	240	0	0	0	.00
Δονούμενος	240	0	0	0	.00
Δυσάρεστος	240	0	0	0	.00
Ζωηρός	240	0	0	0	.00
Άσχημος	240	0	0	0	.00
Μεσαίος	240	0	0	0	.00
Φωτάρας	240	0	0	0	.00
Valid N (listwise)	240				

a. StudyGroup = NH72



Descriptive Statistics[a]

	N	Range	Minimum	Maximum	Mean
Φωτεινός Λαμπερός	144	10	0	10	1.17
Βαθύς	144	10	0	10	1.47
Ζεστός	144	10	0	10	2.22
Στροφφυλεμένος	144	10	0	10	1.40
Γεμάτος Πλήρης	144	10	0	10	2.07
Πλούσιος	144	9	0	9	1.61
Κρουστικός	144	10	0	10	1.21
Παχύς	144	9	0	9	1.24
Σκληρός	144	9	0	9	.79
Θαμπός	144	8	0	8	.94
Τραχύς	144	10	0	10	.92
Απαλός	144	9	0	9	1.72
Λεπτός	144	10	0	10	1.03
Σκοτεινός	144	8	0	8	1.04
Οξύς	144	9	0	9	1.70
Τσαλακωμένος	144	6	0	6	.44
Ελαφρύς	144	7	0	7	1.29
Διαπεραστικός	144	9	0	9	1.40
Πυκνός	144	10	0	10	1.21
Φωνακλάδικό	144	0	0	0	.00
Τρεμάμενος	144	0	0	0	.00
Μηχανικός	144	0	0	0	.00
Χαλασμένος	144	0	0	0	.00
Ηλεκτρονικός	144	0	0	0	.00
Δονούμενος	144	0	0	0	.00
Δυσάρεστος	144	0	0	0	.00
Ζωηρός	144	0	0	0	.00
Ασχημος	144	0	0	0	.00
Μεσαίος	144	9	0	9	.27
Φωτάρας	144	0	0	0	.00
Valid N (listwise)	144				

a. StudyGroup = SNHL72

Error Bars

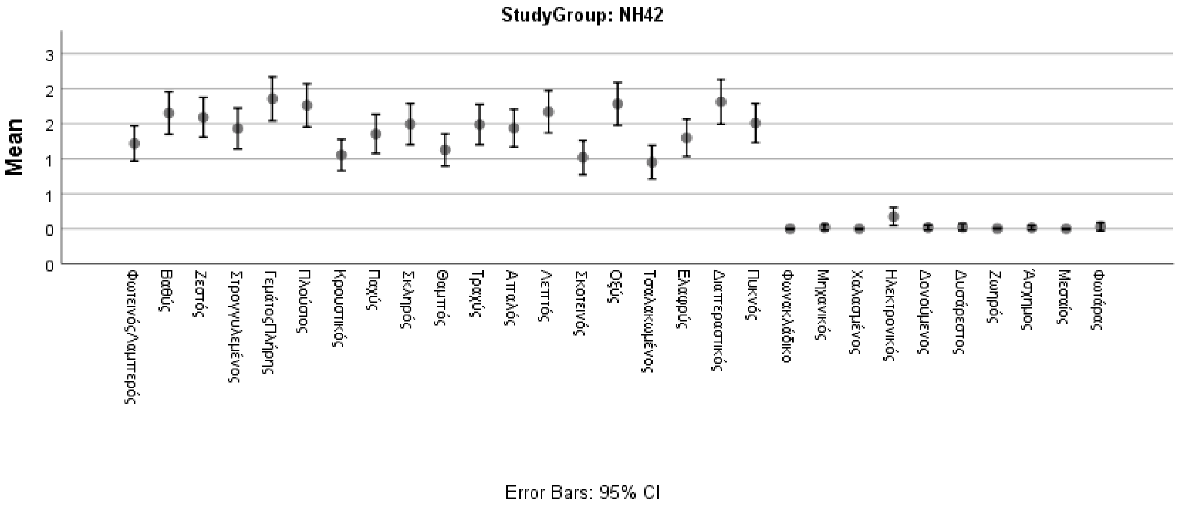


Figure 4

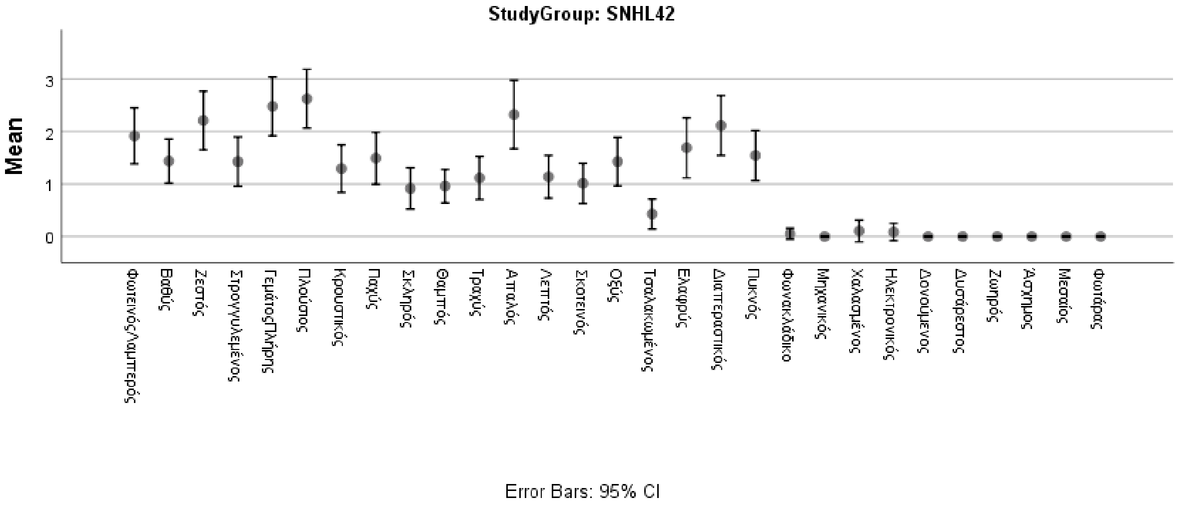


Figure 5

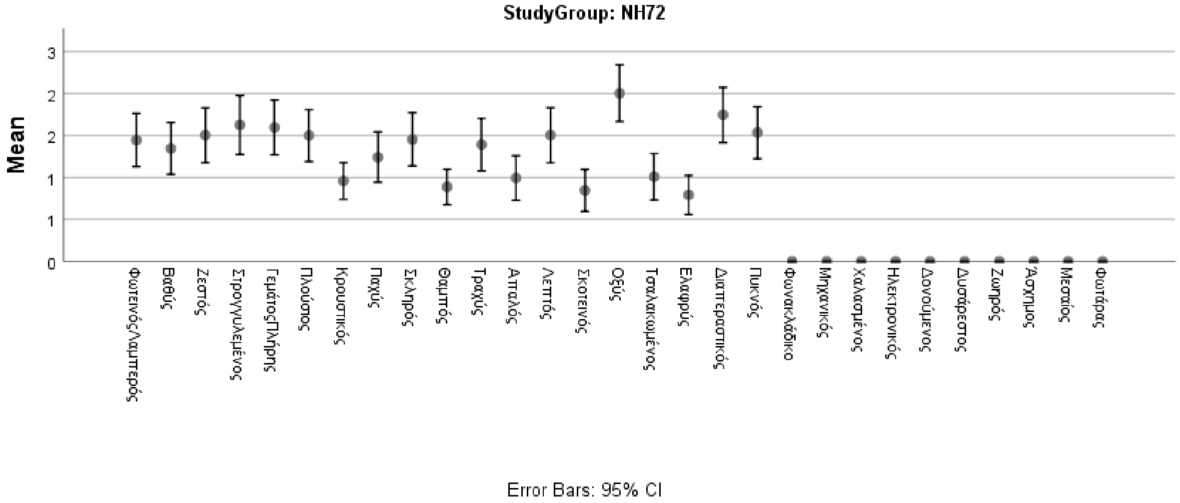


Figure 6

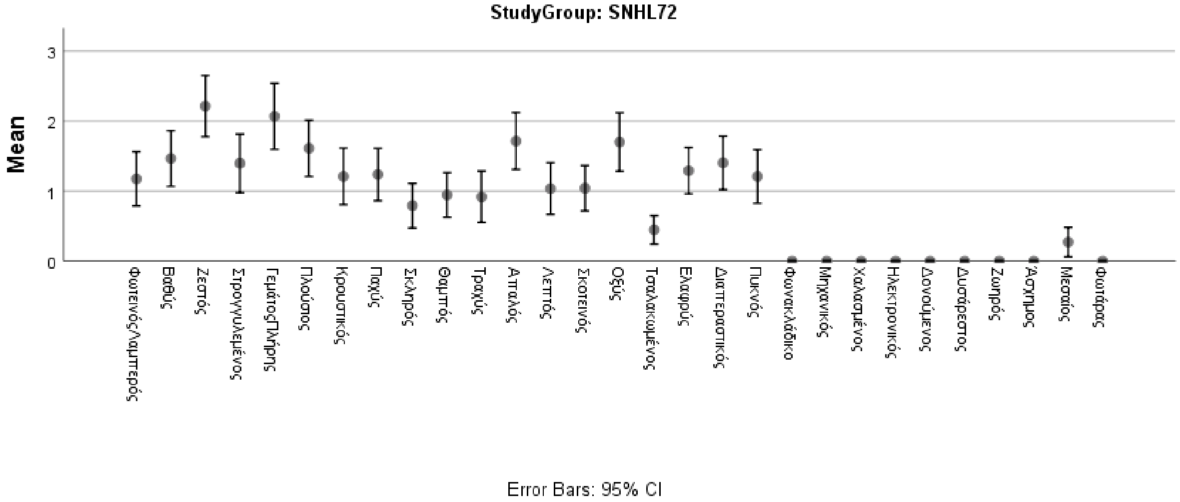


Figure 7

From these tables, we can notice a semantic characteristic choice preservation between the NH and SNHL group, regardless of the presented loudness levels. However mean level differs for the same choices between loudness levels. Most importantly, there are evident differences between groups as, different semantic characteristics were attributed to sounds, for the two main study groups.

Another point of significance which is evident in the data analysis, is that free choices collected the lowest mean scores in general, compared to the given semantic attributions. The last free choice description ‘’Φωτάρας’’ is a particular subject’s sound attribution to a particular musician that held the same instrument and his tone bared resemblance to the wav sound presented.

Means for every semantic attribution on every individual subject were calculated per group and are exhibited on Tables 8.1-8.4 found in the Appendix.

Comparing Means

In order to determine the specific semantic attributions that lead to perception change, we compared groups and subgroups with the one-way ANOVA technique. For the groups NH42dB and SNHL42dB, of statistical significance were Φωτεινός/Λαμπερός, with a p value of (,013), Ζεστός (,047), Πλούσιος (,009) and Απαλός (,004). All perceptional attributions were found greater in the group SNHL42, as there seems to be a significant change in perception due to HL.

Sequentially, we applied the same methods for NH72 and SNHL72 groups and statistical significance was detected in Ζεστός (,010), Σκληρός (,007), Απαλός, (,002), Τσαλακωμένος (,005) and Ελαφρύς (,013). Subjects with HL seem to shift their perception at the particular loudness levels to Ζεστός, Απαλός and Ελαφρύς, and away from Σκληρός and Τσαλακωμένος, compared to their normal hearing counterparts.

For this first two compared groups, of notable importance is the consistency of statistically significant perception changes for Απαλός and Ζεστός, both indicating a perception shift towards them when HL is taken into account.

To continue with, we then examined the test-retest groups, in different loudness situations, in order to determine if loudness is a part of perception shifts, in NH subjects. Απαλός with a p value of ,024 was again found to play a major role, between NH42 and NH72 groups with its mean dropping as overall loudness escalated. For the SNHL42 and SNHL72 groups, however loudness increase, seemed to affect even more semantic attributions. A mean decrease was computed, for Φωτεινός/Λαμπερός (,023), Πλούσιος (,003) and Διαπεραστικός (,034), while a mean increase was detected for the free choice adjective Μεσαίος (,039).

As loudness seems to have an important role in sound perception, especially in HL groups, we took liberty of comparing two groups that varied in both loudness levels and HL, to have a first look into what effects does loudness changes and HL combined have. We compared SNHL42dB and NH72 groups, to find that HL in lower sound levels shift their perception towards Ζεστός (,027), Γεμάτος/Πλήρης (,006), Πλούσιος (<,001), Απαλός (<,001) and Ελαφρύς (,001), and away from Τσαλακωμένος (,016).

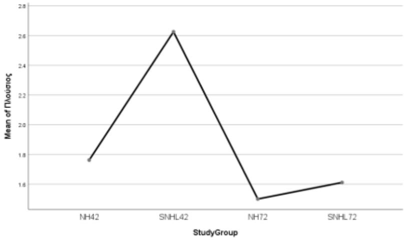


Figure 8

In order to try and explain the question on whether loudness, HL, or a combination are to be held responsible about perception shifts found in our results, we indicatively look on two variables. Πλούσιος, was found to be significantly different in both NH42-SNHL42 and SNHL42-SNHL72 tests, which points to the fact that maybe loudness combined with HL have a stronger effects, and that is why changes are not evident in normal hearing subjects, following a loudness change, thus for particular semantic attributions, the combined effects is much greater, and cannot be easily determined.

However, if we look at Figure 9, The effect of Απαλός, is more consistent in HL groups, but does also have a significant effect detected based only on loudness changes in normal hearing, pointing towards a dynamic relation between hearing loss and sound presentation loudness levels, regarding timbre perception

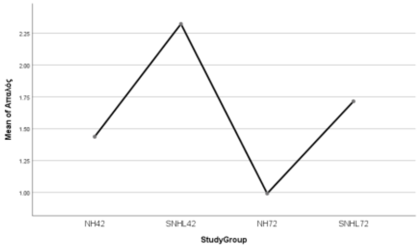
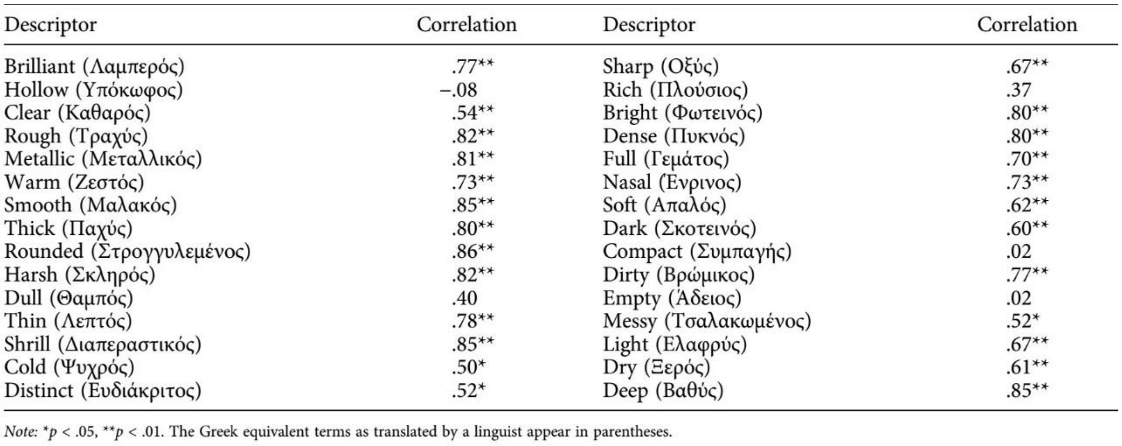


Figure 9

At this point, following the work of Zacharakis, Pastiadis, Reiss (38), we include a table for the English language correlated equivalents, for the semantic attribution in our study.

Table 9



Descriptor	Correlation	Descriptor	Correlation
Brilliant (Λαμπερός)	.77**	Sharp (Οξύς)	.67**
Hollow (Υπόκωφος)	−.08	Rich (Πλούσιος)	.37
Clear (Καθαρός)	.54**	Bright (Φωτεινός)	.80**
Rough (Τραχύς)	.82**	Dense (Πυκνός)	.80**
Metallic (Μεταλλικός)	.81**	Full (Γεμάτος)	.70**
Warm (Ζεστός)	.73**	Nasal (Ενρινος)	.73**
Smooth (Μαλακός)	.85**	Soft (Απαλός)	.62**
Thick (Παχύς)	.80**	Dark (Σκοτεινός)	.60**
Rounded (Στρογγυλεμένος)	.86**	Compact (Συμπαγής)	.02
Harsh (Σκληρός)	.82**	Dirty (Βρώμικος)	.77**
Dull (Θαμπός)	.40	Empty (Άδειος)	.02
Thin (Λεπτός)	.78**	Messy (Τσαλακωμένος)	.52*
Shrill (Διαπεραστικός)	.85**	Light (Ελαφρύς)	.67**
Cold (Ψυχρός)	.50*	Dry (Ξερός)	.61**
Distinct (Ευδιάκριτος)	.52*	Deep (Βαθύς)	.85**

Note: *$p < .05$, **$p < .01$. The Greek equivalent terms as translated by a linguist appear in parentheses.

Principal Axis Factoring

Dimension reduction strategies (PFA) were used to determine principal factors for each group and subgroup with Bartlett's test showing significance for all results. Three main factorσs were extracted for each subgroup, consisting of semantic attributions for each factor. Coefficient values less than 0.40 were supressed in order to have a better understanding of the main coefficients for each factor. Oblique rotation was used (Direct oblimin), and the number of factors was set to 4, in reference with and accordance to the scree plot. Loadings of more than 0,54 were included in our principal factors.

For the first group with the Label NH 42dB the first component stood for 23.052% of the values whilst the 2nd stood for 19.229% the 3rd for 11.606% and the 4th for 6.470%. The pattern matrix, revealed the four main factors being the following

Table 10-NH42 Factors

Factor 1	Γεμάτος/Πλήρης, Πλούσιος, Πυκνός, Ζεστός, Στρογγυλεμένος, Παχύς, Βαθύς
Factor 2	Σκληρός, Τραχύς, Οξύς/Διαπεραστικός, Τσαλακωμένος
Factor 3	Ελαφρύς, Απαλός, Λεπτός
Factor 4	Θαμπός and negatively with Φωτεινός/Λαμπερός

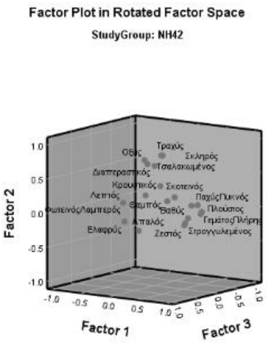


Figure 10

The second group was the SNHL42 dB subgroup, where the first factor, stood for 35,799% of values whilst the 2nd for 17,942% the third for 11,496% and the 4th for 6.278% of the values.

The 4 principal factors consisted of

Table 11-SNHL42 Factors

Factor 1	Παχύς, Στρογγυλεμένος, Γεμάτος/Πλήρης, Πλούσιος, Πυκνός and negatively with Λεπτός
Factor 2	Σκληρός, Τραχύς, Τσαλακωμένος, Οξύς
Factor 3	Φωτεινός/Λαμπερός, Διαπεραστικός, Ελαφρύς,
Factor 4	Σκοτεινός, Ζεστός

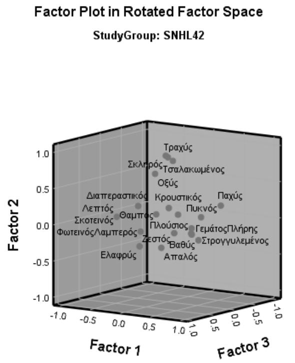


Figure 11

The third group, which was the retested 1st group on a different loudness level, of 72 dB, exhibited a 27,260% for the first factor, a 17,340% for the second, a 11,453 for the third and a 5,936% for the 4th. Factors were determined as follows

Table 12-NH72 Factors

Factor 1	Πλούσιος, Γεμάτος/Πλήρης, Ζεστός, Στρογγυλεμένος, Πυκνός
Factor 2	Διαπεραστικός, Οξύς, Σκληρός, Τραχύς, Λεπτός, Τσαλακωμένος
Factor 3	Negatively with both Ελαφρύς and Απαλός
Factor 4	Παχύς, Σκοτεινός, Θαμπός

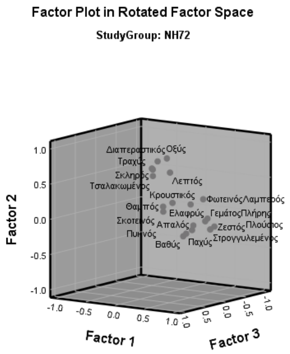


Figure 12

The last group, consisted of some retested SNHL subjects and some first time examined subjects with SNHL, at the level of 72dB. The first factor stood for 20,816%, the 2nd for 13.047% and the third for 10,715%, while the 4th for 6.672% determining the four factors consisting of

Table 13-SNHL72 Factors

Factor 1	Πλούσιος, Στρογγυλεμένος, Ζεστός
Factor 2	Σκληρός and negatively with Ελαφρύς
Factor 3	Διαπεραστικός, Οξύς, Λεπτός
Factor 4	Παχύς, Βαθύς, Πυκνός

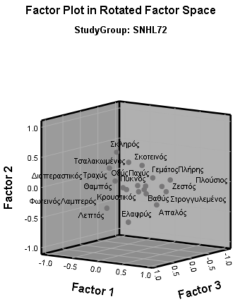


Figure 13

Correlations

Unweighted factor means per subject, were used to perform Spearman correlations with the audiological characteristics of each group. Results were calculated for PTA thresholds, DP and TE OAE Levels, for both ears, and the point of statistical significance will be exhibited below. It is noted that factor correlation values are exhibited in an ascending numeric order.

Note for all tables that:

*correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

For the first group (NH42), were we had a significant number of subjects, PTA results revealed strong correlations for all factors for both ears at frequencies 500-1000Hz.

Table 14-PTA Correlations NH42

	Factors	1	2	3	4
AudiogramRight500	Correlation Coefficient	.782**	.841**	.737**	.635*
	Sig. (2-tailed)	.001	.000	.003	.015
	N	14	14	14	14

AudiogramRight1000	Correlation Coefficient	.671**	.810**	.775**	.498
	Sig. (2-tailed)	.009	.000	.001	.070
	N	14	14	14	14
AudiogramLeft1000	Correlation Coefficient	.561*	.708**	.386	.432
	Sig. (2-tailed)	.037	.005	.173	.123
	N	14	14	14	14

Interestingly, the correlations for 500Hz in the Right ear, did not correspond to statistically significant correlations in the left ear.

Since positive correlations were made for our factors for PTA thresholds, we would expect negative correlations for our DP Levels, since threshold increase has a counter effect to DP levels increase, which would actually possibly describe, a healthier hearing system.

This is indeed the case, as shown in our DP levels results

Table 15-DPLevels NH42

	Factors	1	2	3	4
DPLevel1000Right	Correlation Coefficient	-.425	-.733**	-.359	-.522
	Sig. (2-tailed)	.130	.003	.207	.056
	N	14	14	14	14
DPLevel1000Left	Correlation Coefficient	-.345	-.613*	-.292	-.613*
	Sig. (2-tailed)	.227	.020	.311	.020
	N	14	14	14	14
DPLevel1500Left	Correlation Coefficient	-.354	-.538*	-.248	-.530
	Sig. (2-tailed)	.215	.047	.392	.051
	N	14	14	14	14

Our most strong correlations seem to be with our second factor, which was Texture. higher PTA thresholds at around 1000Hz, but unfortunately at 42dB, TEOAE levels did not support the correlation validity, and in addition to this, scattered factor correlations, not consistent through cross test validation, or right and left ear occurrence, seem to blur our understanding of the results.

Moreover, our SNHL42 group, showed no correlations of statistical significance to any audiological features, most possibly due to the fact that the sample size was extremely small (4 subjects).

Low loudness levels seem to murk sound timbre perception, thus being possibly also accountable for the mixed results in our 1st NH42 group. It is noted that the two groups of 42dB should be revisited, with larger sample sizes and using weighted coefficient aggerates, by means and for reasons we will describe in the discussion section.

Regarding our main groups at loudness level of 72 dB, results bare an enriched resemblance to our NH42 group, showing strong correlation values at frequencies 500 and 1000Hz, but this time with most of our factors.

Table 16-PTA NH72

	Factors	1	2	3	4
AudiogramRight500	Correlation Coefficient	.895**	.811**	-.357	.798**

	Sig. (2-tailed)	.000	.004	.311	.006
	N	10	10	10	10
AudiogramRight1000	Correlation Coefficient	.885**	.840**	-.436	.931**
	Sig. (2-tailed)	.001	.002	.208	.000
	N	10	10	10	10
AudiogramLeft1000	Correlation Coefficient	.696*	.696*	-.261	.609
	Sig. (2-tailed)	.025	.025	.466	.062
	N	10	10	10	10

DP levels, interestingly did not support our PTA threshold correlations, but seem to agree significance with our 1st, Mass factor, with negative correlations at 1500 Hz bilaterally.

Table 17-DPLevels NH72

	Factors	1
DPLevel1500Right	Correlation Coefficient	-.636*
	Sig. (2-tailed)	.048
	N	10
	Factors	1
DPLevel1500Left	Correlation Coefficient	-.770**
	Sig. (2-tailed)	.009
	N	10

Notably, significant differences were located at 8 and 9kHz, concerning our first factor, but this time positively correlated.

Table 18-DPLevels NH72

	Factors	1
DPLevel8000Right	Correlation Coefficient	.766**
	Sig. (2-tailed)	.010
	N	10
DPLevel9000Right	Correlation Coefficient	.806**
	Sig. (2-tailed)	.005
	N	10

TEOAE Level, did not verify our DP Level correlations but both TEOAE Levels and DPSNR values, did exhibit related factor correlations to our significant correlations, with high presentation values, however not found as statistically significant possibly due to low sample sizes. Other statistically significant correlations were found in our DPSNR and TEOAE correlations, but were scattered and not bilaterally validated, for the normal hearing, although bilateral values were high at the same frequencies bilaterally.

Quite importantly, tympanic reflex thresholds, show no significant correlations with timbre perception up to this point, for the already tested groups.

Our last group, SNHL72, was consisted of a sample size of 6. Thresholds exhibited lack of variance and tended towards solely high frequency HL and notches.

Table 19-PTA SNHL72

	Factors	1	2	3	4
AudiogramRight3000	Correlation Coefficient	.261	-.986**	-.377	.174
	Sig. (2-tailed)	.618	.000	.461	.742
	N	6	6	6	6
AudiogramLeft3000	Correlation Coefficient	-.029	-.943**	-.429	-.086
	Sig. (2-tailed)	.957	.005	.397	.872
	N	6	6	6	6

A strong correlation was found for our second factor in PTA thresholds for the 3000Hz frequency, with a negative correlation, fact supported by our DP Level correlation and extended to 4000Hz, although not located bilaterally with statistical significance.

Table 20-DPLevels SNHL72

	Factors	1	2	3	4
DPLevel3000Right	Correlation Coefficient	.029	.771	.257	.200
	Sig. (2-tailed)	.957	.072	.623	.704
	N	6	6	6	6
DPLevel3000Left	Correlation Coefficient	-.200	.886*	.200	-.086
	Sig. (2-tailed)	.704	.019	.704	.872
	N	6	6	6	6
DPLevel4000Left	Correlation Coefficient	.029	.943**	.429	.086
	Sig. (2-tailed)	.957	.005	.397	.872
	N	6	6	6	6

DP level correlations for the 2nd factor, were validated from TEOAE correlation values, regarding the approximate frequency of 4kHz, displaying a robust correlation, evident in correlations int his frequency range, for any audiometric test measure.

Table 21-TELevels SNHL72

	Factors	1	2	3	4
TELevel3970Right	Correlation Coefficient	.143	.829*	.657	.314
	Sig. (2-tailed)	.787	.042	.156	.544
	N	6	6	6	6
TELevel3970Left	Correlation Coefficient	.029	.829*	.771	.086
	Sig. (2-tailed)	.957	.042	.072	.872
	N	6	6	6	6

Interestingly so, we should mention that TESNR correlation values were also significantly important, for the particular frequency, bilaterally, but for our 3rd factor, which however also described Texture, as our 2nd aforementioned factor, located in previous SNHL72 correlations. For this particular group Tympanic reflexes at the same frequency agreed on a significant correlation at the 4kHz frequency, for the 2nd factor, but only unilaterally. It should be noted that the correlation value was negative, which indicates that threshold measurements in general are inversely affiliated with Level measurements, as would be expected, but also might suggest that reflexes, can actually be a correlation reference, for measured sounds of certain loudness.

Table 22-Reflex Ipsilateral SNHL72

	Factors	1	2	3	4
Reflexipsi4000Right	Correlation Coefficient	.000	-.956**	-.478	.000
	Sig. (2-tailed)	1.000	.003	.338	1.000
	N	6	6	6	6

Discussion

Following our semantic attribution analysis, many interesting perception shifts were noted, from our Normal Hearing to SNHL groups, showing sensitivity and variance through different stimuli loudness levels. When taking semantic representation mean results per group, into account, an in-group choice preservation is noticed for a numerous amount of adjectives. NH groups, regardless of the loudness levels, seemed to agree on specific characteristics that described fullness, richness and generally were related to the body characterization of a sound. (Γεμάτος/Πλήρης, Πλούσιος, Στρογγυλεμένος,). Secondly, we can also notice a rise in means in the NH72 group compared to NH42 one, for shrillness and sharpness (Οξύς, Διαπεραστικός), as far as perception is concerned. The previous characteristics that described sound fullness, exhibited a small drop in means inversely related to loudness.

Our four groups were compared using ANOVA, to determine which of the previous results would be statistically significant among groups. For the NH groups, Soft with a p value of ,024 was the most sensitive to loudness presentation levels, inversely associated with loudness increase. In the SNHL groups, loudness increase seemed to have a greater effect, affecting means for much more semantic representations, such as Brightness, Richness and Shrillness, all of which decreased with loudness increase. Although small sample sizes in both SNHL groups, could severely impair results, we can notice the same semantic attribute mean fluctuation, but in a greater extent than the NH group, results that imply a magnification of effects in timbre perception, with loudness changes, but also validates the findings in our NH group, as both NH and SNHL groups, tend to describe sounds mainly with the same set of adjectives, mentioned above.

Cross group comparisons revealed significant changes in timbre perception for Brightness, Warmth, Richness and Softness for the 42 dB NH-SNHL group comparison. For the 72dB NH-SNHL group comparison, Warmth, Softness, Roughness and Lightness, all seemed to be significantly different, with softness presenting a p value of ,002, and subjects with HL shifting their attention towards Warmth, Softness and Lightness, and away from Rough and messy characterizations of sounds.

Interestingly Softness seemed to play a major part in loudness increase for the NH group, but also seemed to have an effect when HL was present. Our results suggest that overall, subjects with HL tend to characterize sounds as softer and lighter than their NH counterparts. Effects in timbre perception for NH and SNHL groups, are not only significant but also tend to be enhanced by the changes in loudness presentation, suggesting that Loudness and Timbre are at least two dynamically correlated entities, if not a single multidimensional unity.

Results from our dimension reduction with Principal Axis Factoring determine 4 major factors.

Our first major factor, seems to consistently describe fullness and space occupation among groups, therefore and in accordance to previous research on the subject (38,39) where the Luminance, Texture, Mass model (LTM) was proposed, Mass seems to be the most accurate descriptor for our principal factor.

However, although our second factor, also consistent among groups had semantic attributions that could propose Texture as a main descriptor, Weight was also a key feature in our semantic characterizations, not found in our loadings along with Mass, which would explain Texture as an independent entity. Therefore, we could propose Touch or Consistency, as an overall descriptor of Texture and Weight. However, given the fact that weight was a small factor part, and given that it can also possibly be described by Texture, we will have to look at our results when significantly more subjects are measured, in order to decide. Our third and for principal factors seemed to have variations amongst groups, other times presenting itself as the opposite of our first or second factor, and other times describing Visual characteristics, such as deep, dark, or dull and negatively correlated with brightness. Therefore, although Luminance could be accounted for some of our adjective descriptions, there is a part of semantic attributions that describe visual characteristics not defined by luminance, but overall sense of sight in space or overall Transparency and Opacity (clarity vs murkiness). That is why we would propose an alternative, broader descriptor, which would be Vision. To conclude with we eventually propose the model MTV, to incorporate previous findings on the subject, broadening its description capability, pointing towards a sensory oriented perception model.

Summing our factors for the first NH42group we would find: 1. Mass (fullness) 2. Texture (thin and edgy) 3. Texture (soft and thin) 4. Vision (opacity)

For our SNHL42 group, due to our small sample (4 subjects), although our factors fall into our general factor categories MTV, we only consider our first principal factor Mass to be of importance, while our other factors, share a mixture of Texture and Visual characteristics.

For our 3rd major group NH72, our main factors are 1. Mass (fulness) 2. Texture (thin and edgy) 3. Texture (rough and heavy) and 4. Vision (opacity)

Our last group SNHL72, presented factor interpretation as follows: 1. Mass (fulness) 2. Texture (rough and heavy) 3. Texture (thin and edgy) and 4. Vision (opacity).

It is obvious from our analysis that Mean comparing and PAF results, tend to describe the same semantic attributions as significant, but not in a consistent manner. Texture describing adjectives, tend to appear statistically more significant in our mean comparisons, but Mass factor seems to arise as the most robust in our PAF results. This could be attributed to the fact that even though, Mass descriptors presented high coefficient loadings, in our PAF small sample sizes did not manage to make our results statistically significant, whereas Texture descriptors were consistently found significant, in our mean comparisons and our PAF results. We can confidently however support, that Mass was our main factor, with some significant results spotted in our mean comparisons.

Another emerging point of importance, other than sample size, seemed to be unweighted coefficients. Since we would expect opposite descriptors such as Bright and Dark, to be strongly negatively correlated, but negative correlations in our correlation matrix were evident but weak, we had to look into the measurements of our subjects. Since means were used for every subject, we noticed that for many subjects, values close to zero or 0 values were to be held accountable. It seems that since 0 value for a descriptor, was the easy go to answer, when someone judged an adjective as irrelevant, means tended to cancel each other out or stand close to 0, if both opposites were judged as irrelevant, not giving us the magnitude of negative correlations, we would expect for opposite adjectives, decreasing validity and moreover weakening our correlation coefficients and their possible statistical significance. Therefore, it seems mandatory to propose a weighted coefficient for our factors' mean aggerates, based on the differentiation between two groups of subjects. One that would consider some adjectives as irrelevant to timbre description, scoring 0 values, and another that considers the adjective relevant. A weighted value for our coefficients would be computed, based on each group's overall percentage, giving us stronger coefficients and significance, overcoming the 0-value issue.

We then correlated the mean loading per subject, to their audiological results, based on groups. For our NH42 group, significant positive correlations were presented for all factors at frequency 500, for our first two factors at 1000 for the PTA threshold results. However not all results were located bilaterally, except the 1000Hz correlation with our second factor, Texture, fact supported by our DP Level negative correlations.

However, TEOAEs Levels did not cross validate our outcomes, at 42 dB, but exhibited scattered significant correlations, not bilaterally consistent or located in our previous group results.

Our second group, SNHL42, unfortunately could not present almost any results, due to extremely low sample size.

The 3rd group, the retested, NH42 subjects at the 72dB loudness levels, presented with almost the same outcomes when correlated to their PTA results, with the 42dB group. Mostly our two main factors were significantly and positively correlated with 500 and 1000Hz, with the 1kHz frequency bilaterally validated. DP levels however were negatively correlated at 1500Hz, with our first, Mass factor. Another point of interest in this group, is that significant positive correlations were evident in 8 and 9 kHz, for our 1st Factor, unfortunately unilaterally. This would imply that, if PTA threshold correlations were taken into account, Mass, or in other words, sound fullness, is positively correlated with better hearing at high frequencies, and negatively correlated with better hearing at low frequencies for the normal hearing population, thus low-mid and high frequencies are inversely correlated for Mass perception, fact that is more evident with an increase in loudness, and supports our hypothesis, of loudness being a magnifying factor for our perception. Although TEOAE levels, did not support our outcomes with statistical significance, high correlation scores, were measured at the same frequencies with our more robust PTA and DP level correlations. This would again suggest that larger sample sizes, will probably give us statistical significance in the future, cross validating our results.

For our last Group, SNHL72, although sample size was again small, significant negative correlations of 3000Hz with our Texture factor were found in our PTA thresholds, and supported by our DP Level for the nearby frequency of 4kHz, which would mean that better thresholds at this frequency range would suggest a lighter, less harsh perception of sound for the SNHL72 group. TEOAE Levels confirm our outcomes, and for the first time interestingly so, so did Tympanic Ipsilateral Reflexes.

DP and TESNRs, did not appear to be particularly sensitive, in order to determine correlations for sound perceptions, at this point, and in general, so did Tympanic reflexes, which remains to be determined in the future progress of this research.

Audiological results do support our two main factors, Mass and Texture, importance, but also our loudness effect magnification for the computed principal factors. Significant differences in sound perception have been found, both for our comparison between normal hearing subjects and subjects with HL and Loudness presentation levels. It is also evident that we would need larger samples and weighted coefficients, in order to achieve better understanding, for both audiometric correlations and semantic attributions per group. We should also take under consideration the possible adjective choice bias, for our Normal hearing groups, as the same people took part in both groups, thus perception could have been set, explaining low results in significant mean differences between the two groups, but however also validating the reason we believe that loudness has a magnification factor on timbre perception.

Lastly, perception results, and perception shifts through loudness levels, or because of HL, should be also studied on individual music instrument acoustic properties, in order to understand the physical sound characteristics that contribute towards the particular shifts. Finally, we would have to take into account that not only our SNHL sample size was insufficient, but also showed not particular fluctuations, other than high frequency loss, and high frequency notches, which is probably an important alleviating factor for our results.

Last but not least, from the confined number of previous research on timbre perception in HL (55,56), we must consider differentiating timbre discrimination research to timbre perception, as subjects with HL that correctly identify music instruments, still seem to rely on different factors, and most importantly, have different perceptual inclinations about the given music sounds, even though they do reach to the same identification conclusion. This could only make us, finally question whether identification and perception are the same thing, or if they stand independently, with timbre perception being a founding contributor, to later identification, and loudness acting as a perception regulator, but not baring the same direct magnitude effect for instrument identification.

Conclusion

This research, signs the beginning of a study that has the possibility to determine specific changes in timbre perception in SNHL population, and question the fact that timbre stand independently as far as perception is concerned, against loudness.

Our outcomes suggest that changes in loudness seem to alter, and mainly magnify timbre perception’s semantic attributions, especially for the SNHL groups. In addition to this, Hearing loss does seem to have an effect on timbre perception, whether this effect is perception concentration shifting towards

other main factors, or generally, altered whatsoever. Our results comply with previous research on the matter, of timbre being able to be described mainly by the factors Mass, and Texture (38,39), and moreover suggest that Vision, opacity or lack thereof, can be appointed as a new extended factor of previous Luminance, suggesting the model MTV, for the semantic representations of timbre perception.
In accordance to previous research on Timbre perception in HL (55), intensity seems to be an important factor for perception, magnifying results in means, Especially for SNHL subjects, decreasing the perceptive qualities chosen in low intensity levels, and affecting a great number of them.

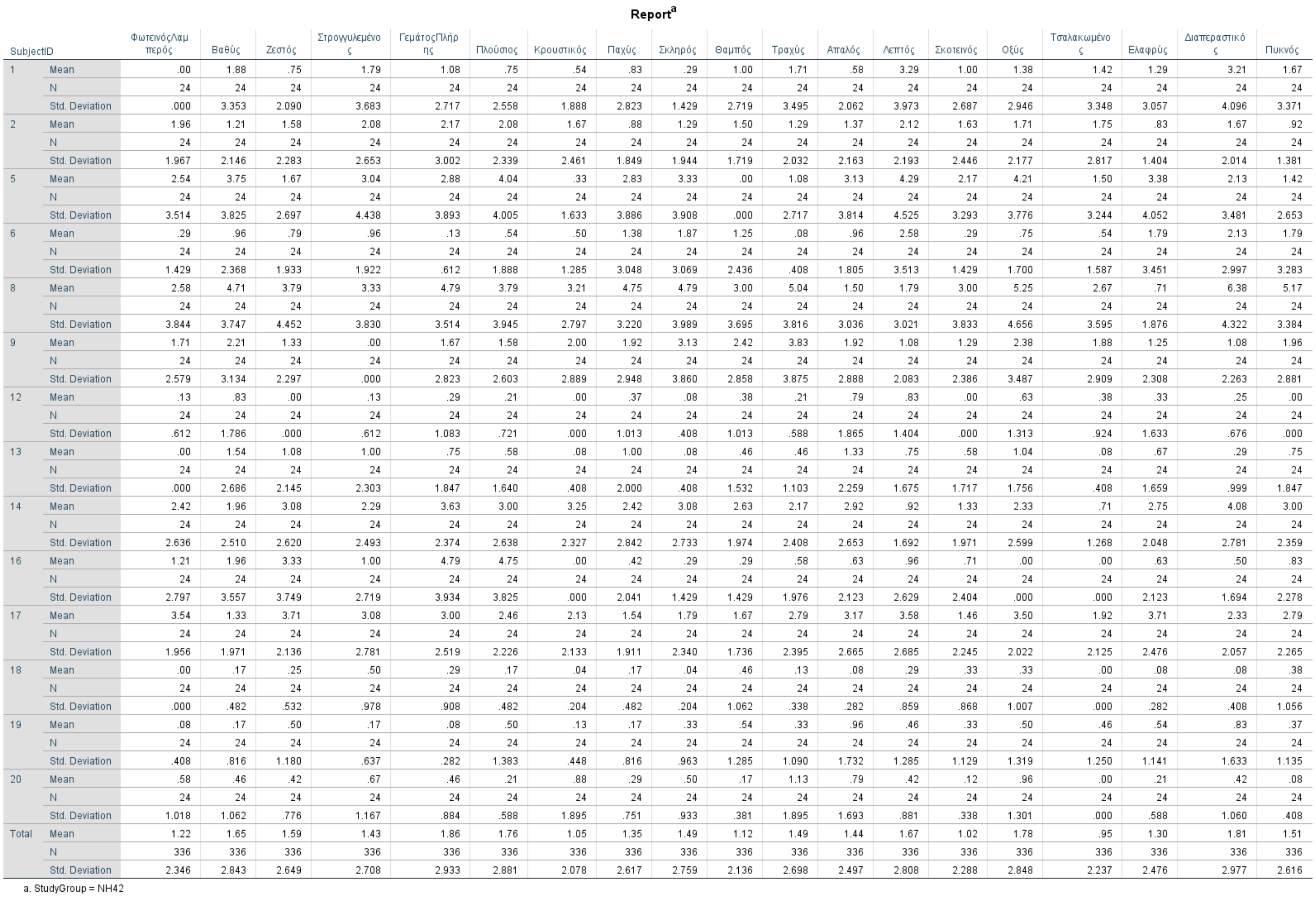
PTA threshold levels and DPOAE amplitudes, seems to display sensitivity, and can be correlated with our perception results, more than TEOAEs and Reflexes, measures for which their significance, remains to be determined in the progress of this study. The main factors that appear to be most important seem to be our first two main factors, as already suggested, Mass and Texture.

Audiometric result correlations could also suggest the perception of timbre relying on other frequencies for our NH groups compared to our SNHL subjects, as factors like Mass emergingly seemed to be dependent on certain frequencies positively, and their opposite counterpart frequencies positively (low to high), supporting the idea that timbre perception is a fluctuating mechanism that could contribute in timbre perception compensation.

We conclude that, our results tend to show interesting audiological correlation outcomes, and cross group comparisons do support the perception shifts we described, but possibly need larger sample sizes, audiometric result variety for our SNHL group and weighted mean coefficient values, in order to have robust results, as well as inclusion of many variables, such as music education, noise exposure and other related data collected, that were not put to use at this point of the study.

Our future progress on this research will incorporate dissimilarity perception test results, in order to draw greater conclusion on their relation with timbre perception compared to semantic judgments.

Appendix

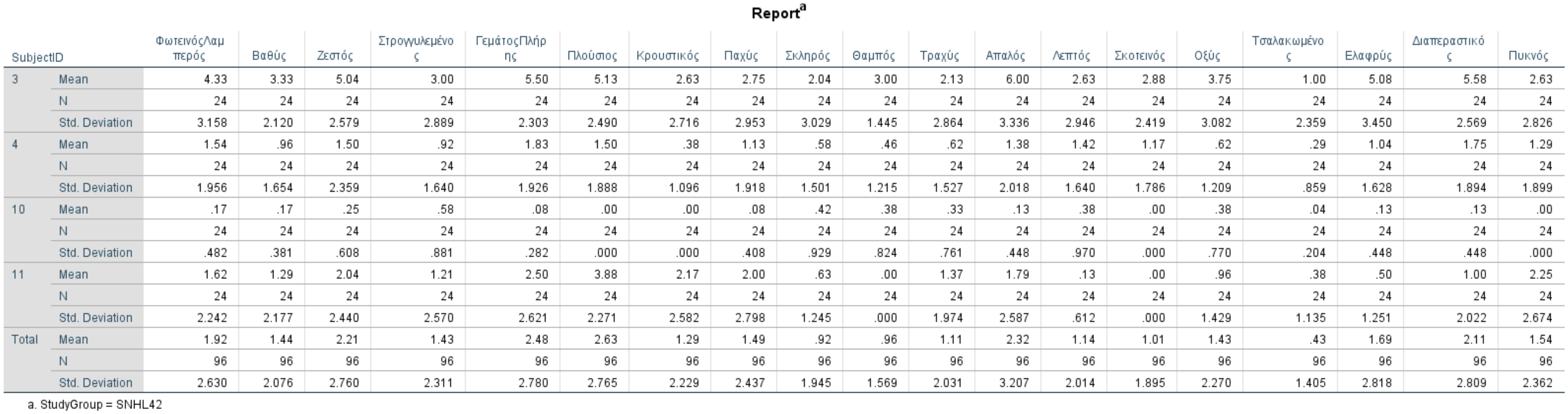


Report[a]

SubjectID		ΦωτεινόςΛαμπερός	Βαθύς	Ζεστός	Στρογγυλεμένος	ΓεμάτοςΠλήρης	Πλούσιος	Κρουστικός	Παχύς	Σκληρός	Θαμπός	Τραχύς	Απαλός	Λεπτός	Σκοτεινός	Οξύς	Τσαλακωμένος	Ελαφρύς	Διαπεραστικός	Πυκνός
1	Mean	.00	1.88	.75	1.79	1.08	.75	.54	.83	.29	1.00	1.71	.58	3.29	1.00	1.38	1.42	1.29	3.21	1.67
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.000	3.353	2.090	3.683	2.717	2.558	1.888	2.823	1.429	2.719	3.495	2.062	3.973	2.687	2.946	3.348	3.057	4.096	3.371
2	Mean	1.96	1.21	1.58	2.08	2.17	2.08	1.67	.88	1.29	1.50	1.29	1.37	2.12	1.63	1.71	1.75	.83	1.67	.92
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.967	2.146	2.283	2.653	3.002	2.339	2.461	1.849	1.944	1.719	2.032	2.163	2.193	2.446	2.177	2.817	1.404	2.014	1.381
5	Mean	2.54	3.75	1.67	3.04	2.88	4.04	.33	2.83	3.33	.00	1.08	3.13	4.29	2.17	4.21	1.50	3.38	2.13	1.42
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.514	3.825	2.697	4.438	3.893	4.005	1.633	3.886	3.908	.000	2.717	3.814	4.525	3.293	3.776	3.244	4.052	3.481	2.653
6	Mean	.29	.96	.79	.96	.13	.54	.50	1.38	1.87	1.25	.08	.96	2.58	.29	.75	.54	1.79	2.13	1.79
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.429	2.368	1.933	1.922	.612	1.888	1.285	3.048	3.069	2.436	.408	1.805	3.513	1.429	1.700	1.587	3.451	2.997	3.283
8	Mean	2.58	4.71	3.79	3.33	4.79	3.79	3.21	4.75	4.79	3.00	5.04	1.50	1.79	3.00	5.25	2.67	.71	6.38	5.17
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.844	3.747	4.452	3.830	3.514	3.945	2.797	3.220	3.989	3.695	3.816	3.036	3.021	3.833	4.656	3.595	1.876	4.322	3.384
9	Mean	1.71	2.21	1.33	.00	1.67	1.58	2.00	1.92	3.13	2.42	3.83	1.92	1.08	1.29	2.38	1.88	1.25	1.08	1.96
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.579	3.134	2.297	.000	2.823	2.603	2.889	2.948	3.860	2.858	3.875	2.888	2.083	2.386	3.487	2.909	2.308	2.263	2.881
12	Mean	.13	.83	.00	.13	.29	.21	.00	.37	.08	.38	.21	.79	.83	.00	.63	.38	.33	.25	.00
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.612	1.786	.000	.612	1.083	.721	.000	1.013	.408	1.013	.588	1.865	1.404	.000	1.313	.924	1.633	.676	.000
13	Mean	.00	1.54	1.08	1.00	.75	.58	.08	1.00	.08	.46	.46	1.33	.75	.58	1.04	.08	.67	.29	.75
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.000	2.686	2.145	2.303	1.847	1.640	.408	2.000	.408	1.532	1.103	2.259	1.675	1.717	1.756	.408	1.659	.999	1.847
14	Mean	2.42	1.96	3.08	2.29	3.63	3.00	3.25	2.42	3.08	2.63	2.17	2.92	.92	1.33	2.33	.71	2.75	4.08	3.00
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.636	2.510	2.620	2.493	2.374	2.638	2.327	2.842	2.733	1.974	2.408	2.653	1.692	1.971	2.599	1.268	2.048	2.781	2.359
16	Mean	1.21	1.96	3.33	1.00	4.79	4.75	.00	.42	.29	.29	.58	.63	.96	.71	.00	.00	.63	.50	.83
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.797	3.557	3.749	2.719	3.934	3.825	.000	2.041	1.429	1.429	1.976	2.123	2.629	2.404	.000	.000	2.123	1.694	2.278
17	Mean	3.54	1.33	3.71	3.08	3.00	2.46	2.13	1.54	1.79	1.67	2.79	3.17	3.58	1.46	3.50	1.92	3.71	2.33	2.79
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.956	1.971	2.136	2.781	2.519	2.226	2.133	1.911	2.340	1.736	2.395	2.665	2.685	2.245	2.022	2.125	2.476	2.057	2.265
18	Mean	.00	.17	.25	.50	.29	.17	.04	.17	.04	.46	.13	.08	.29	.33	.33	.00	.08	.08	.38
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.000	.482	.532	.978	.908	.482	.204	.482	.204	1.062	.338	.282	.859	.868	1.007	.000	.282	.408	1.056
19	Mean	.08	.17	.50	.17	.08	.50	.13	.17	.33	.54	.33	.96	.46	.33	.50	.46	.54	.83	.37
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.408	.816	1.180	.637	.282	1.383	.448	.816	.963	1.285	1.090	1.732	1.285	1.129	1.319	1.250	1.141	1.633	1.135
20	Mean	.58	.46	.42	.67	.46	.21	.88	.29	.50	.17	1.13	.79	.42	.12	.96	.00	.21	.42	.08
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.018	1.062	.776	1.167	.884	.588	1.895	.751	.933	.381	1.895	1.693	.881	.338	1.301	.000	.588	1.060	.408
Total	Mean	1.22	1.65	1.59	1.43	1.86	1.76	1.05	1.35	1.49	1.12	1.49	1.44	1.67	1.02	1.78	.95	1.30	1.81	1.51
	N	336	336	336	336	336	336	336	336	336	336	336	336	336	336	336	336	336	336	336
	Std. Deviation	2.346	2.843	2.649	2.708	2.933	2.881	2.078	2.617	2.759	2.136	2.698	2.497	2.808	2.288	2.848	2.237	2.476	2.977	2.616

a. StudyGroup = NH42

Table 8.1



Report[a]

SubjectID		ΦωτεινόςΛαμπερός	Βαθύς	Ζεστός	Στρογγυλεμένος	ΓεμάτοςΠλήρης	Πλούσιος	Κρουστικός	Παχύς	Σκληρός	Θαμπός	Τραχύς	Απαλός	Λεπτός	Σκοτεινός	Οξύς	Τσαλακωμένος	Ελαφρύς	Διαπεραστικός	Πυκνός
3	Mean	4.33	3.33	5.04	3.00	5.50	5.13	2.63	2.75	2.04	3.00	2.13	6.00	2.63	2.88	3.75	1.00	5.08	5.58	2.63
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.158	2.120	2.579	2.889	2.303	2.490	2.716	2.953	3.029	1.445	2.864	3.336	2.946	2.419	3.082	2.359	3.450	2.569	2.826
4	Mean	1.54	.96	1.50	.92	1.83	1.50	.38	1.13	.58	.46	.62	1.38	1.42	1.17	.62	.29	1.04	1.75	1.29
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.956	1.654	2.359	1.640	1.926	1.888	1.096	1.918	1.501	1.215	1.527	2.018	1.640	1.786	1.209	.859	1.628	1.894	1.899
10	Mean	.17	.17	.25	.58	.08	.00	.00	.08	.42	.38	.33	.13	.38	.00	.38	.04	.13	.13	.00
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.482	.381	.608	.881	.282	.000	.000	.408	.929	.824	.761	.448	.970	.000	.770	.204	.448	.448	.000
11	Mean	1.62	1.29	2.04	1.21	2.50	3.88	2.17	2.00	.63	.00	1.37	1.79	.13	.00	.96	.38	.50	1.00	2.25
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.242	2.177	2.440	2.570	2.621	2.271	2.582	2.798	1.245	.000	1.974	2.587	.612	.000	1.429	1.135	1.251	2.022	2.674
Total	Mean	1.92	1.44	2.21	1.43	2.48	2.63	1.29	1.49	.92	.96	1.11	2.32	1.14	1.01	1.43	.43	1.69	2.11	1.54
	N	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96
	Std. Deviation	2.630	2.076	2.760	2.311	2.780	2.765	2.229	2.437	1.945	1.569	2.031	3.207	2.014	1.895	2.270	1.405	2.818	2.809	2.362

a. StudyGroup = SNHL42

Table 8.2

Report[a]

SubjectID		ΦωτεινόςΛαμπερός	Βαθύς	Ζεστός	Στρογγυλεμένος	ΓεμάτοςΠλήρης	Πλούσιος	Κρουστικός	Παχύς	Σκληρός	Θαμπός	Τραχύς	Απαλός	Λεπτός	Σκοτεινός	Οξύς	Τσαλακωμένος	Ελαφρύς	Διαπεραστικός	Πυκνός
21	Mean	.17	1.29	.79	.62	.71	.71	.21	.71	.67	.00	1.08	.00	2.50	.79	2.50	.67	1.00	2.75	1.46
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.565	2.440	1.865	1.861	1.654	1.805	.588	2.136	2.014	.000	2.620	.000	3.563	2.226	3.190	1.949	1.842	3.429	2.413
25	Mean	2.75	2.42	2.58	4.17	2.33	3.17	.71	2.33	3.87	.62	1.08	1.33	1.88	3.62	2.83	1.42	1.58	2.00	1.92
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.870	3.035	3.335	3.897	3.319	3.185	1.829	3.522	3.591	1.555	2.339	2.408	3.221	3.214	3.319	2.948	2.842	2.978	3.049
28	Mean	2.29	3.13	3.33	2.96	4.00	3.63	1.13	3.04	3.25	1.00	3.96	1.13	1.83	1.67	3.29	3.67	.29	3.83	4.08
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.250	3.745	3.875	3.793	3.464	3.487	1.650	3.483	3.870	1.180	3.940	2.559	3.074	2.259	3.770	3.571	1.042	3.807	3.269
32	Mean	.83	1.29	.08	.46	.25	.46	.08	.50	.42	1.13	1.21	.88	.83	.00	1.13	.29	.08	.42	.42
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.834	2.422	.408	1.560	1.225	1.560	.408	1.474	1.283	2.328	1.693	1.825	2.057	.000	1.918	1.233	.408	1.139	1.442
33	Mean	.21	1.04	1.54	1.21	1.92	1.29	.25	.67	.67	.21	.29	1.08	.83	.38	.83	.13	.33	1.00	1.13
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.833	2.293	2.843	2.654	3.120	2.274	.847	2.078	1.551	.658	.908	2.412	1.857	1.837	1.523	.612	1.167	1.888	2.050
34	Mean	1.21	1.88	1.58	1.79	2.63	2.21	2.42	1.96	1.71	1.54	1.38	1.08	.54	.46	1.58	.50	.38	2.75	2.00
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.043	2.092	2.125	2.226	2.143	2.206	2.062	2.116	2.032	1.888	2.123	1.558	1.285	1.382	2.125	1.180	1.056	2.212	2.246
35	Mean	1.50	.67	1.04	1.46	.54	.83	1.46	.67	1.42	.92	.88	1.04	1.25	.50	1.75	.96	.88	1.38	1.25
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.085	1.606	2.177	2.146	1.615	1.341	2.105	1.606	1.932	1.717	1.569	2.177	2.048	1.142	1.700	1.574	1.676	1.996	1.847
37	Mean	4.25	1.08	3.67	3.00	2.92	2.38	2.67	1.75	1.79	2.88	2.67	2.54	4.13	.88	4.08	2.17	3.00	2.42	2.83
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.658	2.125	2.239	2.934	2.653	2.428	1.949	2.400	2.226	2.173	2.854	3.270	2.879	1.569	2.903	2.334	2.844	2.339	2.531
38	Mean	.00	.25	.00	.08	.00	.04	.04	.29	.04	.29	.08	.25	.13	.00	.46	.29	.17	.38	.21
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.000	.737	.000	.408	.000	.204	.204	.624	.204	.624	.408	.532	.338	.000	.932	.751	.637	.770	.658
40	Mean	1.25	.42	.42	.50	.67	.29	.63	.50	.71	.29	1.29	.58	1.13	.17	1.58	.00	.21	.54	.04
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.452	1.283	.830	1.319	.816	.624	1.469	.978	1.160	.859	1.944	1.018	1.569	.482	1.742	.000	.658	.977	.204
Total	Mean	1.45	1.35	1.50	1.62	1.60	1.50	.96	1.24	1.45	.89	1.39	.99	1.50	.85	2.00	1.01	.79	1.75	1.53
	N	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240
	Std. Deviation	2.488	2.434	2.574	2.769	2.576	2.425	1.713	2.368	2.500	1.664	2.457	2.084	2.586	1.985	2.660	2.178	1.827	2.579	2.444

a. StudyGroup = NH72

Table 8.3

Report[a]

SubjectID		ΦωτεινόςΛαμπερός	Βαθύς	Ζεστός	Στρογγυλεμένος	ΓεμάτοςΠλήρης	Πλούσιος	Κρουστικός	Παχύς	Σκληρός	Θαμπός	Τραχύς	Απαλός	Λεπτός	Σκοτεινός	Οξύς	Τσαλακωμένος	Ελαφρύς	Διαπεραστικός	Πυκνός
15	Mean	2.04	2.71	2.58	2.42	3.42	2.04	2.96	2.63	1.25	2.54	2.33	1.21	2.08	2.12	2.04	.17	1.29	1.54	2.71
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	3.653	3.581	3.658	3.911	3.889	3.355	3.983	3.360	2.674	3.176	3.749	2.734	3.787	2.894	3.653	.816	2.368	2.889	3.850
23	Mean	3.25	1.83	3.96	2.13	4.63	3.67	1.54	2.25	1.00	1.71	1.58	3.71	2.08	1.54	3.29	1.00	1.96	4.38	2.83
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.472	2.140	2.116	2.092	2.039	1.926	1.841	2.345	1.956	1.922	2.636	2.579	2.302	1.793	1.967	1.818	2.074	1.861	2.334
41	Mean	.58	.71	1.88	.25	.79	1.08	.46	.13	.75	.33	.50	.17	1.25	1.13	3.21	.75	.00	.92	.33
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	1.472	1.876	2.692	1.225	2.187	2.225	1.021	.612	2.048	.917	1.383	.816	2.308	2.290	2.570	1.622	.000	1.840	1.167
42	Mean	.08	1.17	1.79	1.08	1.08	.54	.25	1.00	.08	.25	.08	2.79	.54	.42	.21	.00	2.46	.00	.17
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.282	1.880	2.000	1.976	1.840	1.179	1.032	1.668	.282	.847	.408	2.085	1.141	1.176	1.021	.000	2.021	.000	.816
43	Mean	1.00	1.46	1.04	1.88	1.92	1.38	1.92	.79	1.12	.71	.58	1.21	.00	.63	.83	.37	.88	.83	.83
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	2.106	2.502	2.177	3.097	2.812	2.410	3.035	2.021	2.401	1.628	1.792	2.226	.000	1.469	2.120	1.173	2.050	2.057	1.523
44	Mean	.08	.92	2.04	.62	.58	.96	.13	.63	.54	.13	.42	1.21	.25	.42	.63	.38	1.17	.75	.38
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Std. Deviation	.408	1.692	2.177	1.135	1.412	1.876	.612	1.689	1.179	.612	.881	2.322	.897	1.060	1.096	.875	1.786	1.359	1.135
Total	Mean	1.17	1.47	2.22	1.40	2.07	1.61	1.21	1.24	.79	.94	.92	1.72	1.03	1.04	1.70	.44	1.29	1.40	1.21
	N	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144
	Std. Deviation	2.354	2.418	2.650	2.534	2.867	2.447	2.458	2.266	1.939	1.935	2.230	2.477	2.248	1.964	2.537	1.233	2.014	2.324	2.332

a. StudyGroup = SNHL72

Table 8.4

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