

Are orthoptic measures robust during exposure to unpleasant environmental noise?

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Abstract

Aim: Orthoptic clinics are sometimes noisy and sometimes quiet. This study experimentally tested how this noise might affect some orthoptic measures. The experiment looked for changes in measurements of visual acuity (VA), RAF rule and autorefractometry during exposure to unpleasant environmental noise.

Methods: In a counterbalanced repeated measures experiment 12 participants aged between 19 and 24 years, with normal vision, had their VA, RAF rule accommodation and accommodation to targets at three distances measured (0.33, 3 and 6 m). These were measured in two sessions, each lasting about 15 minutes, conducted on separate days. One session involved exposure to a recording of continuous loud unpleasant noise; the other, control session was conducted in a quiet environment. Within each session the measures above were made twice: at the start and end of each session. Participants also commented on their experience of each session.

Results: Although the majority of participants found the noisy environment unpleasant, the environmental noise produced no significant effects on VA, time to perform VA, RAF rule and accommodation, or variation in accommodation to targets.

Conclusion: The tests used here appear robust to the effects of unpleasant environmental noise when used on adult participants with normal vision. Possible reasons for this are discussed. It remains to be tested whether such noise might affect either those who have compromised vision or children, who may require more effort to perform these tests.

Key words: Accommodation, Noise, RAF rule, Visual acuity

Introduction

The levels of noise on hospital wards can have negative effects on both patients and staff.^{1–3} The level of noise can be as high as 70 dB,¹ equivalent to exposure to loud conversations at about 1 m. Some orthoptic clinics are probably similarly noisy, with the level of noise often varying between different visits of the same patient to the same clinic. To our knowledge this has not been

measured, nor has whether different clinical measures are obtained when repeated on visits with different levels of noise.^{4,5} This study aimed to explore this.

Studies in noisy hospital environments have found significant negative effects on levels of annoyance and stress.⁶ The autonomic nervous system is involved in the way the human body reacts to stress, and high levels of noise can increase blood pressure and other stress indicators.^{7,8} Both the sympathetic and parasympathetic divisions of the autonomic nervous systems are involved in accommodation.^{9–12} If a patient were to feel stressed in a noisy clinical environment it would not be socially accepted for them to respond by fighting or fleeing. The examination would still proceed. What effect does this have on the patient? For example, where the patient is required to accommodate on different targets, will they over-accommodate? It is known that 'effort-to-see' can affect vergence and accommodation;¹³ for example, simply requiring participants to do mental arithmetic can cause a 0.1 dioptre (D) increase in accommodative level, with similar effects on vergence.¹⁴ The noisy environment we report (see Table 1 and Methods section) may produce a greater effort-to-see than this, as it used a mixture of sounds from an online study of 'horrible sounds'.^{15–17}

Our experiment tested the effect this environmental noise had on visual acuity (VA), the near point of accommodation with the RAF rule and autorefractometry. If our environment caused an effort-to-see similar to doing mental arithmetic then this was unlikely to show itself in a change in acuity, as the 0.1D change in accommodation would cause little blurring of targets in our young adult population. However, we might expect the noisy environment we created to cause greater effort-to-see, which should show itself in measurements taken with the RAF rule and autorefractor, when compared with measures taken in our (control) quiet environment.

Methods

Participants

Twelve volunteers (10 females, 2 males) aged between 19 and 24 years were recruited from the University of Sheffield student orthoptist population. Most (9) were first-year undergraduates in their first term so were naïve to the tests. Because of the use of the autorefractor all were effectively emmetropic and either wore contact lenses to correct refractive error or had no refractive error. The participant information sheet warned that if they had 'high anxiety' levels or high blood pressure

Table 1. The left-hand column lists some of the noise segments that were mixed to make the mp3 file played during the noisy environment conditions. The shading in the columns shows approximately where the segments appeared in the first 160 seconds of the noise stimulus. The sounds did not occur at these exact times as this would have made the noise too predictable.

Noise:	Time noise started (s)																
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160 =>...
Door creak																	
High-pitched tone																	
Babies crying																	
Low machine rumble																	
Creaky wheel																	
Sniffing nose																	
Out-of-tune violin																	
Objects falling																	
Alarm clock																	
High-pitched warble																	
Out-of-tune orchestra																	
Radio being tuned																	
Rubbed polystyrene																	
Dentist's drill																	
Electric whisk																	
Overhead aeroplanes																	
Jet taking off																	

they should not take part in the experiment. No participant reported these. The experiment was approved by the Academic Unit of Ophthalmology and Orthoptics Ethics Committee.

Equipment and stimuli

The study took place in a clinic-like room. Snellen charts and a mirror were used for the 6 m vision test, with the participant placed at an appropriate distance (3 m) and height to read the chart. The RAF rule was used to measure the near point of accommodation and a stopwatch to ensure testing of each participant for the same duration. The Shin-Nippon autorefractor was used to refract the participant as they looked at three distances: at a Snellen stick letter at 0.33 m, or Snellen chart letters at 3 m or, viewed using a mirror, at 6 m.

The sounds used to create the noisy environment had been voted ‘unpleasant’ in an on-line study (see www.sound101.org ‘Bad Vibes’ link). Examples are a baby crying, a high-pitched warning sound and a door creaking (Table 1). Such sounds often occur in clinical settings.⁵ The sounds were mixed to make an mp3 file such that they began at unpredictable times with often more than one sound occurring simultaneously. The first 160 seconds of this ‘composition’ appears schematically in Table 1. The mp3 player was connected to a speaker system with subwoofer in the corner of the room away from the participant. Apparatus was not available to measure the sound level but it was estimated to have peak intensity between 60 and 70 dB at the source, equivalent to being in a room with several people talking loudly, and was unpleasant particularly when trying to concentrate or perform a task. The first author, who

performed the tests, felt that the noisy environment was more unpleasant than most noisy clinics she had worked in while the quiet environment was quieter than a typical clinic.

Design and procedure

To counterbalance for order effects the 12 participants were tested in two groups of six in a repeated measures design. Group 1 was tested first under quiet conditions and group 2 first under noisy conditions. Both groups returned within a week to perform the tests under the other condition. Several dependent variables were measured including: VA with Snellen charts (but converted to logMAR^{18,19}), time taken to perform VA, the near point of accommodation in millimetres with the RAF rule, and accommodation level at 0.33 m, 3 m and 6 m. Ideally logMAR charts would have been used but such back-illuminated charts were unavailable in our laboratory.

Participants were tested individually between 9 a.m. and 4 p.m. on weekdays. They were given an information sheet outside the clinic room. To avoid influencing participant behaviour the sheet did not explicitly state the purpose of the study, but did state they could withdraw from the experiment at any time. In the simulation of the noisy clinic the noise was turned on before the participant entered the room and kept on throughout the testing. In the simulation of the quiet clinic there was no extra noise or unnecessary talking. Throughout the experiment the room was lit only by two Snellen charts; this allowed the participant to see the RAF rule type and made autorefractor measures more reliable as pupils were dilated. Under each condition tests were performed twice: once soon after arrival, and so after only brief

exposure to noise if that was the condition, then again after exposure for about 7 further minutes. In the quiet control condition all tests were also performed twice at equivalent times. Under both conditions all tests were carried out in the same order in an identical way and in the same area of the room for all participants. In the noisy condition the examiner was also exposed to the same uncomfortable setting. To reduce any effect the examiner might have had on the patient, such as speeding up tests in order to shorten her exposure time to the noise, the tests were timed: RAF rule tests were given a limit of 30 seconds and the autorefractor measurements 50 seconds per distance, thus exposing the examiner and every participant to the same amount of noise in each session. Each session lasted about 15 minutes. Rather than rush the participant the time taken to achieve the best VA was timed. If a better vision eye was found, that eye was used for RAF rule and autorefraction. The right eye was used if VA was equal in both eyes. Accommodation on the RAF rule was then measured with the participant's other eye occluded and unocular accommodation measured by asking the participant to read aloud the N5 print. The point at which the participant could no longer read the print was recorded in millimetres. This was performed three times and timed. The participant was then seated at the autorefractor. The examiner held a Snellen target at 0.33 m and the participant was asked to read down while 10 accommodation measurements were taken. Ten readings were taken as the participant read down the Snellen chart at 6 m in the mirror and 10 readings while reading the chart at 3 m. The participant then sat back and rested for 3 minutes.

The three vision tests were then repeated in the same order, with a different Snellen chart used. The examiner used separate result sheets for the two sessions, reducing the possibility of bias caused by seeing the previous results. At the end of the session the participant was asked to comment about any auditory noise present in the session and how they felt it might have affected their performance.

Statistical analysis

The autorefractor mean spherical equivalent data were calculated using the spherical and cylindrical powers provided at each measurement according to the formula:

$$MSE = \frac{\text{spherical power} + \text{cylindrical power}}{2}$$

Analyses of variance were performed using Statview (SAS Institute, USA). Further differences were analysed with *t*-tests.

Results

Visual acuity (VA)

The VA of each participant was recorded at the start and end of each session. VA was recorded in Snellen lines during the experiment but converted to logMAR for ease of analysis.^{18,19} As can be seen from Fig. 1, which shows

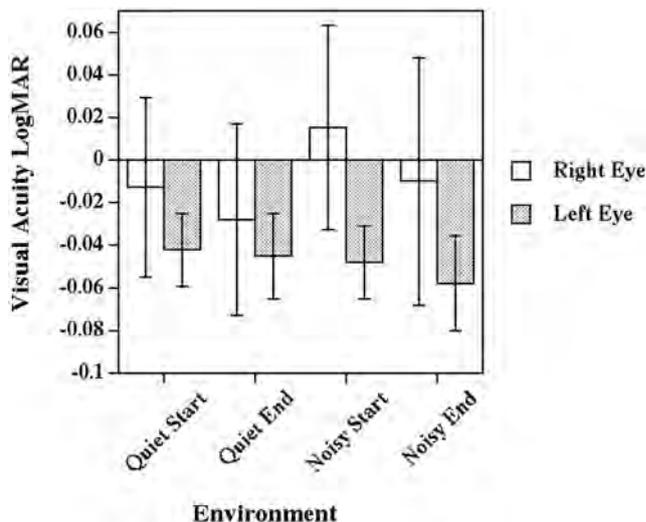


Fig. 1. Bar chart showing the mean right and left eye (shaded) visual acuity in logMAR units of the 12 participants at the start and end of the simulated noisy and quiet clinical environments. The error bars are ± 1 SE.

the group means with standard error bars, the visual acuities appear not to change under the different conditions.

This was tested with a four-factor mixed measures ANOVA with factors: Order (Quiet or Noisy session first), Environment (Noisy or Quiet), Time (Start or End of Session) and Eye (Left or Right). This showed that exposure to noise did not have an overall significant effect ($F_{1,10} = 0.367, p > 0.05$). The overall mean visual acuity under quiet conditions was -0.03 logMAR (± 0.08 standard deviation) and under noisy conditions was -0.03 logMAR (± 0.09). If the effect of noise was different between the start and end of the noisy condition session this would have led to a significant interaction of the Environment and Time factors, but this was not significant ($F_{1,10} = 0.465, p > 0.05$).

The ANOVA did show an overall significant difference between the VA of the eyes ($F_{1,10} = 6.789, p < 0.05$), with the left eye (mean -0.05 logMAR ± 0.06) having on average better acuity than the right eye (mean -0.01 logMAR ± 0.1); no interactions involving the Eye factor were significant. The order in which the participant was exposed to noise did not have an overall effect ($F_{1,10} = 1.602, p > 0.05$), and Order showed no significant interactions with other factors.

The time taken to measure the VA was measured for both eyes under all conditions. The overall mean time from the noisy and quiet environments was 30.8 s and 28.6 s, respectively. Testing did, therefore, take slightly longer in the noisy environment but an ANOVA performed on these data was not significant ($F_{1,10} = 1.610, p > 0.05$), and no other factors or interactions were significant.

RAF rule

Three RAF rule measurements were taken for each participant at both the start and end of both sessions. As

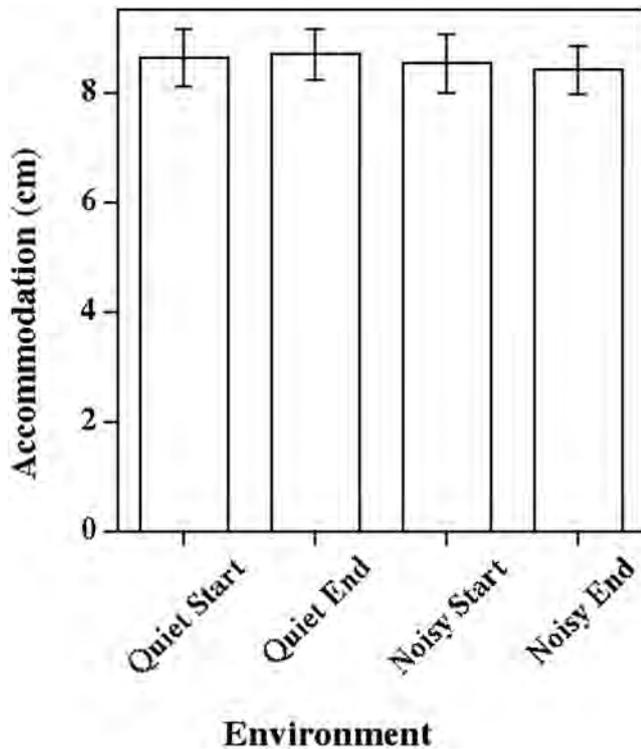


Fig. 2. Bar chart showing the mean accommodation of the 12 participants measured on the RAF rule in centimetres, at the start and end of the simulated noisy and quiet clinical environments. The error bars are ± 1 SE.

can be seen the mean values, plotted in Fig. 2 with standard error bars, are slightly smaller under the noisy condition (overall mean 8.5 cm, ± 1.7), than the quiet condition (overall mean 8.7 cm, ± 1.7). A three-factor mixed measures ANOVA with factors Order, Environment and Time showed no overall difference between the two environments ($F_{1,10} = 0.180, p > 0.05$) and no interactions with this factor were significant. The order

in which the participant was exposed to the noise did not have an overall effect ($F_{1,10} = 1.247, p > 0.05$) and this factor showed no significant interactions with others.

Accommodation with the autorefractor

For each target distance 10 measurements were taken and the mean spherical equivalent calculated. The group mean data are plotted on the vertical axis of Fig. 3 with standard error bars, for the start and end of each session, with expected accommodation for each of the target distances shown on the horizontal axis. The figure seems to show little difference between corresponding measures. This was tested with a four-factor mixed measures ANOVA with factors Order, Environment, Time and Target Distance (0.333 m, 3 m or 6 m). The only significant factor was Target Distance ($F_{2,20} = 512.693, p < 0.0001$), as would be expected. The mean accommodation under all the noisy conditions (mean 1.3 2DS ± 1.61) was smaller than that in the quiet environment (mean 1.22DS ± 1.63). This difference is close to the 0.1D reported in other studies and was close to being significant, but was not ($F_{1,10} = 4.345, p > 0.05$). No other factors or interactions were significant, such as the interaction between the Environment and Time factors ($F_{1,10} = 0.530, p > 0.05$). The order in which the participant was exposed to noise did not have an overall effect ($F_{1,10} = 1.749, p > 0.05$) and this factor showed no significant interactions with others.

Each participant provided 10 measurements of accommodation under each condition. It was possible that the noisy environment did not affect the mean accommodation values but did make accommodation more variable. To assess this the standard deviation of each participant's 10 recordings was calculated for each condition and analysed in the same way as the mean data. This revealed no significant effects.

Subjective responses

After testing, 10 of 12 participants said they found the

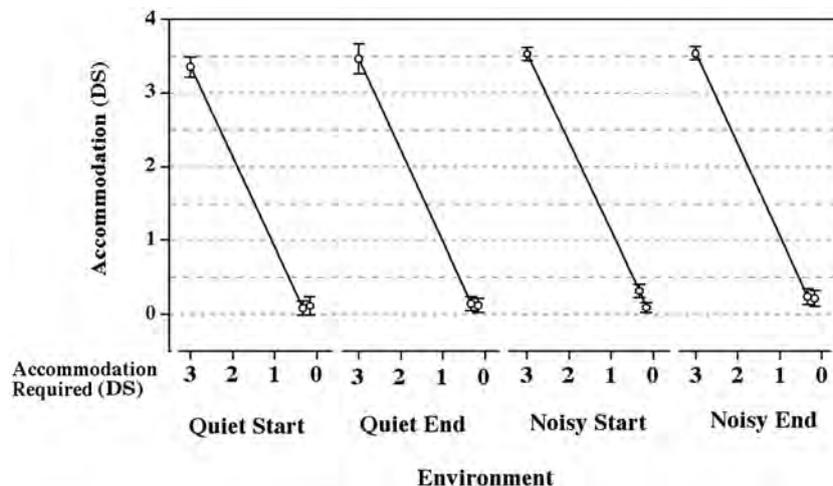


Fig. 3. Line graphs of mean accommodation data. Expected accommodation for each of the target distances (0.33 m requires 3 DS, and so on) is shown on the horizontal axis for the start and end of each environment. The vertical axis shows the mean accommodation measures from the 12 participants. The errors bars are ± 1 SE.

noisy environment uncomfortable to sit in and harder to concentrate in. The examiner also found the noisy 'working' environment more stressful.

Discussion

For the three vision tests used here no evidence was found that the noisy environment had any significant effect on measurements. Any changes were small (Figs. 1–3). As stated earlier, it was expected that noise might not affect VA but we expected to find changes due to 'effort-to-see' in the RAF rule and autorefractor measurements, as they are both sensitive enough to detect the 0.1D changes typically reported.^{13,14} Although for accommodation the overall difference between the noisy and quiet environments was about 0.1D, this was not significant. Similarly the RAF rule overall mean value was about 2 mm closer under the noisy conditions than under quiet, but this difference was not significant.

One possible reason the noisy environment used here was not effective in causing larger differences is that it did not produce enough stress. The majority of participants found the environment unpleasant but it would have been useful to have had objective measures of their stress levels as in other studies.⁵ Also for ethical reasons the participants were 'only' exposed to 15 minutes of noise and were informed that noise exposure was going to be limited in duration; this contrasts with other studies conducted on wards where the noise was both more prolonged and more unpredictable. Perhaps, therefore, our noise was less stressful as participants knew it would end soon and indeed were informed that they could end it sooner if they wished. Perhaps the same noise delivered in a less 'friendly' way would have different effects.^{20–23}

Our control condition was a quiet environment, but given the finding that classical music can slightly improve stereo-acuity²⁴ and generally improve performance^{25–27} it would be of interest to include a pleasant environment to compare with the noisy environment. Testing stereo-acuity under these different conditions may also be of interest.

We only tested participants with no visual problems, so it is possible that even if the noise did cause stress this was not sufficient to impair their vision as they required little 'effort to see'. It would be of interest, therefore, to test those with visual problems, who may require more effort to perform vision tests. It would also be of interest to test the effects of such noise on the performance of children, as they are more likely to be distracted. However, there would be ethical issues in using our experimental design with children. A feasible study with children might be one where naturally occurring noise levels were measured during each appointment to see whether performance was affected.

Conclusion

No evidence was found that environmental noise had any significant effect on measures of VA or accommodation. This may suggest that these tests are robust to environmental noise. This is good news, as they are used often in noisy clinical settings. However, it is

possible, and this remains to be tested, that these tests may be less robust when testing children and/or patients with visual problems under noisy or quiet or more pleasant conditions.

Competing interests: The authors have no competing interests.

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