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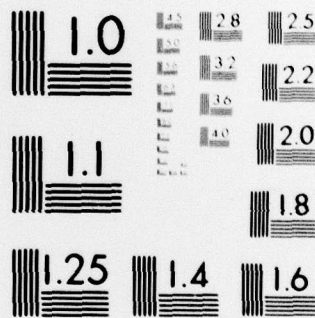
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Final Report

TEMPORAL FACTORS IN SONAR TARGET CLASSIFICATION: THEORETICAL AND EXPERIMENTAL ANALYSIS

John A. Swets

ONR CONTRACT NUMBER N00014-76-C-0893

WORK UNIT NUMBER NR 196-145

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

The objective of this contract was to conduct research on perceptual and
decision processes involved in the detection, identification, and scaling
of complex visual patterns, with emphasis on temporal aspects of the
patterns and processes. During the three and one-quarter years of the
project, five BBN technical reports were prepared and distributed, each
describing a substantial experiment or set of experiments; all five have
been or will be published in the archival literature. A book chapter not

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distributed as a BBN technical report was also prepared. A bibliography of these reports is appended. Also appended is a list of individuals who have been associated with project.

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TO: Chief of Naval Research, Arlington, Virginia 22217

           Attention: Engineering Psychology Programs, Code 455,

           Drs. M. A. Tolcott and J. J. O'Hare

FROM: Dr. John A. Swets

           Bolt Beranek and Newman Inc.,

           Cambridge, Massachusetts 02138

SUBJECT: Final report of work completed under the support of

           Contract N00014-76-C-0893, Work Unit NR 196-145,

           between Bolt Beranek and Newman Inc. and the

           Engineering Psychology Programs, Office of Naval

           Research.

I. This constitutes a final report of work completed under the support of Contract N00014-76-C-0893, Work Unit NR 196-145, between Bolt Beranek and Newman Inc. and the Engineering Psychology Programs, Office of Naval Research. The contract was initiated 1 June 1976 and was terminated 31 August 1979.

II. The objective of this contract was to conduct research on perceptual and decision processes involved in the detection, identification, and scaling of complex visual patterns, with emphasis on temporal aspects of the patterns and processes. During the three and one-quarter years of the project, five BBN technical reports were prepared and distributed, each describing a substantial experiment or set of experiments; all five have been or will be published in the archival literature. A book chapter not distributed as a BBN technical report was also prepared. A bibliography of these reports is appended. Also appended is a list of individuals who have been associated with the project.

III. The research is described here by means of abstracts of the five technical reports and the book chapter. A concluding abstract, prepared for an international congress, summarizes the main part of the work done under the contract.

1. <u>Signal Detection and Identification at Successive</u>
    <u>Stages of Observation</u>

    The relationship of signal identification to signal
    detection was examined in a series of experiments. The
    signals were idealized lines and patterns of lines in a
    spectrographic display. On each trial, progressively
    more of the complete spectrogram was exposed in
    successive observation intervals and the observer made
    both detection and identification responses after each
    interval that were based on the accumulating evidence.
    One model employed conceives of detection and
    identification as proceeding together over time as
    parts of a unified process. A second model employed
    shows how the <u>joint detection-and-identification</u>
    <u>ROC</u> -- a Relative Operating Characteristic that relates
    the joint probability of correct detection and correct
    identification to the probability of a false
    detection -- may be predicted from the simple detection
    ROC. Both models were supported by the data.

    (Technical Report 3535; published in <u>Perception &</u>
    <u>Psychophysics</u>, 1978, <u>23</u>(4), 275-289.)

2. <u>Identification and Scaling of Complex Visual Patterns</u>

    Experiments were conducted to examine the detection and
    identification of complex visual patterns, representing
    various underwater sounds, in terms of stimulus
    dimensions indicated by a psychological scaling
    analysis of similarity judgments. Psychological
    dimensions differed somewhat between naive and
    experienced observers, and between visual and auditory
    representations, but high correlations with physical
    dimensions were found in all cases. A second
    objective of the study was to relate identification to
    detection, over successive stages of relatively long
    signals. The ROC analysis developed for detection of
    signals in random noise was applied to discrimination
    of wanted and unwanted signals. The analysis of
    stimulus dimensions enabled qualitative predictions of
    the relative levels of detection and identification for
    different sets of wanted and unwanted signals. The
    "joint" ROC, based on the probability of correct
    detection <u>and</u> identification, provided quantitative
    benchmarks for these predictions.

    (Technical Report 3536; combined with Technical Report
    3719 for publication as "On the prediction of
    confusion matrices from similarity judgments,"
    <u>Perception & Psychophysics</u>, 1979, <u>26</u>(1), 1-19.)

3. <u>On</u> <u>The</u> <u>Prediction</u> <u>of</u> <u>Confusion</u> <u>Matrices</u> <u>from</u> <u>Similarity</u>
    <u>Judgments</u>

    This study of human identification of complex visual
    stimuli is a step toward an integrated description of
    the perceptual process whereby stimuli are represented
    psychologically and the decision process that makes use
    of this stimulus representation in selecting an
    identification response. A multidimensional scaling
    procedure was applied to judgments of stimulus
    similarity to derive the dimensions of a perceptual
    space and the relative loci of stimuli in that space,
    and a probabilistic decision model based on weighted
    interstimulus distances was developed to predict the
    confusion matrices in various identification tasks.
    The high accuracy of the predictions supplies a strong
    validation of the use of multidimensional scaling
    procedures to reveal perceptual structure, in
    demonstrating the ability of that structure to acccount
    for behavior in an independent task. From the other
    point of view, the empirical success of this approach
    suggests a relatively simple and practical means of
    predicting, and possibly enhancing, identification
    performance for a given ensemble of visual or auditory
    stimuli.

    (Technical Report 3719; published in <u>Perception</u> <u>&</u>
    <u>Psychophysics</u>, 1979, <u>26</u>(1), 1-19.)

4. <u>The</u> <u>Observer's</u> <u>Use</u> <u>of</u> <u>Perceptual</u> <u>Dimensions</u> <u>in</u> <u>Signal</u>
    <u>Identification</u>

    We examine a model of the process of stimulus
    identification, which assumes that complex visual or
    auditory stimuli are represented as vectors in a
    multidimensional perceptual space, and which postulates
    a simple probabilistic decision process based on the
    geometric structure of the perceptual space. We
    present evidence from several conditions of an
    identification task that human observers engage in a
    continuing, dynamic process in which dimension salience
    weights are tuned to optimize identification
    performance. In addition, we verify the reliability of
    the INDSCAL multidimensional scaling procedure in
    deriving the geometric structure of the observers'
    perceptual space for the set of visual spectrograms
    used in our identification tasks. We also present
    evidence supporting an assumption of dimensional
    decomposability made in the decision process. Finally,
    we observe that the model is successful in accounting

for approximately 90 percent of the variance in individual confusion matrices, averaged over 18 observers x conditions.

(Technical Report 3930; to appear in Attention and Performance VIII, R. S. Nickerson (ed.) Hillsdale, N. J.: Lawrence Erlbaum Associates, in press.)

5. Identification of Confusible Curvilinear Shapes: Prediction of Individual Confusion Matrices

Identification confusion matrices were obtained from three observers for a set of nine closed, curvilinear shapes. These stimuli, biological in appearance, varied along two nonverbalizable physical dimensions related to the angles of rotation of two of six underlying component forms. Two perceptual dimensions, each linearly related to one of the two physical dimensions, were derived from multidimensional scaling of pair-wise similarity judgments. Using this derived perceptual space and a probabilistic decision model, we were able to account for 95 percent of the variance in individual observer's confusion matrices.

(To appear as Technical Report 4196; to be submitted to Perception & Psychophysics.)

6. Perceptual Spaces Revealed by Multidimensional Scaling Procedures

The development of multidimensional scaling (MDS) procedures in recent years has allowed us to pursue the concept that a complex auditory or visual stimulus can be represented psychologically as a point in a multidimensional perceptual space. In this paper we review the literature which has applied MDS procedures to similarity judgments and to identification confusion matrices to obtain information both about the set of dimensions underlying perception of a set of complex stimuli in the multidimensional space. We also raise the question, what should we require of a multidimensional representation to consider it valid? We suggest one criterion -- prediction of independent data -- and present a model and two sets of data which illustrate the point.

(To appear in "Auditory and Visual Pattern Recognition, D. J. Getty and J. H. Howard, Jr. (eds.) Hillsdale, N. J.: Lawrence Erlbaum Associates, in press.)

7.   <u>Perceptual Dimensions</u>:   <u>Similarity and Identification</u>

We describe a view of stimulus identification that
assumes (1) that complex visual or auditory stimuli are
represented perceptually as vectors in a
multidimensional Euclidean space, and (2) that the
probabilities of identification responses are
determined by relative interstimulus distances in the
perceptual space. In practice, we derive the
dimensions of the perceptual space, and the loci of the
stimuli within the space, from application of a
multidimensional scaling procedure to pairwise
judgments of stimulus similarity. Based on the derived
interstimulus distances, we then predict the
identification confusion matrix for individual
observers by means of a probabiliistic decision model.
In a series of three experiments, the model has
accounted for an average of more than 90 percent of the
observed capability in 33 individual confusion
matrices.

Three different sets of complex visual stimuli have
been used: (1) a set of 27 synthesized two-formant
spectrograms, suggestive of speech spectrograms, which
varied along three physical dimensions, (2) a set of 8
spectrograms of real, underwater sounds, and (3) a set
of 9 shapes, organic in appearance, that varied along
two nonverbalizable physical dimensions. In each case,
we derived a perceptual space that could be directly
related either to the manipulated physical dimensions
(sets 1 and 3) or to physical measures derived from an
analysis of the signals (set 2).

Our decision model assumes that perceptual dimensions
are not necessarily weighted equally in determining
interstimulus distance, and that the relative
magnitudes of these dimension salience weights may
differ across observers. Furthermore, we suggest that
these weights may be adaptively tuned by an observer in
order to optimize identification performance, the
criterion depending upon both the task and the stimulus
set. In an experiment in which observers identified a
subset of four "signals," among a set of eight stimuli,
with a different subset of four defined as signals in
each of 3 conditions, we observed that the patterns of
dimension salience weights varied across conditions.
Moreover, each observed pattern of weights was
generally in agreement with the theoretical pattern of
weights that would maximize the probability of correct
identification. We have also demonstrated the dynamic

properties of the tuning process in another experiment in which the relative usefulness of a particular dimension was drastically reduced from the first condition of the experiment to the second. Analyzing successive blocks of trials within the second condition, we observed the pattern of dimension weights to change gradually for several observers, from near optimum for the first condition to near optimum for the second.

The use of multidimensional scaling procedures to reveal perceptual structure receives substantial validation from our results, in demonstrating the ability of that structure to account for identification performance in an independent task. At the same time, we gain confidence in the decision model, in demonstrating its predictive accuracy based on an independently derived perceptual space. Finally, this approach suggests a relatively simple and practical means of predicting, and possibly enhancing, identification performance for a given set of visual or auditory stimuli.

(This abstract will appear in the Proceedings of the XXIInd International Congress of Psychology, Leipzig, 1980.)

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Bibliography

Swets, J. A., Green, D. M., Getty, D. J., and Swets, J. B. Signal detection and identification at successive stages of observation. BBN Technical Report 3535, July, 1977. Also published in Perception & Psychophysics, 1978, 23(4), 275-289.

Swets, J. A., Green, D. M., Getty, D. J., and Swets, J. B. Identification and scaling of complex visual patterns. BBN Technical Report 3536, November, 1977. Combined with Technical Report 3719 for publication as "On the prediction of confusion matrices from similarity judgments," in Perception & Psychophysics, 1979, 26(1), 1-19.

Getty, D. J., Swets, J. A., Swets, J. B., and Green, D. M. On the prediction of confusion matrices from similarity judgments. BBN Technical Report 3719, October 1977. Also published in Perception & Psychophysics, 1979, 26(1), 1-19.

Getty, D. J., Swets, J. B., and Swets, J. A. The observer's use of perceptual dimensions in signal identification. BBN Technical Report 3930, June, 1979. To appear in Attention & Performance VIII, R. S. Nickerson (ed.) Hillsdale, N. J.: Lawrence Erlbaum Associates, in press.

Getty, D. J. Perceptual spaces revealed by multidimensional scaling procedures. To appear in Auditory and Visual Pattern Recognition, D. J. Getty and J. H. Howard, Jr., (eds.). Hillsdale, N. J.: Lawrence Erlbaum Associates, in press.

Getty, D. J., and Swets, J. A. Perceptual dimensions: Similarity and identification. To appear in the Proceedings of the XXIInd International Congress of Psychology, Leipzig, 1980.