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Effects of background noise alternating between two levels at varying time intervals on human perception and performance

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Noise
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4pNSa1. Effects of background noise alternating between two levels at varying time intervals on human perception and performance

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This research experiment aims to better quantify human perception and performance under increased background noise levels of varying intervals. Twenty-seven participants were tested over five 30 minute sessions where they were subjected to RC-29(H) and RC-47(RV) conditions created by broadband noise fluctuating on different time intervals. These intervals varied from two minutes to ten minutes, simulating the conditions of a noisy HVAC system turning on and off. The performance results of an arithmetic test dealing with short-term memory and a subjective questionnaire will be presented and compared to a similar test using broadband noise bursts and correlated to noise metrics such as perceived level (PL) and L1-L99. [Work supported by a NASA Nebraska Space Grant.]

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INTRODUCTION

Background noise in the built environment can have a significant impact on the occupants' comfort and performance. One aspect that has not been thoroughly explored is what effect time-varying fluctuations in the background noise level on a larger time scale (e.g. minutes) may have on human performance and perception. Wang and Novak (2010) found that one of the six noise conditions tested that simulated turning a heat-pump on and off every 30 seconds produced the highest subjective ratings for annoyance and distraction in that study, as well as an incongruous loudness rating as compared to its sone value or A-weighted equivalent sound level. Generally, heating, ventilation, and air-conditioning (HVAC) systems are not expected to vary across such a short time period (30 seconds), but some ill-behaved HVAC systems may cycle every few minutes, resulting in time-varying noise levels.

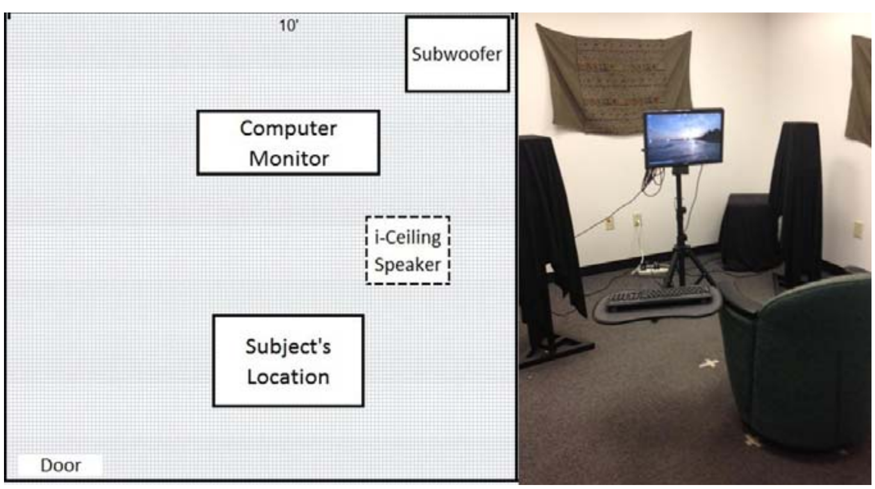
The study reported herein seeks to measure human responses under background noise that is alternating between two different levels (one low and one high) at four different time intervals: two, five, eight, and ten minutes. Under each test condition, subjects completed arithmetic tests dealing with short-term memory as well as subjective questionnaires. The motivating question is: do the shorter time intervals of variation have different effects on human performance and perception than the longer ones?

METHODOLOGY

Twenty-seven subjects were tested ranging in age from 19 to 38 years old, with the average age being 24 years old. There were 15 male and 12 female participants. All participants were screened to have hearing thresholds below 25 dB hearing level in each ear from the 125 to 8000 Hz octave bands.

Each subject participated in four 30-minute sessions, during which they were subjected to broadband noise at room criteria ratings of RC-29(H) and RC-47(RV) that alternated at specific time intervals. The time intervals of variation tested were two, five, eight, and ten minutes and would remain the same during one 30-minute test session. The presentation order of the four noise conditions was randomized among participants using a Latin square design.

All testing was conducted in the Nebraska Test Chambers at the Peter Kiewit Institute (PKI) on the University of Nebraska campus, prior to the 2012 PKI renovation. The test room construction consisted of gypsum board walls, a carpeted floor, and acoustical ceiling tiles, and was acoustically isolated from the surrounding rooms with a staggered wood stud construction resulting in STC 47. The room dimensions were 10' x 10'10" x 8'. The average mid-frequency reverberation time was 0.25 seconds. The test room contained a chair for the subject, a computer monitor and wireless keyboard for the subject to perform the arithmetic task, and two loudspeakers to output the sound signal, arranged as shown in Figure 1.



(a) (b)

FIGURE 1. (a) Plan diagram of test chamber (b) Photo of test chamber

The loudspeakers used were a JBL Northridge ESeries subwoofer and an Armstrong i-ceiling loudspeaker. The i-ceiling loudspeaker resembles an acoustic ceiling tile and was situated next to a diffuser. The two other loudspeakers covered in fabric, visible in Figure 1b, were being used for another test utilizing the same test chamber. An adjacent room contained the test computer and Armstrong i-ceiling controls.

Ten second .wav files for the RC-29(H) and RC-47(RV) were created and calibrated using CoolEdit. Two, five, eight, and ten minute .wav files were then created for each noise condition using the original ten second .wav files. An envelope was applied to the RC-47(RV) .wav files using Cool Edit to yield a transition similar to an HVAC system turning on and off.

During each 30-minute session, the test subject would complete an arithmetic task and a subjective questionnaire. The first five minutes of the session would be a practice session to allow for the subjects to refamiliarize themselves with the arithmetic task. The subjects were given twenty minutes to work on the arithmetic task, followed by five minutes at the end of the session for filling out the subjective questionnaire.

The arithmetic test consisted of problems requiring the subject to find the difference between a six-digit number and a four-digit number in their head. The test questions were designed after similar previous studies by Broadbent (1958) and Woodhead (1964). A six-digit number was presented on the screen for ten seconds. This number was then replaced by a four-digit number and a text box for the subject to input an answer. This remained on the screen until the subject submitted their answer. Each problem was followed by a fifteen second intermission.

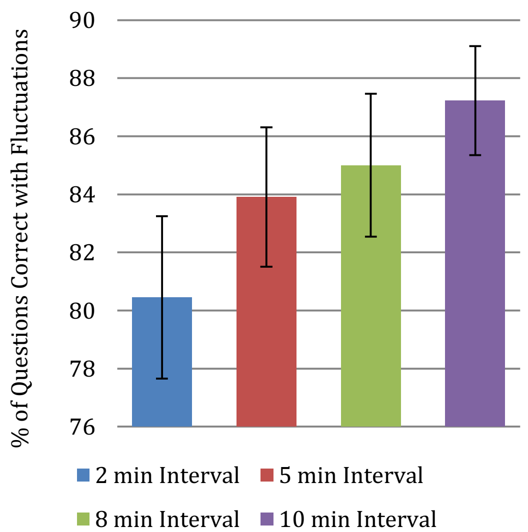
To control for difficulty, only the digits 1, 2, 3, and 4 were used in the test questions, and each test question required subjects to "borrow" (in subtraction, borrowing is when the top number is smaller than the bottom number in an individual column and a digit needs to be borrowed from column immediately to the left) three times. A number of unique sets of 45 questions were created and associated with each sound condition. These questions were presented in the same order to each subject, while the order of sound conditions was randomized. No subject finished all the questions in a set within the allotted time.

All four of the test sessions were completed after subjects had already used the same test format (arithmetic test and subjective questionnaires) in three other hours of subjective testing, with regard to a related study on impulsive noise (Ainley 2012).

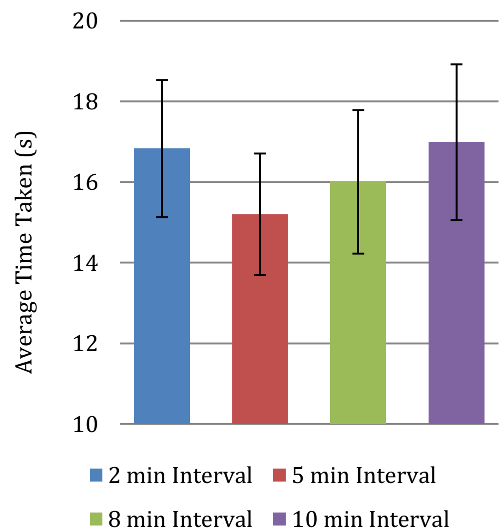
RESULTS AND DISCUSSION

Task Performance Results

Two metrics were used to measure task performance: the total percentage of correct answers and the average time taken to perform the individual arithmetic tasks. The results of each can be found in Figure 2. (The bars in all subsequent figures indicate standard error of the means.)



(a)



(b)

FIGURE 2. (a) Average percent of arithmetic questions answered correctly for each test condition (b) Average time taken to answer arithmetic questions for each test condition

The percentage of questions answered correctly (Fig. 2a) displays the expected trend of an increase in accuracy with an increase in interval duration, varying from an average of 80.5% for the two-minute interval up to an average of 87.2% for the ten-minute interval. The average time taken (Fig. 2b) remained fairly constant with the shortest being on average 15.2 seconds for the five-minute interval and the longest being on average 17.0 seconds for the ten-minute interval.

It does appear that, in terms of average percent correct, the two-minute interval condition shows significantly lower results than the others; ongoing statistical analyses of the results will be presented at the ICA Montreal meeting.

Subjective Perception Results

The subjective questionnaire contained ten questions, five of which pertained to noise perception. On a seven-point scale, subjects ranked the loudness of noise, changes in noise over time, rumble of noise, annoyance to noise, and distraction caused by noise. The results of these five subjective questions can be seen in Figure 3 through Figure 7.

As shown in Figure 3, the loudness of all four interval conditions were ranked on average between 4.22 and 4.44, showing little variation. This can be expected because the two alternating sound levels were the same across all sessions. The amount of time exposed to each level was approximately the same across all sessions as well.

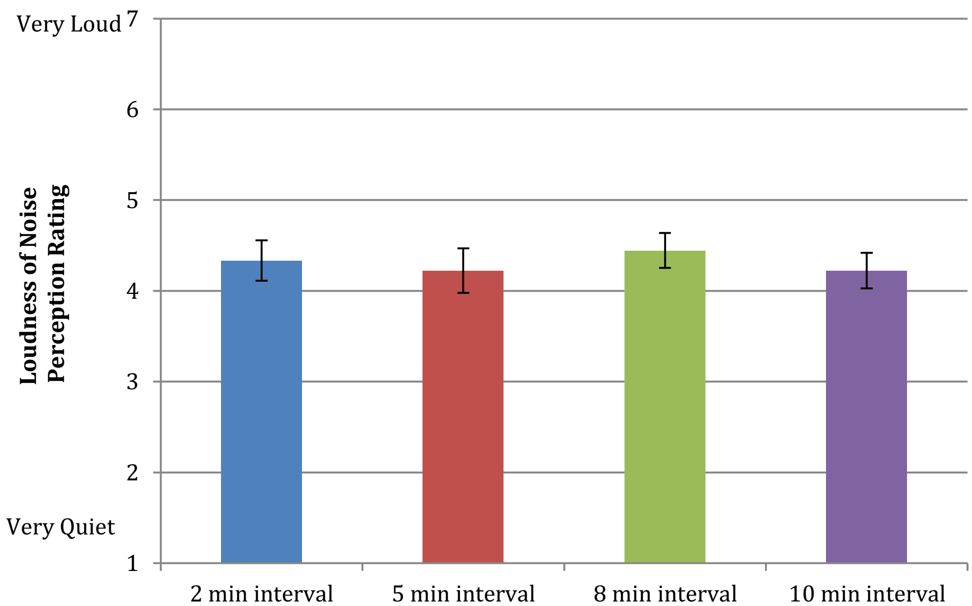


FIGURE 3. Average loudness of noise perception rating for each test condition

A decreasing trend in the perception of changes in sound can be seen in Figure 4 from the two-minute interval session to the ten-minute interval session, with an average rating of 4.63 for the two-minute interval down to an average 3.41 rating for the ten-minute interval. This result is also logical.

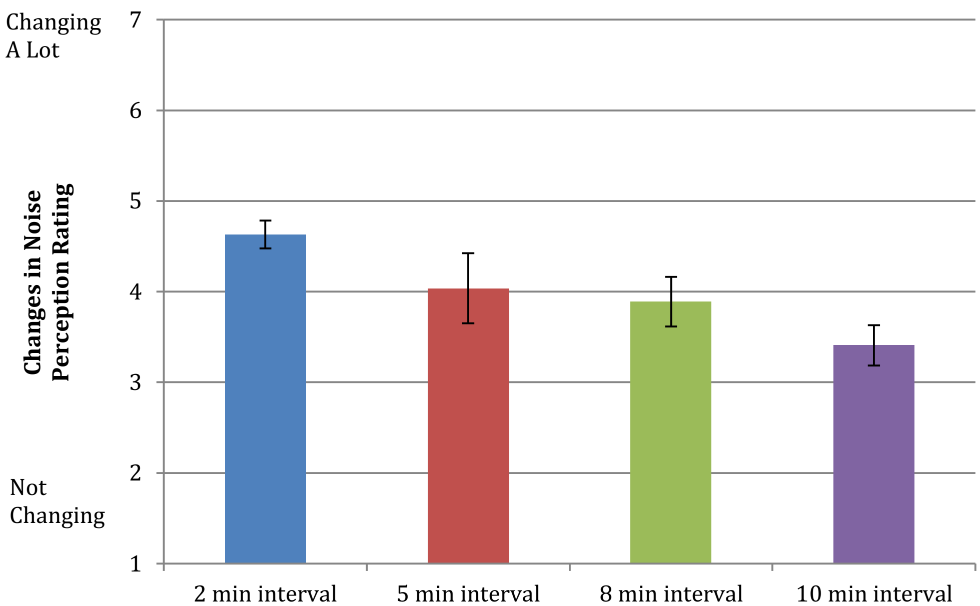


FIGURE 4. Average changes in noise perception rating for each test condition

As shown in Figure 5, rumble of the noise was consistently ranked between 4.30 and 4.60 on average.

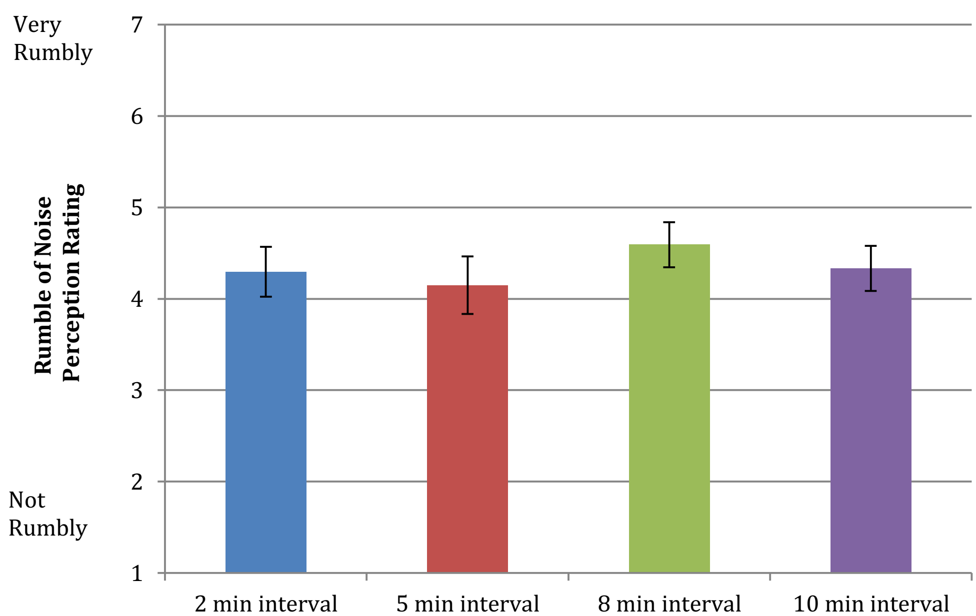


FIGURE 5. Average rumble of noise perception rating for each test condition

Annoyance of the noise ratings were on average at or below 4.00 for the three longer interval durations (Fig. 6), while the two-minute interval was rated 4.30 on average. This suggests that an acceptable limit for the time interval of varying noise levels may be between two and five minutes, similar to the task performance results.

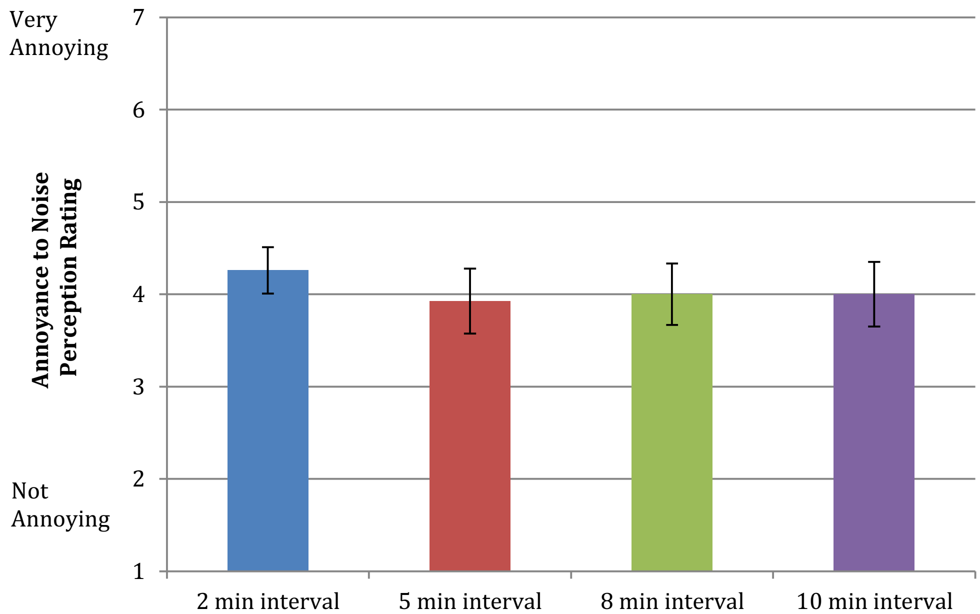


FIGURE 6. Average annoyance of noise perception rating for each test condition

From Figure 7, distraction was rated on average between 3.67 for the five-minute interval and 3.96 for both the two- and eight-minute intervals.

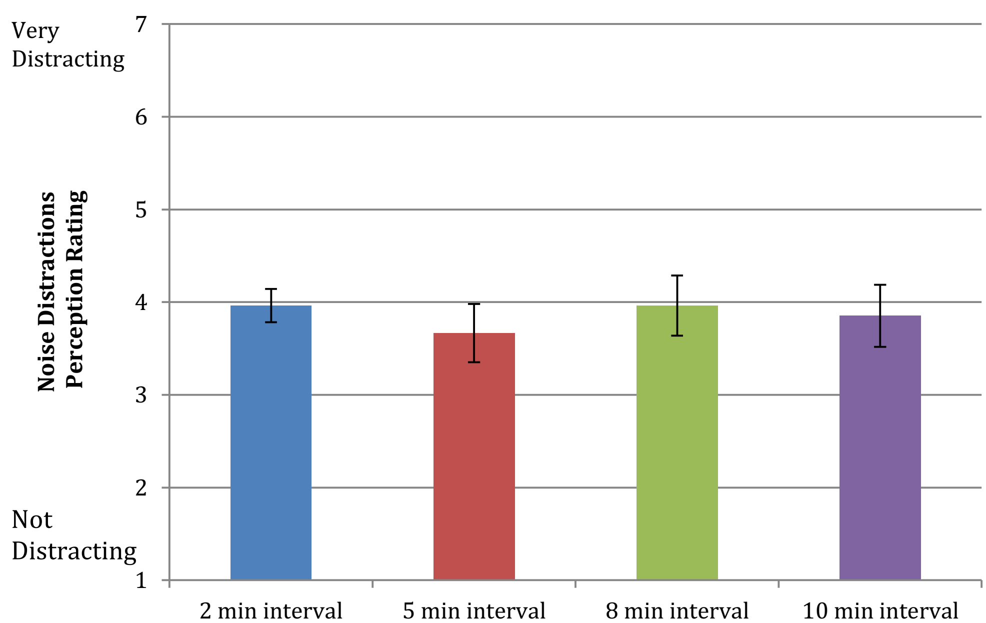


FIGURE 7. Average distraction perception rating for each test condition

Further statistical analyses of these results to determine which differences are statistically significant will be presented at the ICA Montreal meeting.

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REFERENCES

Ainley, C. A. (**2012**) *Effects of Short Noise Bursts on Human Performance and Perception*, MS Thesis, University of Nebraska - Lincoln.

Broadbent, D. E. (**1958**) “Effect of noise on an ‘intellectual’ task,” J. Acoust. Soc. Am. **30**, 824-827.

Wang, L. M. and Novak, C. C. (**2010**) “AB-10-019: Human performance and perception-based evaluations of indoor noise criteria for rating mechanical system noise with time-varying fluctuations (1322-RP),” ASHRAE Transactions, **116**, Part 2, 553-568.

Woodhead, M. M. (**1964**) “The effect of bursts of noise on an arithmetic task,” Am. J. of Psych. **77**, 627-633.