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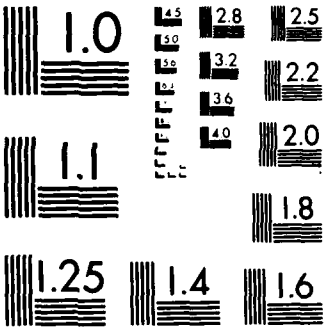

# RECOGNITION OF ISOLATED NON-SPEECH SOUNDS

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Six experiments were completed and analyzed. These studies addressed the role of uncertain causation in the identification of sounds. In particular, the experiments examined the hypothesis that identification takes longer as the number of alternative causes of the sound increases. Issues related to this hypothesis were also investigated. Summaries of these experiments are included.


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## SUMMARY OF PROGRESS

1. Six experiments were completed and analyzed. These studies addressed the role of uncertain causation in the identification of sounds. In particular, the experiments examined the hypothesis that identification takes longer as the number of alternative causes of the sound increases. Issues related to this hypothesis were also investigated. Summaries of these experiments are included.

2. Results of the research have been documented in the following reports:

Ballas, J. A., & Sliwinski, M. J. (1986). Causal uncertainty in the identification of environmental sounds. (Tech. Rep. ONR-86-1). Washington, D. C.: Georgetown University, Department of Psychology.

Ballas, J. A., Sliwinski, M. J. & Harding, J. P. (1986, May). Uncertainty and response time in identifying non-speech sounds. Presented at the 111th Meeting of the Acoustical Society of America, Cleveland, OH.

Ballas, J. A., & Howard, J. H., Jr. (1987). Interpreting the language of environmental sound. Environment and Behavior, 19, 91-114.

Ballas, J. A., Dick, K.N., & Groshek, M.R. (in press) Failure to recognize "recognizable" sounds. In Proceedings of the 1987 Annual Meeting of the Human Factors Society, Santa Monica, CA: The Human Factors Society.

Ballas, J. A. & Sliwinski, M. J. (1987) Causal uncertainty in the identification of environmental sounds. Manuscript submitted for publication.

Abstracts of each of these reports are included.

## COMPLETED EXPERIMENTS

The experiments completed in the period of this contract were designed to assess several aspects of the role of multiple causality in the recognition of environmental sound. Experiments 1 and 3 were particularly important. Experiment 1 demonstrated that listeners take longer to identify sounds as a function of the number of alternative causes of the sound. In this regard, the study replicated the finding of Ballas, Sliwinski, and

Harding (1986). But this replication revealed the form of the function more exactly and extended the finding to a larger set of sounds. Experiment 3 verified this relationship between identification time and causal uncertainty in a paradigm that was a reversal of Experiment 1. Listeners were primed with either high or low probability causes and subsequently presented with a sound that might have been produced by the cause. They verified the high probability causes more quickly than the low probability causes, analagous to the finding of Experiment 1. The other four experiments were designed to study issues related to the role of multiple causality. Experiment 2 verified that sounds produced by different causes can be confused in a forced-choice task. Furthermore, the degree of confusion between two types of sound is related to the response proportions found in an unconstrained identification task such as Experiment 1. Experiments 4 and 5 suggested that listeners have implicit knowledge about the number of alternative causes for sounds and can estimate the alternative causal magnitude. Experiment 6 examined the degree of stereotypy for a set of sounds, in preparation for a future experiment that will assess the relative roles of stereotypy and alternative causation in sound recognition. The results of the first three experiments were documented in a technical report (Ballas & Sliwinski, 1986). The results of the second three experiments are documented in a technical report in preparation, entitled "Listeners' implicit knowledge of environmental sounds: Multiple causation and stereotypy". The following summaries of the experiments outline the method and principal results.

## Experiment 1

The first experiment was a study of the identification of 41 environmental sounds. The hypothesis was that the identification time for these sounds would be a function of the number of alternative causes for the sound, a variation of the Hick-Hyman law (choice reaction time is a function of the logarithm of the number of alternatives). Response time to identify the sound was recorded, averaged across listeners, and examined as a function of the causal uncertainty of each sound. This uncertainty measure was obtained by applying the equation for uncertainty from Information Theory to the identification responses. The results were consistent with the Hick-Hyman law although the function obtained was different than the common logarithmic relationship because the distribution of response times was truncated. The experiment also demonstrated the reliability of the measure of causal uncertainty. The measure requires the sorting of identification responses into categories of similar causation. Criteria have been developed to guide the sorting process. Three sorters including one who was naive about the nature of the study were highly reliable in their categorization of the sounds.

## Experiment 2

The second experiment determined whether the responses that listeners made in identifying environmental sounds were reasonable, especially when several different types of responses were given for a particular sound. Two types of causal events were chosen, stapling and switching a pull-chain or a push-dimmer light. These events produce a sound consisting of two dominant transients and listeners had shown confusion between these events by citing them as the cause of a particular sound (Ballas & Howard, 1987). Thirty examples of the sound of each event were produced by varying the production characteristics. The resulting sounds were recorded and presented to listeners for forced-choice classifications. Some of the sounds were incorrectly identified, even though the listeners had to choose only between the two alternatives. Thus, the acoustic "signature" of these types of events can be confused. Analyses also revealed that the degree of confusion paralleled the relative citation of these two events as causes in Experiment 1. These results provided evidence toward the validity of the uncertainty values as a measure of sound recognizability measure.

## Experiment 3

The third experiment tested whether the time to verify a cause of a sound would be a function of the probability of the cause. Listeners were presented with descriptions of events as primes prior to the sound. Upon presentation of the sound, they had to verify or negate the cause. High and low-probability causes were taken from the identification responses in Experiment 1. Improbable causes were also used to elicit negation responses. It was found that high probability causes quicken sound identification compared to low probability causes. This experiment was particularly important in demonstrating that causal probability influences identification time even when the framing of an identification response is not a factor. Listeners were given the cause beforehand, and only had to verify this cause upon hearing the sound.

## Experiment 4

The procedure used to estimate causal uncertainty required the collection of and sorting of identification responses from a sample of the population. Because the cognitive process implied by the role of causal uncertainty assumed that listeners were informed about alternative causes, it was hypothesized that they would be able to produce direct estimates of causal magnitude.

In this experiment, listeners were asked to estimate the number of alternative causes for a sound. These estimates were averaged and found to correlate significantly with previous estimates of causal uncertainty and measures of identification performance. However, these estimates did not correlate as well with measures of identification performance as did the uncertainty measure calculated from sorted identification responses.

## Experiment 5

The direct estimation paradigm used in Experiment 4 was continued in this experiment except that listeners were given anchors for the number of possible causes of the sounds. These anchors were based upon the results of Experiment 1. With these anchors, the range of the estimates increased, but the resulting estimates correlated less with calculated causal uncertainty than the estimates from Experiment 4. Thus, listeners were not more accurate in estimating causal magnitude when they were informed of the range of causal magnitude. Taken together, Experiments 4 and 5 demonstrated that direct estimates of causal magnitude are closely related to calculated causal uncertainty and identification response time and imply that listeners have implicit knowledge about the relative magnitude of causal uncertainty.

## Experiment 6

The priming paradigm of Experiment 3 was patterned after studies on semantic memory in which an observer is asked to decide the class membership of a word. Response time is related to the size of the class. Later work in semantic memory found that typicality of the word as a member of the category also determines response time. That is, items are classified more quickly if they are good examples of the category. In our work, sound typicality might have a similar role. To assess this effect, an experiment was planned similar to Experiment 3, with the added variable of sound typicality. That is, high and low typicality sounds were added as targets for the high and low probability causal primes. This study utilized a set of sounds that had high and low typicality exemplars. Thus, it became necessary to determine the typicality of different sounds, and Experiment 6 was designed for this purpose. In order to avoid a bias in sampling stimuli, listeners were asked to describe the acoustical characteristics of their stereotype of each of a set of sounds. Because previous research showed that listeners are poor at describing more than one acoustic characteristic of a complex sound, the listeners were also asked to produce the sounds vocally. Temporal pattern characteristics such as repetition and pitch shifts were particularly evident in their production of the sound.

Results indicated that the sounds varied in typicality, with some consistently described and produced in the same manner by all listeners. Others were not described or produced in a standard form. These results were used to define a set of typical and non-typical sounds for a priming study.

## REPORT ABSTRACTS

Ballas, J. A., & Sliwinski, M. J. (1986) Causal uncertainty in the identification of environmental sounds. (Tech. Rep. ONR-86-1). Washington, D. C.: Georgetown University, Department of Psychology.

This report is of an investigation into: 1) whether the recognition of an isolated environmental sound depends upon the number of different events that could cause the sound; 2) a method of quantifying the number of causal events; and 3) the cognitive processes that mediate the effect of multiple causation. Research in the past has focused on the acoustics of the sound in an attempt to determine which features the listener uses in recognition. However, it is well known that recognition is influenced by expectations, particularly about the number of alternatives. Three experiments on the effect of alternative causes are reported. The results of the first experiment replicated earlier results that the Hick-Hyman law applies to environmental sound identification and demonstrated the reliability of a measure of causal uncertainty. The second experiment provided evidence toward the validity of this measure. The third experiment demonstrated that high probability causes quicken sound identification compared to low probability causes. This effect was found in individual listeners.

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Ballas, J. A., Sliwinski, M. J. & Harding, J. P. (1986, May). Uncertainty and response time in identifying non-speech sounds. Paper presented at the 111th Meeting of the Acoustical Society of America, Cleveland, OH.

It was hypothesized that the identification of isolated, non-speech, environmental sounds depends upon the number of potential causes of the sound. This hypothesis rests on two assumptions: 1) the acoustic effects of the potential causes are perceptually ambiguous; and 2) the process of recognizing a sound involves a memory search of the potential causes. These two assumptions correspond to two perspectives that might be adopted in research in this area. The psychoacoustic perspective would emphasize the study of the acoustic properties of the sounds and the resolving capabilities of the auditory system. The cognitive perspective would emphasize the form of memory representation and the memory search processes involved in identification.

The hypothesis requires that the set of potential causes be defined. An indirect method of defining this set was used. Listeners' identification responses were sorted by similar causation and used to calculate uncertainty, a measure from Information Theory. This measure is related to response time by the Hick-Hyman law, and an experiment was designed to test this relationship in the context of environmental sound recognition. Identification times were taken and averaged across listeners for a set of 28 short duration sounds taken from sound effects records. Uncertainty correlated significantly with identification time ($r = .66$, $p < .001$), suggesting that identification takes longer as the number of causes increases. Alternative explanations include familarity of the identifying words and stimulus intensity differences. Subsequent data analyses discounted both alternatives.

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Ballas, J. A., & Howard, J. H., Jr. (1987). Interpreting the language of environmental sound. Environment and Behavior, 19, 91-114.

Comparisons are made between the perception of environmental sound and the perception of speech. With both, two types of processing are involved, bottom-up and top-down, and with both, the detailed form of the processing is, in several respects, similar. Recognition of isolated speech and environmental sounds produces similar patterns of semantic interpretations. Environmental sound "homonyms" are ambiguous in much the same manner as speech homonyms. Environmental sounds become integrated on the basis of cognitive processes similar to those used to perceive speech. The general conclusion is that environmental sound is usefully thought of as a form of language.

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Ballas, J. A., Dick, K. N., & Groshek, M. R. (in press) Failure to identify "identifiable" sounds. In Proceedings of the 1987 Annual Meeting of the Human Factors Society. Santa Monica, CA: The Human Factors Society.

Sound recognition is an important and sometimes crucial task. Research has demonstrated that the uncertainty measure from information theory can be used to quantify the recognizability of a sound, and that this measure is related to important aspects of recognition performance. This paper is on the consistency of this measure for a set of sounds that have high prima facie recognizability. The reliability of the measure is also investigated. Two sets of 19 sounds were obtained for the stimuli. Two examples of each sound were obtained from sound effects records and one example was used in each set. Two groups of students, high school and college, listened to the sets with

individuals listening to one or the other set. Each student wrote down their identification of the sound. These identification responses were used to estimate response uncertainty by sorting the responses into categories of similar events.

The reliability of the two sorters was significant, $r = .87, .90$, $p < .001$, for the two sets of sounds. The reliability of the measure for the two examples of the sounds was significant, $r = .70, .84$, $p < .001$ for sorters 1 and 2, respectively. Correlations of uncertainty values from different sorters and different sets of sounds were also significant, $r = .76, .66$, $p < .001$. The range of uncertainty for the different sounds was from 0.0 for a baby cry to 4.00 for a bus pulling away.

Three results from this study are important. First, as found in other studies, the reliability of sorters is significant given the use of the sorting criteria. Second, the values of the uncertainty measure are reliable for different examples of sounds. This suggests that a measure can be developed for a generic version of the sound and used as an index of the recognizability of the sound. Finally, the set of sounds used in this study varied in recognizability even though they have been used in a manner which would require that all the sounds be easily recognizable in the general population. Thus, ad hoc judgments about the recognizability of a sound are unwarranted, and a procedure similar to that used in this study should be used to evaluate recognizability.

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Ballas, J. A., & Sliwinski, M. J. (1987) Causal uncertainty in the identification of environmental sounds. Manuscript submitted for publication.

This manuscript is a revision of the technical report by Ballas and Sliwinski (1986) for possible publication in the human factors literature.

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## Future Work

Future work should focus on the nature of the cognitive processes that mediate the effect of causal uncertainty. Research on the way people categorize natural sounds would further our understanding of the knowledge that listeners have about sound in general and illuminate the structure of their knowledge for types of sound. In order to pursue this area of research, studies should be conducted to categorize a representative set of sounds on identifiability. Once a range of identifiable sounds is available, the role of acoustic and cognitive attributes of the sounds in contributing to sound identifiability can be assessed.

Recognition time may vary by the type of sound for at least two types, animal sounds and signalling sounds. This is evidenced by the fact that recognition times for signalling sounds were quicker than the times for other sounds used in experiment one. If this finding is supported by further experiments, it would begin to reveal the form of the cognitive process that mediates the identification of environmental sounds, and the role that multiple causality plays in this process. For example, a difference in identification time between classes of

sounds would suggest that the perceptual or cognitive encoding of these sounds is determined by a clustered, hierarchical organization scheme. In testing this, a set of sounds matched for duration should be used in a response time task. The response time data should be analyzed to determine if differences exist between classes of sounds. If these differences are verified, then a follow-up study could examine whether the differences are eliminated if the listener is prompted by a description before the sound is presented and asked to verify it as a cause. If the differences are eliminated by this prompt, then the differences would be attributed to memory retrieval rather than acoustic analysis. If they are not eliminated, then differences in perceptual acoustic analysis would be suggested.

Another important issue is the role of context in the identification of sound "homonyms." The context is provided by a sequence of environmental sounds into which the "homonym" is embedded. The same sound embedded into different contexts should be interpreted differently. For example, the light switch sound that is confused as a stapler could be presented within a set of paper shuffling sounds and within a set of sounds characteristic of entering a room. The former context should act in a top down manner to suggest a stapler event for the sound whereas the latter context will suggest that a light has been switched on. Such an effect, if found, is exactly analogous to the role of context in the top-down processing of homonyms in speech.

Mediation processes should also be studied directly. Mediation processes within the framework of information processing theories include encoding, pattern recognition, and memory storage and retrieval. Research should examine the encoding of environmental sounds. One particular question to be addressed is whether the encoding of physical properties of environmental sounds precedes semantic encoding of the sound.

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