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**PLEASANTNESS AND CUED RECALL PERFORMANCE FOR ENVIRONMENTAL**

**SOUNDS**


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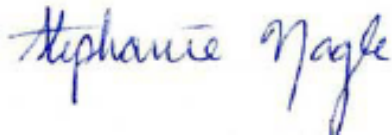
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This is to certify that the thesis prepared by Laura Sherry entitled *Pleasantness and Cued Recall Task Performance for Environmental Sounds* has been approved by the thesis committee as satisfactorily completing the thesis requirements for the degree of Doctor of Audiology.

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# ABSTRACT

PLEASANTNESS AND CUED RECALL PERFORMANCE FOR ENVIORMENTAL
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Laura Sherry

The objective of the present study was twofold: to obtain subjective ratings of pleasantness for a set of thirty-six environmental sounds and to determine if the pleasantness of these sounds is related to performance on a cued-recall task. Fourteen participants rated a set of thirty-six environmental sounds for pleasantness. A multidimensional scaling approach was used to determine the perceptual pleasantness space for this sound set. This analysis revealed that sounds clustered along the dimensions of naturalness and continuousness. An additional sample of thirty participants performed a cued recall task, in which listeners were asked to judge whether sounds had been presented during a previous study phase. The results of this experiment indicated no significant relationship between sound pleasantness and accuracy on the cued recall task. A relationship between false memories and pleasantness appeared to be present, with more false memories occurring for unpleasant sounds. However, this relationship did not reach a level of significance. The results of this investigation suggest that continuousness and naturalness are related to pleasantness for environmental sounds. Future research on environmental sound perception should focus on determining the nature of a potential relationship between pleasantness and recall for environmental sounds.

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**CHAPTER 1**

**Introduction**

The human auditory system is capable of processing and decoding a wide variety of complex auditory stimuli including speech, music and environmental sounds. Environmental sounds can be defined as "all naturally occurring sounds, other than speech and music" (Gygi, Kidd, & Watson, 2007, p. 839). Environmental sounds can also be thought of as sounds which have causal relationships to the event that created the sound (Ballas, 1993). For example, the sound of rain falling is causally related to the event of rainfall and would therefore be classified as an environmental sound. In contrast, the meaning of sounds of speech and language are defined by social constructs. The auditory information gathered through speech is not causally related to an event, and would therefore not be classified as an environmental sound. All sounds, including environmental sounds, can be described by their physical properties such as frequency, timing and intensity characteristics. Sounds may also be described according to how they are subjectively experienced using perceptual qualities such as roughness, pleasantness and naturalness. Currently, there is no agreed upon taxonomy for the classification of perceptual qualities of environmental sounds (Gygi & Shafiro, 2010). Investigating the perceptual qualities of environmental sounds provides insight into how these sounds are stored, retrieved and identified within human consciousness and may further inform the development of structured classification taxonomies.

# CHAPTER 2

## Literature Review

Various environmental sounds are introduced into the auditory system continuously and simultaneously. The cognitive and auditory processes responsible for translating these complex acoustic signals into meaningful information are not yet fully understood. Bregman (1990) initially described the human ability to decode acoustic information as "auditory scene analysis". Auditory scene analysis is the process of separating and identifying each individual sound source that is present in an acoustic environment (Bregman, 1990). Listeners identify sounds as belonging to either the same stream or different streams by using spatial location cues, formant relationships, amplitude fluctuations and onset and offset timing (Bizley, & Cohen, 2013; Bregman, 1990). These strategies are "bottom-up" and largely automatic processes, which are unaffected by attention, experience or listener expectations (Bregman, 1990; Gutschalk & Dykstra, 2014).  However, the success of these scene analysis processes do depend upon a healthy, intact auditory system. When the auditory system is no longer intact, due to factors such as hearing loss or aging, auditory scene analysis and initial stream segmentation is compromised compared to normal hearing populations (Gygi & Shafiro, 2013; Rimmele, Sussman, & Poeppel, 2015; Shafiro, Gygi, Cheng, Vachhani & Mulvey, 2011).

Although bottom-up features, such as temporal cues and other physical qualities of the signal are integral to accurate sound perception, other "top-down" factors are also important. For example, environmental context, listener expectations, and the affective or emotional experiences evoked by the sound have been shown to affect environmental sound perception (Gaver, 1993; Marcell, Borella, Green, Kerr & Rogers, 2000). More complex cognitive processes are likely responsible for processing acoustic information in this manner (Gaver, 1993). Research conducted on the phenomenon of change deafness indicates that environmental sound perception is affected by attention and memory, especially when the differences between environmental sounds present in the environment are very small (Gregg & Synder, 2012). In contrast to the abilities used for auditory scene analysis, these "top-down" processes such as attention and memory are dependent on the previous experiences of the listener (Gaver, 1993). This type of sound processing has been termed "ecological perception" (Gaver, 1993; Gibson, 2014). Despite the ubiquity of environmental sounds in everyday life, a review of the literature indicates that few studies have investigated the ecological perception of environmental sounds.

**Linguistic Correlates**

The limited literature on environmental sound perception stands in stark contrast to the large body of work pertaining to how linguistic information is parsed and represented. The framework laid by linguistic researchers will likely be relevant to environmental sounds perception research, because both speech and environmental sounds are complex acoustic signals which listeners must decode into useful information. Both speech signals and environmental sounds are processed via the auditory pathway.

They are then relayed through complex cortical networks in the brain for higher cognitive processing. The approaches used to discover the underlying mechanisms of speech perception may be extended to research on environmental sound perception.

A connectionist model of speech perception has been widely accepted (McClelland & Elman, 1986; Seidenburg, 1994; Takac, Benuskova, & Knott, 2012). This model posits that humans represent language via a system of nodes and connections between nodes (Dell, Chang & Griffin, 1999; McClelland & Elman, 1986; Seidenburg, 1994). Each possible characteristic of every stimulus is represented by a node that is either excited or inhibited by that stimulus. When a stimulus is presented, the activated nodes will spread, and the path with the greatest amount of overall stimulation will lead to a word and set of associated words that become available for retrieval (McClelland & Elman, 1986).

According to the connectionist model, the probability of each node becoming active in response to a stimulus is not equal. When a listener is confronted with linguistic information, several factors affect the pattern of activation and, consequentially, the retrieval of that information. For example, word frequency, the average regularity of occurrence within a language, imaginability or concreteness, as well as grammatical, lexical, and phonetic features all affect linguistic retrieval (Dell, Chang & Griffin, 1999). The influence of the features that effect linguistic retrieval gives insight into how semantic information is encoded and how the relationships underlying the connectionist model may be formed.

**Familiarity Effects: Speech**

Previous research suggests that familiarity is a relevant factor in the perception of both language and environmental sounds (Hocking, Dzafic, Kazovsky & Copland, 2015; Paivio, 1969). Listeners tend to report greater familiarity for high frequency words versus low frequency words. Further, listeners respond more quickly and accurately to frequently used words than to less frequently used words (Balota & Chumbley, 1984; Jescheniak & Levelt, 1994).

**Familiarity Effects: Environmental Sounds**

The impact of familiarity on the processing of environmental sounds has been explored and appears to follow a pattern similar to language-based tasks (Ballas, 1993; Marcell et al., 2000; Shafiro, 2008). Environmental sounds with greater familiarity are identified with greater speed and accuracy than those rated as unfamiliar (Ballas, 1993; Marcell et al., 2000; Shafiro, 2008). Gygi and Shafiro (2011) found that listeners who were previously familiarized to the environmental sound stimuli could identify sounds more quickly and accurately within their natural environmental context than listeners who were not familiarized. Further, Ballas (1993) identified a correlation between ecological frequency and environmental sound identification accuracy, where sounds that occurred more often in the everyday environment were also identified more accurately. These results suggest that learning and previous experiences influence individual's ability to efficiently process acoustic stimuli. Previous research has revealed many similarities in environmental sound processing and language processing. Therefore, it is likely that

several of the strategies used for the storage and retrieval of environmental sounds and language are common to both input types.

**Imaginability**

Research on language processing suggests that the listener's ability to imagine a word also affects retrieval speed and accuracy (Hocking et al., 2015; Paivio, 1969). Abstract words are more slowly retrieved than concrete words, which can be easily connected with a mental picture (Paivio, 1969). There is currently no normative data for the imaginability of sounds (Hocking et al., 2015). However, previous research suggests that environmental sound identifiability is related to how easily the listener can form a mental picture of the sound (Ballas, 1993). Sounds that are easily imagined are also more easily identified (Ballas, 1993).

**Organizational Structure of Speech and Environmental Sounds**

Although it is well documented that familiarity and imaginability are relevant factors in the perception of both speech and environmental sounds, other factors are not shared between stimulus types. For example, lexical information is organized by grammatical class. Mistaken replacements of words by native speakers are more likely to happen within the same grammatical class than between grammatical classes (Fromkin, 1984). While environmental sounds cannot be classified into grammatical categories, a clear hierarchical taxonomy exists in which listeners identify and attribute meaning to environmental sounds (Houix, Lemaitre, Misdariis, Susini & Urdapilleta, 2012). Environmental sounds are likely organized, at least in part, based on semantic categories. Gaver (1993) provides a conceptual framework for understanding semantic categories of

environmental sounds, which is based primarily on the sound creating object. Performance is significantly poorer on change detection tasks when environmental sounds from a shared semantic category are presented, compared to conditions where sounds are from different semantic categories (Gregg & Samuel, 2009). Identification performance is also influenced by semantic category effects; poorer performance when a sound is presented outside of its typical (semantically congruent) context (Gygi & Shafiro, 2011). These results indicate that relationships between environmental sounds exist, making it easier to recognize the difference between two less-related sounds than two sounds that are closely related. However, the nature of these relationships are not fully understood.

Several researchers have asked listeners to sort environmental sounds into separate categories in order to gain insight into relationships between environmental sounds (Gygi et al., 2007; Houix et al., 2012; Marcell et al., 2000). In these categorization tasks, listeners classified environmental sounds according to one of several possible classification methods. These classification methods include: the acoustic features of the sounds, such as rhythmic or sharp (Gygi et al., 2007), the source of the sound; for example, liquids, animals or sports (Gygi et al., 2007; Marcell et al., 2000; Vanderveer, 1979). Participants have also categorized sounds based on the function of the sound source, such as weapon or tool (Marcell et al., 2000) Additionally, sounds can be classified based on the emotional responses to the sound, such as annoying or startling (Gygi et al., 2007). Finally, the location or context in which the sound typically occurs, such as kitchen or bathroom can be used to categorize environmental sounds (Gygi et al., 2007; Marcell et al., 2000).

Emotional and affective responses provoked by environmental sounds, such as the perception of pleasantness, are particularly interesting because they have been linked to other perceptual features. Pleasantness ratings have been correlated with assessments of naturalness, familiarity, arousal, and roughness (Marcell et al., 2000). Sounds with a high pleasantness rating have been associated with the perception of naturalness (Marcell et al., 2000). The perceptions of roughness, loudness and emotional arousal have negatively correlated with perceptions of pleasantness (Bonebright, 2001). Additionally, environmental sounds that are longer in duration have been rated as more pleasant than shorter duration sounds (Marcell et al., 2001).

Perceptions of pleasantness may also affect identification. Hocking et al. (2013) found that environmental sounds with a high pleasantness rating were more likely to be correctly identified. A relationship between pleasantness and familiarity has also been established. Participants are more likely to rate pleasant environmental sounds as familiar (Marcell et al., 2001).

Although it has been established that both pleasant and familiar sounds are more easily identified, and pleasant sounds are rated as more familiar; it is unclear if the perceptual relationship between familiarity and pleasantness affects listeners' ability to later recall these sounds (Hocking et al., 2013; Marcell et al., 2001; Schneider et al., 2008). Previous research indicates that individuals use several strategies, known as heuristics, to maximize processing speed and efficiency (Jacoby & Dallas, 1981; Wagner & Gabrieli, 1998). The fluency heuristic is one such strategy. The fluency heuristic describes the tendency to favor items in which the decision-maker can process more easily or fluently (Voltz, Shooler & Von Cramon, 2010; Wagner & Gabrieli, 1998).

When people are asked to make a judgment between two options with respect to a certain criterion, they will select the option that is more quickly and easily processed (Gigerenzer & Gaissmaier, 2011). Processing fluency is often measured experimentally by recording the time it takes for an individual to recognize or identify the stimulus (Voltz et al., 2010). Processing fluency is also highly related to familiarity (Voltz et al., 2010). Because pleasant sounds are rated as more familiar, it is logical to predict that pleasant sounds would also be more quickly and easily retrieved.

**Rating Scales**

Previous investigations of environmental sound perception have primarily utilized identification, categorization tasks, and rating scales to investigate relationships between the subjective qualities of environmental sounds (e.g. Bradley & Lang, 2000; Hocking et al., 2013). Rating scales are a tool used to measure the presence of subjective quality, such as pleasantness, familiarity, or naturalness (Bradley & Lang, 2000; Hocking et al., 2013). The rater is presented with a statement or question and asked to indicate where the sound, or pair of sounds falls along a continuum of values. Each site along the continuum represents a different amount of the subjective quality of interest. Rating scales are commonly used in marketing, customer reviews, and political polls (Bargagliotti & Li, 2013). Additionally, numerous environmental sound perception investigations have used rating scales to determine the listeners' subjective responses to environmental sounds (Bonebright, 2001; Dickerson, Perelman, Gaston, Foots & Mermagen, 2015; Hocking et al., 2013; Marcell et al., 2000). A rating scale will represent a decision-maker's opinion differently than a binary scale because a more detailed representation of the raters' perceptions can be gathered (Bargagliotti, 2013).

Nominal, interval or ordinal scales can be used to develop rating scales (Brown & Daniel, 1990). For research purposes, however, an interval scale is preferred because the distance between each increment is even and corresponds with the same amount of increase in the quality being measured (Brown & Daniel, 1990). Limitations of rating scales include variations in rater interpretation and variation within each rater's behavior. The utility of the rating scale is limited by the investigators inability to control for individual differences between raters that may affect their rating behavior (Brown & Daniel, 1990). The possibility of variability between raters in their interpretation of the task must be managed through thoughtful organization and wording (Brown & Daniel, 1990). It is possible that two people can have identical perceptions but choose different values on a rating scale (Brown & Daniel, 1990). Additionally, the same person may choose different values on a rating scale from each time they complete the task (Brown & Daniel, 1990; Preston & Colman, 2000). This phenomenon is called intraobserver inconsistency (Brown & Daniel, 1990; Preston & Colman, 2000). While intersubject and intrasubject variability remains a limitation of using rating scales in research, evidence suggests that self-reported emotional response is consistent across time within the same person (Larsen & Diener, 1987).

**Visual Models of Perceptual Relationships**

Models of perceptual relationships are most appropriately represented in a visual domain, where Euclidian distances are used to represent the perceptual similarity of stimuli (Shepard, 1980). A smaller distance between two points plotted in this manner represents a closer perceptual relationship. Additionally, predictions can be made based on these relationships (Shepard, 1980). The probability that a person will generalize that

a novel stimulus is a member of a certain category can be calculated based on the strength

of perceptual similarity between that stimulus and other members of that category

(Shepard, 1987). Researchers have long been interested in the relationships of various

stimuli within this "perceptual space."

Recently, the perceptual relationships between a set of familiar environmental

sounds have been mapped along the dimension of perceived similarity in using a

multidimensional scaling (MDS) technique (Dickerson et al., 2015). MDS is a statistical

analysis method that takes one-by-one comparisons between items as input, simplifies the

data, and allows a visual representation of the data to be displayed (Hout, Papesh &

Goldinger, 2013).  For example, in an MDS representation of similarity judgments

sounds that are rated as more similar are closer in MDS distance than sounds that are

rated as dissimilar. This technique has been used by several previous researchers

investigating the perception of environmental sounds (Bonebright, 2001; Dickerson et al.,

2015; Gygi et al.; 2010). Pairwise comparisons or stimuli sorting tasks are generally

required to utilize a multidimensional scaling approach (Bonebright, 2001). Other

approaches that may be used to derive the nature of perceptual relationships between

specific stimuli include independent components analysis and principle components

analysis. These statistical techniques simplify a data set and allow the underlying

constituent parts of a signal or data set to be segregated (Dunterman, 1989).

**Statement of Purpose**

The current investigation seeks to examine environmental sounds in regard to

perceived pleasantness and to examine a potential relationship between these ratings and

performance on a behavioral task. Previous research on environmental sound perception

has found that subjective ratings do influence performance on certain tasks. For example,

Dickerson et al., (2015) discovered a relationship between ratings of similarity and the

ability to detect change in an environmental sound. The present study seeks to determine

if a similar relationship between subjective ratings and performance extends to

evaluations of pleasantness and performance on a cued-recall task.

To evaluate this relationship, two experiments were conducted. In the first, a

groups of participants provided ratings for environmental sounds. In the second

experiment, a group of participants provided ratings for only one half of the sound set.

This group was then asked to recall which sounds they had previously rated. The rating

phase of experiment two served as the participants' "study phase", preparing them for the

cued recall task (test phase).

Previous research suggests that pleasantness is correlated with familiarity; high

pleasantness ratings predict feelings of familiarity (Hocking et al., 2013). This connection

between pleasantness and familiarity is important because there is evidence in the

memory literature that more familiar items are processed more easily (Voltz et al., 2010).

The relationship between pleasantness and familiarity for pleasant and unpleasant

environmental sounds was evaluated by pairing the ratings from Experiment 1 with recall

performance during the test phase of Experiment 2. It was hypothesized that participants

would indicate that they heard pleasant sounds more often than unpleasant sounds.

Pleasant sounds that had actually been heard would be easier to remember because

pleasant sounds may be more familiar. Pleasant sounds that had not been heard before

could be subject to a fluency effect (Wagner & Gabrieli 1998). Therefore, more false alarms due to false memories were expected for pleasant sounds.

Hit rate was used to measure recall accuracy for the cued recall task (Verde, Macmillan & Rotello, 2006). Hit rate was calculated as the number of correct responses for target sounds divided by the total number of trials. The rate of false memories was evaluated using the false alarm rate. A false alarm response indicates that a listener believed that they have heard a sound in the study phase, when they actually have not. (Roediger & McDermott, 1995; Verde, Macmillan & Rotello, 2006). False alarm was calculated as the number of incorrect responses for lure sounds.

# CHAPTER 3

## Research Methodology

### Experiment 1

Experiment one was a stimulus characterization task. The purpose of this experiment was to gather data on the pleasantness of the environmental sound set and to discover perceptual relationships between these sounds. These pleasantness ratings would then be used to compare to performance in Experiment 2.

**Participants.** Data from 14 participants were collected. These participants were undergraduate students at Binghamton University in Binghamton, New York. Course credit was awarded for their participation in this experiment. Pure tone air conduction thresholds of 25 dB HL or better were measured in all participants at all octave frequencies between 500 Hz and 8000 Hz prior to testing to ensure normal hearing sensitivity. Information about participant age and gender was not collected.

**Materials.** Testing was conducted in a quiet room and participants were seated at a laptop computer and closed circumaural Beyer Dynamic T 70. Data were collected using E-Prime software.

**Stimuli.** Thirty-six sound stimuli were used. Table 1 lists the set of environmental sound stimuli. Eighteen of these stimuli have been used previously in research from Dickerson and colleagues (2015). An additional eighteen stimuli were collected from www.freesound.org. All sounds were truncated to 1000 milliseconds in duration, with 5ms linear on and off ramps to prevent acoustic transients. All sound modifications were done using Adobe Audition (CS 6). The sample was selected to be representative of

sounds which could be heard in an urban or suburban environment. A variety of sound

sources were chosen, such as vehicles, animal vocalizations, and household products.

Table 1

*Environmental Sound Stimuli Included in Pleasantness Task*

| Stimuli Number | Sound Label |
| --- | --- |
| 1 | Alarm Clock |
| 2 | Baby 1 |
| 3 | Baby 2 |
| 4 | Bell 1 |
| 5 | Bell 2 |
| 6 | Bike 1 |
| 7 | Bike 2 |
| 8 | Bus 1 |
| 9 | Bus 2 |
| 10 | Cans 1 |
| 11 | Cell Phone 1 |
| 12 | Crickets 1 |
| 13 | Crickets 2 |
| 14 | Dog 1 |
| 15 | Dog 2 |
| 16 | Ducks |
| 17 | Guitar |
| 18 | Helicopter 1 |
| 19 | Helicopter 2 |
| 20 | Jackhammer |
| 21 | Lighter |
| 22 | Metal Scraping |
| 23 | Motorcycle |
| 24 | Airplane 1 |
| 25 | Airplane 2 |
| 26 | Water Pouring |
| 27 | Rain |
| 28 | Shop-vac 1 |
| 29 | Shop-vac 2 |

| 30 | Stream |
|----|--------|
| 31 | Tank |
| 32 | Tea Kettle |
| 33 | Truck 1 |
| 34 | Truck 2 |
| 35 | Walking |
| 36 | Walking 2 |

**Procedure.** The environmental sound stimuli listed in Table 1 were presented individually to each participant. Participants were asked to indicate the pleasantness of each sound using a Likert scale of 1 to 7. A score of 1 indicated that the sound was very unpleasant and a score of 7 indicated that it was very pleasant. Each participant rated each sound 5 times.

**Analysis.** The average pleasantness rating score for each sound was calculated. Upper and lower quartiles of average pleasantness ratings were calculated. A difference score matrix was created and that 36 x 36 difference matrix was subject to Multidimensional scaling (MDS) analysis, a method which uses multiple comparisons to predict the nature of perceptual relationships. Euclidian distance scores between sounds in the stimulus set were calculated. The goal of this MDS analysis was to reveal the number of dimensions participants use to evaluate the pleasantness of these sounds.

The pleasantness ratings for these sounds were also analyzed to determine if pleasantness was dependent on the naturalness or continuousness of the sound. Sounds were categorized as natural or mechanical and continuous or impulsive prior to the analysis. The mean pleasantness ratings of natural sounds were compared to those of man-made sounds and mean pleasantness ratings of continuous sounds were compared to those of impulsive sounds.

**Experiment 2**

**Participants**. Data from 30 participants were collected. All participants were recruited from the Towson, Maryland area. One participant was excluded from analysis because an incorrect rating scale was used. Of the 29 participants included for data

analysis, 11 were male and 18 were female. The mean age of participants was 26.52 years, with a range of ages from 20 years to 43 years. Pure tone air conduction thresholds of 25 dB HL or better were measured in all participants at all octave frequencies between 500 Hz and 8000 Hz prior to testing.

**Materials**. Hearing sensitivity was measured with a Grason-Stadler Instruments 61 audiometer and EAR-tone 3A insert earphones using the modified Hughson Westlake technique (Carhart & Jerger, 1959). Testing was conducted in a sound proof booth and participants were seated at a Lenovo ThinkPad laptop computer and wearing TDH-90 headphones. Data was collected using E-Prime software.

**Stimuli.** The same set of thirty-six environmental sound stimuli used in Experiment 1 were used. These sounds are divided into sounds used as targets and sounds used as lures. Table 2 lists all sound stimuli, divided into the group of the targets and lures.

**Procedure.** This experiment had two phases, a study phase (or encoding phase) and a test phase. During the study phase participants performed a similar rating task as experiment 1. Participants were asked to indicate the pleasantness of each sound using a Likert scale of 1 to 7. Only the sounds listed in the column titled "Targets" in Table 2 were presented during the study phase. A score of 1 indicated that the sound was very unpleasant and a score of 7 indicated that it was very pleasant. Each participant rated each sound 5 times. The rating task was a way to provide an initial stimulus encoding period to the participants, prior to their cued-recall task.

After performing the stimulus rating task, participants performed a cued-recall test, where half of the sounds were "old" (previously presented for study) and half are "new". The sounds listed in the column titled Targets in Table 2 were the old sounds. The sounds listed in the column titled Lures in Table 2 were the new sounds. Participants were asked to indicate which the sounds were "old" or "new" by pressing a corresponding key on a keyboard.

**Analysis.** The objective of the Experiment 2 analysis was to obtain a measure of recall accuracy. Hit and false alarm rates were calculated using this information. A hit was defined as correct identification of an old sound as old. A miss was defined as a response of new when the sound was, in fact, old. A false alarm was defined as a new sound being identified as old. A correct rejection signified that the listener judged new sounds as new. The hit, miss, false alarm, and correct rejection rates of pleasant sounds were compared to those of unpleasant sounds.

**Hypotheses**

The following four hypotheses were tested in these experiments:

1. Sounds that are more natural will be rated as more pleasant than sounds that are mechanical.

2. Sounds that are continuous will be rated as more pleasant than sounds that are impulsive.

3. Old sounds rated as highly pleasant, operationally defined, as having ratings in the top 25% of the scale, will be more accurately identified as old during Experiment 2.

4. New sounds that received high pleasantness scores during Experiment 1 will produce more false alarms than lures that received low pleasantness scores.

Table 2

*Environmental Sound Stimuli Included in Pleasantness Task*

| Targets (Old) | | Lures (New) | |
|---|---|---|---|
| Stimulus Number | Sound Label | Stimulus Number | Sound Label |
| 1 | Alarm Clock | 19 | Jackhammer 1 |
| 2 | Baby 2 | 20 | Baby 1 |
| 3 | Bell 2 | 21 | Bell 1 |
| 4 | Bike 2 | 22 | Bike 1 |
| 5 | Bus 2 | 23 | Bus 1 |
| 6 | Crickets 1 | 24 | Crickets 2 |
| 7 | Dog 1 | 25 | Dog 3 |
| 8 | Duck Call | 26 | Cell Phone 1 |
| 9 | Guitar | 27 | Rain |
| 10 | Helicopter 2 | 28 | Helicopter 1 |
| 11 | Metal 1 | 29 | Cans |
| 12 | Plane 1 | 30 | Motorcycle 2 |
| 13 | Pouring 1 | 31 | Tank 1 |
| 14 | Shop-vac 1 | 32 | Shop-vac 2 |
| 15 | Stream | 33 | Plane 3 |
| 16 | Tea Kettle | 34 | Lighter |
| 17 | Truck 2 | 35 | Truck 1 |
| 18 | Walking 1 | 36 | Walking 2 |

*Note.* $n =$ 14. All thirty-six sounds were presented in a random order.

**Chapter 4**

**RESULTS**

**Analysis: Experiment 1**

The purpose of this experiment was to characterize thirty-six environmental sounds along the parameter of pleasantness, as well as to determine if pleasantness was related to the qualities of naturalness or continuousness for these stimuli. Fourteen participants rated environmental sound stimuli for pleasantness using a scale of 1 to 7. A score of 1 represented a rating of very unpleasant, while a score of 7 represented a rating of very pleasant. Data were analyzed using IBM SPSS software. The acoustic properties of the sound stimuli were analyzed using PRAAT software. Pitch and harmonicity were calculated using autocorrelation or the SPINET algorithm.

Mean pleasantness scores ranged from 1.69 to 6.63. This range indicates that participants used nearly the entire available scale. The sound with the lowest mean pleasantness score was the Alarm Clock and the sound with the highest mean pleasantness score was the Guitar. The average pleasantness rating trended toward slightly unpleasant (M = 3.30, SE = 0.22). Table 3 displays mean pleasantness ratings for the 36 environmental sound stimuli divided in to quartiles.

Table 3

*Means and Standard Deviations for Pleasantness Rating by Quartile*

| Quartile 1 | Mean | SE | Quartile 2 | Mean | SE | Quartile 3 | Mean | SE | Quartile 4 | Mean | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alarm Clock | 1.50 | 0.09 | Helicopter 2 | 2.36 | 0.06 | Dog1 | 2.94 | 0.06 | Tea Kettle | 3.99 | 0.06 |
| Shop-vac 1 | 1.76 | 0.04 | Helicopter 1 | 2.55 | 0.04 | Duck Call | 3.01 | 0.03 | Crickets 1 | 4.09 | 0.06 |
| Bus1 | 1.79 | 0.03 | Bike2 | 2.68 | 0.04 | Bike 1 | 3.11 | 0.07 | Dog 3 | 4.25 | 0.06 |
| Bus2 | 1.93 | 0.04 | Plane 1 | 2.69 | 0.07 | Baby 2 | 3.15 | 0.07 | Lighter 1 | 4.49 | 0.04 |
| Shop-vac 2 | 1.96 | 0.07 | Plane 3 | 2.69 | 0.04 | Baby 1 | 3.17 | 0.06 | Crickets 2 | 4.89 | 0.05 |
| Jackhammer 1 | 1.99 | 0.07 | Metal 1 | 2.72 | 0.07 | Bell 1 | 3.33 | 0.08 | Pouring1 | 5.72 | 0.08 |
| Tank 1 | 2.13 | 0.05 | Cell 1 | 2.87 | 0.06 | Bell 2 | 3.47 | 0.06 | Stream | 6.47 | 0.08 |
| Truck 1 | 2.16 | 0.06 | Motorcycle 2 | 2.87 | 0.06 | Walking 1 | 3.74 | 0.06 | Rain | 6.48 | 0.10 |
| Truck 2 | 2.29 | 0.05 | Cans 1 | 2.91 | 0.07 | Walking 2 | 3.96 | 0.06 | Guitar | 6.63 | 0.04 |

*Note. n* = 14. Pleasantness ratings were obtained using a scale of 1 (very unpleasant) to 7 (very pleasant).

A multidimensional scaling procedure was conducted using the ASCAL algorithm. Figure 1 displays the multidimensional scaling solution from the pleasantness rating data. A 2-dimensional solution provided a clear representation of the data. This solution had a stress-value of 0.02, indicating excellent goodness of fit. Inspection of Figure 1 indicates that a distinction emerged between natural sounds and mechanical sounds and between continuous and impulsive sounds. Naturalness was likely expressed along the x-axis, with more natural sounds primarily represented in quadrants I and IV. Less natural, mechanical and man-made sounds were primarily found towards the right side of the MDS graph, primarily in quadrants II and III.

The y-axis likely represents a continuum of impulsive sounds to continuous sounds. Impulsive sounds such as bells chiming and crickets chirping were found in the upper quadrants, I and II. Continuous sounds such as vehicle motors and running machinery, running water and the alarm clock were found in quadrants III and IV.

K-means cluster analysis was used to determine that the sounds grouped into three distinct clusters. Figure 2 depicts the additional K-means cluster analysis. Cluster 1, signified by red text, contained natural sounds and sounds created by water. The sounds found in Cluster 1 could be characterized as more ambient or atmospheric than sounds in other clusters. Cluster 2, represented in black text, contained human and animal vocalizations as well as alerting sounds such as the cell phone, bicycle bell and tea kettle. Sounds in Cluster 3 are represented by green text and included continuous mechanical and industrial sounds such as the jackhammer, helicopter, truck and bus.
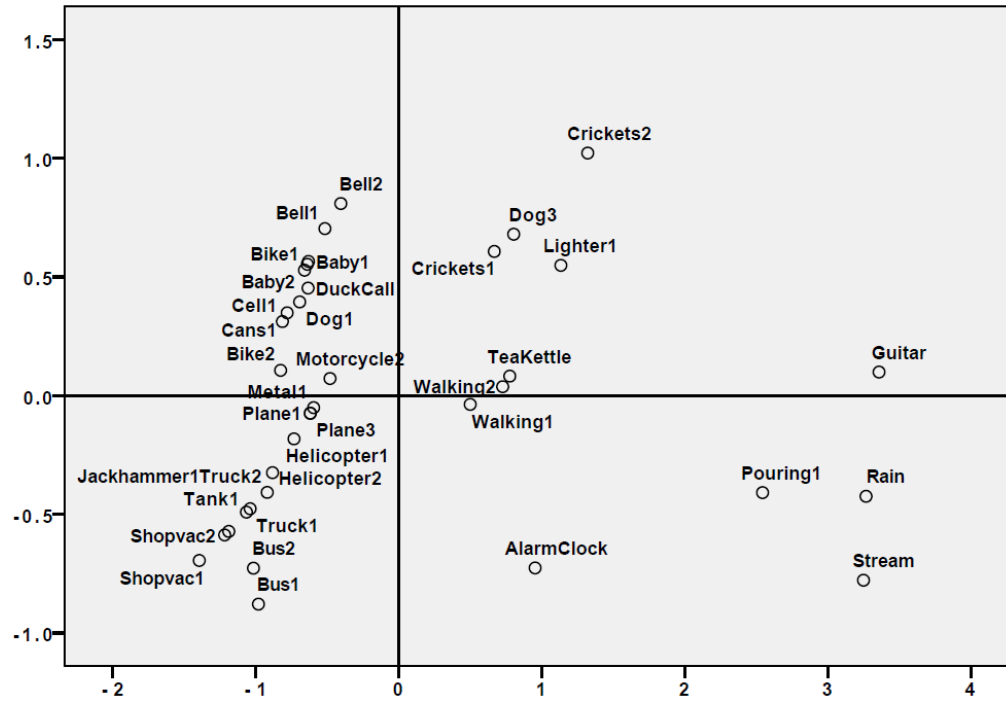
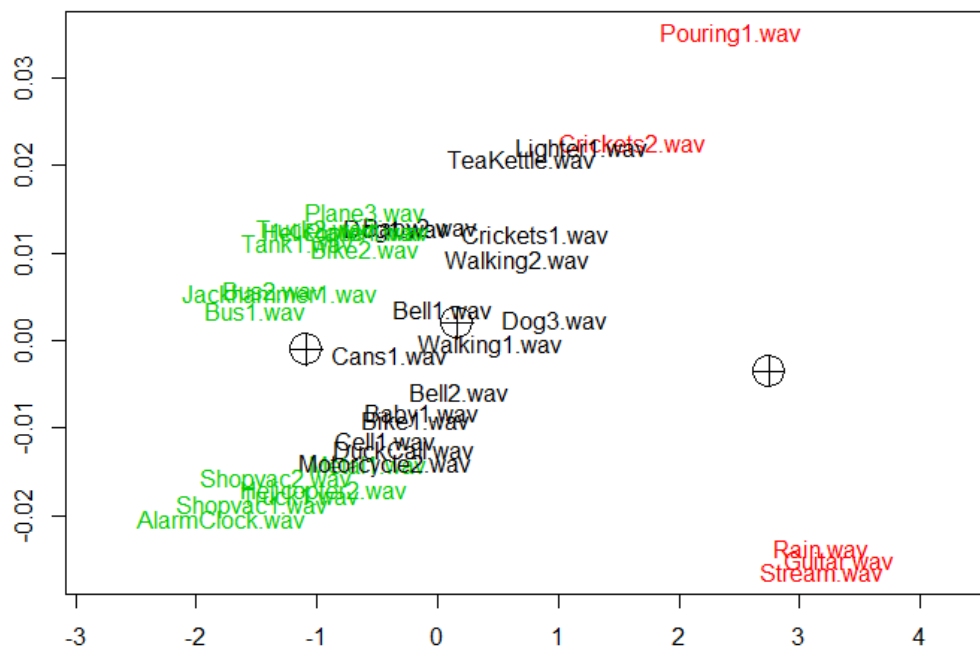*Figure 1.* MDS solution for thirty-six environmental sounds rated for pleasantness.

*Figure 2.* Multidimensional scaling solution after performing additional K-means cluster analysis.

Sounds group into three distinct clusters.

**Hypothesis 1**

The thirty-six environmental sounds included in this investigation represented a broad array of environmental sounds arising from a variety of sound sources, including natural and mechanical sound sources. Pleasantness ratings for natural sounds were compared to those of mechanical sounds. Natural sounds were operationally defined as occurring in a rural environment, but not arising from human or animal activity. Mechanical sounds were operationally defined as a having non-vehicular sound source which involves a metal object. Table 4 displays the means and standard errors of pleasantness ratings for natural sounds and mechanical sounds. A paired samples t-test indicated that mean pleasantness ratings for these two groups of sounds were significantly different, $t(3) = -3.27$, $p < .05$, $M_{diff} = 2.41$, with natural sounds rated as significantly more pleasant (M = 5.49, SE = 0.59) than mechanical sounds (M = 3.07, SE = 0.52)

Table 4

*Pleasantness Rating Means and Standard Errors of Four Mechanical and Four Natural Sounds*

| | Mechanical | | | Natural | |
| --- | --- | --- | --- | --- | --- |
| | Mean | SE | | Mean | SE |
| Lighter 1 | 4.49 | 0.04 | Rain | 6.47 | 0.10 |
| Jackhammer 1 | 1.99 | 0.07 | Stream | 6.47 | 0.08 |
| Bike 1 | 3.11 | 0.07 | Crickets | 4.10 | 0.06 |
| Bike 2 | 2.69 | 0.04 | Crickets 2 | 4.90 | 0.05 |
| Total | 3.07 | 0.53 | Total | 5.49 | 0.59 |

**Hypothesis 2**

The sound stimuli were also categorized according to the acoustic features of the sounds. From the set of thirty-six sounds, seven sounds were identified as impulsive and another seven as continuous. These sounds were categorized as continuous or impulsive based on the results of previous analysis conducted by Dickerson and colleagues (2015). That investigation analyzed twenty-five environmental sounds, eighteen of which are used in the present study, along the dimension of similarity (Dickerson et al., 2015). The results of the investigation indicated that these sounds cluster into three groups. These clusters were: 1) repeating impulsive sounds 2) continuous sounds with periodic spectral peaks 3) continuous sounds with flatter spectra (Dickerson et al., 2015). Sounds in the present study were defined as impulsive if they clustered with the repeating impulsive sounds from Dickerson et al., (2015). Sounds were defined as continuous if they clustered with the sounds defined as continuous, regardless of spectral content, in the previous investigation.

Table 5 displays the means and standard errors of the group of continuous sounds and the group of impulsive sounds. A paired samples t-test revealed that the two groups differed significantly, $t(6) = -10.19$, $p < .01$, $M_{diff} = -1.19$. Impulsive sounds were rated as significantly more pleasant (M = 3.12, SE = 0.10) than continuous sounds (M = 1.96, SE = 0.06). However, it is important to note that every sound selected for these comparisons was man-made. Therefore, it is unclear if these patterns are able to be extend to other sound classes, such as natural sounds.

Objective acoustic measures of the sounds, such as pitch and harmonicity, were also analyzed to determine if these qualities were related to pleasantness. The average pitch and harmonicity were significantly correlated to each other ($r = .36$, $p = .028$); however, no significant relationships were observed between these acoustic measures and pleasantness.

Table 5

*Means and Standard Errors for Seven Continuous Sounds and Seven Impulsive Sounds*

|  | Continuous | | | Impulsive | |
|---|---|---|---|---|---|
|  | Mean | SE |  | Mean | SE |
| Jackhammer 1 | 1.99 | 0.07 | Bell 1 | 3.33 | 0.08 |
| Tank 1 | 2.13 | 0.05 | Bell 2 | 3.47 | 0.06 |
| Shop-vac 1 | 1.76 | 0.04 | Bike 1 | 3.11 | 0.07 |
| Shop-vac 2 | 1.96 | 0.07 | Bike 2 | 2.69 | 0.04 |
| Truck 1 | 2.16 | 0.06 | Baby 1 | 3.16 | 0.06 |
| Bus 1 | 1.79 | 0.03 | Baby 2 | 3.14 | 0.07 |
| Bus 2 | 1.93 | 0.04 | Dog 1 | 2.94 | 0.06 |
|  |  |  |  |  |  |
| Total | 1.96 | 0.05 | Total | 3.12 | 0.06 |

**Analysis: Experiment 2**

The analysis for experiment two is restricted to the data collected during the test phase, the cued-recall task. Cued recall data was only collected at the Towson University site. The relationship between pleasantness and recall used data collected in both Experiments 1 and 2.  During the cued recall task, participants were asked to indicate if sounds were old or new.  Old sounds were sounds that were rated for pleasantness during the study phase. New sounds were ones that were not included during the study phase. This group of participants rated only eighteen sounds for pleasantness. Therefore, half of the sounds were old sounds and half were new sounds.

Figure 3 displays the average hit, miss, false alarm, and correct rejection rates across all stimuli.
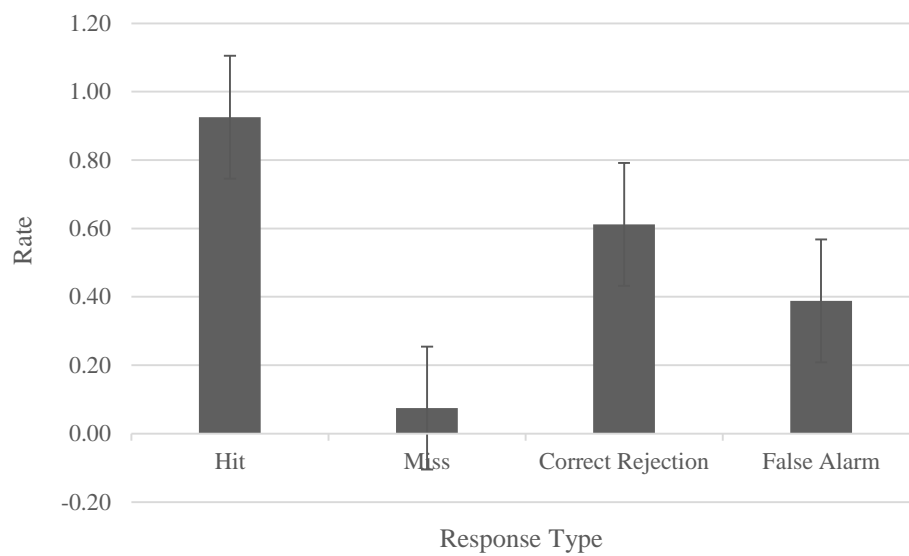
*Figure 3.* Overall hit, miss, correct rejection and false alarm rates for 18 targets and 18 lures.

**Hypothesis 3**

It was predicted that sounds which were rated as very pleasant would be more accurately identified as old or new during the cued recall task. The set of 36 sounds was divided into quartiles according to mean pleasantness rating score. Table 3 lists pleasantness ratings by quartiles. The sounds in the top quartile included nine sounds. These sounds had average pleasantness scores of 3.99 to 6.63. The range of mean pleasantness scores for the sounds in the lowest quartile was 1.5 to 2.29. This quartile included nine sounds.

The pleasantness ratings the study phase of Experiment 2 were compared to the pleasantness ratings gathered in Experiment 1. A Pearson product moment correlation indicated a strong significant correlation ($r = 0.95$, $p < 0.01$) between pleasantness ratings from these two samples. Data from the cued recall task in Experiment 2 was then compared to rating data gathered in Experiment 1.

Recall accuracy was evaluated for target sounds using hit rate. Hit rate was calculated as number of instances that a participant correctly identified an old sound, divided by total trials for each sound for each participant. These scores were then averaged across participants to obtain an average hit rate for each of the 36 sounds. Figure 4 displays hit rate for each sound. Overall, participants performed well on this task. The hit rate for this task was high (M = .93, SE = 0.007). The sound that was correctly recalled most often was the Tea Kettle sound, with a hit rate of 99%. The sound that was least often correctly recalled was the Helicopter 2 sound, with a hit rate of 90%. A one-way repeated measures ANOVA was conducted to determine if hit rate differed significantly as a function of the

sound stimulus. Hit rate did not vary as a function of stimulus $F(17, 46) = 1.56, p > .05$. A Pearson correlation was conducted to determine if there was a relationship between pleasantness and hit rate. There was no significant correlation between hit rate and pleasantness ($r = .16, p > .05$), indicating that participants' ability to remember sounds which had previously been presented was not influenced by the pleasantness of those sounds.
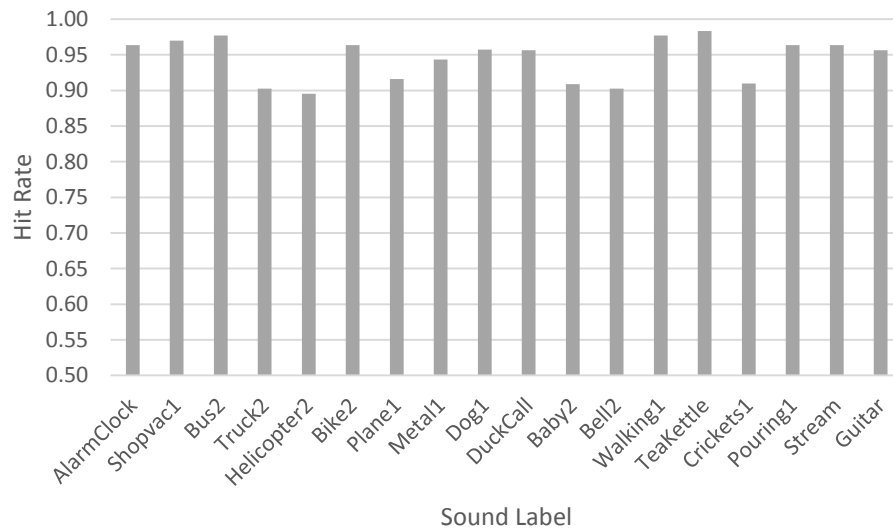


*Figure 4.* Bar graph of average hit rate for each old sound stimulus. Stimuli are organized from lowest average pleasantness rating to highest average pleasantness rating.

**Hypothesis 4**

Because familiar items are more accurately recalled, and there is a relationship between pleasantness and familiarity, it was predicted that pleasant sounds would have a higher rate of false memories, or false alarms. False alarm rate was calculated as the number of instances that a participant mistakenly identified a new sound as old. The false alarm rate was generally low (M = 0.39, SE = 0.07), indicating that participants could identify new sounds accurately. Figure 5 displays the average false alarm rate for each sound. A one-way repeated measures ANOVA was conducted to determine if the false alarm rate varied by stimulus. The effect of stimulus was significant $F(17, 476) = 45.29$, $p < .001$. These results suggest that some stimuli were easier to reject than others. For example, the Shop-vac 2 sound produced a false alarm rate of nearly 100% across all participants (M = 0.93, SE = 0.02). This sound had a low pleasantness rating (M = 1.96). In contrast, the Rain sound produced a much lower overall false alarm rate (M = .11, SE = .04) and had a much higher average pleasantness rating (M = 6.47).

Additionally, a moderate negative correlation was found between pleasantness and false alarm rate; however, it did not reach a level of significance ($r = -.43$, $p = .07$). This relationship is depicted in Figure 6. This correlation suggests that participants tended to have more false memories for unpleasant sounds than for pleasant sounds. These results suggest that participants could more accurately reject new sounds that were pleasant than new sounds that were unpleasant.
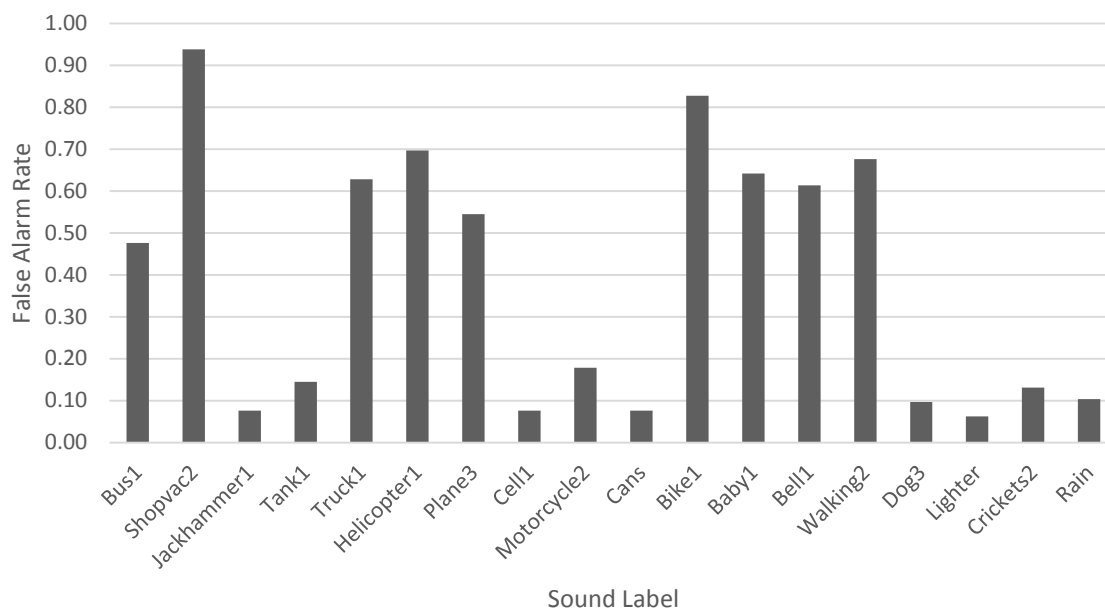
*Figure 5.* Bar graph of average false alarm rate by sound. Sounds are organized from lowest average pleasantness to highest average pleasantness.
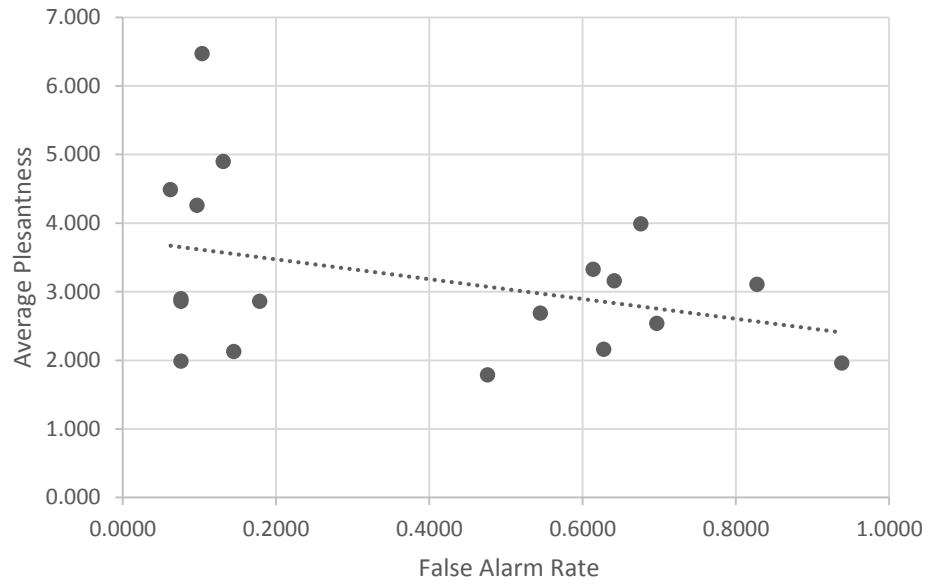
*Figure 6.* Scatter plot depicting the relationship between average pleasantness rating and average false alarm rate.

**CHAPTER 5**

**Discussion**

**Experiment 1**

The primary goal of Experiment 1 was to characterize the structure of the perceptual space along the dimension of pleasantness for a set of thirty-six environmental sounds. The wide range of pleasantness ratings (1.50 – 6.63) and overall mean pleasantness rating of the sound set (M = 3.30) were similar to previous research using comparable methodology (Marcell et al., 2000). These results indicate that listeners tend to provide a varied array of pleasantness ratings, centered around sounds with neutral pleasantness. These results support the continued use of similar Likert rating scales as a useful tool for the investigation of environmental sound perception.

The types of sounds rated as very pleasant were also consistent with previous research (Marcell et al., 2000). The most pleasantly rated sounds in both the present study and Marcell et al., (2000) consisted of musical instruments and sounds involving water. The sound of a jackhammer was among the least pleasantly rated sounds in both the current study and the findings of Marcell and colleagues (2000). Additionally, sounds involving impacts of metal objects were rated as very unpleasant in both studies.

The MDS clusters are organized in reference the physical source of the sound, which is consistent with the findings of previous research on environmental sound perception using multidimensional scaling (Gygi, Kidd & Watson, 2003; Marcell et al., 2000). For example, all human or animal vocalizations grouped in Cluster 2 in the present study. Similarly, Gygi, Kidd & Watson (2003) found that environmental sounds grouped

as two clusters: vocalizations and non-vocalizations. These sound-source based groupings are also consistent with investigations utilizing categorization tasks (Marcell et al., 2000; Vandereer, 1979). When listeners are asked to separate environmental sounds into categories, they tend to do so based on sources or typical location of occurrence of the sounds, rather than on acoustic properties such as pitch or sound quality (Marcell et al., 2000; Vandereer, 1979). Gaver (1993) characterized this listening type of listening as source-oriented. The results of the current investigation are consistent with findings of the aforementioned studies and suggest that sound-source orientated perceptual categories are maintained when pleasantness is the perceptual dimension of interest.

Examination of the MDS solution also revealed that the perceptual pleasantness space was similar to the perceptual similarity space found by Dickerson et al., (2015). The perceptual similarity space was generated using a subset of the current stimuli and also revealed clusters based upon continuousness (Dickerson et al., 2015). In both investigations, sounds that were continuous tended to group together and sounds that were impulsive grouped in separate clusters. Previous research supports the relationship between pleasantness and the spectral qualities of environmental sounds, such as complexity and continuousness (Bonebright, 2001; Marcell, 2000). The results of the present study support previous findings demonstrating that sounds with similar continuousness tend to be rated similarly in regard to pleasantness.
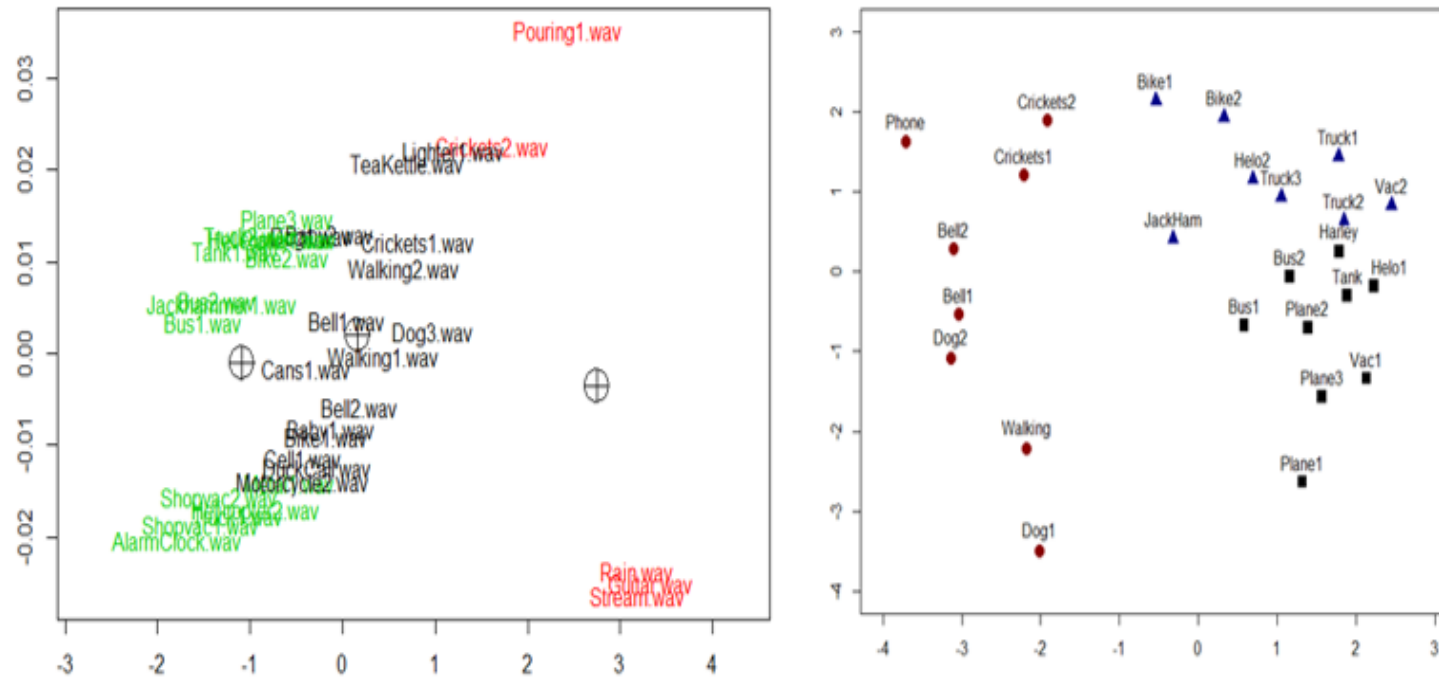
Figure 7. The MDS pleasantness solution for the present study (left) in which red cluster contain natural sounds and water sounds, the black cluster contains many human and animal vocalizations and the green cluster contains mechanical and industrial sounds. The MDS similarity space (right) from Dickerson et al., (2015) in which red dots were repeating impulsive sounds, blue triangles were continuous sounds with spectral peaks and black squares were spectrally flat. In both solutions, continuous sounds and impulsive sounds formed separate clusters.

It was also predicted that natural sounds would be rated as more pleasant than mechanical sounds. The results of the analysis support this hypothesis. A significant difference in pleasantness ratings was found between the natural and mechanical sounds listed in Table 4. These results are in agreement with findings by Marcell and colleagues (2000), in which the sounds rated as most pleasant included natural sounds such as the ocean, birds chirping and rain. The sounds rated least pleasantly were mechanical sounds such as the jackhammer, car crash and gun shots.

Previous research has found a relationship between spectral qualities such as pitch and perceptual qualities such as similarly (Ballas, 1993; Gygi, Kidd & Watson, 2007). However, no relationship was found between pleasantness and pitch in the current study, nor was a relationship found between harmonicity and pleasantness. These results suggest that pitch and harmonicity have only a minor, if any, influence on a listeners' subjective experience of pleasantness for this sound set. It is possible that relationships between pitch, harmonicity and pleasantness may exist for other environmental sound sets.

**Experiment 2**

Recall accuracy for target sounds was predicted to increase as pleasantness ratings increased. Generally, the data did not support this hypothesis. No significant differences in hit rate were found between sounds rated as very unpleasant and sounds that were rated as very pleasant. Because overall accuracy was very high, with participants obtaining an average hit rate of 93%, it is possible that a ceiling effect prevented an underlying pattern from emerging. Future investigations could pose a more

difficult task so that hit rate would be more varied and stronger correlations could potentially emerge. Additionally, although the inferential statistical analyses did not reach a level of significance, an interesting pattern between pleasantness and hit rate emerged from the descriptive analysis.

Bradley and Lang (2000) found that sounds with very high pleasantness ratings and very low pleasantness ratings were remembered more frequently during a free recall task. Evidence of a similar pattern emerged for the measure of hit rate in the present study. Examination of Figure 3 indicates that sounds which had lower average hit rates had average pleasantness ratings closer to the median of the data set, indicating more neutral pleasantness. This may suggest neutral sounds may be less easily recalled. It is important to note, however, that other sounds with neutral pleasantness ratings had high hit rates. Examples of such sounds were Dog 1 and Duck Call. It is possible that these high hit rate sounds with neutral pleasantness ratings share a separate quality makes them more memorable. It is well understood that a variety of factors, such as familiarity and imaginability affect an individual's ability to retrieve a given stimulus (Ballas, 1993; Houix et al., 2012). The overall effect of pleasantness may have been masked by another stimulus factor which makes these particular sounds more memorable. Perhaps a pattern similar to the findings of Bradley and Lang (2000), with sounds rated at extremes of the pleasantness spectrum being more accurately recalled, may have emerged given a different or larger sound set.

False alarm rate was also calculated to measure false memories for new sounds. It was predicted that a higher false alarm rate would be measured for pleasant sounds because previous research has demonstrated that familiar items are more easily recalled

and pleasantness is correlated with familiarity (Marcell et al., 2000). The correlation between pleasantness and false alarms indicated the opposite pattern. As pleasantness increased, false alarms decreased. However, the results of the correlation trended towards, but did not reach, significance. This indicates that there is no significant relationship between false alarm rate and pleasantness. Again, perhaps a separate quality of the sound stimuli is preventing a clear relationship between false alarm rate and pleasantness from emerging. The accuracy of retrieval and recall can be influenced by a variety of factors (Ballas, 1993; Houix et al., 2012).

**Limitations**

Several limitations of this investigation were identified. The participant groups were comprised of primarily Caucasian, college-educated, young adults. It is possible the results of this investigation would not extend to populations of different ages, races, or education levels. It is also unclear if data obtained for this sound set would apply to a larger set of environmental sound stimuli or to environmental sounds as a whole. Obtaining similar results in future research using a variety of sound types would provide evidence as to whether these results represent the qualities of environmental sounds in general.

The lack of variability in the Experiment 2 recall data and the potential ceiling effect represented a limitation of this investigation. Future research could employ a more difficult task, such as a free recall task or an addition of an intermediate task to serve as waiting period between initial target sound presentation and the recall task. A more difficult task may allow additional patterns and relationships to emerge.

**Potential Impact and Future Directions**

A dearth of literature on environmental sound perception exists. However, this area of research could assist in understanding human perception, creating convincing artificial soundscapes and eliciting appropriate emotional responses in audio or video media.

Obtaining normative data on the pleasantness ratings of environmental sounds may assist in the selection of environmental sounds for a variety of purposes. Having objective data on the pleasantness of environmental sounds may be useful when selecting these sounds for commercial marketing or artistic purposes, as these endeavors frequently seek to elicit an emotional response from the viewer. These results may also be of interest to researchers interested in the deleterious effects of environmental noise on human populations. If researchers have evidence that particular types environmental sounds tend to be more or less pleasant, they may focus future research on determining if less pleasant sounds are more disruptive in the natural environment. This may eventually lead to more focused acoustical engineering to address only the most bothersome environmental noise.

These analyses may assist in the selection of environmental sound stimuli for future research investigations which seek to control for or manipulate the pleasantness of the stimuli. For example, the results of the current study may assist in the research on change deafness. Previous research on change deafness indicated that listeners tend to be more aware of a change in the acoustic environment when sounds are very perceptually different and/or belong to a different perceptual category (Gregg & Samuel, 2009). The results of the current investigation extend the body of knowledge about how

environmental sounds fall into perceptual categories according to the dimension of pleasantness. Future research on change deafness could investigate if category membership in the pleasantness space influences the likelihood that a listener experiences change deafness.

Finally, the relationship between a perceptual quality and an old/new cued recall task represents a unique methodological approach on environmental sound perception research. Other investigations employing behavioral tasks have used free recall tasks or sound source identification tasks (Bradley & Lang, 2000; Hocking et al., 2013). Utilizing a cued-recall old/new paradigm allows for an investigation of the relationship between memory and pleasantness, whereas sound source identification tasks do not. An old/new paradigm provides a uniform and controlled set of lures so that false alarm rate can be analyzed by stimulus type; whereas, a free recall task allows for a very wide variety of incorrect responses. Future investigations may employ methodology similar to the present study to investigate other dimensions of environmental sounds. Obtaining ratings for different perceptual parameters, such as familiarity, on this sound set could help to elucidate the relationship between pleasantness, familiarity and memorability.

The results of this investigation suggest that pleasantness is a relevant factor in the perception of environmental sounds. Pleasantness ratings of these sounds revealed that sounds form perceptual clusters with other sounds arising from similar sounds sources. These sounds also group according to continuousness and naturalness. Although, recall accuracy could not be definitively linked to pleasantness ratings, future investigations can build upon these findings to investigate other sound types and

perceptual attributes. Eventually, a comprehensive perceptual taxonomy for

environmental sounds may be achieved.

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Supervisor: various

## Professional Memberships

*Student Academy of Audiology (SAA)*
        Student Member (August 2013-present)