

## Effect of auditory attention on the speed of pitch recognition of a tone

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(Received 6 January 2000)

Keywords: Attention, Cue, Pitch recognition, Auditory backward recognition masking

PACS number: 43.66.Lj, 43.66.Mk

### 1. Introduction

Research of the spatial attention has shown that the attention on the particular location influences the speed of auditory and visual information processing. In auditory perception, it has been reported that the auditory attention accelerates the speed of tone detection.<sup>1)</sup> However, to our knowledge, the effect of auditory attention on the speed of recognition for a particular attribute of a sound, such as pitch and timbre, has not been investigated.

In this paper, we examine the effects of auditory attention on the speed of pitch recognition of a tone. In the present study, two kinds of tones, a cue tone and a pair of test tones, are used. The cue tone is presented to either ear assuming that the tone would make the subject's attention focus on the particular ear. The test tones are used to measure the speed of the pitch recognition, which consist of two consecutive tones, *i.e.* target and masker. In this study, the duration of auditory backward recognition masking (ABRM)<sup>2)</sup> is used as a measure for the speed of pitch recognition, because the duration of ABRM is assumed to reflect the time to extract the pitch information of a tone. The duration of ABRM is quantitatively measured by using the technique similar to that employed by Foyle and Watson.<sup>3)</sup> By using this technique, frequency discriminabilities of the target are measured for selected amounts of duration of silence between the target and the masker. The duration of ABRM, in this technique, is defined as the duration which the frequency discriminability of the target is interfered by the masker. After the cue tone is presented, the test tones are presented either ipsilaterally (hereafter called "ipsilateral cue condition") or contralaterally ("contralateral cue condition") to the ear which the cue-tone is presented. There are four combinations for the presentation of the cue tone and test-tones when considering both the cue conditions for each of the right and left ears. The effect of the cue tone is evaluated by comparing the difference in the speed of pitch recognition between the two cue conditions, separately for each ear.

### 2. Method

Sound stimuli consist of three pure tones as shown in Fig. 1.

A 400 ms, 800 Hz cue tone was followed by a 400 ms silence. A 20 ms target, either  $(800 - \Delta f/2)$  Hz or

$(800 + \Delta f/2)$  Hz, and a 100 ms, 800 Hz masker were separated by a variable delay,  $\Delta t$ . Value of  $\Delta f$  was selected among twenty possible values ranging from 2 to 60 Hz in equi-log steps. The duration of  $\Delta t$  was 0, 20, 40, 80, 160, 320, or 500 ms.

All tones were generated by a computer. The amplitude envelope of each tone has a ramped rise/decay during 2.5 ms. The SPL during flat envelope was 65 dB SPL. The sound was presented through the headphones (STAX SR-1). The experiment was conducted in a soundproof booth.

Each trial began with a 250 ms visual sign on the computer screen, followed by a 250 ms pause. Then a cue tone was presented to either the right or left ear. After a 400 ms silence, a target and a masker were presented either the right or left ear. The subject's task was to identify whether the target was lower or higher than the masker by pressing one of two buttons labeled as "Higher" and "Lower", respectively. A 500 ms visual feedback of the correct response was displayed on the computer screen after a 2-s response interval. The intertrial interval was 1 s. Subjects were instructed to ignore the cue tones, in order to concentrate on the pitch judgement of the target.

On each trial, the computer automatically varied the value of  $\Delta f$  by an adaptive-tracking procedure,<sup>4)</sup> to investigate the frequency discriminability of the target for each of the 28 conditions  $[(2 \text{ cue conditions}) \times (2 \text{ ears of test-tones presentation}) \times (7 \Delta t\text{'s})]$ .

The subjects participated in ten sessions. Ten adults were used as the subjects. All the subjects had normal hearing. Each session consisted of fifteen blocks of 56 trials. Within each block, the 56 independent conditions  $[(2 \text{ cue conditions}) \times (2 \text{ ears of test-tones presentation}) \times (2 \text{ targets}) \times (7 \Delta t\text{'s})]$  were arranged to occur with equal probability and presented randomly.

### 3. Results

In order to estimate the duration of ABRM, a psychometric function of the just-discriminable frequency difference versus  $\Delta t$  was obtained by using the method similar to that Foyle and Watson employed,<sup>3)</sup> independently for each ear in each cue condition. The psychometric function is approximated as

$$y = A \exp(-\Delta t/\tau) + B \quad (1)$$

where  $y$  indicates of the just-discriminable frequency

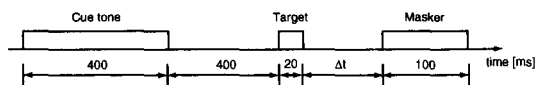


Fig. 1 Schematic display of the three tone sequences.

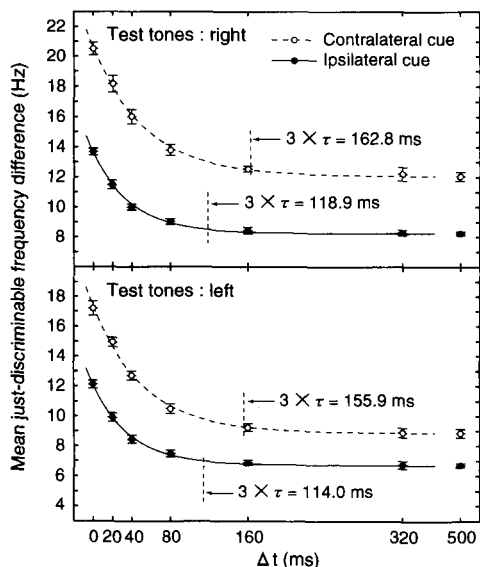


Fig. 2 Average values of the JDFD (just-discriminable frequency difference) for the ten subjects as a function of  $\Delta t$  and the cue condition. The upper and lower panels show the results of the right and left ears, respectively. The curves in dashed and solid lines show the fitted psychometric functions as expressed in Eq. 1 (see text) with  $B=500$  ms. The calculated  $3 \times \tau$  value are shown in each cue condition on each panel. Error bars represent the calculated standard error of mean.

difference (JDFD). JDFD for each of the four conditions decreases as  $\Delta t$  increases, and attains an asymptotic value for  $\Delta t > 320$  ms. To estimate the rate of decay  $\tau$  of each psychometric function, the value of  $B$  is set to the value at  $\Delta t = 500$  ms. After modifying Eq. 1 as  $\ln(y_i - B) = \ln(A_i) - \Delta t / \tau_i$  (Eq. 2),  $\tau_i$  was estimated from the values  $(y_i - B)$  for each of  $\Delta t = 0, 20, 40, 80, 160, 320$  ms. The rate of decay,  $\tau$ , was calculated from the slope of the regression line of the modified psychometric function as expressed by Eq. 2. The estimation errors were minimized by using the least square method. The  $3 \times \tau$  value was defined as the duration of ABRM.<sup>3)</sup> The data plots of JDFD, the

fitted psychometric functions as expressed in Eq. 1, and the calculated  $3 \times \tau$  values are shown in Fig. 2.

In the result for both ears, there is a considerable difference in the duration of ABRM ( $3 \times \tau$  value) between the two cue conditions. The duration of ABRM is about 40 ms shorter in the ipsilateral cue condition than in the contralateral condition. The difference is statistically different ( $p < 0.05$ ) using a test for comparison of two slopes of the regression lines<sup>5)</sup> applied to the linearized psychometric functions as expressed in Eq. 2.

#### 4. Discussion

The duration of ABRM ( $3 \times \tau$ ) showed the different value between the ipsilateral and the contralateral cue. This fact suggests that the speed of pitch recognition is affected by the attention. In this case, the duration of ABRM was markedly short when the test tones were presented ipsilaterally than contralaterally to the cue tone ear. This result indicates that the speed of pitch recognition of the target is faster when the cue tone is presented to the same ear, which the test tones were presented, than to the opposite ear of the test-tone presentation. However, from the result of the present experiment, we can not say whether the speed of pitch recognition is accelerated by the ipsilateral cue, or decelerated by the contralateral cue. For this issue, the detailed investigation will be reported in the near future.

#### 5. Conclusion

In this paper we reported about the effect of the auditory attention on the speed of pitch recognition of the tone. What we newly found in the ABRM experiment were that (1) the speed of pitch recognition was affected by the auditory attention, and that (2) the speed of pitch recognition was faster when the test tones were presented to the same ear (ipsilateral) with the cue tone than to the opposite ear (contralateral) to the cue tone.

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