The influence of the interaction between ideational factors, frequency and stimulus factors on reported unpleasantness of recorded sounds

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ABSTRACT

A set of six sounds was recorded that can be described as grinding, screeching and scraping, all of which likely to be describe as sounding unpleasant. An ideational factor was manipulated as a task variable so that the presence or absence of evocative descriptions might influence the reported unpleasantness of the presented sounds. . A good example of the influence of such ideational factors on the reported unpleasantness of recorded sounds is the inclusion of a description of fingernails scraping across a blackboard when presenting the sound of a sharp object scraping across a slate surface. The sounds were also manipulated through spectral processing and presented to listeners in full broadband spectrum, as well as a highpass-filtered version and lowpass-filtered version, both with a cutoff frequency of 500Hz. These three versions were presented with and without ideational descriptors and unpleasantness ratings were collected via marks made on a 50-mm graphic scale. Median values of these ratings suggest that the frequency content above 500Hz contributes most to unpleasantness, and that ideational factors have greater effect when describing sounds with this higher-frequency content.

1. INTRODUCTION

The effect on human responses to sound identified as unpleasant is a widely researched area. This study aims to examine the range in response of human listeners to sounds created specifically to put a them in a state of discomfort and/ or annoyance, so that they may rate the sounds on a scale of unpleasantness. Previous studies by Cox, Ely, Boyd and Halpern et al. (Cox, 2008; Cox, 2008; Ely, 1975; Boyd, 1959; Halpern, Blake, & Hillenbrand, 1986) have investigated the perception of unpleasant or horrible sounds, and their findings have been carefully considered when creating stimuli for this study.

Anechoically recorded broadband spectra stimuli were used in the experiment with the intent of being most unpleasant to the listener. Several studies have been done on the common adverse reactions to unpleasant sounds, in particular nails scratching down a blackboard, which has been extensively referenced as one of the most painful sounds for listeners (Boyd, 1959). Both Boyd and Halpern et al. (Halpern, Blake, & Hillenbrand, 1986) found in their experiments that the presence of mid to high frequency components were a contributing factor to the unpleasantness of the chalkboard scraping sound. Interestingly, Halpern also stated that the low frequency component of these unpleasant sounds contributed to the discomfort associated. This study will look at the perceptual ratings of unpleasantness for stimuli of full broadband spectrum, as well as frequency content exclusively above and below 500 Hz. The filtering at 500 Hz cut off frequency was chosen to determine if, as hypothesized, the mid – high frequency content of scraping and grinding sounds are indeed contributors to the perceived unpleasantness of the stimuli, while also comparing the rated unpleasantness of the isolated low frequency content for the same set of sounds.

Previous studies by Cox (2008) have shown that the ideation of a given sound can increase the emotional response to that sound. That study looked at visually manipulated ideation, while this study aims to explore the effect of verbal ideation on a listener's response. In this study, the term ideation will be used to describe the presence of a related verbal description presented immediately prior the corresponding stimulus playback for the purpose of creating a sense of anticipation and expectation for the listener.

As is found in literature on annoying, painful and unpleasant sounds, the results depend heavily on the stimuli used and perhaps to a lesser extent, on the individual differences between participants. The six recorded sounds used in the current study were intended to produce two individual sounds for each descriptor of three categories; grinding, scraping and screeching.

The current study aims to answer three questions,

1. Does the presence of verbal ideation prior to a listener hearing an unpleasant sound, increase the unpleasantness experienced?
2. Does separating the high and low frequency content of broadband test stimuli have an increase or decreased effect on the reported unpleasantness of sounds; If so, which bands are considered more unpleasant to listeners?
3. Upon undertaking a simple listening task, do ratings of perceived unpleasantness increase when stimuli are heard for a second time?

2. METHOD

2.1 Stimuli

A combination of sounds were recorded in the University of Sydney's acoustics laboratory anechoic chamber. A total of 18 stimuli were produced from six original recordings, each processed to present three different spectral shapes. For each of the six recorded sounds an original broadband spectrum was presented, as well as high and low-pass filtered version each at 500Hz cut off frequency. Figure 1 shows an example of the three spectral version used for each recorded sound. All sounds were short samples made three seconds in duration for the purpose of time conservation and listener engagement in the task. All samples were equally normalised in Matlab after spectral processing to ensure the effect of amplitude was excluded from the listening task. The test was lead by the author and playback for all participants were set equally ensuring no variation of SPL form one participant to the next.

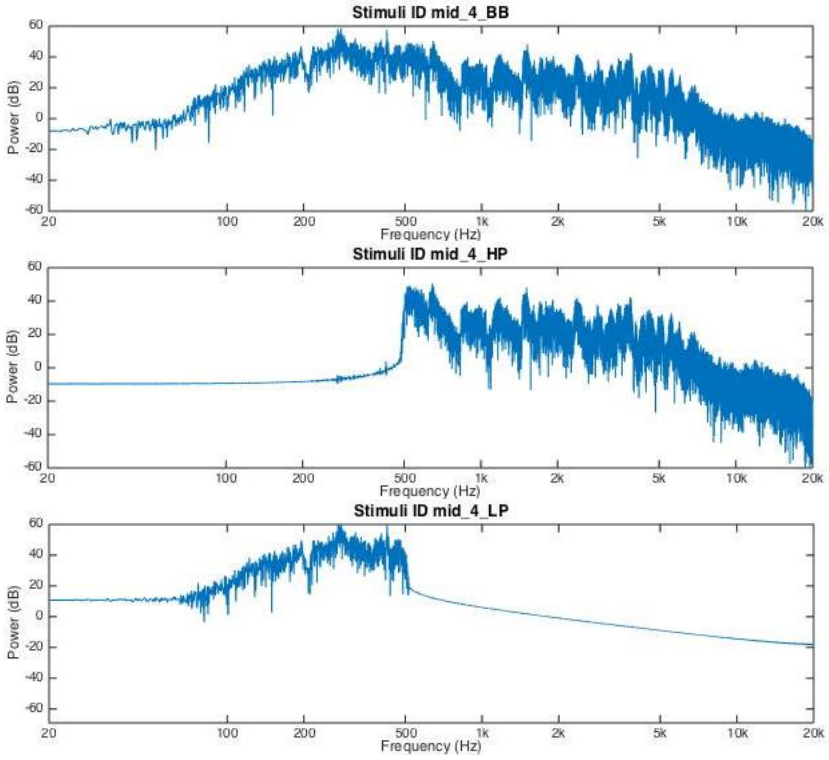

Figure 1. Top to bottom. Stimulus number 4, identification name mid_4. Top: original, broadband frequency spectrum; Middle: High-pass filtered version at 500Hz cut off frequency spectrum; Bottom: Low-pass filtered version at 500Hz cut off frequency spectrum.

Previous studies on annoying sounds have often referred to nails scraping down a blackboard to describe what is typically perceived as an annoying, and even painful sound for listeners (1). On this basis, the sounds recorded are described as grinding, screeching and scraping, all with the intension of a negative and painful association for listeners.

Sounds were recorded in an anechoic chamber and chosen based their aversive sounds to both the author and performers. Three key types of sounds were created using various instruments and tools.

1. A combination of violin and viola played below the bridge with a heavy bow as shown in Figure 2. This technique was used to create the grinding and screeching recordings used as broadband stimuli in the final listening test. Variation in the pressure, the speed and the combination of strings played simultaneously created diversity in the collection of sounds gathered from this technique.

Figure 2. Heavy bowing of viola strings below the bridge creating the grinding and screeching sound

2. A smooth metal on metal scraping/ swirling sound was recorded and used as one of the broadband test stimulus. The sound was made using a metal coat hanger sliding along a metal ruler as seen in Figure 3.

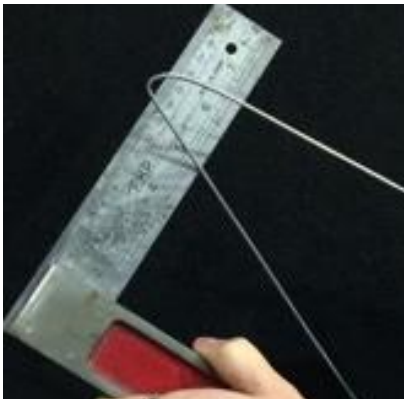

Figure 3. Smooth metal surface being stroked by a metal coat hanger to create a gentle scraping sound

3. A harsh metal scraping sound was made by using the flat tip of a metal screwdriver, and slowing pulling it down the length a rough metal file with some pressure as shown in Figure 4. This recorded sound was used as one the broadband test stimulus in the study.

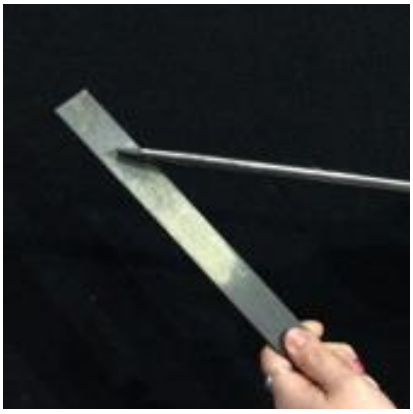

Figure 4. Flathead screwdriver scraping down a coarse metal wood-file.

The 18 test stimuli were broken into two sets for the listening test, each comprising of three types of recorded sounds, a grinding, a screeching and a scraping sound, and were presented with three different spectral energy distributions, as shown in Figure 1.

2.2 Procedure

Two sets of 9 stimuli were used for the purpose of counter balancing in 4 different trial groups of listeners. Each trial group had different conditions regarding the set of sounds that included ideation, and the order in which the listeners were presented with the stimulus sets. Participants consisted of mixed gender adults between the ages of 23 and 54 with no known hearing impairments. Age and gender was not found to be of significant effect in undertaking the listening task. Table 1 shows how each trial group was broken into two sets of sounds, with and without ideation, with Group 1 and Group 2 having ideation in the first set of sounds, and Group 3 and Group 4 having ideation in the second set of sounds. The set of sounds presented first and second were also swapped in Group 2 and Group 4 so that Set 2 was heard first and Set 1 second. This counter balancing was designed to reduce the risk that results could be biased towards higher average ratings in any one condition due to prior exposure to ideational descriptions, or due to prior experience in rating other sounds in the listening task.

Trial Group 1	**Trial Group 2**	**Trial Group 3**	**Trial Group 4**
Ideation	**Ideation**	**NO ideation**	**NO ideation**
Set 1	Set 2	Set 1	Set 2
NO ideation	**NO ideation**	**Ideation**	**Ideation**
Set 2	Set 1	Set 2	Set 1

Table 1. Counter balancing of stimulus order and ideation for four trial groups of listeners.

A recorded voice described each stimuli and was saved as a file to be played prior to the test stimulus in the ideation condition of the listening task. A total of 16 participants rated the test stimulus along a 50-mm graphic scale ranging from least unpleasant to most unpleasant. Four participants were randomly assigned to each trial group and asked to put a mark along the line in response to the stimulus with least unpleasant at the bottom and most unpleasant at the top of the line. Stimuli were presented the stimuli using AKG model K240 headphones with a constant playback level. File names and ideation descriptions are shown in Table 2 for the 2 sets of stimuli.

	SET 1	**Ideation Script**	**SET 2**	**Ideation Script**
1	mid_1_BB_i mid_1_BB	the sharp sound of metal of metal scraping	mid_4_BB_i mid_4_BB	a confronting scraping sound, not unlike nails down a chalkboard
2	mid_1_HP_i mid_1_HP	a piercing metal on metal whirling and scraping	mid_4_HP_i mid_4_HP	a hollow, piercing scraping noise
3	mid_1_LP_i mid_1_LP	a full, dark whirling rumble	mid_4_LP_i mid_4_LP	a dark rumbling scraping sound
4	mid_2_BB_i mid_2_BB	a confronting creaking sound	mid_5_BB_i mid_5_BB	A coarse metal file being scraped by a sharp metal tool
5	mid_2_HP_i mid_2_HP	a bright hollow creaking sound	mid_5_HP_i mid_5_HP	a bright metallic scraping sound
6	mid_2_LP_i mid_2_LP	a dark rumbling sound	mid_5_LP_i mid_5_LP	a full low rumbling not unlike being under dumped under a wave
7	mid_3_BB_i mid_3_BB	a screeching violin bow played below the bridge	mid_6_BB_i mid_6_BB	an intense grinding sound that has swirling tones throughout
8	mid_3_HP_i mid_3_HP	a sharp piercing violin squealing out of tune	mid_6_HP_i mid_6_HP	a bright squealing grinding noise
9	mid_3_LP_i mid_3_LP	a dark whirling sound	mid_6_LP_i mid_6_LP	a fairly dark, whirling noise

Table 2. File naming convention for Set 1 and Set 2 of test stimuli with script of ideational descriptions.

Files ending in "_i" were only played before the test signal for conditions that required ideation. For conditions with no ideation, the test signals were played alone. An example of 4 test signals rated on the scale provided to participants is shown in Figure 5.

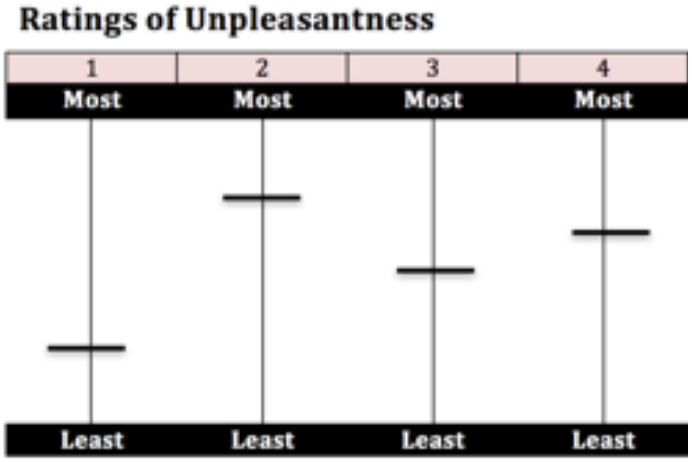

Figure 5. An example of a participants rating of unpleasantness on a scale from least to most unpleasant

For each set of nine stimuli, a randomized order of playback was created for each condition. This ensured that the order in which listeners were presented with stimulus did not make an idiosyncratic contribution to responses gathered. To help listeners familiarize with the listening task, the same two test signals were presented as an example for two practice trials before proper trials were initiated for each set of nine stimuli.

3. RESULTS

Data was collected from the 16 participant rating sheets and compiled using a numbered rating system between 0 and 50 for each sample. The median values were calculated and are presented in Figure 6.

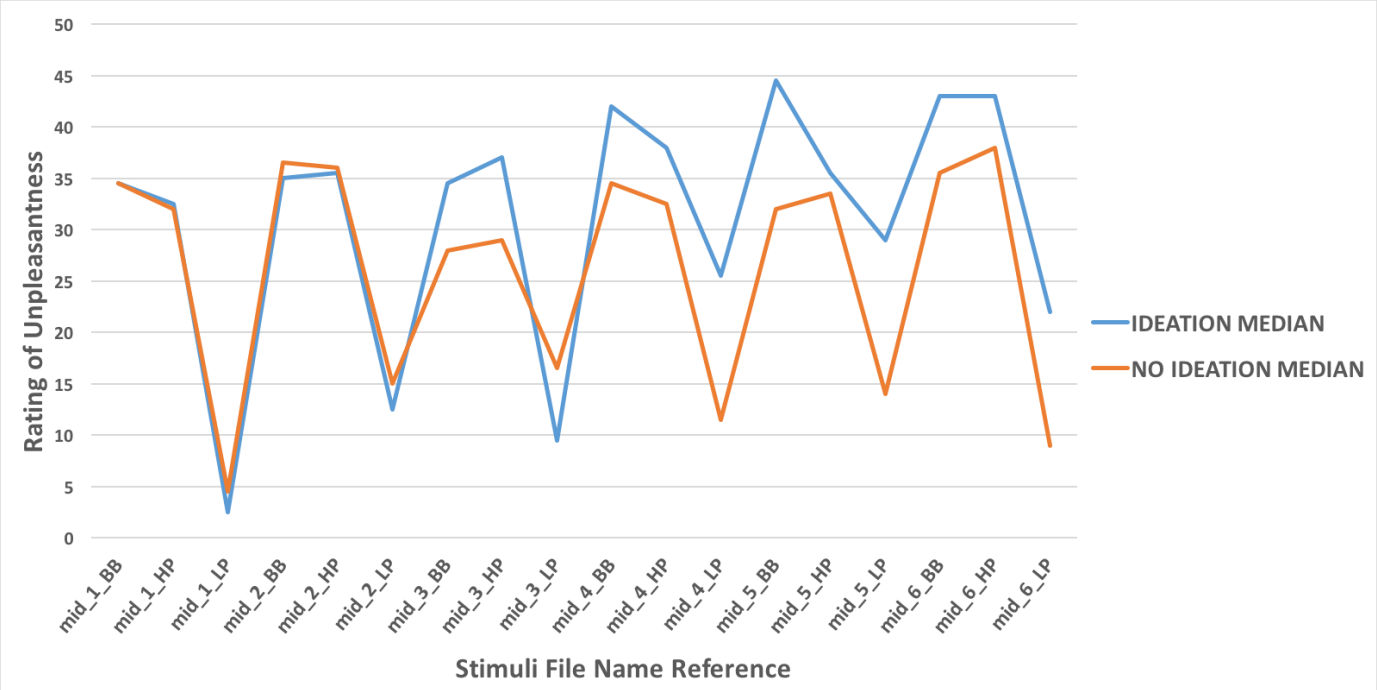

Figure 6. Median Values of Rated Unpleasantness from 16 participants for 18 different test stimuli varying in spectral content and in the presence of ideation descriptors.

For test stimuli ending in "_BB" the full broadband spectrum of the recorded sound was retained, while the corresponding "_HP" and "_LP" for the same numbered sample refer to the high-pass and low-pass filtered version with a cut-off frequency of 500Hz.

Figure 6 shows that the low-pass versions of each sound were rated significantly lower for each of the 6 recorded sounds when compared to the high-pass and broadband version from the same recordings. On average there is a 4-point difference in reported unpleasantness when comparing the high-passed version and low-passed versions of each recorded sound. The same trend is true for both conditions with and without ideation.

Though 66% of all samples and broadband only samples showed in increase in rated unpleasantness with the introduction of ideation it is unclear if this is true for all adverse sounds. Recorded sounds 1 and 2, part of set 1, both demonstrated similar ratings with and without ideation, while samples 3, 4, 5 and 6 showed a greater variation in conditions, suggesting that the ideation does in fact increase the rating of unpleasantness. 83% of the high-pass samples showed that when ideation is presented prior to listening to a sample, listeners are more likely to have a greater aversion to the sound.

It is interesting to note that there was an increase in rated unpleasantness for the two practice stimuli upon hearing them for the second time. There was an overall average of 11% increase in rated unpleasantness when listeners heard the stimulus for the second time. For example, Stimulus 1 had a 10% increase, while Stimulus 2 had a 12% increase in rated unpleasantness. Although the pre-test trials were not part of the experimental trials, it is clear that this trend should be taken into account in further studies, since these results suggest that the perception of unpleasant sounds on earlier trials can have such a great effect on the perceived unpleasantness of stimuli on later trials.

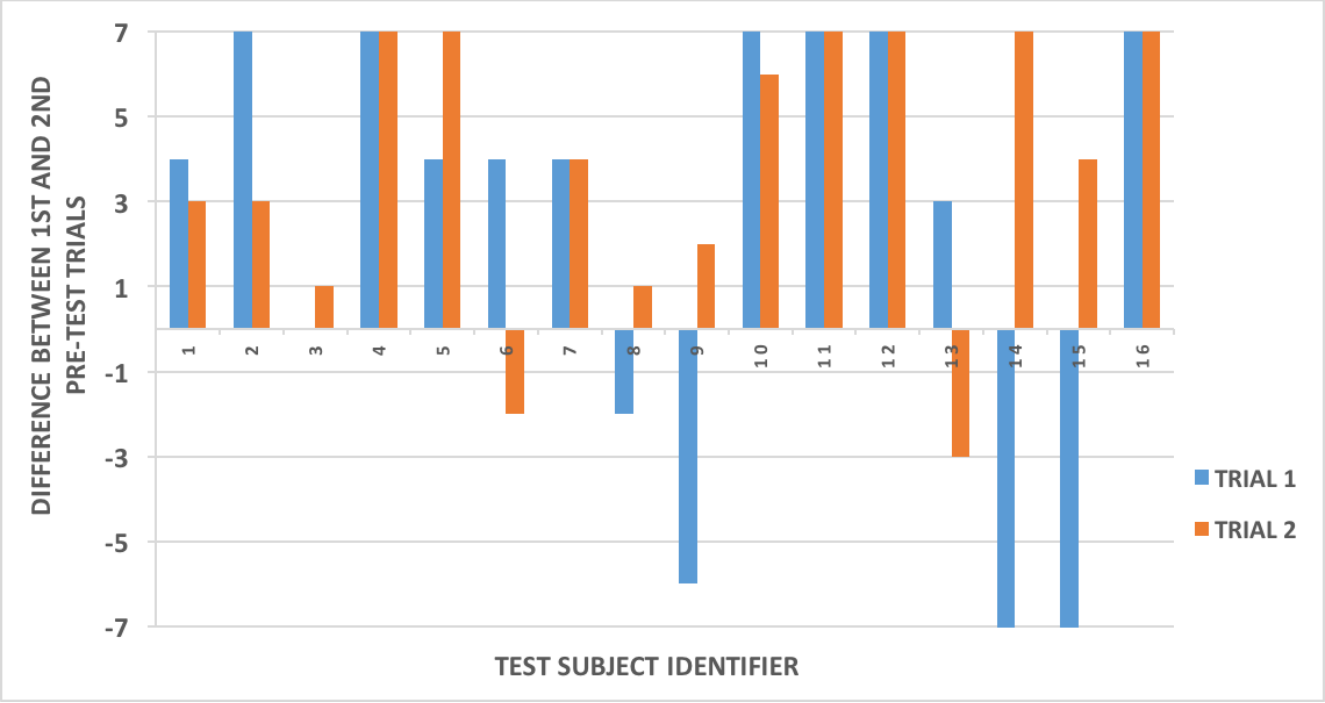

Figure 7. Difference in rated unpleasantness for 2 trial stimulus between 1st set and 2nd set of listening task.

The results also showed that on average listeners rated the same test stimuli 2 – 3% more unpleasant when the set of sounds were played second compared to listeners from other trial groups that rated the same set of sounds first. 61% of test signals with no ideation showed an increase in unpleasantness when auditioned in the second set, while 78% of signals with ideation showed an increase in unpleasantness when auditioned in the second set of sounds. This finding is in line with results showing the presence of ideation increases unpleasantness, and it also further supports the connection between the repetition of unpleasant sounds and the perceived unpleasantness for listeners.

4. DISCUSSION

The results collected from 16 participants in a listening task showed that for the recorded sounds used, listeners perceived frequency content above 500Hz to be more unpleasant than the low frequency content below 500Hz for the same recordings. On average there was a 40% difference in rating between the unpleasantness of low-pass and high-pass versions of the recorded sounds. This is a significant finding, and for the signals tested, it can be claimed that the major contributor to perceived unpleasantness is the frequency content above 500Hz. Because the sounds used in the test stimuli only consisted of 6 original recordings made using stringed instruments and metal object, the perception of unpleasantness cannot be generalised for all sounds without further study on a wider range of test stimuli.

While test signals were normalised and played back at a moderate volume via headphones, it was noted that perceived loudness was not equal, as low frequency content was reported to sound 'quieter'. It was also noted that several of the participants' experiences cringing and expressed more disgust in facial expressions when ideation was heard before a test signal. Some participants even made verbal comments such as 'it's much worse with the description'. Although the question whether or not the ideation made the sound feel more unpleasant, in further studies, this might be helpful in gaining insight into the role of conscious thoughts on perceived unpleasantness of human listeners.

The results suggest that ideation does in fact influence the perceived unpleasantness of recorded sounds, particularly for samples with frequency content above 500Hz. Because of the small sample group, and the limited number stimuli, the results must be regarded as only suggestive that verbal ideation might increase unpleasantness in general for most annoying, painful or unpleasant sounds, however for conditions of this study, 85% of participants found the high-pass versions with ideation to have a greater rating of perceived unpleasantness than when the same sounds were presented without any ideation.

5. CONCLUSIONS

Most relevant to the hypothesis, the results of the study show that for recorded sounds described as grinding, screeching and scraping, frequency content above 500Hz is perceived more unpleasant than that below. This study looks specifically at the recorded sounds described, and in turn cannot be conclusive in saying that all annoying sounds above 500Hz are considered more unpleasant, however results shows that is true for the sounds in this study.

Ideational factors showed an increase in perceived unpleasantness for broadband and high-passed stimuli, however was less of a contribution when lower rated low-passed stimuli were compared. It was also found that the longer listeners were participating in the rating task, an increase of unpleasantness was reported for 85% of listeners. Due to the small test group, more studies need to be done to determine an average amount of increased unpleasantness, and the effect continuous repetition has when rating unpleasantness.

6. ACKNOWLEDGEMENTS

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REFERENCES

Abe, K., Suzuki, Y., & Sone, T. (1999). The effects of visual information on the impression of environmental sounds. *Inter-noise, 99*, 1177 - 1182.

Boueri, M., & Kyirakakis, C. (2004). Audio Signal Decorrelation Based on a Critical Band Approach. AES 117th *Convention.* San Francisco: Audio Engineering Society.

Boyd, G. F. (1959). Auditory irritants and impalpable pain. Journal of General Psychology, 60, 149 - 154.

Cox, T. J. (2008). Scaping Sounds and Disgusting Noises. Applied Acoustics, 69, 1195 - 1204.

Cox, T. J. (2008). The effect of visual stimuli on the horrribleness of awful sounds. Applied Acoustics, 69(8), 691 – 703.

Ely, D. J. (1975). Aversiveness without pain: Potentiation of imaginal and auditory effects of blaockboard screeches. *Bulletin of the Psychonomic Society, 6*, 295 - 296.

Halpern, D. L., Blake, R., & Hillenbrand, J. (1986). Psychoacousics of a chilling sound. Perception & Psychophysics, *39*(2), 77 - 80.

Ioannidou, C., Santurette, S., & Jeong, C.-H. (2016, March 23). Efftect of modualtion depth, frequency and intermittence on wind turbine noise annoyance. *Jounral of the Acoustical Society of America, 139*(3), 1241 – 1251.

Leventhall, G., Pelmear, P., & Benton, S. (2003). A review of Published Research on Low Frequency Noise and its *Effects.* London: Department for Environmental, Food and Rural Affairs.

Lewis, J. S., Kersten, P., McCabe, C. S., McPerson, K. M., & Blake, D. R. (2007). Body perception disturbance: A contribution to pain in complex regional pain syndrome (CRPS). *Pain, 133*, 111 - 119.

Terrace, H., & Stevens, S. S. (1962). The Quantification of Tonal Volume. American Journal of Psychology, 75, 596 – 604.