3.4 Auditory Threshold

This experiment is a normal hearing test in which the subject indicates via a hand held, push button device, the lowest loudness intensity (dB) that can be heard for a particular frequency. The H_0 being tested is that N_2O has no effect on the human auditory threshold for each individual frequency.

All the data was simultaneously analysed using Program 5V (see Methods 4.0 Data Analysis) and the data decomposed into single degree-of-freedom regression terms and covariates to produce the following table:

Wald tests of significance of fixed effects and covariates.

Factors	df	Chi-square	p-value
Treatment	1	0.01	0.907
Age	1	0.32	0.571
Frequency (kHz)	1	140.72	<0.001
Ear	1	28.91	<0.001
Gender	1	0.06	0.799

It is interesting to note the lack of significance of treatment influences (i.e. changes in N_2O concentration) on hearing. It was demonstrated that N_2O did influence MEP changes and it could almost be expected that the changes in MEP should influence hearing, but in this group of subjects, the hearing changes did not occur. There were no significant differences between the groups in each of the factors of age, and gender.

There were however significant differences between the frequencies which is to be expected as a wide range of frequencies were employed. Significant differences did occur between the left and right ear and this could be explained by the subject's left side of the body being positioned closer to the anaesthetic machine. The anaesthetic machine made inherent noises and these noises could have masked some of the frequencies or matched the loudness of some frequencies, especially since this test explored the lowest intensity levels for each frequency. Thus with the left ear being closer to the machine more masking could occur in that ear and the right ear was not as affected. There was a 1.3 unit difference between the two ears. This confirms the two other tests, Intensity Matching and Subjective Intensity, had loudness levels that were not influenced by the inherent machine noises. Intensity Matching testing employed the reference threshold level 20 dB higher than the Auditory Threshold level, and the intensity levels for Subjective Intensity were 40, 60 and 80 dB, thus there was no masking of tones.

A further regression analysis was done and a relationship was found that could possibly predict the threshold levels ("*dB* ") by the frequency ("*kHz* ") and which ear was utilised:

Right ear: $dB = 19.1 - 1.3 - (0.15 \times kHz) = 17.8 - (0.15 \times kHz)$

Left Ear: $dB = 19.1 + 1.3 - (0.15 \times kHz) = 20.4 - (0.15 \times kHz)$

Within each of the factors, the individual groups were analysed to determine means and standard deviations and any significant differences. This is discussed below.

3.4.1 Treatment Influences

(1) Overall there were no significant differences between the various stages ($p=0.907$, $df=1$). Thus the null hypothesis (H_o) holds true as 10% and 20% N_2O does not affect auditory threshold levels in this group of subjects.

(2) As stated in Methods 2.4 Auditory Threshold and 4.0 Data Analysis, the statistical analysis was done between the frequencies and all stages ($n=32$, $p<0.05$). The n-value indicates all the data recorded, e.g. for age and gender divisions both left and right ear recordings were combined. The most notable features were:

(i) Auditory threshold at 500 Hz (a, 10%, 20% and b) was significantly different from other thresholds at 2, 3, 4, 6, and 8 kHz, in all stages ($p<0.05$).

(ii) Auditory thresholds at 1 and 1.5 kHz (a, 10%, 20% and b) were not significantly different to all other frequencies ($p>0.05$).

(iii) Auditory thresholds at 2, 3, 4, 6 and 8 kHz were not significantly different from each other ($p>0.05$).

(iv) Other significant differences were:

(a) between 8 kHz (b) to 1 kHz (a and 20%) and 1.5 kHz (a, 20% and b) ($p<0.05$).

(b) between 500 Hz (a) and 1 kHz (10%) ($p<0.05$).

The mean results and standard deviations are on Table 4.1 with an accompanying Graph 4.1. To test the H_0, a comparison between the stages of individual frequencies was conducted and results are in Table 4.2, resulting in no significant difference between the stages and this confirms the H_0 that N_2O does not affect hearing in terms of auditory threshold at an objective level.

The frequency 4 kHz was chosen for other experiments as it was in the centre of the sensitive hearing range for the human ear and this experiment confirms that fact.

3.4.2 Age

(1) Overall there were no clinically significant differences between the two age groups ($p=0.571$, $df=1$). One would think that age may have an influence in hearing but in this group of subjects there was not such an age differential between the groups in relation to hearing threshold levels.

(2) For the over 25 years old age group, the comparisons between all frequencies and all stages were not significantly different ($p>0.05$), except in one instance and that was between 500 Hz (20%) and 3 kHz (b) ($p<0.05$).

Table 4.3 show the mean and standard deviations of the minimal threshold intensity levels for the over 25 year old age group while Table 4.4 shows the same for the under 25 year old age group.

For the under 25 years old age group, comparisons between all frequencies and all stages are the same as the "3.4.1 Treatment Influence" results except in Point (iv) which is:

(i) Significant differences were between:

(A) 8 kHz (10%) to 1.5 kHz (a and b) ($p<0.05$) which is the same as Treatment Influence, but a stronger p-value.

(B) 8 kHz (20%) to 1.5 kHz ($p<0.05$).

(C) 8 kHz (b) to 1.5 kHz (a and b) ($p<0.05$).

(D) 1.5 kHz (a) to 3 kHz (b) and 4 kHz (a, 10% and b) ($p<0.05$).

(ii) No significance between 1 kHz (10%) and 500 Hz (a) ($p>0.05$).

There were no significant differences in comparisons within individual frequencies between the stages for both age groups (see Table 4.2) and this agrees with the H_0.

3.4.3 <u>Ear</u>

(1) Significant differences were seen between the left and right ears ($p<0.001$, df=1) and as explained previously, the position of the left and right side in proximity to the anaesthetic machine had an influence on hearing threshold levels.

(2) For left ear, comparisons between all frequencies and all stages were the same as the "3.4.1 Treatment Influence" results except for Points (i) and (iv) which are:

(i) There was no significant difference between:

(A) 500 Hz (a) to 6 kHz (10% and 20%).

(B) 500 Hz (20%) to 6 kHz (10% and 20%).

(C) 500 Hz (b) to 6 kHz (10%) ($p>0.05$).

(ii) No significant differences between:

(A) 500 Hz (10%) to 6 kHz (a, 10% and 20%).

(B) 500 Hz (b) to 6 kHz (20%) ($p>0.5$).

The mean and standard deviations of the minimal threshold intensity levels for the left ear, are on Table 4.5. Comparing means within individual frequencies for the left ear across the stages also complies with the H_0 (Table 4.2).

For the right ear, comparisons between all frequencies and all stages were the same as for the "3.4.1 Treatment Influence", except in Points (i) and (iv) which are:

(i) 6 kHz is not significantly different to 500 Hz in all stages ($p>0.05$).

(ii) 2 kHz (a, 10% 20% and b) is not significantly different to 500 Hz (10%, 20% and b) ($p>0.05$).

(iii) 8 kHz (a and 20%) is not significantly different to 500 Hz (10%, 20% and b) ($p>0.05$).

(iv) 500 Hz (20% and b) ($p>0.05$) and 4 kHz (20%) are not significantly different ($p>0.05$).

The mean and standard deviations of the minimal threshold intensity levels for the right ear are on Table 4.6. Comparing means within individual frequencies for the right ear across the stages also complies with the H_0 (Table 4.2).

3.4.4 <u>Gender</u>

(1) Overall there were no clinically significant differences between the various stages ($p=0.799$, $df=1$).

(2) For the female group, comparisons between all frequencies and all stages are the same as the "3.4.1 Treatment Influence" results except for in Points (i) and (iv) which are:

(i) 500 Hz (a) is not significantly different to 2 kHz (a, 10% and b), 6 kHz (a, 10%, 20% and b) and 3 kHz (b) ($p>0.05$).

(ii) 500 Hz (10% and 20%) is not significantly different to 2, 3, 4, 6 and 8 kHz (a, 10%, 20% and b) ($p>0.05$).

(iii) 500 Hz (b) is not significantly to 2 kHz (a, 10%, 20% and b), 6 kHz (a, 20% and b) and 3 kHz (a and b) ($p>0.05$).

Table 4.7 show the mean and standard deviation for the female group. There were no significant differences in comparisons of individual frequencies between the stages for this gender group (see Table 4.2) and this agrees with the H_0.

For the male group, comparisons between all frequencies and all stages are the same as the "3.4.1 Treatment Influence" results except for in Points (i) and (iv) which are:

(i) No significant differences were between 500 Hz (b) with 6 kHz (a, 10%, 20% and b) ($p>0.05$).

(ii) No significant differences were between 500 Hz (a and 10%) with 6 kHz (20%) ($p>0.05$).

Table 4.8 show the mean and standard deviation for the male group. Comparing means within individual frequencies across the stages also complies with the H_0 (Table 4.2).

3.5 Intensity Matching

This experiment tested the hearing memory of subjects, by comparing 12 sounds (6 in each ear) to a reference sound (at 4 kHz frequency). Each ear was tested independently and the reference sound was only given once at the start of each test, in each stage, and was 20 dB higher than the threshold intensity for 4 kHz in Air (a) stage for that ear being tested. The comparison sounds were either +5, 0 or -5 dB around that reference sound. As mentioned in Methods, 2.5 Intensity Matching and 4.0 Data Analysis, there are two types of analysis.

This first type of analysis was done by simultaneously comparing the number of correct (0) answers between the different stages (Program 5V (see Methods 4.0 Data Analysis)). From the analysis, ANOVA (repeated measures) with a significance p-level of 0.01, there were no statistically significant differences for the correct answers between the different groups within treatment stages, age, ear nor gender factors.

Wald tests of significance of fixed effects and covariates.

Factors	df	Chi-square	p-value
Treatment	3	1.11	0.775
Age	1	0.05	0.478
Ear	1	0.96	0.327
Gender	1	1.21	0.271

This indicates that there was no influence from N_2O on hearing memory and confers with the H_0.

Below is the second type of analysis in which the number of responses are reported including the direction in which the subjects were willing to label a sound, i.e if it was incorrectly answered was it considered louder or softer than the reference sound. Each specific group will be looked at.

3.5.1 Treatment Influences

(1) Overall there were no significant differences between the various stages (p=0.775, df=3). Thus the null hypothesis holds true as 10% and 20% N_2O does not influence memory in this group of subjects.

(2) Table 5.1 indicates the number of responses for each stage and the total. There were 16 subjects who completed all four stages and each subject gave 12 answers in each stage, thus 192 answers were given in total.

There were 64% correct (0) answers and 36% incorrect answers (+1, -1). In the incorrect group, 26% answered "-1" and the remaining 10% answered "+1". This indicated that when subjects interpreted and made judgement on the comparison sound, relative to the reference sound, they were more likely to answer correctly or state that the comparison sound was quieter than the reference sound.

3.5.2 Age

(1) No significant differences existed between the different age groups ($p=0.478$, $df=1$).

(2) The number of responses for the over 25 year age group are on table 5.2 and for under 25 years age group are on table 5.3. There were 65% correct (0) answers and of the 35% incorrect answers (+1, -1), of which 25% were -1. This indicates that the subjects interpreted the comparison sound to be the same as, or quieter than, the reference sound.

3.5.3 Ear

(1) No significant differences existed between the left and right ears ($p=0.327$, $df=1$).

(2) Data is presented on table 5.4 (left ear) and 5.5 (right ear). Left ear had 66% correct (0) answers while right had 62%. About 74% of the combined incorrect answers show that the comparison sound was judged to be the same as, or quieter than, the reference sound.

3.5.4 Gender

(1) No significant differences existed between the female and male groups ($p=0.271$, $df=1$).

(2) Table 5.6 shows female and table 5.7 shows male results. There were approximately 63% correct (0) answers and around 27% were -1 while about 10% were +1. Subjects interpreted the comparison sound to be the same as, or quieter than, the reference sound.

3.6 Subjective Intensity

Subjects were given a 10 cm analogue line and asked to rate the loudness of a 4 kHz tone of varying intensities (40, 60 and 80 dB).

This test gave the subject a range rather than discrete choices as in the Intensity Matching test.

The H_0 states that there is no influence of N_2O on the subjective hearing perception of 4 kHz at various intensity levels. Two methods of analysis were done as stated in Methods: 2.6 Subjective Intensity and 4.0 Data Analysis.

All data was simultaneously analysed with ANOVA (repeated measures) with a significance p-level of 0.01. There were no statistically significant differences between the different groups within age, ear nor gender factors. There were significant differences between the treatment stages (air and N_2O stages, $p=0.005$). Thus the H_0 doesn't hold true and the alternative hypothesis is accepted that 10% and 20% N_2O has an effect on hearing the various intensity levels. The intensity levels (dB level, $p<0.001$) were also significantly different indicating that the levels could not be easily misinterpreted as the same.

Wald tests of significance of fixed effects and covariates.

Factors	df	Chi-square	p-value
Treatment	1	7.86	0.005
Age	1	0.03	0.871
Ear	1	3.20	0.074
Gender	1	0.17	0.684
Intensity (dB)	1	1.93	<0.001

A further regression analysis was done using the same Program 5V, and a relationship was found that one could possibly equate to predict the intensity score ("Int." (mm)) at various intensity levels ("dB") and treatment stage ("R" (% N_2O)) combinations:

$$\text{Int.} = -42.2 - (0.54 \times R) + (1.65 \times dB)$$

3.6.1 Treatment Influences

(1) Significant differences existed between the treatment stages ($p=0.0005$, $df=1$). Thus there was some influence of N_2O on subjective auditory perception by the volunteer.

(2) The following analysis documents the influence of N_2O on the loudness intensity (40, 60 and 80 dB at 4 kHz) reported.

Table 6.1 lists the means and standard deviations of loudness intensity reported for all subjects for two controls in air (Air (a) and (b)) and during 10% and 20% N_2O inhalation. Table 6.2 summarises the statistical comparison.

As expected, in both control conditions (Air (a) and (b)), the mean values recorded for each intensity level was statistically significant between each level, i.e. 60 dB intensity level was significantly greater than that of 40 dB but less than that of 80 dB ($p<0.001$).

The principle finding was in comparing mean values of 60 dB to other loudness levels and between stages. When comparing 60 dB during 10% N_2O inhalation stages to the first control stage (Air (a)), subjects reported the loudness level of 60 dB to be significantly different ($p<0.05$). At 20% N_2O, the 60 dB was not significantly different from the loudness intensity of 40 dB (Air (a)) nor to 60 dB (Air (b)). This infers that under 10% and 20% N_2O inhalation the 60 dB intensity level appears quieter than under control conditions. Since 60 dB (20%) is not significantly different to 60 dB (Air (b)), it may imply that the breathing medium conditions in Air (b) may have not fully resolved back to normal, that is there may still be some N_2O persisting in the subjects' system.

There were significant differences in comparisons between the different intensities in both Air (a) and (b) stages indicating the three intensities were distinctly different (see Table 6.2). There was no significant differences when comparing the values within each intensity level between the two control stages which indicated that the subjects had returned to normal after at the completion of the experiment.

There was no significant effect on the low (40 dB) and high (80 dB) intensities under N_2O inhalation compared to controls. The smaller standard deviation values associated with these scores probably reflect the bunching of scores at the end of the visual analogue scale.

3.6.2 Age

(1) No significant differences existed between the age groups ($p=0.871$, $df=1$).

(2) Means and standard deviations for the over and under 25 years of age groups are shown on Tables 6.3 and 6.5 respectively.

Tables 6.4 and 6.6 are the comparison tables for over and under 25 years of age groups. Both age groups showed similar non-significant differences between 40 dB (a, 10% and b) and 60 dB (10% and 20%) ($p>0.05$).

The under 25 year age group (see Table 6.6) had significant differences between 60 dB (a and b) and 60 dB (10% and 20%) ($p<0.05$), unlike the over 25 year age group (see Table 6.4).

The over 25 year age group had no significant differences between 60 dB (a) and 80 dB (all stages), which was consistent throughout the whole experiment ($p>0.05$). This could be due to the effect of age on hearing, as the average scores for the 80 dB level appeared slightly lower than those in the under 25 year age.

This indicates that both N_2O and the age of the volunteer could have influence on the subjective perception of sound intensities (loudness).

3.6.3 Ear

(1) No significant differences existed between the left and right ear groups ($p=0.074$, $df=1$).

(2) Means and standard deviations for left and right ear are shown on Tables 6.7 and 6.9 respectively.

Both left and right ears show similar comparisons to the general data whereby 60 dB (10% and 20%) were not found to be significantly different from 40 dB (all stages) ($p>0.05$). This could indicate that N_2O has an influence on hearing perception.

The left ear (see Table 6.8) consistently did not exhibit significant differences between 60 dB (a) and 80 dB (all stages) ($p>0.05$), and could be due to the proximity of the left ear to the anaesthetic machine.

The right ear (see Table 6.10) has non-significant differences between 80 dB (10%) and 60 dB (a and b) ($p>0.05$). This also supports the previous finding that N_2O influences subjective perceptions.

3.6.4 Gender

(1) No significant differences existed between the two gender groups ($p=0.684$, $df=1$).

(2) Means and standard deviations for female and male gender groups are on Tables 6.11 and 6.13 respectively.

Females (see Table 6.12) had consistently no significant differences between 60 dB and 80 dB in and between all stages ($p>0.05$). Comparisons of 60 dB to 40 dB levels indicate that under the influence of 10% and 20% N_2O, these levels are perceived as similar ($p>0.05$), while comparisons to the controls, Air (a) and (b), show significant differences ($p<0.05$). For the female group, there were 34 non-significant differences noted between various intensities which is higher than in the male group which is 21. This may indicate that either there were insufficient female participants or that the females tended to record their answer in the centre of the recording line.

Males (see Table 6.14) have similar non-significant comparisons between 40 dB (a, 10% and 20%) and 60 dB (10% and 20% N_2O) ($p>0.05$) like the females.

These results indicate a possibility that N_2O influences the subjective perceptions of sound loudness regardless of gender differences.

Table 1.1

Mean personal physical data of the subjects.

	Male	Female	Total
Age (years)	23.6 (n=11)	24.4 (n=5)	23.9 (n=16)
Height (cms)	174.2 (n=10)	165 (n=5)	171.3 (n=15)
Weight (kgs)	71 (n=10)	58.2 (n=5)	66.7 (n=15)

Table 2.1

Mean blood pressure (mmHg) recordings of all subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Systolic	118 (±15) (n=16)	118 (±10) (n=15)	118 (±13) (n=14)	119 (±10) (n=10)
Diastolic	72 (±11) (n=15)	76 (±12) (n=15)	77 (±14) (n=13)	80 (±16) (n=9)

Table 2.2

Mean blood pressure (mmHg) recordings for subjects over 25 years of age (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Systolic	120 (±5) (n=6)	121 (±4) (n=6)	120 (±5) (n=5)	115 (±5) (n=4)
Diastolic	79 (±9) (n=5)	81 (±10) (n=5)	80 (±13) (n=4)	74 (±19) (n=3)

Table 2.3

Mean blood pressure (mmHg) recordings for subjects under 25 years of age (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Systolic	117 (±18) (n=10)	116 (±12) (n=10)	116 (±16) (n=9)	122 (±11) (n=6)
Diastolic	69 (±11) (n=10)	73 (±12) (n=10)	76 (±15) (n=9)	83 (±16) (n=6)

Table 2.4

Mean blood pressure (mmHg) recordings for female subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Systolic	109 (±14) (n=5)	113 (±8) (n=5)	107 (±10) (n=4)	114 (±4) (n=3)
Diastolic	71 (±14) (n=5)	76 (±15) (n=5)	74 (±16) (n=4)	78 (±18) (n=3)

Table 2.5

Mean blood pressure (mmHg) recordings for male subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Systolic	122 (±14) (n=11)	120 (±11) (n=11)	122 (±12) (n=10)	122 (±11) (n=7)
Diastolic	73 (±11) (n=10)	76 (±11) (n=10)	79 (±14) (n=9)	81 (±17) (n=6)

Table 2.6

Mean heart rate (beats/minute) for all subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Heart Rate	74 (±8) (n=16)	72 (±13) (n=16)	71 (±12) (n=15)	70 (±15) (n=11)

Table 2.7

Mean heart rate (beats/minute) for subjects over 25 years of age (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Heart Rate	73 (±4) (n=6)	70 (±17) (n=6)	68 (±16) (n=6)	70 (±21) (n=4)

Table 2.8

Mean heart rate (beats/minute) for subjects under 25 years of age (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Heart Rate	76 (±10) (n=10)	74 (±10) (n=10)	73 (±9) (n=9)	71 (±12) (n=7)

Table 2.9

Mean heart rate (beats/minute) for female subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Heart Rate	71 (±7) (n=5)	72 (±6) (n=5)	71 (±6) (n=5)	67 (±4) (n=3)

Table 2.10

Mean heart rate (beats/minute) for male subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Heart Rate	76 (±9) (n=11)	73 (±15) (n=11)	72 (±15) (n=10)	72 (±17) (n=8)

Table 2.11

Mean haemoglobin oxygen saturation (%) for all subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Saturation	98 (±1) (n=16)	99 (±1) (n=16)	99 (±1) (n=15)	98 (±1) (n=12)

Table 2.12

Mean haemoglobin oxygen saturation (%) for subjects over 25 years of age (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Saturation	99 (±0) (n=6)	99 (±1) (n=6)	99 (±1) (n=6)	97 (±1) (n=4)

Table 2.13

Mean haemoglobin oxygen saturation (%) for subjects under 25 years of age.

	Air (a)	10% N_2O	20% N_2O	Air (b)
Saturation	98 (±1) (n=10)	99 (±1) (n=10)	99 (±1) (n=9)	98 (±1) (n=8)

Table 2.14

Mean haemoglobin oxygen saturation (%) for female subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Saturation	98 (±1) (n=5)	99 (±0) (n=5)	99 (±0) (n=5)	98 (±1) (n=4)

Table 2.15

Mean haemoglobin oxygen saturation (%) for male subjects (including standard deviations).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Saturation	98 (±1) (n=11)	98 (±1) (n=11)	99 (±1) (n=10)	98 (±1) (n=8)

Table 2.16

Hearing: "Did the examiner's voice seem distant/normal/close?" (Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Distant	1	2	5	1	6	15
Normal	13	13	10	14	7	57
Close	2	1	1	0	1	5

Table 2.17

Hearing: "Did the examiner's voice seem distinct/normal/muffled?" (Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Distinct	9	6	8	5	3	31
Normal	7	9	7	11	7	41
Muffled	0	1	1	0	3	5

Table 2.18

Hearing: "Did the examiner's voice sound echoing/normal/clear?"
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Echoing	3	2	4	1	3	13
Normal	6	9	9	11	8	43
Clear	7	5	3	3	3	21

Table 2.19

Hearing: "Did the examiner's voice seemed high/normal/low pitched?"
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
High	2	3	5	2	5	17
Normal	14	12	10	13	9	58
Low	0	1	1	1	0	3

Table 2.20

Hearing: "Do you hear any humming/no/ringing noises?"
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Hums	2	1	2	0	1	6
Nothing	13	15	11	14	8	61
Rings	1	0	3	0	3	7

Table 2.21

Thermal Sensations: Cold/Fine/Hot/Other

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Cold	0	0	0	0	0	0
Fine	13	9	10	13	10	55
Hot	2	4	4	2	5	17
Other	1	3	2	0	0	6

Table 2.22

Vision: Blurred/Normal/Clearer/Colour Changes

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Blurred	0	3	3	1	3	10
Normal	16	13	11	13	6	59
Clearer	0	0	0	1	1	2
Colour	0	0	0	0	1	1

Table 2.23

Smells: Perfume/Pungent/Dusty/Rubbery/None/Other
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp -ective View	Total
Perfume	0	1	1	0	1	3
Pungent	2	0	0	2	0	4
Dusty	0	0	0	0	0	0
Rubbery	0	7	5	1	4	17
None	12	5	9	11	6	43
Other	0	2	1	1	3	9

Table 2.24

Taste: Sweet/Salty/Sour/Bitter/Other/None
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp -ective View	Total
Sweet	1	0	0	1	0	2
Salty	0	0	2	0	2	4
Sour	0	0	0	0	0	0
Bitter	0	0	1	0	1	2
Other	2	0	0	0	0	2
None	13	16	13	15	15	69

Table 2.25

Concentration: Easy/Normal/Difficult

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Easy	3	1	2	2	2	10
Normal	11	9	6	14	2	42
Difficult	2	6	8	0	9	25

Table 2.26

Body Sensations: Excited/Normal/Relaxed

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Excited	2	2	0	0	2	6
Normal	9	6	6	9	2	32
Relaxed	5	7	9	7	11	39

Table 2.27

Body Sensations: (Emotions) Happy/Normal/Sad

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Happy	1	2	5	1	6	15
Normal	15	14	11	15	8	63
Sad	0	0	0	0	0	0

Table 2.28

Body Sensations: Lightness/Normal/Heaviness

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Lightness	0	3	8	2	9	22
Normal	15	9	5	13	2	44
Heaviness	1	3	3	1	3	11

Table 2.29

Body Sensations: (Muscle) Tremors/Normal/Stillness

(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Tremors	0	1	1	0	0	2
Normal	14	14	14	16	12	70
Stillness	2	0	1	0	0	3

Table 2.30

Body Sensations: Tingling/None/Paraesthesia
(Number of responses)

	Air (a)	10% N_2O	20% N_2O	Air (b)	Retrosp-ective View	Total
Tingling	0	2	7	0	7	16
None	16	10	5	14	4	49
Paraes-thesia	0	2	2	1	2	7

Table 3.1

Mean middle ear pressure (daPa) for all subjects (including standard deviations) (n=32).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-12 (± 22)	8 (±32)	26 (±26)	5 (±26)

Table 3.2

Mean middle ear pressure (daPa) for subjects over 25 years of age (including standard deviations) (n=12).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-20 (±33)	0 (±37)	20 (±29)	0.5 (±13)

Table 3.3

Mean middle ear pressure (daPa) for subjects under 25 years of age (including standard deviations) (n=20).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-8 (±11)	12 (±28)	29.7 (±24)	8 (±31)

Table 3.4

Mean middle ear pressure (daPa) for left ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-13 (±28)	6 (±40)	24 (±28)	0.8 (±26)

Table 3.5

Mean middle ear pressure (daPa) for right ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-11.6 (±15)	9 (±22)	29 (±24)	10 (±26)

Table 3.6

Mean middle ear pressure (daPa) for females (including standard deviations) (n=10).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-4 (±9)	22 (±9)	35 (±9)	2 (±17)

Table 3.7

Mean middle ear pressure (daPa) for males (including standard deviations) (n=22).

	Air (a)	10% N_2O	20% N_2O	Air (b)
MEP	-16 (±26)	0.8 (±36)	22 (±30)	7 (±29)

Table 3.8

Middle ear pressure (daPa) comparison of stages for all subjects (n=32).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		S	S	S
10% N_2O			S	NS
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.9

Middle ear pressure (daPa) comparison of stages for subjects over 25 years of age (n=12).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		S	S	S
10% N_2O			S	NS
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.10

Middle ear pressure (daPa) comparison of stages for subjects under 25 years of age (n=20).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		S	S	NS
10% N_2O			S	NS
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.11

Middle ear pressure (daPa) comparison of stages for left ear (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		NS	S	NS
10% N_2O			NS	NS
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.12

Middle ear pressure (daPa) comparison of stages for right ear (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		S	S	S
10% N_2O			S	NS
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.13

Middle ear pressure (daPa) comparison of stages for females (n=10).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		S	S	NS
10% N_2O			NS	S
20% N_2O				S
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.14

Middle ear pressure (daPa) comparison of stages for males (n=22).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		NS	S	S
10% N_2O			S	NS
20% N_2O				NS
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.15

Mean Physical Volume (PV) (ml) for all subjects (including standard deviations) (n=32).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.7 (±0.3)	1.6 (±0.3)	1.7 (±0.4)	1.6 (±0.3)

Table 3.16

Mean Physical Volume (PV) (ml) for subjects over 25 years of age (including standard deviations) (n=12).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.7 (±0.3)	1.7 (±0.3)	1.7 (±0.4)	1.8 (±0.3)

Table 3.17

Mean Physical Volume (PV) (ml) for subjects under 25 years of age (including standard deviations) (n=20).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.6 (±0.3)	1.6 (±0.3)	1.6 (±0.3)	1.5 (±0.3)

Table 3.18

Mean Physical Volume (PV) (ml) for the left ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.7 (±0.3)	1.7 (±0.3)	1.7 (±0.4)	1.7 (±0.4)

Table 3.19

Mean Physical Volume (PV) (ml) for right ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.6 (±0.4)	1.5 (±0.2)	1.6 (±0.3)	1.6 (±0.3)

Table 3.20

Mean Physical Volume (PV) (ml) for females (including standard deviations) (n=10).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.6 (+/-0.4)	1.6 (+/-0.2)	1.5 (+/-0.4)	1.5 (+/-0.3)

Table 3.21

Mean Physical Volume (PV) (ml) for males (including standard deviations) (n=22).

	Air (a)	10% N_2O	20% N_2O	Air (b)
PV	1.7 (±0.3)	1.7 (±0.3)	1.7 (±0.3)	1.7 (±0.3)

Table 3.22

Physical Volume (ml) comparison of stages for all data presented, and for age, ear and gender groupings.

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		NS	NS	NS
10% N_2O			NS	NS
20% N_2O				NS
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 3.23

Mean Compliance (Comp) (ml) for all subjects (including standard deviations) (n=32).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.8 (±0.4)	0.8 (±0.5)	0.8 (±0.5)	0.8 (±0.4)

Table 3.24

Mean Compliance (Comp) (ml) for subjects over 25 years old (including standard deviations) (n=12).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.8 (±0.5)	0.8 (±0.5)	0.8 (±0.6)	0.8 (±0.4)

Table 3.25

Mean Compliance (Comp) (ml) for subjects under 25 years old (including standard deviations) (n=20).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.8 (±0.4)	0.8 (±0.5)	0.8 (±0.4)	0.8 (±0.4)

Table 3.26

Mean Compliance (Comp) (ml) the left ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.9 (±0.5)	1.0 (±0.7)	0.9 (±0.6)	0.9 (±0.5)

Table 3.27

Mean Compliance (Comp) (ml) for the right ear (including standard deviations) (n=16).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.7 (±0.2)	0.7 (±0.3)	0.7 (±0.3)	0.7 (±0.3)

Table 3.28

Mean Compliance (Comp) (ml) for females (including standard deviations) (n=10).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.9 (±0.2)	1.1 (±0.5)	0.9 (±0.3)	0.9 (±0.3)

Table 3.29

Mean Compliance (Comp) (ml) for males (including standard deviations) (n=22).

	Air (a)	10% N_2O	20% N_2O	Air (b)
Comp	0.7 (±0.4)	0.7 (±0.5)	0.7 (±0.5)	0.8 (±0.4)

Table 3.30

Compliance comparison of stages for all data presented, and for age, ear and gender groupings.

	Air (a)	10% N_2O	20% N_2O	Air (b)
Air (a)		NS	NS	NS
10% N_2O			NS	NS
20% N_2O				NS
Air (b)				

NS = Not significant ($p>0.05$) S = Significant ($p<0.05$)

Table 4.1

Table of means and standard deviation for the minimal threshold intensity (dB). (n=32)

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	27 (±6)	25 (±9)	27 (±10)	26 (±8)
	1 kHz	18 (±5)	17 (±7)	18 (±7)	17 (±12)
	1.5 kHz	19 (±6)	17 (±8)	18 (±8)	18 (±7)
	2 kHz	11 (±6)	10 (±7)	11 (±7)	10 (±7)
	3 kHz	9 (±6)	9 (±7)	9 (±7)	8 (±7)
	4 kHz	9 (±7)	9 (±7)	13 (±13)	9 (±7)
	6 kHz	13 (±7)	15 (±10)	15 (±10)	13 (±9)
	8 kHz	10 (±9)	9 (±9)	10 (±10)	8 (±9)

Graph 4.1

Minimal hearing threshold Vs.

Normal hearing frequency range (all data).

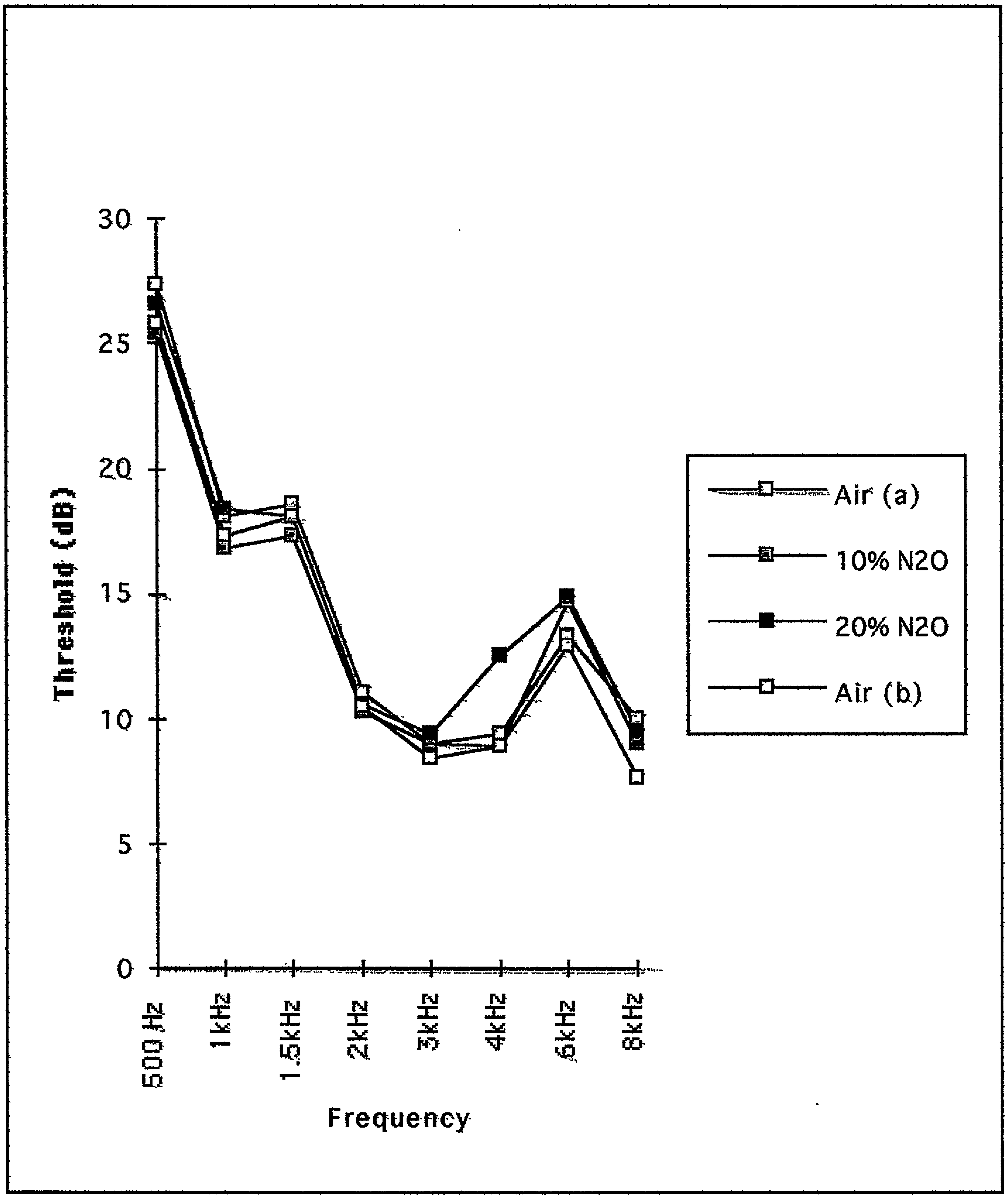

Table 4.2

Comparisons of the threshold level of individual frequencies between the stages,
for example 5 kHz (Air (a) stage) cf 5 kHz (Air (b) stage).

This table is for general data (n=32), over 25 year old age group (n=12), under 25 year old age group (n=18), for left ear (n=15), for right ear (n=15), for female group (n=8) and for male group (n=22).

		Stages: 10% N_2O	Stages: 20% N_2O	Stages: Air (b)
Air (a)	500 Hz	NS	NS	NS
	1 kHz	NS	NS	NS
	1.5 kHz	NS	NS	NS
	2 kHz	NS	NS	NS
	3 kHz	NS	NS	NS
	4 kHz	NS	NS	NS
	6 kHz	NS	NS	NS
	8 kHz	NS	NS	NS
10% N_2O	500 Hz		NS	NS
	1 kHz		NS	NS
	1.5 kHz		NS	NS
	2 kHz		NS	NS
	3 kHz		NS	NS
	4 kHz		NS	NS
	6 kHz		NS	NS
	8 kHz		NS	NS
20% N_2O	500 Hz			NS
	1 kHz			NS
	1.5 kHz			NS
	2 kHz			NS
	3 kHz			NS
	4 kHz			NS
	6 kHz			NS
	8 kHz			NS

NS = No Significant difference * = $P < 0.05$

Table 4.3

Table of means and standard deviation for the minimal threshold intensity (dB) for over 25 years old (n=12).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	28 (±6)	27 (±6)	29 (±7)	28 (±8)
	1 kHz	19 (±5)	19 (±6)	20 (±6)	19 (±6)
	1.5 kHz	18 (±8)	18 (±7)	20 (±8)	18 (±8)
	2 kHz	13 (±8)	12 (±8)	13 (±7)	14 (±8)
	3 kHz	13 (±7)	12 (±9)	13 (±8)	12 (±7)
	4 kHz	14 (±8)	13 (±9)	14 (±9)	13 (±8)
	6 kHz	19 (±6)	23 (±7)	20 (±10)	20 (±8)
	8 kHz	13 (±11)	14 (±11)	15 (±12)	13 (±11)

Table 4.4

Table of means and standard deviation for the minimal threshold intensity (dB) for under 25 years old (n=18).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	27 (±6)	24 (±11)	24 (±11)	24 (±9)
	1 kHz	17 (±6)	15 (±7)	17 (±8)	16 (±6)
	1.5 kHz	19 (±5)	17 (±7)	16 (±8)	18 (±6)
	2 kHz	10 (±6)	10 (±5)	9 (±6)	8 (±5)
	3 kHz	7 (±5)	7 (±5)	7 (±5)	7 (±6)
	4 kHz	6 (±6)	6 (±6)	7 (±6)	6 (±5)
	6 kHz	9 (±6)	8 (±8)	11 (±9)	8 (±5)
	8 kHz	8 (±6)	5 (±6)	6 (±7)	5 (±7)

Table 4.5

Table of means and standard deviation for the minimal threshold intensity (dB) for left ear (n=15).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	29 (±6)	27 (±10)	29 (±11)	28 (±9)
	1 kHz	19 (±5)	18 (±9)	20 (±8)	20 (±5)
	1.5 kHz	19 (±7)	18 (±8)	20 (±8)	20 (±7)
	2 kHz	12 (±6)	11 (±6)	12 (±6)	11 (±6)
	3 kHz	10 (±6)	11 (±6)	11 (±6)	11 (±7)
	4 kHz	11 (±8)	10 (±7)	11 (±8)	9 (±7)
	6 kHz	14 (±6)	14 (±10)	15 (±10)	13 (±9)
	8 kHz	10 (±8)	9 (±8)	10 (±9)	9 (±8)

Table 4.6

Table of means and standard deviation for the minimal threshold intensity (dB) for right ear (n=15).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	26 (±7)	24 (±9)	23 (±9)	23 (±8)
	1 kHz	17 (±5)	23 (±4)	16 (±6)	15 (±6)
	1.5 kHz	18 (±6)	16 (±6)	16 (±8)	15 (±6)
	2 kHz	11 (±7)	10 (±7)	9 (±7)	10 (±8)
	3 kHz	8 (±7)	7 (±7)	8 (±7)	7 (±7)
	4 kHz	8 (±8)	8 (±8)	9 (±9)	8 (±7)
	6 kHz	13 (±9)	14 (±11)	14 (±11)	13 (±9)
	8 kHz	11 (±10)	8 (±10)	10 (±12)	7 (±10)

Table 4.7

Table of means and standard deviation for the minimal threshold intensity (dB) for female group (n=8).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	29 (±5)	21 (±14)	22 (±14)	29 (±6)
	1 kHz	19 (±5)	17 (±7)	15 (±10)	18 (±7)
	1.5 kHz	21 (±5)	18 (±10)	18 (±13)	20 (±7)
	2 kHz	11 (±6)	11 (±4)	9 (±7)	11 (±7)
	3 kHz	9 (±6)	8 (±7)	9 (±6)	10 (±7)
	4 kHz	8 (±7)	7 (±7)	8 (±5)	7 (±5)
	6 kHz	12 (±5)	15 (±13)	12 (±13)	10 (±9)
	8 kHz	9 (±6)	7 (±9)	8 (±10)	7 (±9)

Table 4.8

Table of means and standard deviation for the minimal threshold intensity (dB) for male group (n=22).

		Air (a)	10% N_2O	20% N_2O	Air (b)
Frequency	500 Hz	26 (±7)	27 (±7)	28 (±8)	25 (±9)
	1 kHz	17 (±6)	17 (±7)	19 (±6)	17 (±5)
	1.5 kHz	17 (±6)	17 (±6)	18 (±6)	17 (±7)
	2 kHz	12 (±7)	10 (±7)	11 (±7)	10 (±7)
	3 kHz	9 (±7)	10 (±7)	10 (±7)	8 (±7)
	4 kHz	10 (±8)	9 (±8)	11 (±9)	9 (±8)
	6 kHz	14 (±8)	14 (±10)	15 (±10)	14 (±9)
	8 kHz	11 (±10)	9 (±9)	10 (±11)	8 (±9)

Table 5.1: Intensity Matching.

General data: Number of responses (n=32).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	54	45	50	52	201	26%
0	123	129	121	120	493	64%
+1	15	18	21	20	74	10%
Sum	192	192	192	192	768	100%

Table 5.2: Intensity Matching.

Number of responses for over 25 year age group (n=12).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	18	16	18	16	68	24%
0	46	51	45	45	187	65%
+1	8	5	9	11	33	11%
Sum	72	72	72	72	288	100%

Table 5.3: Intensity Matching.

Number of responses for under 25 age group (n=20).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	36	29	32	36	133	28%
0	77	78	76	75	306	64%
+1	7	13	12	9	41	8%
Sum	120	120	120	120	480	100%

Table 5.4: Intensity Matching.

Number of responses for left ear (n=16).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	30	17	21	23	91	24%
0	58	70	64	61	253	66%
+1	8	9	11	12	40	10%
Sum	96	96	96	96	384	100%

Table 5.5: Intensity Matching.

Number of responses for right ear (n=16).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	24	28	29	29	110	29%
0	65	59	57	59	240	62%
+1	7	9	10	8	34	9%
Sum	96	96	96	96	384	100%

Table 5.6: Intensity Matching.

Number of responses for female subjects (n=10).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	18	15	19	18	70	29%
0	39	40	33	34	146	61%
+1	3	5	8	8	24	10%
Sum	60	60	60	60	240	100%

Table 5.7: Intensity Matching.

Number of responses for male subjects (n=22).

Answers	Air (a)	10% N_2O	20% N_2O	Air (b)	Sum	Percentage
-1	36	30	31	34	131	25%
0	84	89	88	86	347	66%
+1	12	13	13	12	50	9%
Sum	132	132	132	132	528	100%

Table 6.1: Subjective Intensity.

General data's means and standard deviations

(units represent distance along a 100 mm visual analogue scale)

(n=32).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	27	17
	60 dB	64	15
	80 dB	89	10
10% N_2O	40 dB	22	15
	60 dB	45	24
	80 dB	84	12
20% N_2O	40 dB	14	13
	60 dB	40	24
	80 dB	86	11
Air (b)	40 dB	21	17
	60 dB	55	21
	80 dB	88	9

Table 6.2: Subjective Intensity.

Comparison table for general data analysis (n=32).

	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	*										
10% N_2O	40	NS	*	*									
	60	*	*	*	*								
	80	*	*	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	*	*	*	NS	*	*					
	80	*	*	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	*	*	NS	*	*			
	60	*	NS	*	*	NS	*	*	NS	*	*		
	80	*	*	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

Table 6.3: Subjective Intensity.

Means and Standard Deviation for over 25 year age group (n=12).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	34	14
	60 dB	61	9
	80 dB	85	11
10% N_2O	40 dB	28	14
	60 dB	50	20
	80 dB	82	13
20% N_2O	40 dB	14	12
	60 dB	50	17
	80 dB	84	10
Air (b)	40 dB	21	10
	60 dB	51	15
	80 dB	84	10

Table 6.4: Subjective Intensity.

Comparison table for over 25 year age group (n=12).

Stages	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	NS										
10% N_2O	40	NS	*	*									
	60	NS	NS	*	NS								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	NS	*	NS	NS	*	*					
	80	*	NS	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	*	*	NS	*	*			
	60	NS	NS	*	*	NS	*	*	NS	*	*		
	80	*	NS	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

Table 6.5: Subjective Intensity.

Means and standard deviations for under 25 age group (n=20).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	22	17
	60 dB	66	18
	80 dB	92	8
10% N_2O	40 dB	18	15
	60 dB	42	27
	80 dB	86	11
20% N_2O	40 dB	14	14
	60 dB	34	26
	80 dB	87	11
Air (b)	40 dB	21	21
	60 dB	57	24
	80 dB	90	8

Table 6.6: Subjective Intensity.

Comparison table for under 25 years age group (n=20).

	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	*										
10% N_2O	40	NS	*	*									
	60	NS	*	*	*								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	*	*	NS	NS	*	NS					
	80	*	NS	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	NS	*	NS	NS	*			
	60	*	NS	*	*	NS	*	*	*	*	*		
	80	*	*	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

Table 6.7: Subjective Intensity.

Means and Standard Deviation for left ear (n=16).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	25	18
	60 dB	64	17
	80 dB	89	9
10% N_2O	40 dB	18	13
	60 dB	41	25
	80 dB	83	12
20% N_2O	40 dB	14	9
	60 dB	38	26
	80 dB	85	11
Air (b)	40 dB	25	20
	60 dB	47	22
	80 dB	88	9

Table 6.8: Subjective Intensity.

Comparison table for the left ear (n=16).

	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	NS										
10% N_2O	40	NS	*	*									
	60	NS	NS	*	NS								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	*	*	NS	NS	*	NS					
	80	*	NS	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	NS	*	NS	NS	*			
	60	NS	NS	*	*	NS	*	*	NS	*	NS		
	80	*	NS	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

Table 6.9: Subjective Intensity.

Means and Standard Deviation for right ear (n=16).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	28	17
	60 dB	64	14
	80 dB	90	10
10% N_2O	40 dB	25	17
	60 dB	49	24
	80 dB	86	12
20% N_2O	40 dB	14	16
	60 dB	42	23
	80 dB	87	11
Air (b)	40 dB	17	13
	60 dB	64	15
	80 dB	87	9

Table 6.10: Subjective Intensity.

Comparison table for the right ear (n=16).

	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	*										
10% N_2O	40	NS	*	*									
	60	NS	NS	*	*								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	NS	*	NS	NS	*	*					
	80	*	*	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	*	*	NS	*	*			
	60	*	NS	*	*	NS	NS	*	NS	*	*		
	80	*	*	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

Table 6.11: Subjective Intensity.

Mean and standard deviation for female (n=10).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	27	17
	60 dB	61	15
	80 dB	88	8
10% N_2O	40 dB	24	19
	60 dB	47	22
	80 dB	80	12
20% N_2O	40 dB	24	19
	60 dB	45	25
	80 dB	84	10
Air (b)	40 dB	21	15
	60 dB	60	22
	80 dB	87	9

Table 6.12: Subjective Intensity.

Comparison table for female (n=10).

Stages	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	NS										
10% N_2O	40	NS	*	*									
	60	NS	NS	*	NS								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	NS	*						
	60	NS	NS	*	NS	NS	*	NS					
	80	*	NS	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	NS	*	NS	NS	*			
	60	*	NS	NS	*	NS	NS	*	NS	NS	*		
	80	*	NS	NS	*	*	NS	*	*	NS	*	NS	

NS = Not Significant   *= $P < 0.05$

Table 6.13: Subjective Intensity.

Mean and standard deviation for male (n=22).

Stages	Intensity	Mean (mm)	Standard Deviation
Air (a)	40 dB	26	17
	60 dB	65	16
	80 dB	90	11
10% N_2O	40 dB	21	14
	60 dB	44	26
	80 dB	86	11
20% N_2O	40 dB	10	5
	60 dB	38	24
	80 dB	87	11
Air (b)	40 dB	21	18
	60 dB	53	20
	80 dB	88	9

Table 6.14: Subjective Intensity.

Comparison table for male (n=22).

Stages	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	dB levels	40	60	80	40	60	80	40	60	80	40	60	80
Air (a)	40												
	60	*											
	80	*	*										
10% N_2O	40	NS	*	*									
	60	NS	*	*	*								
	80	*	NS	NS	*	*							
20% N_2O	40	NS	*	*	NS	*	*						
	60	NS	*	*	NS	NS	*	*					
	80	*	*	NS	*	*	NS	*	*				
Air (b)	40	NS	*	*	NS	*	*	NS	NS	*			
	60	*	NS	*	*	NS	*	*	NS	*	*		
	80	*	*	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant *= $P < 0.05$

4. Discussion

Contents

The main objective of this study was to determine if N_2O had an influence on hearing. Sixteen volunteers in this study breathed various gaseous mixtures (air, 10% and 20% N_2O with 90% and 80% O_2 respectively) and underwent tests designed to determine their state of consciousness during the procedure, but most importantly to test their hearing.

4.1 Questionnaires

All subjects had minimal or no knowledge of the effects of directly inhaling a $N_2O:O_2$ gaseous mixture, thus allowing an unbiased experience. One person was unable to persist and this was anticipated, as in the dental surgery not every pain control technique is adequate for all patients.

4.1.1 Questionnaire 1

4.1.1.1 Personal Data

Mean age: Ages were within the adult range and not have any ear nor nerve pathologies due to age or wear. Mean height and weight: Both these indices are within acceptable limits for BMI (Body Mass Index) (Wilkinson, 1989). Occupations: Volunteers were from professions that could analyse and communicate their views readily.

Volunteers represented the general Australian community. There were too few a number to distinguish cultural/ethnic differences and intermingling of cultures within the community would be impossible to distinguish any ethnic influences.

4.1.1.2 Past and Current Medical History

There were no influencing current pathologies that could influence the procedure or the testing sequence.

4.1.1.3 Present Physical Status

There were no influencing drugs taken within 24 hours preceding the experiment, except caffeine which may influence physiological factors. Lack of smokers reflects the society's current attitude. Thus the respiratory system in all subjects should perform to its maximum potential. Normal daily routines including sleep suggest that there was minimal interference from possible tiredness. Only two ate within 2 hours of the experiment starting. Food ingestion usually incorporates air and this creates another closed air pocket which can expand under N_2O inhalation and possibly create nausea.

4.1.1.4 Physical Assessment

There did not appear to be any current pathologies detected to interfere with breathing through the nasal passages, nor with performing the tasks, nor with decision making.

4.1.2 Questionnaire 2

This questionnaire was given at the very end of the experiment and designed to summarise the subjective physiological effects of N_2O, e.g. influences on time perceptions, hearing extraneous noises, mental concentration. Subjects were given more latitude in answering to express any or all views that were not previously nor directly questioned.

Statistical analysis was not done on these questions due to the breadth of answers.

Even though this questionnaire is not directly related to the aim of this thesis (i.e. influence of N_2O on hearing) it did determine (i) if they paid attention to the task at hand (e.g. remembering all commands and statement given to them), (ii) if any external noises were influencing their concentration/hearing, and (iii) confirmed that N_2O was employed.

Discussions are printed below for each of the italicised questions asked.

Did you find concentration on the task easy/difficult?

From the results, nine subjects answered easy, seven difficult, one did not answer this question (but this subject answered all others). Even though the seven answered "difficult", they still managed to answer questions and perform all tasks presented.

As mentioned in Methods, this question was used to determine if any of the tasks were easy or difficult. No comments, by the subjects, were made during the experiment about any degree of difficulty, yet retrospectively, the subjects stated that concentration was difficult. If concentration was difficult then one would assume that the performance of tasks would result in many errors or discrepancies and this did not seem to occur. The results from, presumably, the most difficult test for the subjects, i.e. intensity matching, showed that N_2O had no influence in the perception of sounds nor in the subject indicating an answer. It seems that N_2O did not affect the concentration for such a discriminating task, thus concentration appears not to have been adversely affected whilst subjects were under N_2O.

Did you hear any extraneous noises? Y/N What where they?

No extraneous/hallucinogenic noises were heard. The answers indicate that the room was in a quiet part of the hospital and that it was conducted in a quiet part of the day. As stated in Methods that the possibility of extraneous noise influencing the subject's hearing did not eventuate.

Thus there was not the expected auditory "hallucinations" nor imposing background noises being noticed by the subjects, as stated in Methods.

Do you remember any commands/statements given to you during the procedure? Y/N What was it?

Answers to this question involves their concept of "time", in that the subjects have to scan the events over the previous couple of hours of this experiment. Also this question indicates that no unusual nor strange requests, that may have been considered 'out of character' with the experiment, were asked.

Any answer, whether it was none/yes/no, indicated that they were consciously aware of making deliberate responses during the experiment, also, all other assessments should not be invalidated as a rational answer was given to this question.

A common response was that subjects remembered the whole procedure, yet it was difficult to remember every statement accurately, as expected. It is suspected that those that did not answer may have answered "yes". Those that answered "no" or did not give an answer may have found the question was too difficult to be precise about remembering every statement. A reason for their particular answer was not asked.

Did the passage of time seem as quick/slow as you expected it to be?

From the results, two stated that time seemed to pass normally, four replied slower, and ten replied faster. Of the four that did not reply to the previous question on the remembrance of commands, two stated that the passage of time seemed quicker, another wrote that it was quicker through stage 3, and the last one circled "quick" but also wrote "no concept of time because of gas". This "quickness" of time could occur due to the "newness" of experiences. Subjects were unaware of the clock above the anaesthetic machine and were placed facing away from it, thus they had no physical confirmation of time till after the experiment.

From Robson and co-workers (1960) experiment, his subjects experienced time passing quickly however the subjects' measurement of time was slow. The answers in this current thesis indicate that there was an alteration of time perception by the subjects. It also confirms, by the most common response, that time appeared to go "faster".

Did you feel like yawning/coughing during the procedure? Y/N When? Did you feel as though you needed to "pop" your ears at any time? Y/N When?

This question relates directly to the subject's acoustic apparatus and determines subject's comfort. Nitrous oxide can increase pressure in the middle ear and possibly cause pain. Yawning or venting can also occur, which can influence the MEP thus affect the results. Passive venting occurs at 150-300 mm H2O and 67% N_2O (Davis *et al* 1979). The average MEP, for subjects in this thesis, was 26 daPa (see Results Table 3.1, and 1 daPa is equivalent to 1.02 mm H2O) thus pressures in the middle ear were not high enough to cause passive venting. As to the degree of influence that increases in MEP has on the hearing conducted in this thesis, is unknown. Only one can look at the results of the tests and see if any significant effects have occurred.

Answers for both questions were identical: Twelve replied "no" and four replied "yes" that they yawned/coughed/popped their ears. This action leads to the two facts, (1) there was a pressure increase in the middle ear and (2) there is a mechanism which prevent tympanic membrane rupture and is used without conscious effort. This correlates with Matz and co-workers (1967) work that passive venting occurs, through the eustachian tube, when pressures in the middle ear increase, but is only a temporary fall. Davis and co-workers (1979) states that passive venting occurs at between 150-300 mm H2O and pressures in the middle ear did not reach these levels (see Results 3.1 Middle Ear Pressure).

Did you experience any thermal changes in parts of your body and head? Y/N If yes, was it; cold/heat sensations, and where? Could it have been the room?

This question is repeated in another questionnaire, however here it allows the subject to consider if there are any body changes due to the room environment.

Eight subjects had answered that there was a thermal change and that the change was either "warm" or "hot", to some parts or all the body. Eight answered that there was no change, thus were obviously comfortable and did not state that they were "cold" which is as expected, for Kaufman and co-workers (1990) state that in their pilot study, there are warm thermal sensory changes while under 35% N_2O, and this is the same as reported by Bennett (1984).

How you feel during the experiment?

Responses (in Results 1.2) were typical of the effects of N_2O on the body. Kaufman and co-workers (1990) reports of "general heaviness, relaxation or tingling" which is similar to the subjects' experiences.

Would you do it again? Y/N

Fifteen "yes" answers indicates the "agreeability" of the experiment as indicated by the subjects' willingness to do the tasks and undergo N_2O inhalation again. It also indicates that in future experiments, these N_2O levels would be acceptable, and the tasks performed not difficult for the subject.

Any further comments about your sensations under N_2O or the procedure would be appreciated;

The reiteration of previous answers and the positive attitude of the subjects confirms the previous question's answers. It also indicates that the subjects are unable to comment on other lateral aspects of N_2O not brought to their attention, e.g. they were ignorant on the facts of diffusion hypoxia and this phenomena did not seem to disturb them. Also no comment was made on the fact that the initial sensations of N_2O produced a fast approaching "rush" of altered sensation, which took time to get used to. This "rush" was possibly why one 21-year-old male subject halted the procedure after 4 - 5 minutes had elapsed into the initial 10 minute adjustment phase of the 10% N_2O stage and did not complete the experiment due to his inability to cope with feelings of lightheadedness or giddiness.

4.2 Physiological Functions

There were minor fluctuations in physiological variables however these remained within normal limits. (Bennett, 1984)

4.2.1 Blood Pressure (BP)

It was expected that BP changes were not going to be clinically detectable when subjects breathed N_2O relative to breathing air.

All recordings were within normal limits, indicating the safety of the experiment, and no influence of age or gender differences occurred.

4.2.2 Heart Rate (HR)

As expected, the results and analysis were the same as for BP and there were no clinically detectable changes.

4.2.3 Oxygen Saturation (SaO_2)

A statistically significant decrease in SaO_2 levels is expected when room air is used instead of O2, during recovery phase, yet no clinically significant effects in healthy young patients (Milles *et al* 1991).

Results were the same as for BP, however there were two significant ANOVA comparisons. Significant differences were seen between the 20% N_2O stage to Air (a & b) stages ($p<0.05$, $n=6$) (see Results, Table 2.11), even though subjects were not clinically affected. The tissues by this stage of the experiment are and have been fully saturated with O_2 for more than 45 minutes and that is why they are 1% better saturated than in the Air (a and b) stages.

4.2.4 Subjective Perceptions

This assessment had three aims, as described in 2.2.2.5 Subjective Perceptions: (1) to determine if the N_2O produced sensations that are common to its use, (2) the subject's subjective view in hearing a normal human voice and if any changes had occurred in hearing that human voice, and (3) was there a satisfactory level of consciousness as assessed by the subject's ability to answer? This can, in turn, help identify any potential communication problems, and thus possible medico-legal considerations, that may arise in the clinical anaesthetic or dental situation. Statistical analysis need not be done, other than finding the commonest answer.

Hearing; *Did the examiner's voice seem.........?*

To define "acuteness" in hearing, by using analytical methods, is difficult. It seems to be a subjective rather than an objective observation. The questions below were designed to determine any subjective hearing changes.

distant / normal / closer (Table 2.16)

At the 20% N_2O stage, 31% of the responses were "distant", and this agrees with other researchers such as Bailenson (1972) and Spiro (1972), but not Bennett (1984) who states that these changes are noticed at higher concentrations..

distinct / normal / muffled (Table 2.17)

"Normal" was 55% with 38% being "distinct" and this agrees with Spiro (1972), Bailenson (1972) and Bennett (1984). Those that responded "muffled" (3 of 5 "muffled" responses were from a retrospective view) is only a small percentage but may be noteworthy as an increase in MEP does alter the flexibility of the tympanic membrane (see 2.2.3.1 Middle Ear Pressure (MEP)).

echoing / normal / clear (Table 2.18)

"Normal" with 56% responses, while 44% of responses were either echoing or clear. Some of the "clear" answers could possibly be considered "normal", that is hearing without reverberation. This does not agree with Bailenson's (1972) view of "echoing quality" to sound at these N_2O concentration levels.

high pitched / normal / low pitched (Table 2.19)

Of the total responses, 74% replied "normal" and may indicate that N_2O does not alter frequency of sound. Could the responses for "high pitched", whilst under N_2O influence, indicate a possibility of increase in the subject's sensitivity (i.e. "acuity")? What negates this as assessed by the subject's ability to answer? This can, in turn, help identify any potential communication problems, and thus possible medico-legal considerations, that may arise in the clinical anaesthetic or dental situation. Statistical analysis need not be done, other than finding the commonest answer.

Hearing; *Did the examiner's voice seem.........?*

To define "acuteness" in hearing, by using analytical methods, is difficult. It seems to be a subjective rather than an objective observation. The questions below were designed to determine any subjective hearing changes.

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"Normal" with 56% responses, while 44% of responses were either echoing or clear. Some of the "clear" answers could possibly be considered "normal", that is hearing without reverberation. This does not agree with Bailenson's (1972) view of "echoing quality" to sound at these N_2O concentration levels.

high pitched / normal / low pitched (Table 2.19)

Of the total responses, 74% replied "normal" and may indicate that N_2O does not alter frequency of sound. Could the responses for "high pitched", whilst under N_2O influence, indicate a possibility of increase in the subject's sensitivity (i.e. "acuity")? What negates this latter comment is that subjects were more likely to answer "high" or "normal" pitches, as the examiner's voice was female. Further study will need to be done in this area.

humming / nothing/ ringing (Table 2.20)

"Nothing" was the most frequent response. This agrees with other researchers who have found that at higher concentrations hums or buzzes or rings may occur (Bailenson 1972, Spiro 1972, Bennett 1984). In the retrospective view, of being under N_2O, 25% of the responses were either humming/ringing, indicating that these sounds are recognisable. There is the possibility that the increase in MEP, or the effect of the N_2O on the nervous system or in the CNS may create these sounds.

Thermal; *cold / fine / hot / other* (Table 2.21)

Fine (71%), hot (22%) and no-one was cold. These answers relate directly to answers from Questionnaire 2's question: Did you experience any thermal changes in parts of your body and head? Y/N If yes, was it; cold/heat sensations, and where? The answer to both questions resulted in warm thermal changes.

Visual; *blurred / normal / clear / colour changes* (Table 2.22)

There were 82% "normal" responses, with 14% (mainly during N_2O stages) for "blurred" vision indicating the possibility that N_2O affects vision. There was only one response to colour changes, and this was from a retrospective view. Some of the verbal responses were: "images seemed distant", "everything seemed bright". Westerlund and co-workers (1961) stated that some of their subjects had "shrinking fields of vision" which partially agrees with the first statement, but the second statement contradicts the Westerlund's finding that there is a "diminished light perception". All the subjects' responses in this work were with low levels of N_2O, so possibly at higher concentrations the low light perception could possibly be perceived or more pronounced.

Smell; *perfume / pungent / dusty / rubbery / none / other* (Table 2.23)

"No smell" received 57% responses. The next most frequent answer was "rubbery" (22%) and this is to be expected (Bailenson 1972). "Other smells" (12%), i.e. sweet smell, hospital odours were from N_2O or the environment and were expected, given the hospital environment. The "perfume" smell could possibly be interpreted as "sweet".

Taste; *sweet / salty / sour / bitter / other / none* (Table 2.24)

The most frequent answer was "none" (87%). There were no responses for "sweet" during N_2O administration which could indicate that the mask may have an influence on the senses. "Salty" (5%) which was indicated in the 20% N_2O stage and a retrospective view and could possibly be due to the sweat in the mask. "Bitter" response, one only and during N_2O inhalation, is an unusual response and may be due to the mask or sweat within the mask. Low levels of N_2O were used in this work and thus these findings were expected as Kaufman and co-workers (1990) utilised higher concentrations of N_2O and discovered altered taste sensations.

Concentration; *easy / normal / difficult* (Table 2.25)

Considering the responses during N_2O inhalation, and in the retrospective view, all is as expected as with any anaesthetic agent. Retrospectively, 69% of the subjects stated that they had difficulty in concentration, yet they still managed to respond and make definite decisions in their responses during the whole testing procedure. This could also indicate that at these N_2O levels, mental concentration is affected, as N_2O is a mild CNS depressant (Bailenson 1972), but not to such a great extent as to achieve non-cooperation (see 2.1.2 Sequence of Testing for an explanation of CNS effects of N_2O).

Body Sensations; *How do you feel?.....*

excited / normal / relaxed (Table 2.26)

Overall the "relaxed" (51%) and "normal" (42%) responses outweighed the "excited" responses and indicated that subjects were in Zone 1 (6-25% N_2O) of N_2O sedation levels. N_2O does produce a "relaxed" sensation (Bell 1975), but the concentrations were possibly not strong enough to produce a greater number of "relaxed" subjects. The first two stages, Air (a) and 10% N_2O, reported 4 "excited" responses of 31 (13%) and could possibly be due to the 'novelty' of the experiences encountered by the subjects.

happy / normal / sad (Table 2.27)

Responses to "happy" (19%), "normal" (81%) and "sad" (0%) indicated that the experience was pleasant. Under N_2O inhalation, the shift of responses from "normal" to "happy", with the retrospective view of 43% for "happy", hints at agreement with the claim that N_2O is a 'laughing gas' if higher concentrations were used (Parbrook 1967).

body: lightness / normal / heaviness (Table 2.28)

There was a shift from "normal" (94%) in Air (a) to feeling either "heavy" or "light" (55%) in the N_2O stages. It was expected that this sensation was to occur at higher concentrations as Bennett (1984) stated that it should occur at 35-40% N_2O. This could coincide with the relaxed state and the happy mood that the subjects were in, as answered by the previous questions.

muscle: tremors / normal / stillness (Table 2.29)

Some subjects verbally commented on the difficulty to define between "normal" and "stillness", thus most answers were "normal", or that the concentrations were too low to produce a "tremor" as described by Kaufman *et al* (1990). There were 5 non-"normal" responses and they were in Air (a) and N_2O stages.

tingling / no sensations / paraesthesia (Table 2.30)

The responses to "tingling" and "paraesthesia" were as expected during the N_2O stages for Bennett (1984) states that with 10-15% N_2O, there is some tingling and numbness of extremities while paraesthesia could have been induced with the time length that the subject has to sit in one position.

Any comments? Yawning, Coughing, burping?

This last question was for the examiner. It was difficult for the examiner to notice if there were any of these actions occurring as the full face mask was obstructing viewing, and these actions occur so spontaneously as to be difficult to detect.

This questionnaire did show that subjects were conscious and co-operative at all times, although there appeared to be some effect on concentration, the effect was not considered sufficient to impair tests carried out under N_2O. The answers given indicated that no subject experienced any deleterious effects, and that they were relaxed which helps produce unstressed answers and easy performance in the hearing tests.

In relation to the human voice, this questionnaire indicates that there is no conclusive evidence for the subjects having increased "acuity" whilst under the influence of N_2O.

4.3 Acoustic Impedance

Acoustic impedance measurements of the middle ear were made to determine if there were any changes in impedance between the stages. If there were impedance changes then the physical status of the ear was affected (Davis *et al* 1979). Any correlation between the changes in impedance and the changes in breathing medium (i.e. air to N_2O) could be determined. If significant changes in the impedance occurred while subjects were breathing N_2O, and there was a corresponding change in any of the hearing tests, then one could postulate that impedance changes affect how a subject hears sounds.

4.3.1 Middle Ear Pressure (MEP)

Matz and co-workers (1967) states that N_2O can diffuse into an air cavity till it equilibrates with the arterial partial pressures, and as nitrogen is slower to diffuse out of that air cavity then there is an increase in pressure within that air cavity. Matz and co-workers (1967) utilised 66% N_2O was used on cats and the "peak" increase in MEP was seen in about 10-15 minutes. Our experiments waited at least ten minutes for this "peak" effect to occur between all the stages. Changes in MEP can alter the flexibility in the tympanic membrane. The tympanic membrane is known to bulge under N_2O inhalation (Munson 1974) which influences the compliance of the eardrum thus affects hearing (Waun *et al* 1967). The clinical effects on hearing, by 10% and 20% N_2O, are determined in other assessments, such as Auditory Threshold.

When all data were combined, there were significant differences between the stages ($p<0.05$) indicating that N_2O does influence the MEP (Coe 1987), but there was one exception; that is, there was no difference in MEP between 10% N_2O and Air (b) (see below).

Significant differences between the stages ($p<0.05$) for all data presented indicated that there was N_2O in the breathing medium and that MEP is influenced by N_2O inhalation. One exception is between 10% N_2O and Air (b) and this could occur as in Air (b) stage as there was no post-inhalation O_2 given, nor enough time allowed to let the N_2O dissipate out of the subject in order to return the MEP to pre-testing values. This can also give an indication that after either a prolonged N_2O exposure, or high N_2O concentrations, or lack of O_2 after a procedure, that N_2O does take some time to leave the system. Bailie and co-workers (1988) states that N_2O increases MEP both intra- and post-operatively. This may have a influence on hearing and will be discussed in latter sections.

4.3.2 Physical Volume (PV)

Physical volume is the air or gas volume in the external ear canal, from the measuring cuff to the eardrum.

The PV mean values and the standard deviations were within normal limits and no individual PV value was over 3 mls (which indicated if there were any tympanic membrane or eustachian tube abnormality). There were no significant differences between the stages. Dividing the data in age, ear and sexes also provided information that values were within normal limits and no significant differences occurred. This is to be expected as PV measures the volume or space between the measuring device and the eardrum. It also shows that there was no examiner error and that the MEP fluctuations were as accurately recorded as possible.

4.3.3 Compliance (Comp)

Compliance indicates the flexibility of the tympanic membrane to reflect sound and is associated with the flexibility of the oval and round windows (Waun *et al* 1967) (see 2.2.3.3 Compliance (Comp)). If any hearing changes do occur, whilst subjects are breathing N_2O, then any changes in hearing can also be associated with decreases in Comp due to the effects of N_2O in the middle ear.

All means and standard deviations are within normal limits, and no significant differences exist between the stages nor within the age, ear and sex groups. Since there seems to be no significance in Comp between the stages, one can also assume that hearing may not be altered.

4.4 <u>Auditory Threshold</u>

This test was conducted to be the least subjective of all the hearing tests conducted (i.e. the most objective). Comparing within the individual frequencies across the stages (see Table 4.2 in Results) indicated that there was no influence of N_2O on the actual hearing ability and this complies with the null hypothesis (H_o) that N_2O has no influence on hearing.

Comparisons between the frequencies (within and between all stages) will be discussed below.

4.4.1 Treatment Influences

Overall, there was no significance of treatment (i.e. changes in N_2O concentrations) on the hearing as determined by the simultaneous analysis of all data. Thus the H_0 holds true that N_2O has no influence on hearing from this objective test.

The threshold levels for individual frequencies in this work's group of subjects (regardless of the influence of N_2O), indicate an almost normal hearing curve (see Graph 4.1).

The expected threshold level for 500 Hz was higher, relative to other frequency levels (Zwicker *et al* 1990). The 500 Hz and 8 kHz frequency needs to have more intense loudness levels in order to be perceived (Newby 1979). With this information came the expected significant differences between 500 Hz and some other frequencies. As expected, comparing 1 and 1.5 kHz to 500 Hz and 2 kHz gave a non-significant result, for most analyses, as these frequencies are similar.

The most sensitive hearing range, being 1 to 4 kHz, was confirmed as these resulted in the lowest threshold levels. Zwicker and co-worker (1990) stated that in this range, the threshold level can even be below 0 dB.

Zwicker and co-worker (1990) stated that between 5 to 12 kHz, the threshold levels, for an individual, may vary between 0 to 15 dB of each other and has personalised peaks and troughs, and this seems true in the graph of this group of subjects (see Graph 4.1). With 6 kHz, there is a marked peak in threshold but then a decrease in threshold for 8 kHz is noted. There is a possibility of background sound interference from the anaesthetic machine which may mask some frequency's threshold levels (NB: The machine was on in all stages, as not to alter the experimental environment during any stage) (see 4.4.3 Ear, below). All the above observations were generally consistent for all age, gender and ear comparisons.

4.4.2 Age

It is known that aging reduces hearing sensitivity (Zwicker *et al*, 1990). From the simultaneous ANOVA analysis of all data (using Program 5V) there was no influence of age on hearing ($p=0.571$). Thus the H_0 held true and age did not have a significant impact on hearing.

Even though the under 25 year old age group showed the largest number of significant differences (between the individual frequencies and between stages) relative to the over 25 year old age group, overall there was no influence of age on hearing threshold levels in this group of subjects. Possibly a larger group with greater age variation could show some influence of age on threshold levels.

4.4.3 Ear

Simultaneous analysis of all data (using Program 5V) showed significance ($p<0.001$) as ear side had an influence on hearing threshold levels. It was interesting to note that the closeness of the ear to the anaesthetic machine had an influence on auditory threshold by raising it higher than the surrounding frequencies tested, even though there was no such interference for Intensity Matching and Subjective Intensity tests.

When comparing the individual frequencies and stages within each ear (using Statview 512+ and Excel 4.0), the results were similar to the 3.4.1 Treatment Influences, except for the non-significant difference between 500 Hz and 6 kHz. This non-significant difference could be explained by the closeness of the ears to the anaesthetic and associated machines, which had inherent noises. The emanating noises appeared, to the examiner, to be at a quiet intensity level or maybe the frequency of these noises may have "masked" with the perception of 6 kHz. Denes and co-workers (1973) explains that masking can occur in two ways, (1) tones can mask neighbouring frequencies and (2) low frequency tones can mask high frequency tones more effectively than vice versa. The tone or frequency emanating from the anaesthetic machine is unknown. The machines were kept on throughout the whole experiment to create consistency of the environmental noise status, for all stages. It is interesting to note that there was a 2.6 dB difference between the ears (see 3.4 Auditory Threshold).

The right ear had a greater number of non-significant differences between the frequencies than the left which could relate to the proximity of the left ear to the anaesthetic and associated machines may influence hearing perceptions.

4.4.4 Gender

Predominance of male subjects (males n=22, vs females n=8) may have influenced the analysis (using Program 5V, p=0.799), which resulted in the acceptance of the H_0, resulting in that gender had no influence on hearing. A more even number of participants in each gender would be appropriate to determine if gender had an influence on hearing.

4.5 Intensity Matching

This test was to determine if subjects could retain acoustic memory and discriminate auditory tones whilst under N_2O inhalation. Subjects had to compare the varying intensities of a 4 kHz tone to a reference 4 kHz tone.

Using an ANOVA statistical analysis, with repeated measures, there were no significant effects of N_2O inhalation on acoustic memory (p=0.775) thus confirming the H_0. Further neither age (p=0.478), nor ear side (p=0.327) nor gender (p=0.271) had any significant effect on the results.

Overall, there was approximately 66% correct answers, with 33% incorrect answers (see Table 5.1). It could be stated that the subjects had retained their discriminating capacities whilst under the influence of N_2O. In about two-thirds of the total incorrect answers, subjects were willing to state that the comparison sound was quieter than the reference sound regardless if the testing was under air or N_2O inhalation.

The concept of discriminating or interpreting abilities also relies on the capacity to hear accurately. The intensity levels used in this test was about 20 dB higher than the subject's threshold level for 4 kHz. From this knowledge, there should be no problem to hear the sound accurately and it is the subject's discrimination or interpretation that is being tested. However the 5 dB shift from that reference intensity, in some of the comparison sounds, is slight and it was initially considered to have been difficult for the subjects to discriminate between the intensities, however the results show that the subjects could discriminate and remember the reference intensity well.

As stated in Methods 2.5, the Intensity Matching test determines the ability of the subject's auditory sense to remember the intensity of a reference sound, and the ability of that subject to detect, interpret and judge comparison sounds (Glorig 1965). This test chiefly looks at the memory and discriminating (judgement) capacity of the subject's auditory system and it does not appear to be affected by N_2O, thus the H_0 holds true (that memory and discrimination aren't altered whilst subjects are breathing N_2O).

4.6 Subjective Intensity

This is a subjective assessment which allows the subjects to interpret an intensity level by deciding that level of intensity along a 10 cm line. This test gave the subject a range, rather than discrete choices as in the Intensity Matching test.

The H_0 states that there is no influence of N_2O on the subjective hearing perception of 4 kHz at various intensity levels. Two methods of analysis were done as stated in Methods 2.6 Subjective Intensity and 4.0 Data Analysis. Overall, there appears to be an influence of N_2O on hearing 4 kHz at various intensities ($p=0.005$), but this influence was independent of age ($p=0.871$), ear ($p=0.074$), and gender ($p=0.684$) differences. Thus the H_0 doesn't hold and the alternative hypothesis is accepted, i.e. 10% and 20% N_2O had an effect. The three intensity levels were also found to be significantly different from each other ($p<0.001$).

Since the relative intensity level of 60 dB to the other two levels, 40 and 80 dB, is significantly distinct, the relationship between these three intensities gives an indication of subjects' interpretation of sound intensities and how it is influenced by N_2O. It could be explained that the two intensities: 40 and 80 dB, defined the intensity "range" that the subject was given and 60 dB being between the two intensities, then one can determine if 60 dB intensity is similar to a higher or lower intensity by comparing the levels. A sound of 80 dB intensity is a very loud sound thus most subjects recorded a mark on their answer sheet at the very "loud" end of the analogue scale while 40 dB was a quiet sound and most subjects placed a mark in the "soft" end of the analogue scale and a 60 dB sound was scored between the two. Besides determining if N_2O affects the subjective perception of 60 dB, relative to the other two intensities, 60 dB is at an intensity level of human communication. This is important for communication and medico-legal reasons when dealing with patients under the influence of N_2O (Troyer 1983).

The level of 60 dB appears to be similar to 40 dB when heard under N_2O. This seems to contradict the view that hearing becomes more "acute" under N_2O i.e. quieter sounds seem louder. Overall, subjects interpreted the 60 dB level, at 10% and 20% N_2O levels, as "less" loud than in the control stages (i.e. no significant differences to 40 dB ((a) and (b)), but significantly different to 60 dB ((a) and (b)) levels). This is generally consistent in all comparisons.

For comparisons within each age group, the over 25 years group had consistent non-significant differences between all 60 dB (a) and 80 dB (all stages) which shows that either the interpretation or the transmission of sounds does alter with age (see Table 6.4) while under 25 year age group had significant differences between 60 dB (Air (a) and (b)) and 80 dB (Air (a) and (b)) (see Table 6.6).

There was no significant differences noted between the ears on hearing the different intensity levels. The difference that occurred between the left and right ears was that the left ear was closer to the anaesthetic machine (see 4.4.3 Ear), and this could have influenced any minor discrepancies seen between the ears.

There was no significant effect of gender on the hearing of different intensity levels. The insufficient number of female participants may have influenced the results.

Thus for a subjective assessment as this, N_2O possibly influences either the interpretation or the acoustic apparatus in hearing of the various sound levels in unknown ways.

5. Conclusion

This work looked at the effects of nitrous oxide (N_2O) on hearing. It has been a long held belief that the administration of N_2O increases hearing acuity. Increased acuity could be related to the improved ability to hear lower intensity sounds (i.e. quieter sounds).

There have been some studies whereby the participants have noted hearing changes whilst under the influence of various levels of N_2O. The conclusions have been that hearing becomes more acute (Langa 1976), acuity decreases (Westerlund *et al* 1961) or no differences in hearing can be detected (Tomlin *et al* 1973).

Given the inconsistencies in the literature, this study aimed to determine if hearing was altered by 10% and/or 20% N_2O, and if possible, the nature of the effect. Not only is this of scientific interest but the results have implications for care of the patient and the possible medico-legal implications.

Acuity can be related to the hearing threshold where the threshold is defined as the quietest sound that is perceived by an individual, and this gives a quantitative measurement. This study looked at the changes in hearing by comparing changes in threshold measurements (Auditory Threshold), plus the memory retention of sounds (Intensity Matching) and interpretation of various intensities (Subjective Intensity) for quantitative and qualitative analysis of any possible hearing changes. Effects of N_2O on hearing qualities that can't be quantitatively measured, e.g. ringing in the ears, were determined by the Questionnaires. These observations were obtained in the breathing mediums of room air in the control stages, with 10% and 20% N_2O (and supplemental oxygen with a full face mask) in 16 individuals in a quiet hospital office room.

In Auditory Threshold, it was noted that 10% and 20% N_2O did not affect hearing threshold levels in this group of subjects. This test is the most quantitative of all the three hearing assessments used in this study. It appears that the long held belief of hearing becoming more acute under N_2O inhalation, is erroneous, at least in terms of auditory threshold, which could be considered a major determinant of acuity. A notable finding was that Auditory Threshold results for the left ear, which was closer to the anaesthetic machine and was subject to the noise from that equipment, were different to the right ear results. In the other two tests, Intensity Matching and Subjective Intensity, ear side did not have an impact on results as the intensity levels used were about 20 dB higher than the threshold levels (as seen by the Ear's non-significant comparisons in these tests).

In Intensity Matching, there were no significant findings in the results and neither age, ear side, nor gender had any significant effects, thus 10% and 20% N_2O did not affect acoustic memory, perception and discrimination. It is interesting to note that with two-thirds of the incorrect answers, the comparison sound was judged to be quieter than the reference sound. This does have implications for the Subjective Intensity test. If the subjects were more likely to judge an intensity as quieter than it really was, as Intensity Matching results showed, then this correlates with the results from Subjective Intensity as subjects judged that 60 dB was quieter under the influence of N_2O than in the controls.

In Subjective Intensity, there was an influence at 10% and 20% N_2O on this group of subjects when they qualitatively judged the three intensity levels. As stated in the Introduction the increased acuity whilst breathing N_2O is the ability to hear quieter sounds better than during the controls. To hear quieter intensities better is to state that the quieter intensity levels should be interpreted as louder and this is not the case in Subjective intensity.

In summary, it appears that 10% and 20% N_2O, had no significant effect on Auditory Threshold, thus there is no objective evidence that hearing becomes more acute whilst breathing these levels of N_2O. Acoustic memory, discrimination and judgement capacities were also not affected as noted by the lack of significance in Intensity Matching. However in the subjective interpretation of a sound's intensity, there is a significant effect at 10% and 20% N_2O. It appears that subjective interpretation of a sound is altered whilst breathing low levels of N_2O, however there is no evidence that N_2O affects hearing objectively.

6. Appendices

Appendix 6.1: Questionnaire 1

Subject Number: .... Date: ..../........./........
Age (or D.O.B.): .... Sex: M/F Weight: ....kg Height: ....cm
Occupation: ....

Past and Current Medical History: (Write overleaf if space here inadequate)
Have you had past history of;...

(i) acute/chronic hearing problems or ear infections? Y/N
(ii) recent upper respiratory tract infections? Y/N
(iii) neurological problems? Y/N

Present Physical Status:
Was alcohol consumed in the past 12 hours? Y/N How much?...........

Do you smoke? Y/N
If yes, (i) when was last cigarette smoked?.........
(ii) how many cigarettes smoked in an average day?......

When was the last time (and quantity) tea, coffee, or caffeine drinks (e.g. Coke) were drunk?...

In the past 24 hours, did you (i) have a normal nights sleep? Y/N
(ii) performed normal days activities (i.e. tired/excited)Y/N

Physical Assessment:
No pathologies seen/detected in (i) tympanic membrane? Y/N
(ii) oropharynx region? Y/N
(iii) nasal passages clear? Y/N
(iv) handle press button control? Y/N
(v) HR; ....B/min BP; ..../.........mmHg SaO_2; ....%

Consent:
Consent understood and signed? Y/N Initials;..........................

Appendix 6.2: Questionnaire 2

Subject Number: .... Date; ..../......./......

Your assessment/impressions:
Did you find concentration on the task easy/difficult?

Did you hear any extraneous noises? Y/N What where they?

Do you remember any commands/statements given to you during the procedure? Y/N What was it?

Did the passage of time seem as quick/slow as you expected it to be?

Did you feel like yawning/coughing during the procedure? Y/N When?
Did you feel as though you needed to "pop" your ears at any time? Y/N When?

Did you experience any thermal changes in parts of your body and head? Y/N If yes, was it; cold/heat sensations, and where? Could it have been the room?

How you feel during the experiment?

Would you do it again? Y/N

Any further comments about your sensations under N_2O or the procedure would be appreciated;

If any thoughts about the procedure occur in the future, please inform us.

Thank you for your interest and participation.

Appendix 6.3.1: Subjective Perceptions
(Question Sheet used by the subject.)

Hearing; Did the examiner's voice seem..........?

distant / normal / closer

distinct / normal / muffled

echoing / normal / clear

high pitched / normal / low pitched

humming / normal / ringing

Thermal; cold / fine / hot / other

Visual; blurred / normal / clear / colour changes

Smell; perfume / pungent / dusty / rubbery / none / other

Taste; sweet / salty / sour / bitter / other / none

Concentration; easy / normal / difficult

Body Sensations; How do you feel....?

excited / normal / relaxed

happy / normal / sad

lightness / normal / heaviness

tremors / normal / stillness

tingling / normal / paraesthesia

Appendix 6.3.2: Subjective Perceptions
(Answer Sheet used by the examiner.)

Subjective Perceptions Subject Number; .... Date; ....../......./.......

	Air(a)	10%N_2O	20%N_2O	Air(b)	Retro-spective
Hearing; distant/normal/closer	....	....	....	....	....
distinct/normal/muffled	....	....	....	....	....
echoing/normal/clear	....	....	....	....	....
high pitched/norm./low	....	....	....	....	....
humming/normal/ringing	....	....	....	....	....
Thermal; cold/fine/hot/other	....	....	....	....	....
Visual; blurred/normal/clear colour changes	....	....	....	....	....
Smell; perfume/pungent/dusty rubbery/none/other	....	....	....	....	....
Taste; sweet/salty/sour bitter/other/none	....	....	....	....	....
Concentration; easy/normal/difficult	....	....	....	....	....
Body Sensations; excited/normal/relaxed	....	....	....	....	....
happy/normal/sad	....	....	....	....	....
lightness/normal/heaviness	....	....	....	....	....
tremors/normal/stillness	....	....	....	....	....
tingling/norm./paraesthesia	....	....	....	....	....

Any Comments? Yawning, coughing, burping?

Appendix 6.4

Auditory Threshold; Table if H_0 were true.

Comparisons are made within each frequency across the treatment stages.

		$10\% N_2O$	$20\% N_2O$	Air (b)
Air (a)	500 Hz	NS	NS	NS
	1 kHz	NS	NS	NS
	1.5 kHz	NS	NS	NS
	2 kHz	NS	NS	NS
	3 kHz	NS	NS	NS
	4 kHz	NS	NS	NS
	6 kHz	NS	NS	NS
	8 kHz	NS	NS	NS
$10\% N_2O$	500 Hz		NS	NS
	1 kHz		NS	NS
	1.5 kHz		NS	NS
	2 kHz		NS	NS
	3 kHz		NS	NS
	4 kHz		NS	NS
	6 kHz		NS	NS
	8 kHz		NS	NS
$20\% N_2O$	500 Hz			NS
	1 kHz			NS
	1.5 kHz			NS
	2 kHz			NS
	3 kHz			NS
	4 kHz			NS
	6 kHz			NS
	8 kHz			NS

*=P<0.05 **=P<0.01 NS = No significant difference

Appendix 6.5:
Intensity Matching and Subjective Intensity Answer Sheets

Assessor's Notes 3: Subject Number; .... Date; ....../......./.......

* ***Stage 1; Air**

Intensity Matching (L=louder than reference, S=softer, N=no difference)

	Right Ear		Left Ear	
(1)Initial reference at 4 kHz (Threshold level)	.............dB		..........dB	
(2)Threshold level (4 kHz) plus 20 dB	.............dB	L/S/N	..........dB	L/S/N
- 5 dB	.............dB		..........dB	
- 5 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	

Subjective Intensity	Right Ear	Left Ear
40 dB		
60 dB		
80 dB		

* ***Stage 2; 10% N2O**

Intensity Matching

	Right Ear		Left Ear	
(1) Initial reference at 4 kHz (Threshold level)	.............dB		..........dB	
(2) Threshold level (4 kHz) plus 20 dB	.............dB	L/S/N	..........dB	L/S/N
- 5 dB	.............dB		..........dB	
- 5 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	

Subjective Intensity	Right Ear	Left Ear
40 dB		
60 dB		
80 dB		

* *Stage 3; 20-30%N2O   Subject Number;.............Date; ....../......./.......

Intensity Matching

	Right Ear		Left Ear	
(1) Initial reference at 4 kHz (Threshold level)	.............dB		..........dB	
(2) Threshold level (4 kHz) plus 20 dB	.............dB	L/S/N	..........dB	L/S/N
- 5 dB	.............dB		..........dB	
- 5 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	

Subjective Intensity	Right Ear	Left Ear
40 dB		
60 dB		
80 dB		

* *Stage 4; Air

Intensity Matching

	Right Ear		Left Ear	
(1) Initial reference at 4 kHz (Threshold level)	.............dB		..........dB	
(2) Threshold level (4 kHz) plus 20 dB	.............dB	L/S/N	..........dB	L/S/N
- 5 dB	.............dB		..........dB	
- 5 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
0 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	
+ 5 dB	.............dB		..........dB	

Subjective Intensity	Right Ear	Left Ear
40 dB		
60 dB		
80 dB		

Appendix 6.6:

Subjective Intensity: Table if H_0 were true

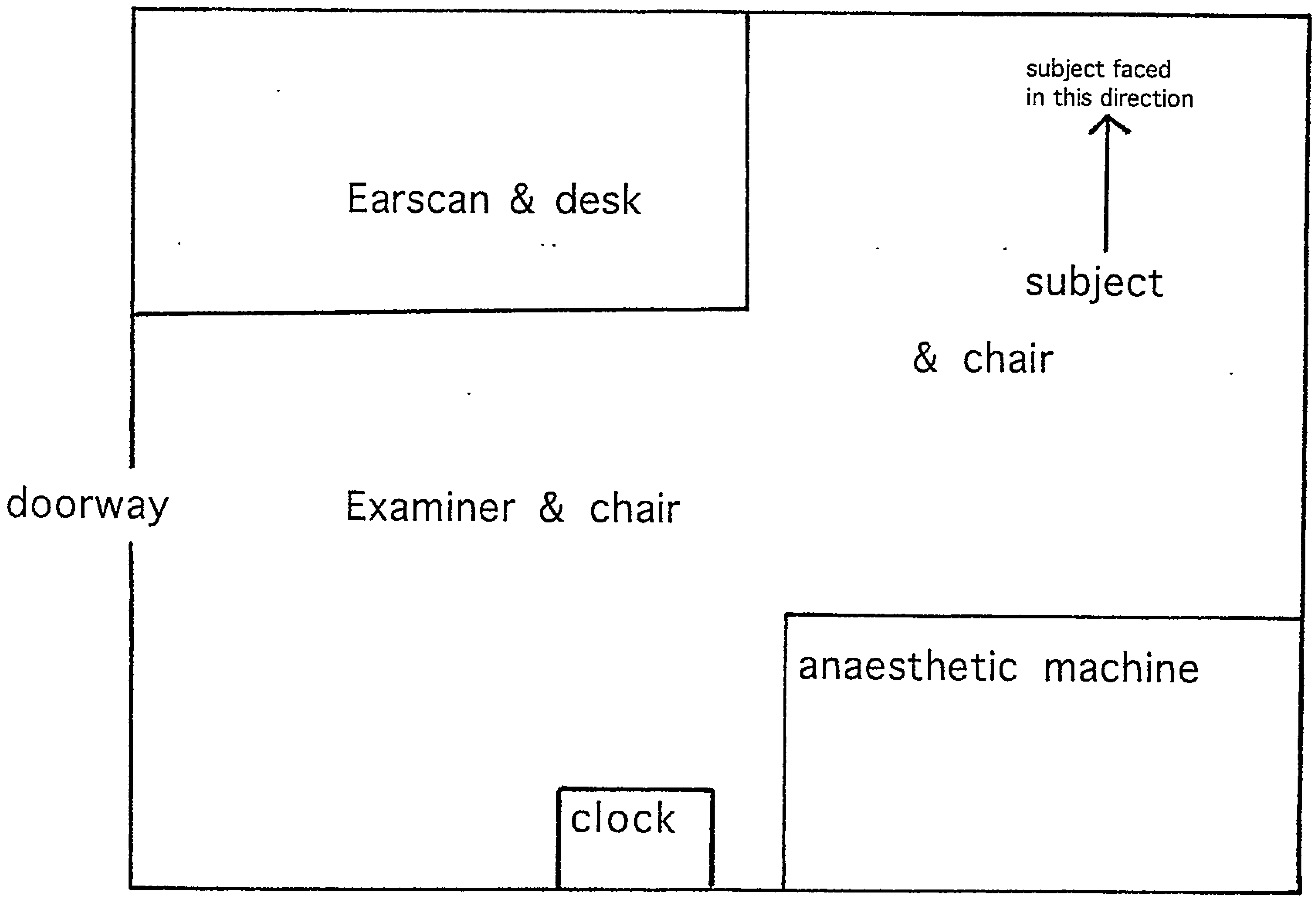
Comparisons are made between the mean values of each loudness level (40, 60 or 80 dB) and between the treatment stages.

	Stages	Air (a)			10% N_2O			20% N_2O			Air (b)		
Stages	Intensity	40 dB	60 dB	80 dB	40 dB	60 dB	80 dB	40 dB	60 dB	80 dB	40 dB	60 dB	80 dB
Air (a)	40 dB												
	60 dB	*											
	80 dB	*	*										
10% N_2O	40 dB	NS	*	*									
	60 dB	*	NS	*	*								
	80 dB	*	*	NS	*	*							
20% N_2O	40 dB	NS	*	*	NS	*	*						
	60 dB	*	NS	*	*	NS	*	*					
	80 dB	*	*	NS	*	*	NS	*	*				
Air (b)	40 dB	NS	*	*	NS	*	*	NS	*	*			
	60 dB	*	NS	*	*	NS	*	*	NS	*	*		
	80 dB	*	*	NS	*	*	NS	*	*	NS	*	*	

NS = Not Significant * = Significant

Appendix 6.7: The room.

This is a floor plan of the room, indicating the positions of the subject and examiner.



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