#190 - Simultaneous Two-Channel Signal Detection, Revisited

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Abstract

This study examined the ability of listeners to monitor events occurring simultaneously in two widely spaced frequency regions. The task was to detect the presence of a low frequency (558 Hz) tone and a high frequency (1791 Hz) tone presented in a 2-interval 4-alternative forced-choice procedure. On every trial, each signal was presented in either the first or second interval independently and the listener was required to indicate the interval of presentation for each signal. The level of each signal was varied separately according to an adaptive tracking procedure to obtain threshold estimates. As a control, thresholds for both signals were also obtained for single-signal presentation. Comparison of thresholds in single- and dual-signal presentation conditions provided an estimate of the costs of monitoring and responding to events in two frequency channels. Signal thresholds were obtained in quiet, in double-notch-filtered Gaussian noise, and in random-frequency multitone maskers. Much larger costs (difference between dual- and single-tone tasks) were found for the masked conditions, especially for the multitone masker. These results suggest that the costs of dividing attention along a particular stimulus dimension depends on both the resources required to solve the task in each signal channel and also the resources required to ignore competing stimuli in nonsignal channels. [Work supported by AFOSR and NIH/NIDCD]

Introduction

- Dual tasks often result in costs (decrements in either reaction time or accuracy) relative to single task performance
  - Processing costs, evaluated using threshold measurements, are often assumed to be related to a "limited pool of processing resources" (involving memory, attention, etc.)
  - Costs associated with monitoring multiple channels in noise (either uncertain target frequency, e.g., Green 1961; Buus et al., 1986; or multiple simultaneous targets, e.g., Sorkin and colleagues, 1971, 72, 76; Buus et al., 1986) are typically relatively small
- Increasing the processing demands required for extracting the targets should result in greater cost
  - Therefore, the context in which the targets are presented may differentially affect performance
  - In informational masking (IM) tasks, in which multiple randomly chosen masker tones are presented on every trial, the target may be more difficult to extract (or segregate) due to target-masker similarity and/or masker uncertainty and thus may result in higher cost
  - Conditions that produce "release from IM" may also produce "release from cost" by reducing the resources required to accomplish the task
- Current experiment:
  - Obtain detection thresholds for two pure tones individually (single task) and together (dual task) in quiet, noise or random multitone masker contexts as well as in a "release from IM" condition (delayed target).
  - Predictions:
    - Cost of processing two targets simultaneously will depend on context with higher cost seen for random multitone maskers.
    - Cost in IM condition will be reduced with target delay.

Methods

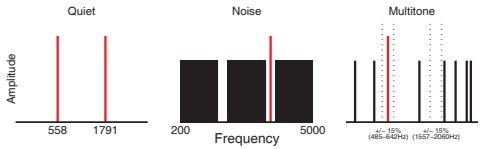


Fig.1: Example spectra of 1 or 2 targets in quiet, noise and multitone contexts. Red lines are the potential targets. Dotted lines are the "protected region" equivalent to noise notches.

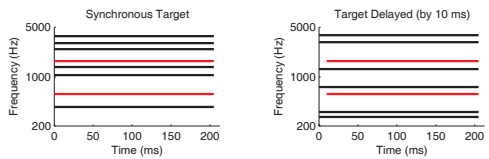
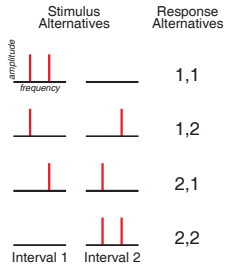


Fig.2: Example line spectrograms of the two multitone cases (with and without target delay)

- Data were collected concurrently at Boston U and U Penn
- **Listeners**: 8 paid college students with normal hearing
- **Task**: Detection of one or two sinusoidal targets in various contexts
- **Targets:** Low tone (558 Hz) and High tone (1791 Hz)
- **Contexts (see Figs 1 and 2):**
  - **Quiet:** no masker baseline; target = 205 ms
  - Double notched **noise** masker
    - Target and masker gated together (205 ms)
    - Noise is 200-5000 Hz with notches +/-15% of target frequencies; constant 50 dB SPL (~14 dB spectrum level)
  - Random **multitone** masker
    - Target/masker gated synchronously (205 ms)
    - 8 components total (including target/s)
    - Masker is constant 50 dB SPL (~41-42dB SPL each :6,7 or 8 comps)
  - Random **multitone** masker with target **delay**
    - Target (195ms) delayed 10ms re: masker

Fig.3: The four stimulus/response alternatives in the 2-tone case



- **Procedure**:
  - **1-tone**: 2I, 2AFC with adaptive (3-down 1-up) target level
  - **2-tones**: 2I, double 2AFC (or 4AFC) with two simultaneous adaptive (3-down 1-up) tracks [the two targets occur in either interval independently leading to the four alternatives in Fig. 3]
  - 60 trials per block
  - Final threshold is average of last 10 (of at least 20) blocks

Results

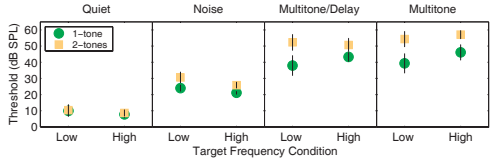


Fig.4: Group mean thresholds for 1 (green) and 2 tones (yellow) in the four context conditions.

- **1-tone** (●):
  - **Context (thresholds):**
    - **8-10 dB** in **quiet**
    - **21-24 dB** in notched **noise**
    - **38-46 dB** for the **multitone** maskers
  - **Target delay** provides only **2-3 dB of release from IM**
  - **Target Frequency:** In quiet and noise the high tone threshold is lowest (2-3 dB); in both multitone cases the low tone threshold is lowest (5-7 dB)
- **2-tone** (■):
  - **Context (thresholds):**
    - **8-10 dB** in **quiet**
    - **25-30 dB** in notched **noise**
    - **50-56 dB** for the **multitone** maskers
  - **Target delay** provides **2-6 dB of release from IM**
  - **Target Frequency**: In quiet and noise the high tone threshold is still lowest (2-5 dB) whereas in the multitone cases, for the delay case the two target thresholds differ by only 1 dB and in the non-delay/synchronous case the low tone threshold is lowest (~3 dB)

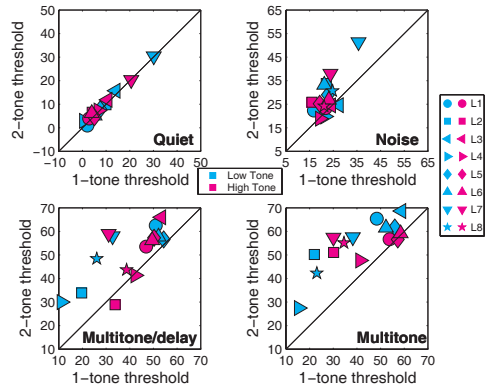


Fig 6: Each symbol represents the mean (across blocks) 1-tone (abscissa) and 2-tone (ordinate) thresholds for an individual listener for low tone (cyan) and high tone (magenta) targets in the four different contexts (panels).

- **Individual differences:** (Every listener is shown in Fig 6)
  - Range of thresholds is the spread along each axis
    - greatest range is in the multitone cases
  - Cost is the vertical distance from the diagonals
    - greatest range of cost is for multitone cases

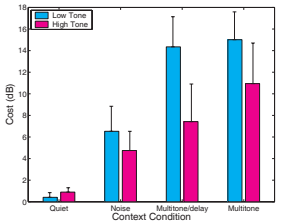


Fig.5: Group mean cost (2-tone threshold minus 1-tone threshold) for each target frequency and context condition.

COST: The difference between the 2-tone threshold and the 1-tone threshold for each target frequency and context is the estimate of cost

- **Context Effect:** Cost depends on context.
  - **No cost** in **quiet**
  - **4–6 dB cost** in **noise**
  - **8-15 dB cost** in **multitone maskers**
- **Target delay:** Although in the right direction, cost is not significantly reduced in the delay condition (probably due to small release from IM).
- **Frequency effect**: The cost tends to be larger for the low tone in the masked conditions (noise and both multitone cases)

Discussion

- The finding of **"no cost" in quiet** is very informative and surprising given the 4-6 dB effect in noise. It shows that for this task (in terms of resources devoted to the target alone) there is no inherent penalty for divided attention, additional memory load or whatever additional resources are required for processing two targets relative to one. The **cost is clearly context dependent**.
- The explanation of **greater cost in the two multitone cases** as compared to noise is probably related to the greater demand on resources required to segregate the targets from the similar and uncertain maskers or greater difficulty in ignoring the masker.
- Unlike previous 1-interval paradigms, **a "no cost" strategy exists** in which the listener could process only one tone in each observation interval. This strategy obviously was not used by our listeners.
- We have no good explanation for the **apparent dependence of cost on target frequency** with the possible exception that the two-tone thresholds in the multitone maskers may have approached some ceiling (an overall "loudness" limit perhaps?).
- If **"release from informational masking**" involves a reduction in processing load then conditions such as target delay (or other manipulations such as cuing) would be expected produce a **"release from cost**" also. This was only weakly evident here probably due to the fact that the delay did not produce much release from IM.
- **Future studies** measuring **reaction times** and producing greater release from IM may also be informative.

Conclusions

- **The cost of processing two targets in different frequency channels depends on context**
  - In **quiet**, there is **no cost**, indicating that it is possible to do the task without a decrement in performance
  - In **noise**, the **cost is minimal**, consistent with earlier reports
  - In random **multitone** maskers, the **cost is substantially larger** and may reflect the additional resources required to ignore the masker (or segregate the target)

Acknowledgements and References

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