1pPPb8. Spatial uncertainty and proximity effects in informational masking identically related to the Simpson-Fitter metric of target-masker separation

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Further evidence is provided suggesting a primary dependence of informational masking (IM) on the stochastic separation of target and masker given by Simpson-Fitter's da [Lutfi et al. (2012). J. Acoust. Soc. Am. 132, EL109-113.]. The stimuli were brief bursts of Gaussian noise or words played in sequence as masker-target-masker triads. The apparent position of bursts (words) from left to right was varied independently and at random on each presentation using KEMAR HTRFs. In the 2IFC procedure the listener's task was to choose the target positioned further to the right. Spatial uncertainty of the masker was increased by increasing the position variance of the masker. Spatial proximity of target to masker was increased by decreasing the position mean-difference between target and masker. Performance in both cases was well described by a single linear function relating d' to da; intercepts differed across listeners, but slopes were similar. Comparable results presented at this meeting for the effects of spectral uncertainty and similarity of target and masker suggest that the statistical properties of signals may be a more significant determinant of IM than their specific acoustic properties.

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INTRODUCTION

In recent years there has been growing interest in masking that has its origin in processes occurring beyond the cochlea – so-call informational masking, IM (Durlach et al., 2003a,b; Kidd et al., 2008). Currently, two major factors are identified with IM, masker uncertainty (Watson, et al. 1976; Neff and Green, 1987; Lutfi, 1993; Oh and Lutfi, 1998) and target-masker similarity (Brungart, 2001; Freyman et al., 1999; Kidd et al., 1994, 2008a,b). The two factors entail quite different manipulations of signals and are deemed to reflect fundamentally different processes resulting in IM. Maskers are made uncertain by varying at random one or more properties of the masker from trial to trial. Target and maskers are made more similar by decreasing their separation in frequency, space or time. Here we present evidence suggesting these manipulations and their effects are just different manifestations of the influence on a single underlying statistical variable representing the information divergence of target and masker. The specific focus is on the spatial properties of the target and masker.

GENERAL APPROACH

Our approach represents a specific application of a larger theoretical framework recently developed to deal with vagaries of the terms ‘noise uncertainty’ and ‘target-noise similarity’ as they have been commonly used in the literature (Lutfi et al. 2012; see Durlach, 2006; Durlach et al., 2003a for a larger description of the problem). Our definitions are consistent with common usage, but quantify these terms in a way that they can be directly compared.

Figure 1 shows the two conditions of the study. The target and masker are brief noise bursts whose angle on the azimuthal plane was varied at random from trial to trial. Let $\mu_T$ and $\mu_M$ denote respectively the mean angle for target and masker, and let $\sigma_T$ and $\sigma_M$ denote the corresponding trial-by-trial variability in angle (normally distributed). Masker uncertainty in this framework is identified with the value of $\sigma_M$ and target-masker similarity with the difference $\mu_T - \mu_M$. The relative effects of $\sigma_M$ and $\mu_T - \mu_M$ are then evaluated in terms of their combined influence on a measure of the information divergence between target and masker, as given by Simpson-Fitter’s $d_a$ (Simpson and Fitter, 1973; cf. Kullback and Leibler, 1951).

$$d_a = \frac{\mu_T - \mu_N}{\sqrt{AVG(\sigma_T^2 + \sigma_N^2)}}$$  \hspace{1cm} (1)

The pivotal feature of this approach is that it uses $d_a$ to quantify the distance between target and masker, comparable to the way that it has traditionally been used to scale the distance between two targets or between target+masker and masker alone. This allows $d_a$ to serve as the standard by which the relative effects of target-masker similarity and masker uncertainty can be meaningfully compared across a wide variety of different stimulus configurations and psychophysical tasks.
METHOD AND RESULTS

Subjects listened to brief Gaussian noise bursts presented in sequence as masker-target-masker triads. The noise bursts were 100 ms in duration and were gated on and off with 10-ms cosine-squared ramps, the inter-burst interval was 100 ms. The perceived spatial locations of the target and masker were varied as described above using KEMAR HRTFs. Two random-location conditions were investigated as described in figure 1. The values of $\sigma_M$ and $\mu_M$ associated with the masker location were chosen to yield a range of values of $d_a$ for each condition. For the masker uncertainty condition $\sigma_M$ ranged from 10-30°. For the target-masker similarity condition $\mu_M$ ranged from 10-25°. The mean and standard deviation of the target location was fixed across conditions at $\mu_T=0^\circ$ and $\sigma_T=25^\circ$. In the two-interval, forced-choice procedure, the listeners task was to judge whether the target moved from right to left or left to right across the two observation intervals. Correct feedback was given after each response. Listeners were 4 male and 4 female students at the University of Wisconsin-Madison ranging in age from 19-22 years.

FIGURE 2. Performance as $d'$ is plotted as a function of $d_a$ for the eight listeners (panels) participating in the study. To constrain azimuthal angles between $-90^\circ$ and $90^\circ$, the three highest values of $d_a$ were forced to correspond to the change in $\sigma_M$ (fixed $\mu_M$) and the three lowest values of $d_a$ were forced to correspond to the change in $\mu_M$ (fixed $\sigma_M$). The curves drawn through the data give the results of a linear regression for which the slope of the best-fitting curve was forced to be the same across all listeners.
Figure 2 gives \(d'\) performance as a function of \(d_a\) for the eight listeners participating in the study (panels). Each point represents the average of 300 trials. To constrain azimuthal angles between -90° and 90°, the three highest values of \(d_a\) were forced to correspond to the change in \(\sigma_M\) (fixed \(\mu_M\)) and the three lowest values of \(d_a\) were forced to correspond to the change in \(\mu_M\) (fixed \(\sigma_M\)). The curves drawn through the data give the results of a linear regression for which the slope of the best-fitting curve was forced to be the same across all listeners (i.e. only the intercept was allowed to vary across individuals). The fitted curves reveal remarkably good agreement in the rate at which performance improves with \(d_a\), this despite significant differences in the overall performance of listeners. The results moreover show a greater dependence of performance on the value of \(d_a\) than on the specific manipulations designed to increase uncertainty regarding the masker location or the similarity of the masker location to that of the target.

CONCLUSION

The present study provides evidence that the effects of the two major factors associated with informational masking, masker uncertainty and target-masker similarity, are just different manifestations of the influence on a common underlying statistical variable representing the *information divergence* of target and noise. The results suggest that beyond the initial transduction of signals the statistical properties of signals have far greater bearing on perception than their specific acoustic properties.

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REFERENCES


