BBSc 389: Independent Study

Assignment 2

"Acoustics in the hospitality Industry: A subjective and objective analysis"

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Contents

Introduction:

This study intends to assess the parameters which constitute acceptability of the acoustic environs of cafes restaurants and bars and the possibility of creating a prediction method or acoustic index by which to rate them objectively via a prescribed method. The study shows a collection of data, subjective and objective, and an informed analysis of its meaning and relationship using statistical modeling. These relationships are summarized in a conclusion describing their influence on overall acceptability of the environments and propose the possibility of further research into creating an accurate model.

Procedure:

The method of collecting data was by way of a prescribed procedure[1], tested and refined to the following steps:

Subjective Analysis through Written Surveys:

Twenty patrons of each establishment were surveyed at random by way of a questionnaire. Participation in the survey was voluntary and participant reserved the right to withhold information as they saw fit.

The questions were designed to assess qualities deemed important to communication effort, noise sensitivity, privacy and overall acceptability of the space. These were the qualities considered to be the influencing factors in speech intelligibility based upon previous research.

To find the strongest relationships between questions the collected data was interpreted using SPSS statistical software version 11.5. The data was run through a factor analysis. The suitability of the data for factor analysis and structure detection was tested using two methods:

- Kaiser-Meyer-Olkin Measure of Sampling

- Bartlets Test of Sphericity

The strongest correlating factors were then grouped as qualities (Degree of Effort, Environmental Awareness, Noise Sensitivity, Disruption by music, Disruption by Kitchen Sources, Degree of Effort, Noise Sensitivity , Privacy, Importance of Speech intelligibility, Acceptability, noise level) dependent upon the constitution of factors and their weight.

The factors were normalized to reveal the relationship of the qualities between each category of establishment. Finally the groups of correlating factors were modeled against acceptability and the objective STI measure, using a linear regression and stepwise linear regression to determine their individual effectiveness and relevance towards creating an index or predictive measure of acoustic qualities.

[1] Bell-Booth J. BBSc 389 Assignment 1

Assumptions:

The linear regression model assumes that there is a linear, or "straight line," relationship between the dependent variable and each predictor.

It is assumed that the random selection of participants is representative of the general patronage of bars, cafes and restaurants

Objective Data Collection

Background Noise Level:

The background noise was recorded at the position of a listeners head in an expected occupant's position, in accordance with Australian New Zealand Standard 2107:2000 (clause 6.1.3) at an occupied time. The background noise was recorded to hard disk using ProTools LE 6.1.1, the Digidesign peripheral MBox USB sound card and AKG C108 omni directional microphone. The level (dB L_{eq}) was measured over a five minute period of the recording using the Bruel & Kjaer 2231 sound level meter, shown to comply with AS 1259.2. The recording was calibrated with a known tone with known SPL recoded at the beginning of each recording, prior to each measurement.

Reverberation Time:

The unoccupied reverberation time (RT30) was measured using winMLS software version 1.2 and the recommended and callibrated Digigram V2 VX pocket sound card[2]. In accordance with the RASTI method[3] the loudspeaker used had a directivity pattern that reflected that of a natural speaker. Also in accordance with the standard the microphone used was omni-directional.

STI:

The STI was calculated using the same winMLS software. Inputs of the STI calculation were the measured reverberation time and background noise levels (dB Leq) and the standard speech levels for normal, raised, loud and shouting as prescribed in the ANSI S3.5: 1997 standard.

Assumptions:

It is assumed that STI is the best method of measuring speech intelligibility for the purposes of this research[4]. The reverberation time, an influential input to the STI calculation, was measured at an approximate distance of 800mm from the speaker. For ease of measurement reverberation was made under unoccupied conditions, thus absorption provided by the occupants is negated.

[2] www.winmls.com
[3] Technical Review no. 3-1985, Bruel & Kjaer
[4] Bell-Booth J. BBSc 389 Assignment 1

Results and Discussion:

Environments:

The premises that took part in the study were cafe's, restaurants and bars in Wellington City, zoned "*suburban centres"* by the district plan, a predominantly commercial yet progressively developing residential area. The area is a busy commercial hub with influential environmental noise factors which vary widely over a 24-hour period[5].

The time that the environmental survey took place varied due to the venues management preference and schedule. However the measurements were taken at relevant times according to the activity of the building, compliant with AS/NZ 2107:2000 (clause 6.1.4).

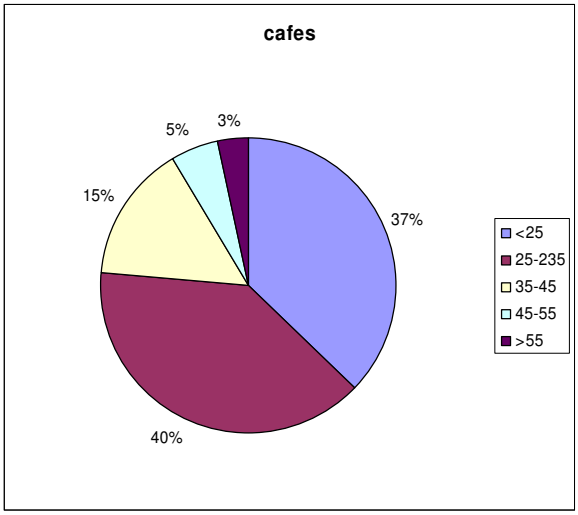
The establishments were defined at the discretion of the conductors of the survey into the three categories, cafes restaurants and bars. These are considered to be representative of cafe's bars and restaurants in general.

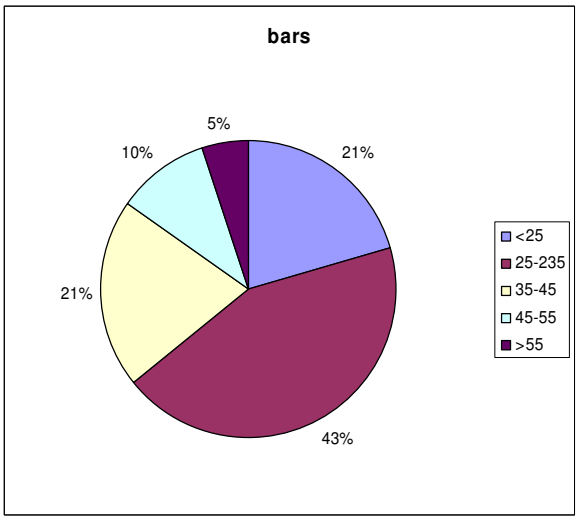
[5] Sound and the Restaurant Environment, Hannah L. 20004

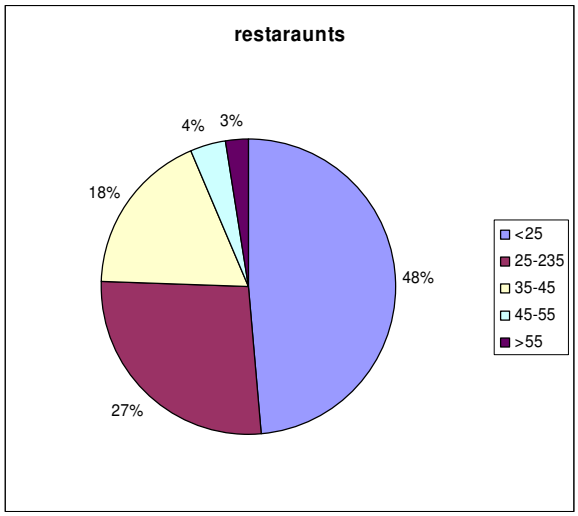
Population:

The results only reflect trends of the population surveyed and not those of the general population, thus an index or predictive method built upon the results only caters for those who already willingly use these spaces. However this does not negate their value as it gives an indication of the existing patronages preferences and tendencies.

The participants surveyed varied in age and sex, the later of which had little relevance. The age range for each category of venue is outlined below.







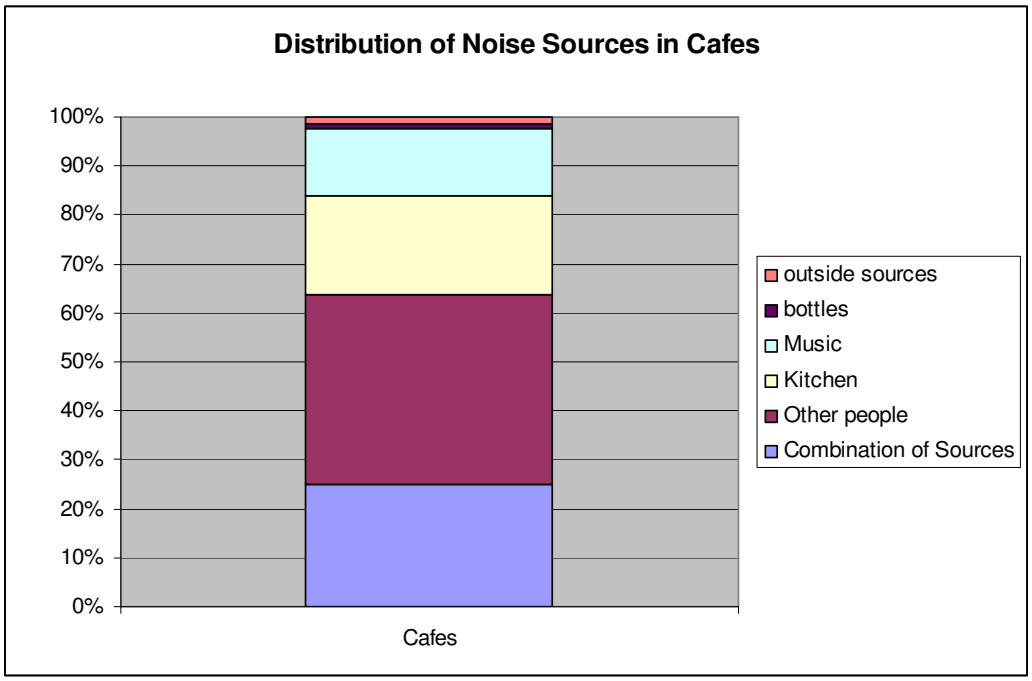
This shows the participants to be predominantly under the age of 35.

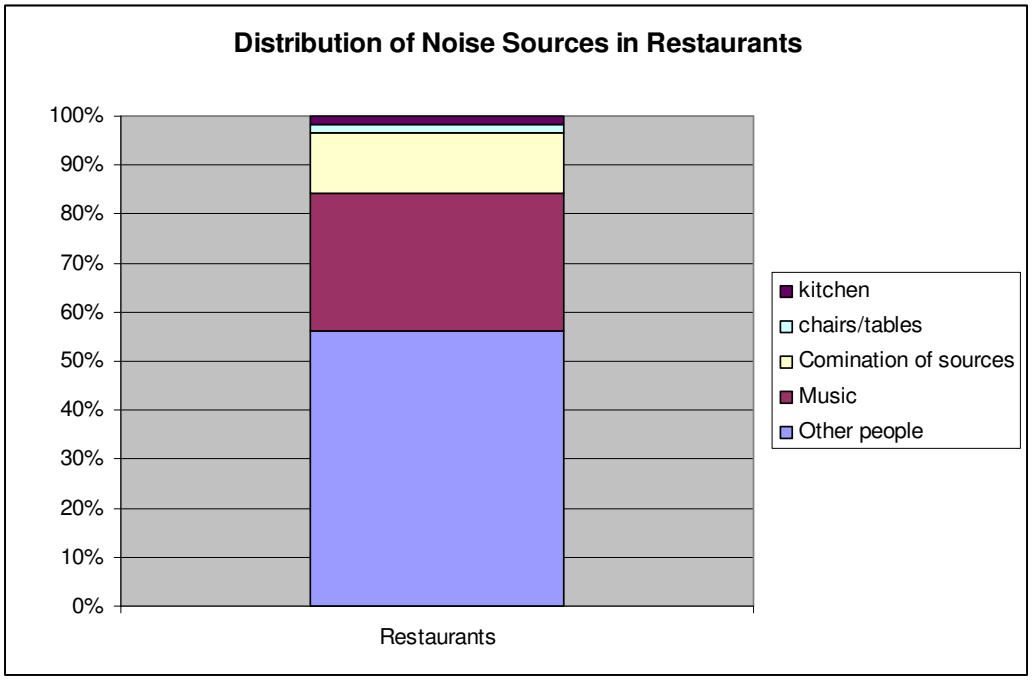
General Conclusions:

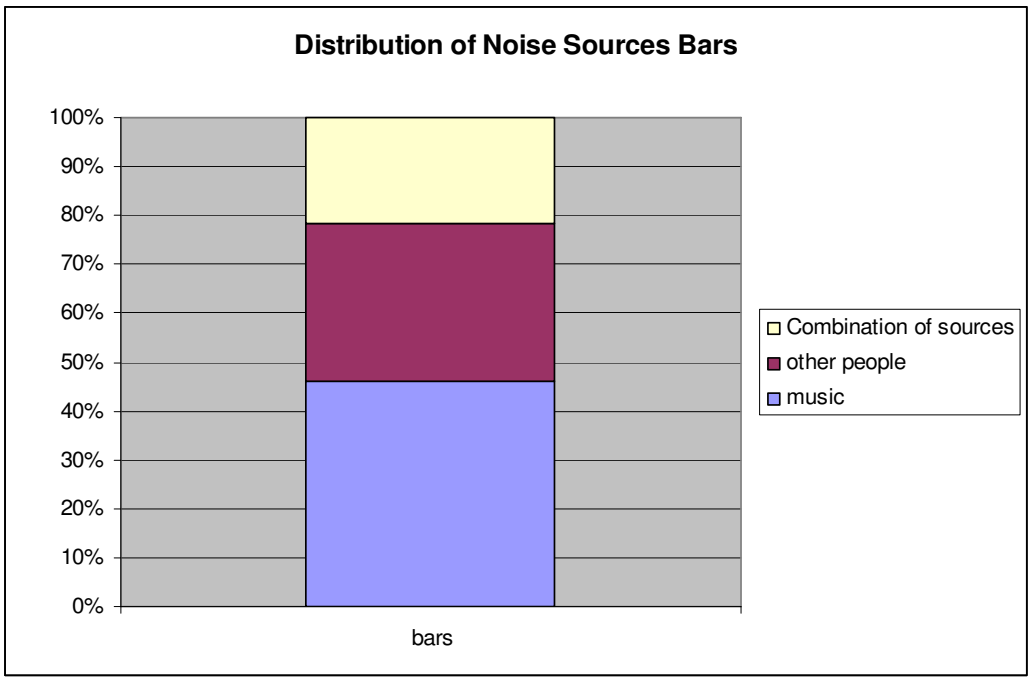
Architectural features:

The general materiality's of all the premises were acoustically reflective; polished timber or tiled floors, gib or concrete walls and partitions and Gib, timber or concrete ceilings. It is presumed that this is a consideration of design for the space to be durable and easily cleanable. This has a negative effect on the acoustic qualities of the space as it increases the reverberation times considerably.

Noise sources:

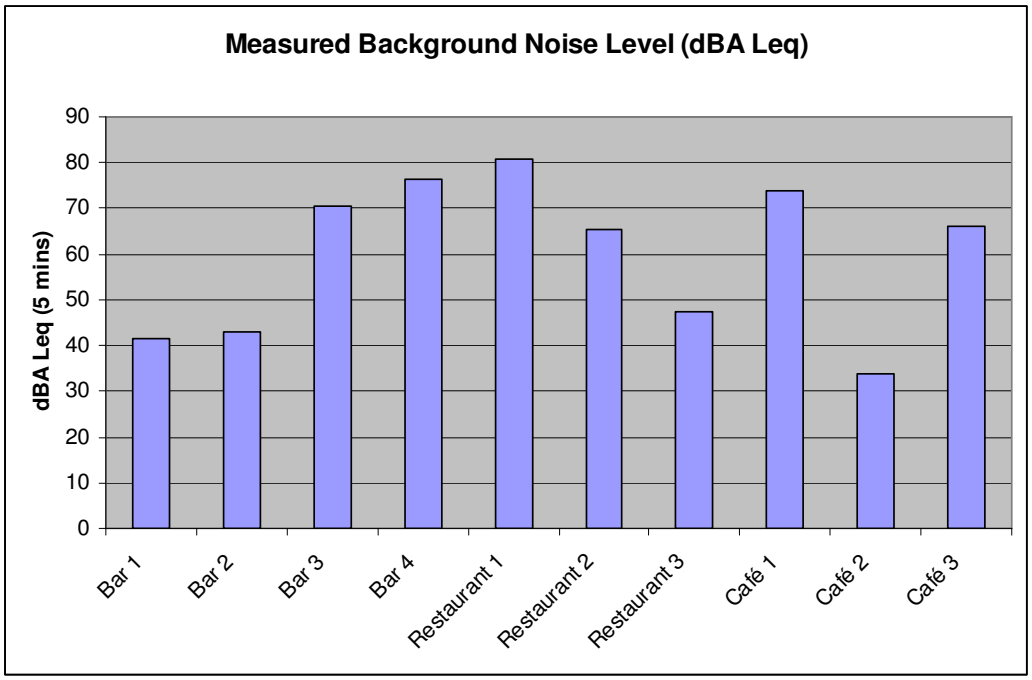


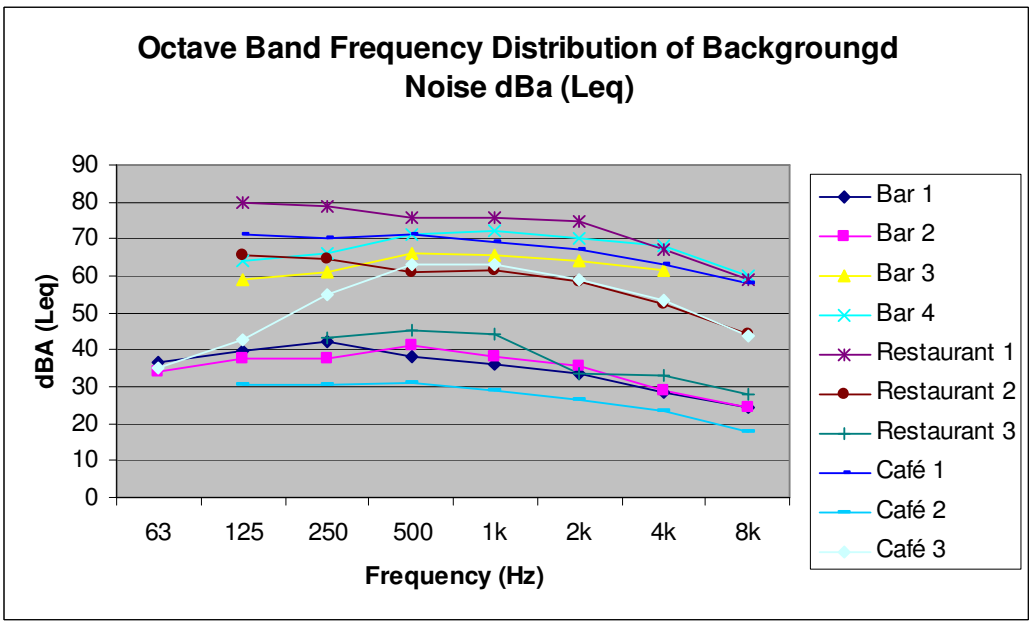




It is apparent from the above tables that the predominant noise sources in all establishments are other occupants and the music being played. A sizable proportion of the contributing noise sources in cafes can be accounted for by kitchen noise. This is largely due to coffee machines and grinders.

Noise Levels:





The above tables show the distribution of background noise level in the surveyed venues and their frequency rating. The range of the measured levels is broad, between 34 dBA (L_{eq}) and 81 dBA (L_{eq}). 60% of the establishments exceed the recommended maximum level of 50 dBA in AS/NZ 2107:2000. However this recommended value is for background noise in ready for occupancy but unoccupied buildings. The standard states that noise will rise above this

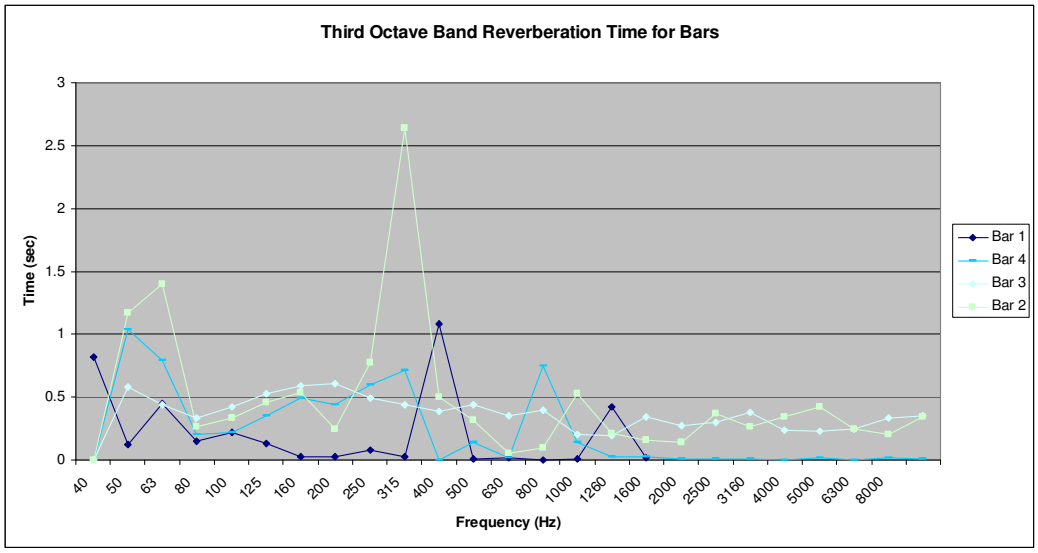
recommended unoccupied level on occupancy[6]. The extreme rises could be explained in relation to the reverberation time and the "café effect" correlating well with the perceived prominent noise sources being sources introduced to the environment.

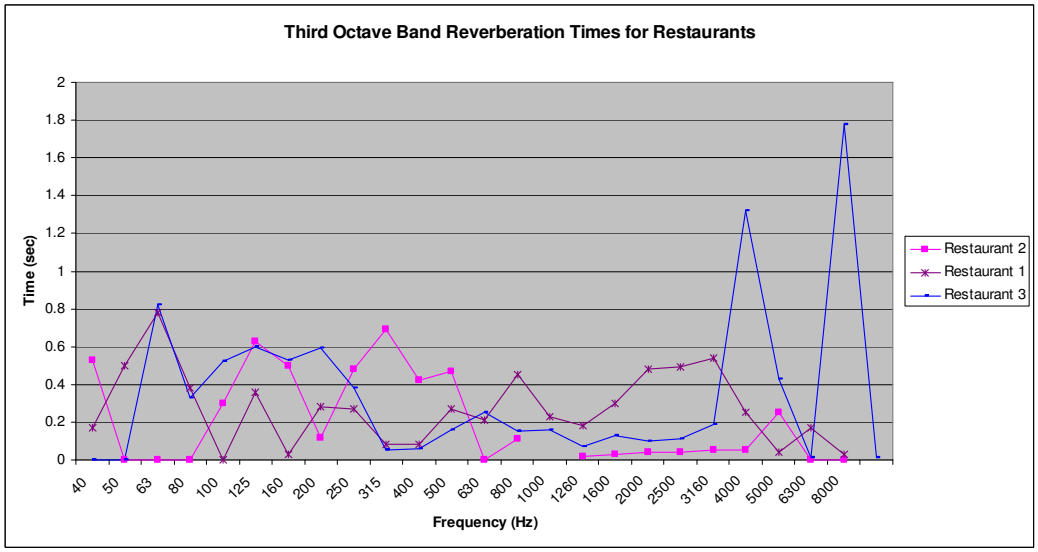
Despite the level being high it is not over the recommended OSH safety limit of 85 dBA (L_{eq})[7].

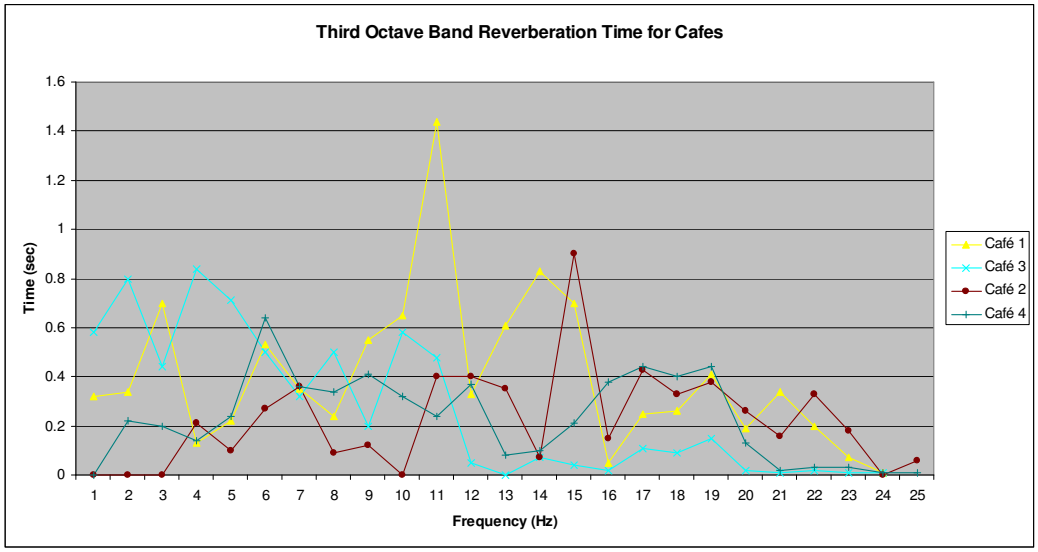
[6] AS/NZ 2107:2000

[7] OSH

Reverberation Time:







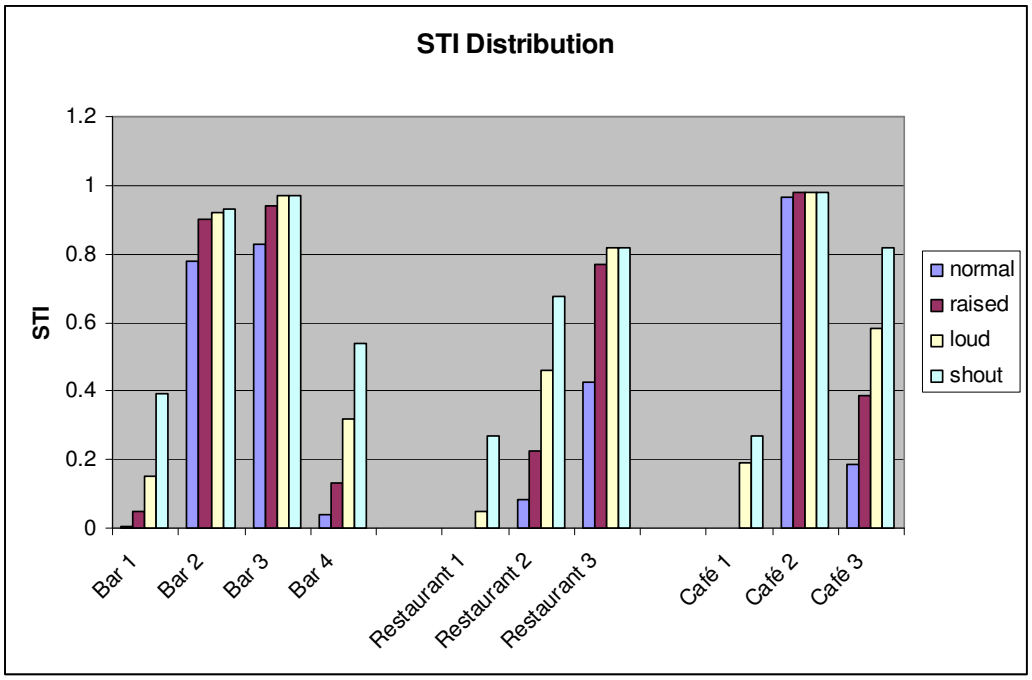
The above graph shows the reverberation time measured in the locations surveyed. It appears the reverberation time is much lower than 1.0 second sitting comfortably in the recommended AS/NZ 2107:2000 time of <1.0 second. However to comply with the method of measuring reverberation time to satisfy the STI method the reverberation time is measured using a loud speaker with the directivity of a natural speaker or human head, as apposed to an omni directional speaker to satisfy the AS 2460 procedure for measurement of reverberation time and thus the AS/NZ 2107:2000[8]. Furthermore the distance between the microphone and speaker is only approximately 800mm to simulate the conditions of natural speaker and listener in café bar and restaurant environments.

The reverberation times of the surveyed venues showed little correlation to there background noise and hence the higher levels in some establishments cannot be explained by the "cafe effect". However this might change if reverberation time was measured in accordance with AS 2460. If this were true it would imply groups of people communicating behaved as omni directional sources.

[8] AS/NZ 2107:2000

Speech Transmission Index:

The graph below illustrates the distribution of STI in the surveyed environments.

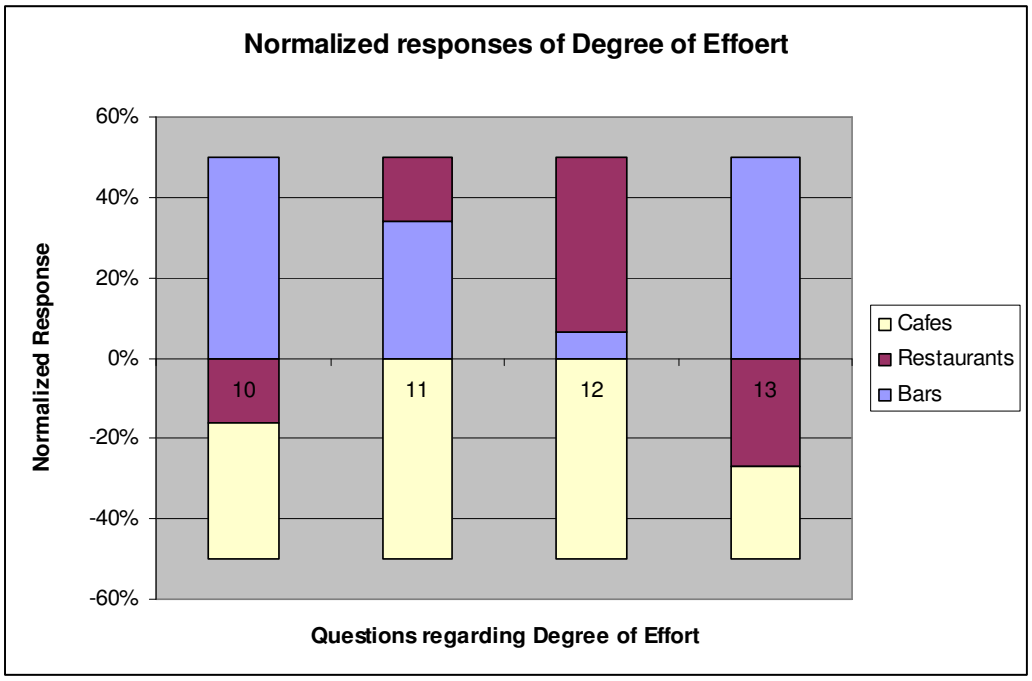


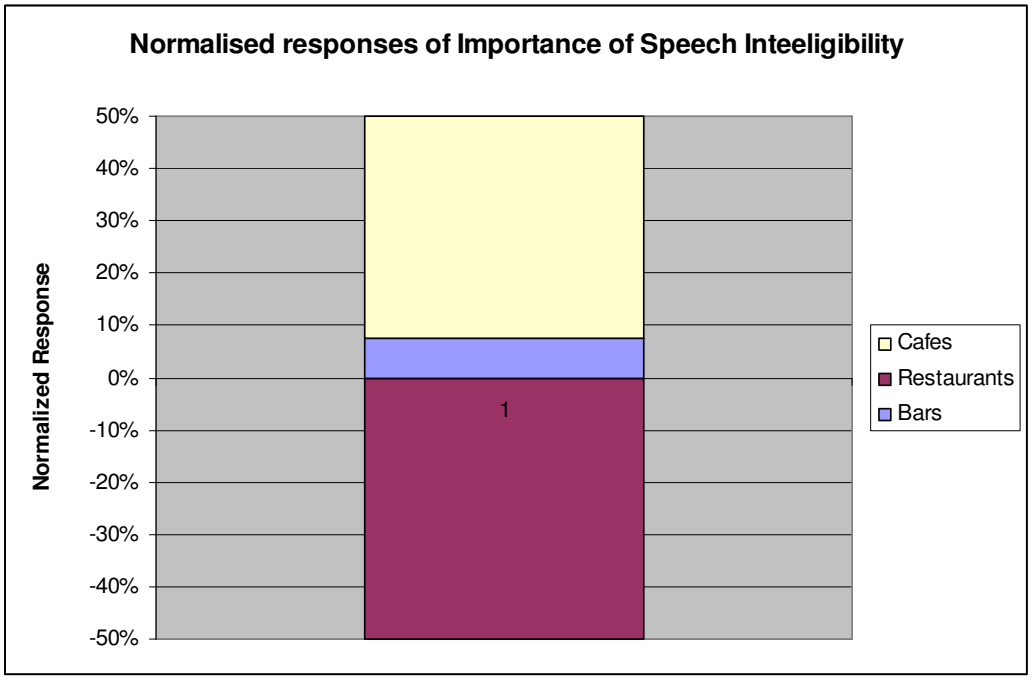
When compared to the background noise level it demonstrates it is easier to attain a higher STI (approaching 1, where 1 is perfect speech intelligibility and 0 is nil) in a lower background noise level. The graph also shows that, in a higher background noise communication is improved exponentially with effort, where as it improves logarithmically in less noisy environments. Both these points illustrate how dependant upon background noise level STI is in these measurements.

Normalised Mean Results

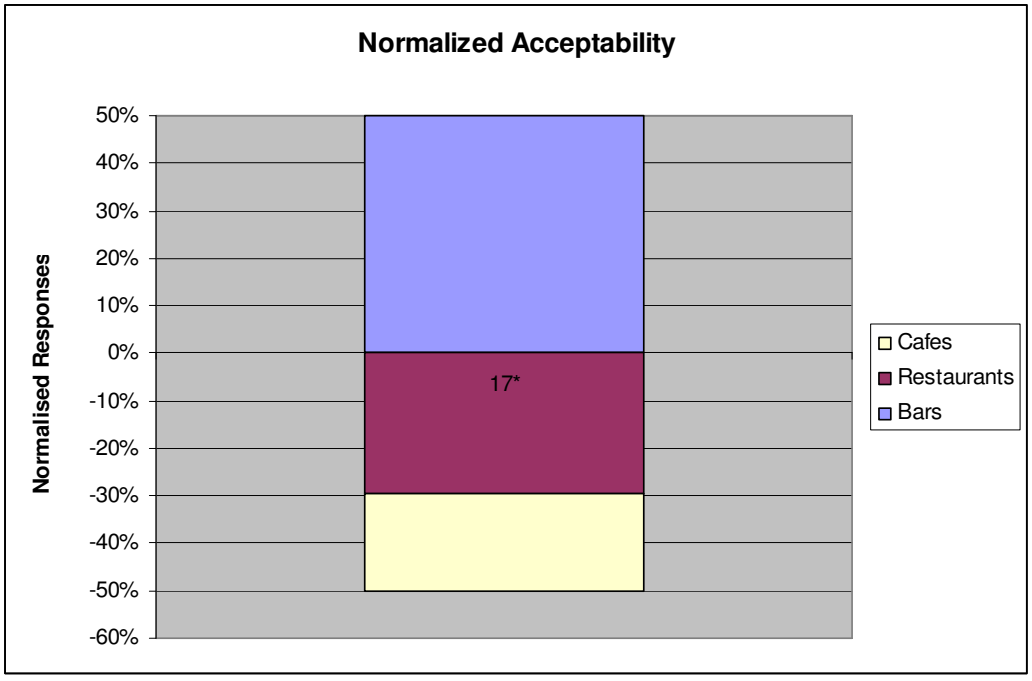
The mean values of significant variables were normalized to reveal some interesting information

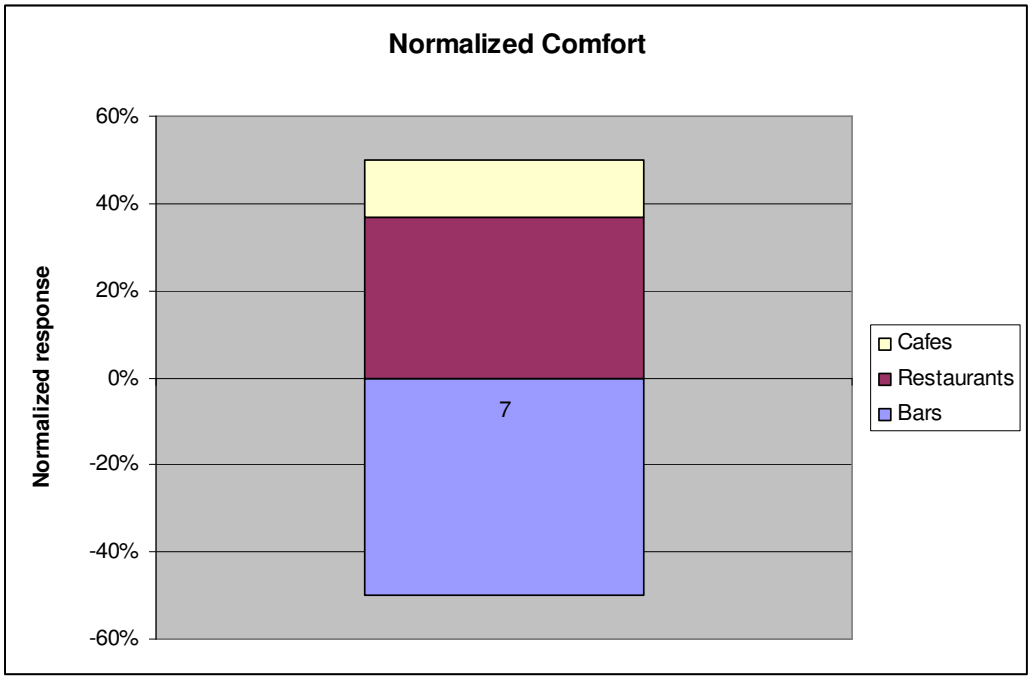
People who frequent cafés required the least amount of effort to communicate. They also rated speech intelligibility more importantly than the patrons of other venues. Interestingly cafes were rated by their occupants as the least acceptable environment.





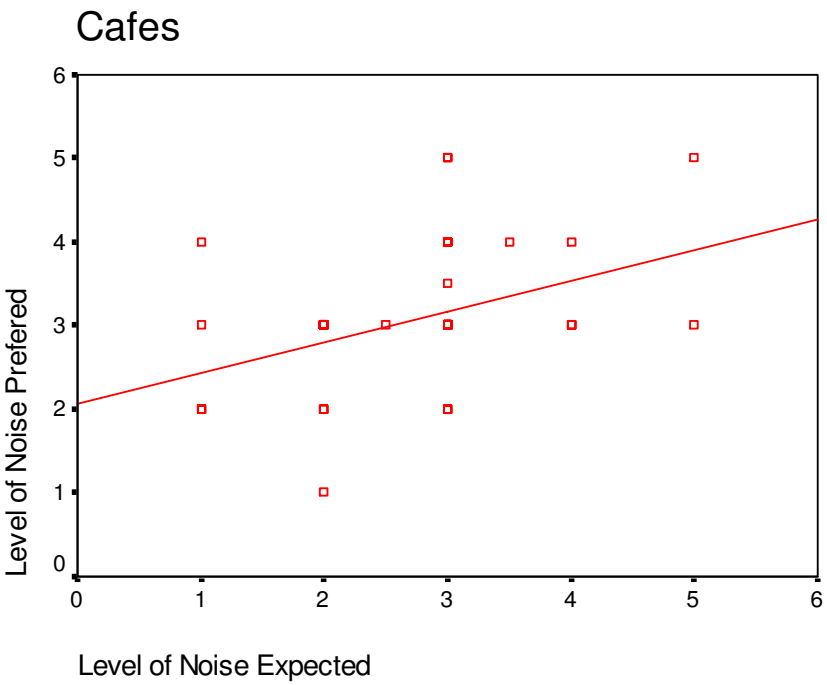
Inversely those surveyed in bars required the most amount of effort to communicate yet were the most comfortable relaxing in a noisy environment. This coincides with the fact that those surveyed in bars rated there environment with a greater level of acceptability.

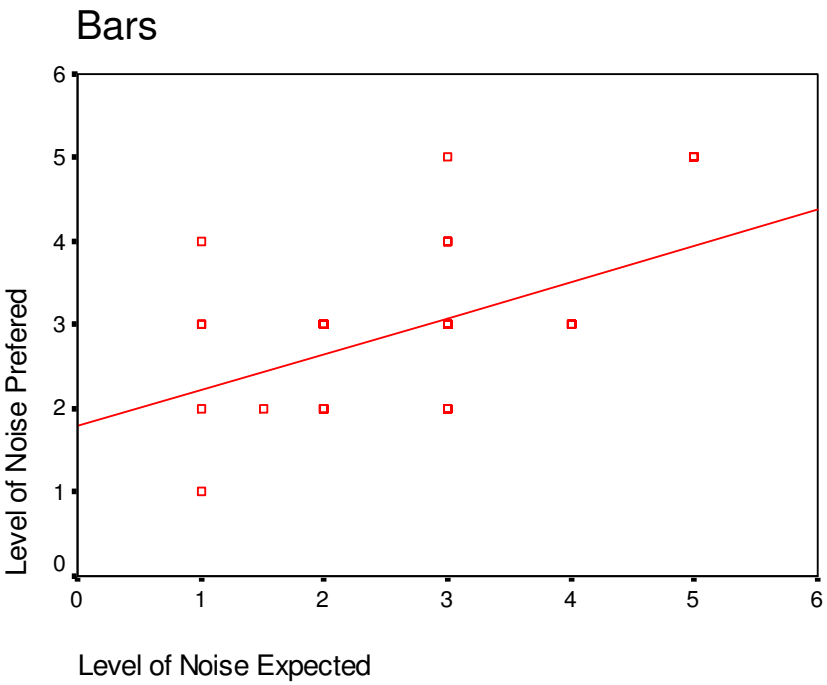


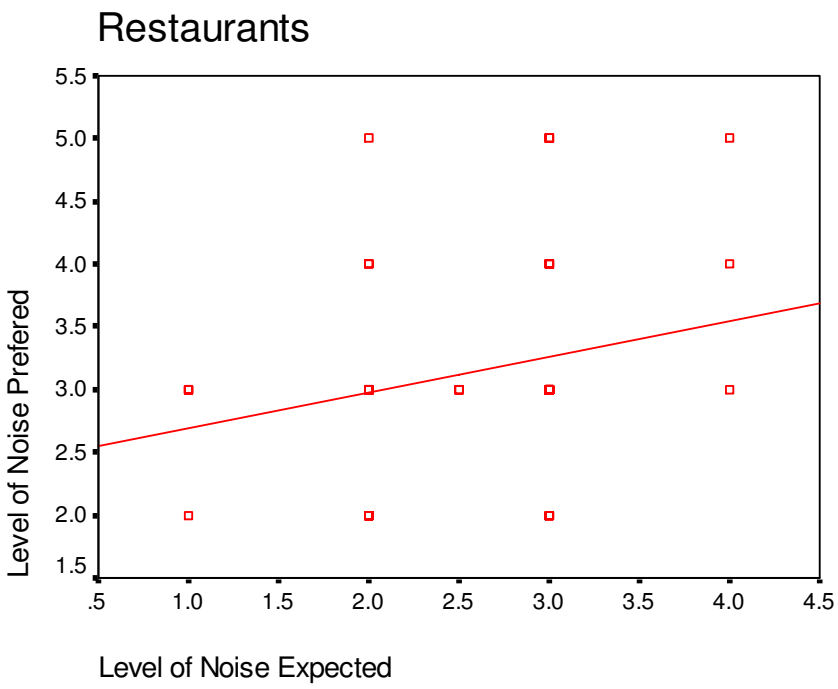


Reciprocally, restaurants, whose patrons were those who found it hardest to relax in a noisy environment, rated speech intelligibility less important to them than the patrons of other venues.

By logic this suggests there is a relationship between expectation and tolerance of acoustic influencing parameters, such as privacy and annoyance created by background noise, worthy of separate study itself. This is supported by the following graphs.


Cafes
Level of Noise Prefered
0
1
2
3
4
5
6
Level of Noise Expected


Bars
Level of Noise Prefered
0
1
2
3
4
5
6
Level of Noise Expected



For the purposes of this study the preceding conclusions highlight the importance of different factors contributing to overall acceptability between each category of venue and therefore a range of different indices or prediction methods for each.

The linear regression of significant factors for each establishment assesses the possibility of creating such indices or methods.

Linear Regression Modelling:

Factor analysis exemplified and weighted the strongest correlating variables. Based on the weighting as a percentage the variables where grouped as factors. The factors were assessed as to ascertain their meaning in relation to acoustic parameters and speech intelligibility; Degree of Effort, Environmental Awareness, Noise Sensitivity, Disruption by Music, Disruption by Kitchen Sources, Degree of Effort, Noise Sensitivity , Privacy, Importance of Speech intelligibility, Acceptability, Noise Level

Linear regression of the factors was used to model the value of the dependant scale variable, acceptability (for the objective case) and STI (for the subjective), on its linear relationship to one or more predictors. Stepwise methods in Linear Regression, where then used to select the "best" model for predicting.

A significance level of 5% was set for all the regressions.

Relationship of significant factors for Café's:

The variables which made up the significant factors and their weightings are described below (all variables can be viewed in the subjective survey in appendix):

Factor						
	Variable	10	11	12	13	14
Degree of Effort	Weighting (%)	21	20	16	22	21
Environmental Awareness	Variable	1	3	21	7	
	Weighting (%)	26	24	26	24	
Noise Sensitivity	Variable	4	7	22		
	Weighting (%)	41	30	29		
Disruption by music	Variable	12	20			
	Weighting (%)	50	50			
Disruption by Kitchen Sources	Variable	5	16			
	Weighting (%)	50	50			

The significant factors and their relationship to acceptability were as follows:

Degree of Effort	r = 0.390
Noise sensitivity	r = 0.288
Disruption by music	r= 0.360
Disruption by Kitchen Sources	r = 0.253

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.464(a)	.216	.162	1.06323	.216	4.015	5	73	.003	1.959

a Predictors: (Constant), FACTOR5, DOFE, NS, FACTOR4, NS2

b Dependent Variable: V17

Stepwise Linear Regression:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.483(a)	.233	.215	1.07640
2	.591(b)	.349	.318	1.00362
3	.646(c)	.417	.374	.96144

a Predictors: (Constant), Zscore(DOFE)

b Predictors: (Constant), Zscore(DOFE), Zscore(SEX)

c Predictors: (Constant), Zscore(DOFE), Zscore(SEX), Zscore(NS)

d Dependent Variable: V17

This implies the model only describes one third of the variation.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	2.369	.161		14.698	.000		
	Zscore(DOFE)	.552	.153	.483	3.617	.001	1.000	1.000
2	(Constant)	2.455	.154		15.988	.000		
	Zscore(DOFE)	.538	.142	.471	3.779	.000	.999	1.001
	Zscore(SEX)	-.428	.157	-.340	-2.732	.009	.999	1.001
3	(Constant)	2.446	.147		16.621	.000		
	Zscore(DOFE)	.411	.148	.360	2.774	.008	.845	1.183
	Zscore(SEX)	-.398	.151	-.316	-2.640	.012	.990	1.010
	Zscore(Environmental Awareness)	.345	.158	.284	2.183	.035	.838	1.193

a Dependent Variable: V17

The stepwise algorithm chooses Degree of effort, Sex and Environmental Awareness as predictors. Acceptability is positively affected by Degree of effort and negatively affected by Sex (being 1 for male 2 for female); the conclusion is that depending on sex (males are more strongly affected) Those who are more aware of their acoustic environment and fell required to make more effort for conversation rate the space as less acceptable (variable 17 rating acceptability is reversed scored so the relationships are also reversed). This implies background noise level created by other patrons, music and kitchen sources (the predominant sound sources in cafes) greatly influence the degree of effort required and thus the acceptability of the space.

The significant factors and their relationship to the STI measure at different speech levels in the linear regression were as follows:

Normal Speech Level - Noise sensitivity r = 0.254

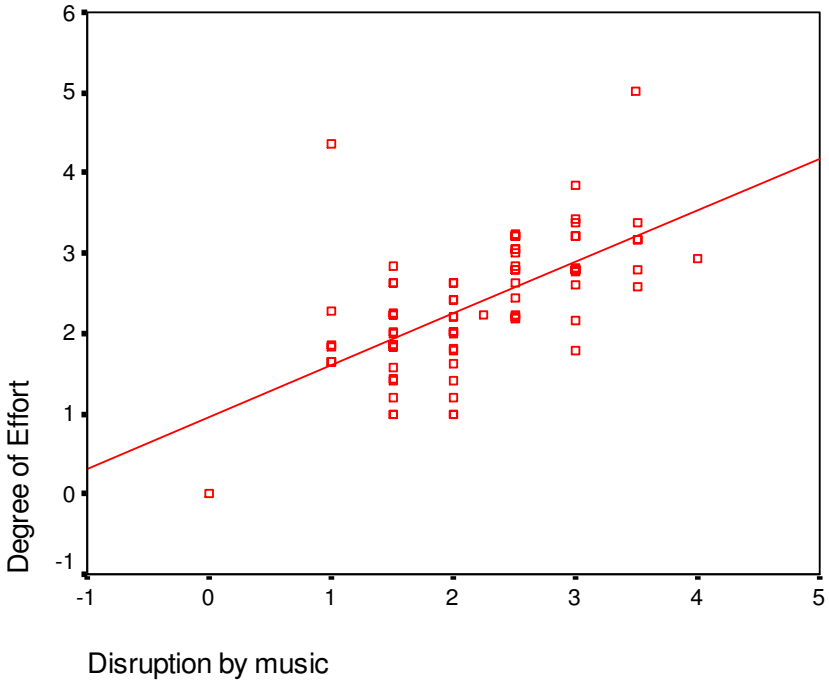
Raised Speech Level - Noise sensitivity r = 0.249

Loud Speech Level - Noise sensitivity r = 0.242

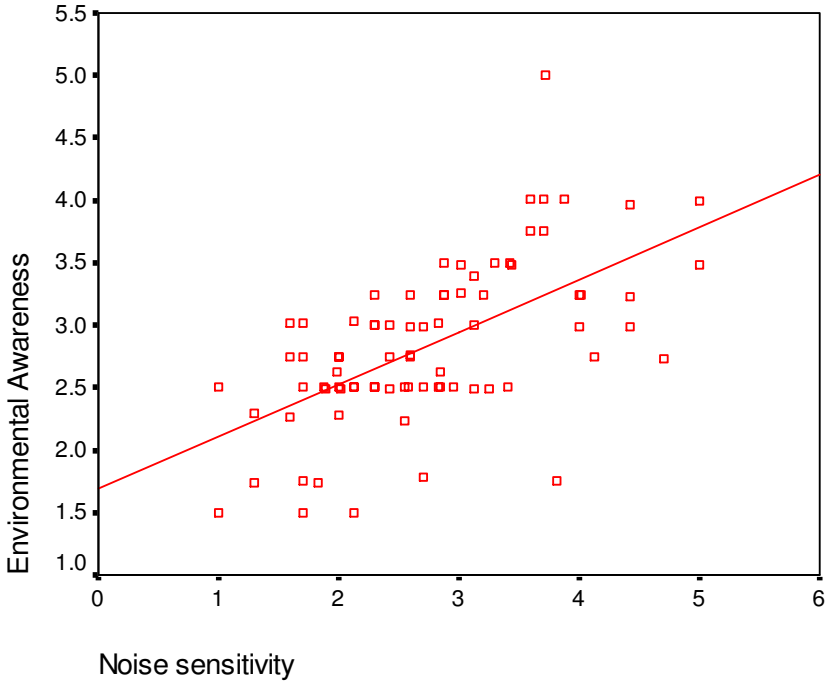
No significant strong relationships between STI and Acceptability were found thus the stepwise linear regression came up blank.

Strong Relationships were also observed between Disruption by music and Degree of effort, also Noise Sensitivity and Environmental Awareness.

Disruption by music Vs Degree of effort



Noise Sensitivity Vs. Environmental Awareness



Relationship between significant factors for Restaurants:

The variables which made up the significant factors and their weightings are described below (all variables can be viewed in the subjective survey in appendix):

Factor						
	Variable	10	11	12	13	22
Degree of Effort	Weighting (%)	20	21	22	22	15
Noise Sensitivity	Variable	2	5	6	7	
	Weighting (%)	26	26	29	20	
Privacy	Variable	18	19			
	Weighting (%)	46	54			
Importance of Speech intelligibility	Variable	1	9			
	Weighting (%)	44	56			
Acceptability	Variable	16	17			
	Weighting (%)	53	47			

None of the factors significantly described their relationship to acceptability.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.834(a)	.696	.660	.59012	.696	19.424	6	51	.000	2.505

a Predictors: (Constant), LEQ, DOFE, PRIVACY, NS, ACCEPT, DUNNO

b Dependent Variable: V17

Stepwise Linear Regression:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.309(a)	.095	.074	.99735

a Predictors: (Constant), Zscore(PRIVACY)

b Dependent Variable: V17

This implies the model only describes one tenth of the variation. Thus it is useless as a predictor.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.356	.150		15.668	.000		
	Zscore(PRIVACY)	.354	.168	.309	2.104	.041	1.000	1.000

a Dependent Variable: V17

The stepwise algorithm chooses Privacy as a predictor. Acceptability is positively affected by the factor Privacy, the conclusion is that as privacy increases Acceptability increases(variable 17 rating acceptability is reversed scored so the relationships are also reversed).

The significant factors describing their relationship to the STI measure at different speech levels were as follows:

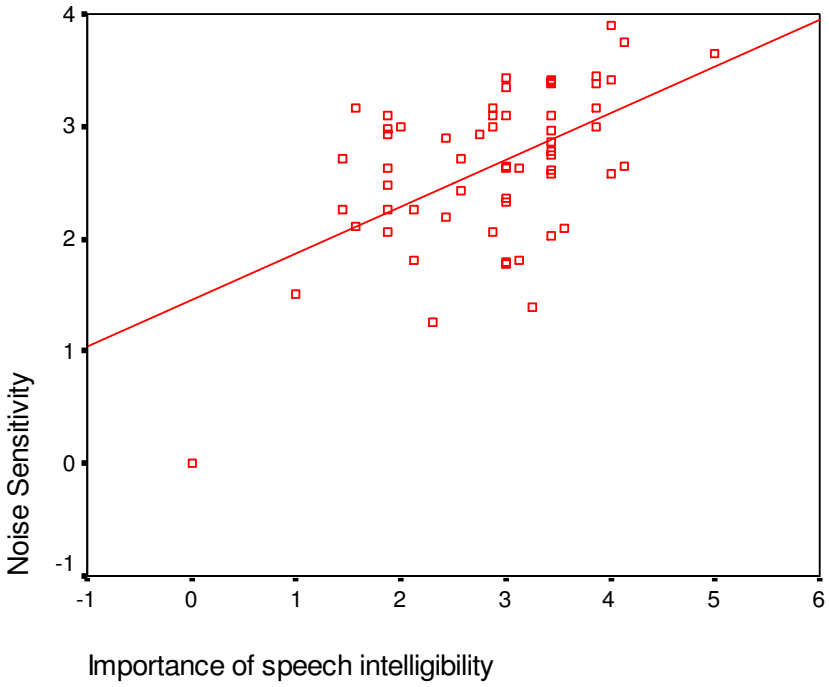
Normal Speech Level - Noise sensitivity r = 0.262

Raised Speech Level - Noise sensitivity r = 0.252

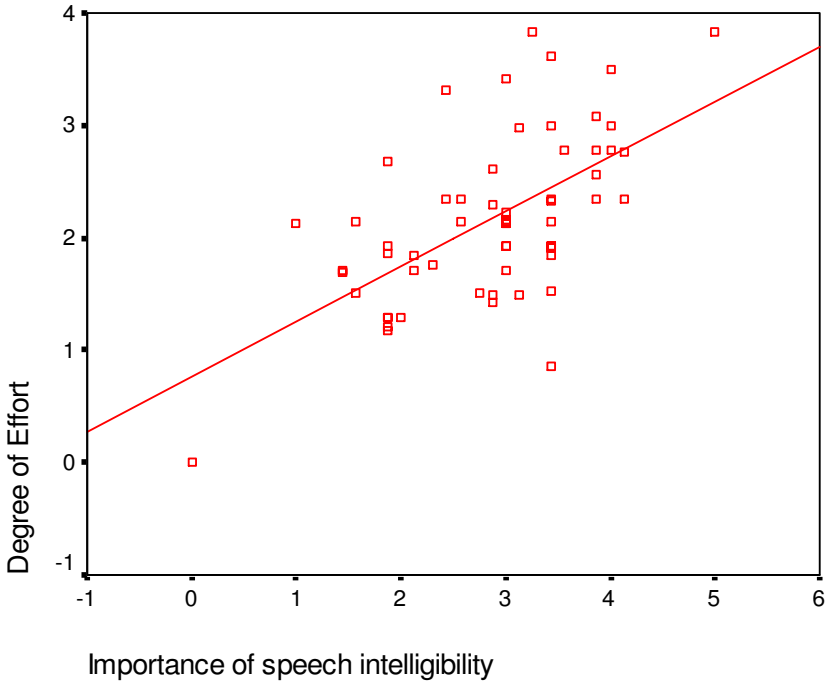
No significant strong relationships between STI and Acceptability were found thus the stepwise linear regression came up blank.

Strong Relationships were also observed between the factors Importance of speech intelligibility and noise sensitivity, also Importance of speech intelligibility and Degree of effort.

Importance of Speech Intelligibility Vs. Noise Sensitivity



Importance of Speech Intelligibility Vs. Degree of Effort.



Relationship between significant factors for Bars:

The variables which made up the significant factors and their weightings are described below (all variables can be viewed in the subjective survey in appendix):

Factor						
Degree of Effort	Variable	10	11	12	13	14
	Weighting (%)	20	23	20	23	15
Noise Sensitivity	Variable	5	6			
	Weighting (%)	45	55			
Importance of Speech intelligibility	Variable	1	9			
	Weighting (%)	53	47			
	Variable	20				
noise level	Weighting (%)	100				

The significant factors describing their relationship to acceptability were as follows:

Degree of effort r = 0.438

Noise sensitivity r = 0.362

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.532(a)	.283	.218	.90346

a Predictors: (Constant), DOFE, PRIVACY, CONTROL, AGE, NS, NSELVL

b Dependent Variable: V17

Stepwise Linear Regression:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.483(a)	.233	.222	.90091

a Predictors: (Constant), Zscore(DOFE)

b Dependent Variable: V17

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	2.125	.105		20.146	.000		
	Zscore(DOFE)	.504	.109	.483	4.643	.000	1.000	1.000

a Dependent Variable: V17

The stepwise algorithm chooses Degree of effort a predictor. Acceptability is positively affected by Degree of effort, the conclusion is that as degree of effort increases Acceptability declines (variable 17 rating acceptability is reversed scored so the relationships are also reversed).

No significant factors describing a relationship to the STI measure at the different speech levels were found.

Conclusions and Discussion:

Cafes:

Cafes were shown to have the least acceptable environment according to their patrons, rating the noise as unacceptable more than the other venues types. Speech intelligibility was important to their patrons more patrons of other environments. A strong relationship between degree of effort and environmental awareness was also observed. It is possible that as background noise in cafes increase the degree of effort increases and thus acceptability falls. A large proportion of noise sources contributing to background noises were those associated with kitchen areas, especially coffee machines and grinders. These sources may contribute a great deal to the overall acceptability of a space.

Restaurants:

From the preceding results one can conclude that restaurants occupants relate the importance of speech intelligibility low. There is also a relationship between importance of speech intelligibility and degree of effort. Privacy and acceptability of the space are also related. This combination of relationships could be described: as speech intelligibility becomes more important degree of effort increases, this make the patron feel like they are breaching there privacy and thus reducing there acceptability of the space. This implies restaurants should provide privacy by means of isolation rather than masking to reduce the degree of effort required to communicate and increase there acceptability.

Bars:

The patrons of bars rated their space more acceptable than any other group. They also identified themselves as the relaxed in noisy environments. However they did require the most effort to communicate. This suggests that a level of tolerance is acquired as the patrons expect a higher level of noise requiring a higher level of speech to be intelligible. This tolerance may also be described by the effect on mood of the alcohol consumed at the time.

A relationship between degree of effort and acceptability suggests that the patrons may be at a limit of effort as they already require the most and more pushes them over the threshold of acceptability. This is supported by the STI value measured more effort provide little improvement in intelligibility and is therefore unrewarding in terms of acceptability.

The Model as a means of Prediction:

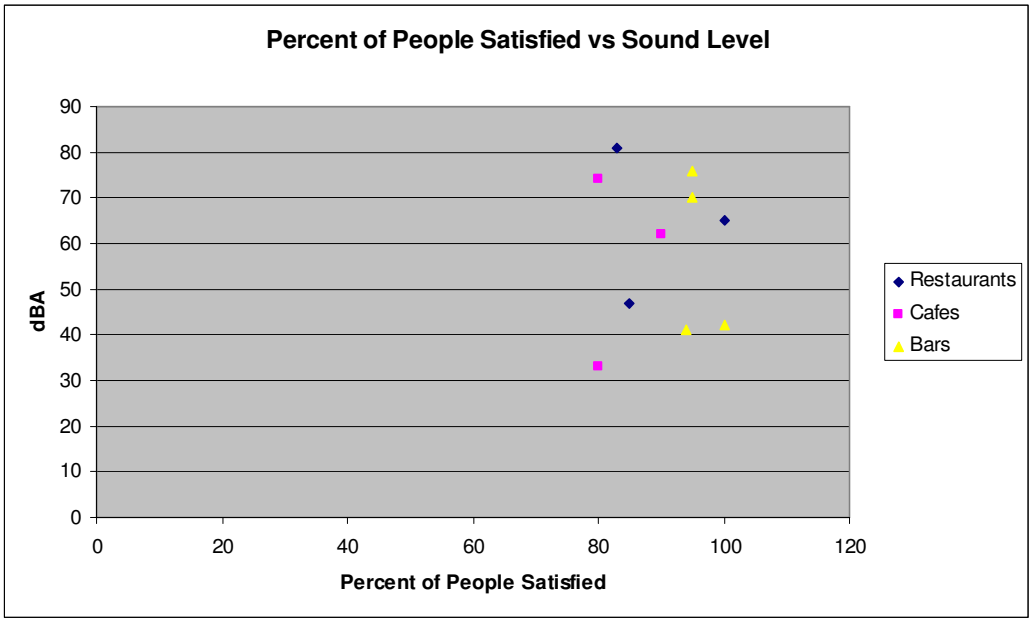
The results of the Stepwise linear progressions imply there is not enough strength in the correlations to create a reliable predictive method based on neither subjective acceptability nor objective measurement of STI.

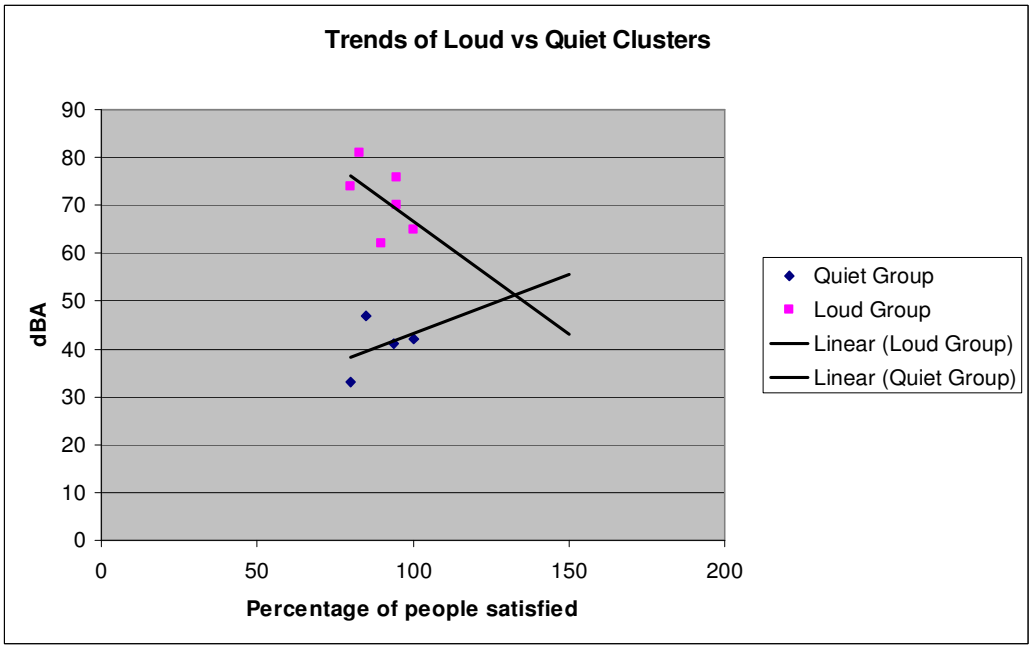
In terms of acceptability the results do not posses enough clout to create a predictive index. The strongest relationship could only describe one third of variation in the model a moderate predictive tool should account for at least 60% of the variance.

However a regression of variable 13, rating the interference of noise to communication, against the STI at the ANSI S3.5:1997 speech levels reveal a weak correlation. This implies the patrons of cafes bars and restaurants are adapting to the acoustic environment by raising there level of speech above what is considered standard. This supports the potential relationship between tolerance and expectation and also suggests that the ANSI speech levels are not in fact representative of normal, raised, loud and shouting levels of speech in these environments. Therefore the STI value obtained for these premises are using the ANSI levels are not a true representation of speech intelligibility.

To aid the production of a more reliable predictive tool research into the levels of speech in relation to comfort in these environments needs to be conducted.

A precursor to such a study would be to assess the relationship between levels of noise and their acceptability. Of the environments surveyed it is apparent two clusters appear: acceptability in louder environments and that in quieter environments.





Those surveyed in louder environments predominantly accepted the level and tended to prefer a little less noise. The majority of those surveyed in a quieter setting also accepted the level and tended to prefer a little more. This result supports the possibility of a relationship between tolerance and expectation. Although acceptability is rated highly for both clusters their tendencies suggest an equilibrium point just above 50 dBA, coincidentally the maximum recommended background noise level for bars restaurants and cafes in AS/NZ2107:2000. This suggests the standard is conservatively low, understandably as the recommended level is for unoccupied spaces. However the range of surveyed establishment is not broad enough to draw any firm results.

Furthermore it is apparent that study into the cause of the elevated background noise levels is relevant. It is suggested the “cafe effect” and the “noise breeds noise” scenario are related to reverberation. This is unclear in these results as the method of measurement of reverberation is based on a natural speaker communicating to a natural receiver. It is possible groups of people behave more like an omnidirectional source and should be simulated as one.

Overall it is apparent that comfortable communication in dynamic acoustical environments like cafes, restaurants and bars is a complex tapestry of factors and difficult to predict accurately.