Massaro, D. W., Cohen, M. M. & Idson, W. L. (1976). Recognition Masking of Auditory Lateralization and Pitch Judgments. Journal of the Acoustical Society of America, 59(2), 434-441

Recognition masking of auditory lateralization and pitch judgments*

Dominic W. Massaro, Michael M. Cohen, and Wendy L. Idson

University of Wisconsin, Madison, Wisconsin 53706
(Received 30 June 1975; revised 10 October 1975)

Two experiments determined backward and forward recognition masking functions in a lateralization task. Observers were presented with a 20-msec pure tone that differed in intensity to the two ears. The task was to indicate whether the tone came from the right or left. A second backward-masking tone interfered with the lateralization of the first test tone if it was presented within 180–250 msec of the first tone presentation. In contrast, a forward-masking tone had to be presented within 80 msec of the test-tone presentation in order to interfere with lateralization of the test tone. The results also showed that observers tended to lateralize the test sound in the direction of the masking sound if the test and masking sounds occurred within a 100-msec period. In a third experiment, subjects were required to identify a test tone as high or low in pitch in a recognition masking task. Although pitch judgments showed as much or more backward masking than lateralization judgments, significantly less forward masking was found in the pitch judgment task. Relative to lateralization judgments, observers showed a smaller tendency to judge the pitch of the test tone in the direction of the pitch of the masking sound.

Subject Classification: [43]65.75,[43]65.54,[43]65.62;[43]65.58.

INTRODUCTION

The present experiments are aimed at studying the temporal course of auditory lateralization and pitch resolution. The task that is employed is a recognition masking situation; two nonoverlapping sounds are presented in temporal proximity and the goal is to measure the influence of one sound on the experience of the other. Masking is observed when one sound interferes with the resolution of the other sound presented earlier or later in time. In backward masking, a second masking sound disrupts perception of an earlier test sound. Forward masking refers to the case in which the masking sound disrupts perception of a later test sound.

The results of recognition masking studies have made apparent some of the structures and processes involved in auditory perception. In a typical backward-masking experiment, two 20-msec tones differing in frequency are used as test sounds. Observers are given a series of identification trials with feedback and trained to call the high-frequency and low-frequency tones "high" and "low," respectively. In the experiment proper, the test tone is followed by a masking tone after a variable silent interval. The test and masking tones are presented at the same intensity. Massaro's (1970) results indicated that the recognition of the test tone improved with increases in the silent intertone interval asymptoting at 250 msec. Massaro (1973) showed that forward masking produces significantly less interference than backward masking. A first sound did not interfere with recognition of a second later sound if the sounds were separated by 60–80 msec of silence. In contrast, backward masking produced interference out to a silent interval of roughly 200–300 msec.

The recognition masking task measures performance of relatively naive subjects under conditions of considerable stimulus uncertainty. The subjects are tested an hour a day for five days. The different experimental conditions are presented in a random order cedures, the results may not define the resolving pow er of the auditory system. On the other hand, perfor mance may characterize certain auditory processes responsible for perceiving sound in authentic listenin situations. Massaro (1975a) discusses the experimen tal methods of the recognition masking procedure, th results utilizing this paradigm in audition, and their theoretical implications.

The present series of experiments asked whether recognition masking would occur when observers are required to lateralize a sound. Subtle interaural tim differences and intensity differences of the sound to the two ears are cues to the location of a sound in sp (Mills, 1972; Woodworth, 1938). The recognition masking studies, on the other hand, show that althou information in a sound is presented within a short tim (20 msec), a longer period (250 msec) may be requir to process this information in order to identify the te sound accurately. We are interested in whether late izing a sound also requires additional processing time after the sound itself is presented.

In one of his last papers, Békésy (1971) reported re sults from a series of backward- and forward-maskin experiments. A listener was presented with two equa loud 35-msec tones, one (1000 Hz) over a single spea er and the other (1500 Hz) over a ring of 12 speakers. The single speaker was usually placed in a different location than the ring of 12 speakers. For example, one case, the listener faced the single speaker with t ring of speakers placed above his head. If the tone over the single speaker was presented 60 msec after the onset of the tone over the ring of speakers, most of the sound was heard as coming from the single spe er. In contrast, when the tone over the ring of speak ers was presented 60 msec after the onset of the tone over the single speaker, most of the sound was heard as coming from the ring of speakers above the listener's head. These results show that Békésy's listener tended to localize two sounds arriving close together xperiments systematically varied of the nature of test .nd masking sounds in order to measure the influence f the perceived direction of one sound on the perceived irection of the other.

Tolkmitt (1974) asked observers to localize 20-msec ure tones at one of eight speakers in a backward-masking task. The masking stimulus was 500 msec of white oise, 30 dB more intense than the 40-dB test tone. 'he masking sound was presented over eight different peakers that were interleaved with the eight test speakrs. Accuracy of localizing a sound played in front of ne listener improved over 40% (in Experiment II) with ncreases in the silent interval between the test and nasking sounds. This study and Békésy's observations re the only studies we have found that have been conerned with the perceptual processing time necessary or auditory localization. The present experiments are imed at determining whether recognition masking is n appropriate paradigm for studying processes inolved in auditory lateralization. If it is, we should e able to provide some information about the dynamic spects of auditory lateralization.

:XPERIMENT I

Subjects were asked to lateralize the direction of a ure tone presented over headphones. The perceived irection of the test tone was varied by producing inraural intensity differences. The task required the bservers to indicate whether a 1000-Hz test tone came rom the right or left of the head. In a pilot experiment, our out of eight observers performed at chance with - and 2-dB intensity differences. In the present exeriments, it was necessary to employ intensity differences of 3- or 4-dB SPL to obtain performance that anged from just above chance to just below perfect cross the different experimental conditions. At first lance, the sensitivity of our observers appears to e somewhat poorer than the psychophysical thresholds eported for highly practiced observers. Mills (1960) resented a 1000-Hz test tone to the middle of the head ollowed by a second 1000-Hz tone either to the left or ight of the test tone. Subjects could recognize the irection of the second tone 75% of the time when there as a 1-dB interaural intensity difference.

There are three apparent reasons why Mills's observrs should have been more sensitive to interaural inensity differences than our observers. Firstly, the est tones in Mill's (1960) study lasted 1 sec, whereas ur test tones were 20 msec in duration. Although we ave not found data on the sensitivity to interaural inensity differences as a function of tone duration, it eems likely that sensitivity would decrease with dereases in tone duration. For example, Mills (1972) reorts data that show sensitivity to phase differences inreases by a factor of 3 as tone duration is increased rom 20 to 1000 msec. Secondly, Mills (1960) employed successive comparison task, whereas our subjects lentified a single test tone in an absolute judgment isk. Sensitivity is usually higher with relative than curate when relative judgments were possible in a successive comparison task than in a single interval absolute judgment task. Thirdly, most of our lateralization judgments were made under difficult recognition masking conditions which reduced average performance in the task. Given these methodological differences, the sensitivity of our observers appears to be reasonably close to what other investigators have reported in lateralization experiments.

A. Method

1. Subjects

Eight subjects participated for five consecutive days in order to fulfill an introductory psychology course requirement.

2. Procedure

The observer's task was to identify the test tone as coming from the right or left. The test tone coming from the right had an intensity of 84 dB to the right ear and 80 dB to the left. The test tone coming from the left had an intensity of 80 dB to the right ear and 84 dB to the left. A masking tone followed the test-tone presentation on $\frac{7}{8}$ of the trials. The masking tone could come from the right, middle, or left depending on the intensities of the tones to the two ears. The intensities of the three masking tones were 86 and 78, 82 and 82, and 78 and 86 dB to the right and left ears, respectively. An 8-dB intensity difference was employed for the asymmetrical masking tones so that the perceived direction of these tones would not be ambiguous as it can be with the 4-dB differences in test tones. On masking trials, one of the three masking tones followed the test tone after an interval of 0, 20, 40, 70, 120, 180, or 250 msec. On $\frac{1}{8}$ of the trials no masking tone was presented. The 48 experimental conditions [(2 test tones)×(3 masking tones)×(8 masking conditions)] could occur with equal probability and were selected randomly with replacement. (The direction of the masking tone was a dummy variable under the no-mask condition.) The subject had 1.5 sec to make his response after the offset of the test tone. Subjects pushed one of two buttons labeled R and L, respectively, indicating whether the test tone came from the right or the left. Feedback was given after the response period by illuminating for 250 msec the symbol R or L, depending on whether the right or left ear had the more intense signal. The intertrial interval was 1 sec.

The intensity difference between the two ears was the only cue to the direction of the test tone. The test tones were stored digitally and played back by a 10-bit digital-to-analog converter (DEC VC8/L). The playback rate was 20 kHz. The sounds to both ears were amplified (McIntosh MC-50 amplifiers) and played over matched headphones (Grason-Stadler TDH-49, held in type 001 cushions). The frequency of the tones was 1000 Hz. Both the test and masking tones lasted 20 msec. The tones began at the zero crossing and reached maximal intensity in $\frac{1}{4}$ of the cycle. The feedback was

Four subjects were tested simultaneously in separate sound insulated chambers for five consecutive days. On each day, two sessions of 305 trials each were given with about a 10-min break between sessions. The first five trials of each session were not recorded. On the first day, the test tones were presented without a masking tone present. On days 2–5 the experiment proper was carried out. The results were pooled over the last four days giving a total of 2400 observations per subject.

B. Results

An analysis of variance was carried out on the percentage of correct identifications with subjects, the direction of the test-tone presentation, the direction of the masking tone, and the seven masking intervals as variables. Average performance improved from 66% at the zero silent interval to 91% at the 250-msec silent interval, $F(6,42)=42$, $p<0.001$. Performance under the no-mask condition averaged 92% correct, essentially equal to performance at the 250-msec interval. There was no significant effect of the direction of the masking tone on performance averaged across the two test-tone presentations.

Figure 1 plots the d' values as a function of intertone interval and the direction of the masking tone. The d' values were computed from the average proportions of right responses to the right and left test tones, respectively. In this case, the probability of a right response given a right test tone would be the hit rate, whereas the probability of a right response given a left test tone would be the false alarm rate. Figure 1 shows that masking occurred with each of the three masking stimuli reaching the asymptotic performance of the no-mask condition at roughly 250 msec. The middle masking tone appeared to produce somewhat more masking than the asymmetrical masking tones at intervals of 70 msec or greater.

In contrast to average test-tone recognition, the di-

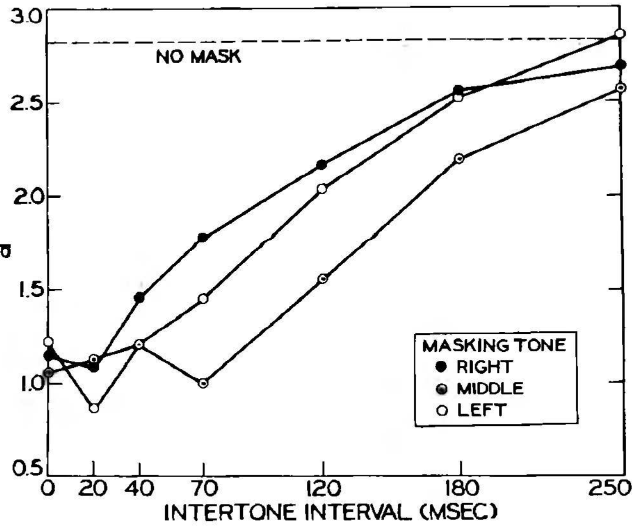


FIG. 1. Recognition performance measured in d' values as

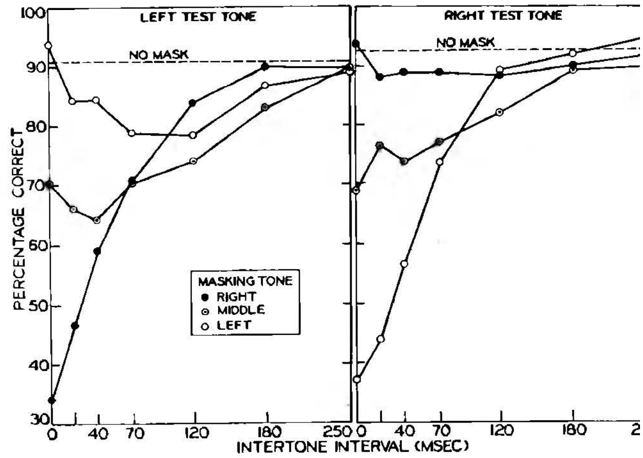


FIG. 2. Percentage of correct recognitions of the left and right test tones as a function of the direction of the masking tone and the duration of the silent intertone interval in Exper ment I.

rection of the masking tone had a significant effect on recognizing the individual test tones. The interaction of the direction of the test tone and the direction of th masking tone was significant, $F(2,14)=26$, $p<0.001$, as was the triple interaction of test direction, mask direction, and intertone interval, $F(12,84)=29$, $p<0.$ The nature of these interactions can be seen in Fig. 2 The figure shows that the identification of both test to improves with increases in the silent interval before the presentation of the middle masking tone (i.e., equ intensity to both ears). In contrast, the amount of interference produced by the masking tones directed to side is a function of both the direction of the test tone and the silent intertone interval.

At intertone intervals of 70 msec or less, the mask ing tone presented to the same side as the test tone produced much less interference with its correct iden tification than the masking tone presented to the opposite side of the test-tone presentation. Percentage o correct identifications of the left test tone followed by the left masking tone decreases and then increases wi increases in intertone interval. Identification of the right test tone followed by the right masking tone sho a similar U-shaped function but is near asymptotic pe formance at all intertone intervals. In contrast, whe the masking tone is presented to the opposite side of the test-tone presentation, performance is below cha at the shortest intertone intervals and increases mon tonically with increases in intertone interval.

The masking tone had a large effect on the subject' marginal probability of a right or left response. Although the overall probability of a right response was about 0.53 with the middle masking tone, observers tended to respond with the alternative that agreed wit the direction of the asymmetrical masking tones. Th probability of a right response was 0.61 when the ma ing tone came from the right and 0.42 when the maski tone came from the left. In terms of signal detection theory, the direction of the masking tone had a signif

:XPERIMENT II

\. Method

Eleven subjects participated for five consecutive days n order to fulfill an introductory psychology course re- ıuirement.

The observer's task was to identify the 20-msec test one as coming from the right or the left under two con- litions. In the forward-masking condition, the test one was preceded by a 20-msec masking tone. The est tone was followed by the masking tone in the back- vard-masking condition. Each trial began with presen- ation of the visual cue 1 or 2 indicating to the subject vhether to identify the first or second tone presented ın that trial. The visual cue lasted 200 msec followed ›y an 800-msec period before the presentation of the est tone. The masking tone either preceded or followed he test tone according to the cue given on that trial. The interval separating the test and masking tones was), 10, 20, 40, 80, 120, 180, or 250 msec. The sub- ect had a 1.5-sec response interval after the offset of he test tone. After the response interval, the visual eedback L or R was presented for 250 msec, indicating vhether the test tone came from the left or the right. The intertrial interval was 1.5 sec.

The observer's task was to identify the test tone as :oming from the right or left. The test tone coming rom the right had an intensity of 83.5 dB to the right ear and 80.5 dB to the left. The test tone coming from he left had an intensity of 80.5 dB to the right ear and 13.5 dB to the left. A masking tone followed or pre- :eded the test tone on each trial. The masking tone :ould come from the right, middle, or left depending ın the intensities of the tones to the two ears. The in- ensities of the three masking tones were 86 and 78, 12 and 82, and 78 and 86 dB to the right and left ears, 'espectively.

In the first session on the first day, subjects identi- ied the test tones without any visual cue or masking

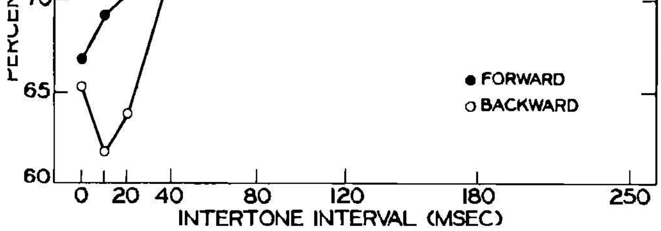


FIG. 3. Percentage of correct recognitions of the direction of the test tone as a function of the silent intertone interval

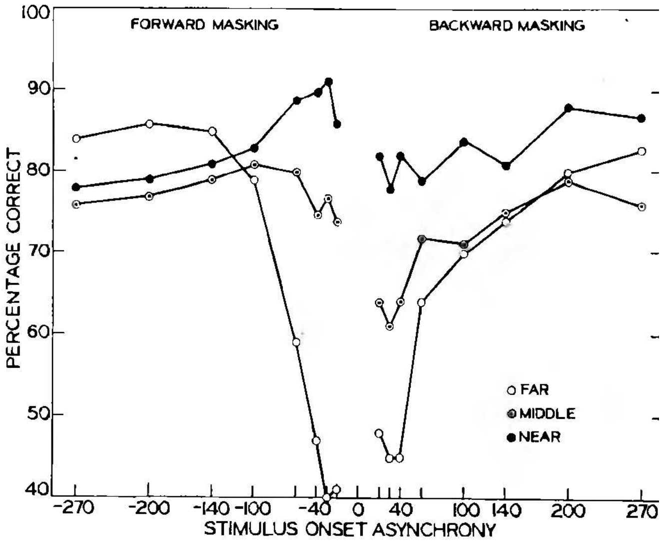


FIG. 4. Percentage of correct recognitions of the test tone as a function of stimulus onset asynchrony in Experiment II. The parameter near, middle, and far gives the relationship between the direction of the test and masking tones.

tone present. In the second session and during the next four days the experiment proper was carried out. All 96 experimental conditions [(forward and backward masking) × (2 test tones) × (3 masking tones) × (8 masking intervals)] could occur with equal probability and were selected randomly with replacement. The results were pooled over the last four days for the data analysis. All other procedural details were the same as in Experiment I.

B. Results

Figure 3 plots the average percentage of correct test-tone identifications as a function of the intertone interval under the backward- and forward-masking conditions. The figure shows that identification improved with increases in the silent intertone interval, $F(7,70) = 34.6$, $p < 0.001$, but at a faster rate under the forward than the backward-masking condition, $F(7,70) = 4.3$, $p < 0.001$. The functions of Fig. 3 show significantly less forward masking than backward masking; performance asymptoted by an 80-msec interval in the forward-masking case but continued to improve to an interval of 180 msec under backward masking.

Figure 4 plots performance under the forward- and backward-masking conditions as a function of the relationship between the test and masking tones. Identification of the right test tone given the right masking tone and the left test tone given the left masking tone is called the near condition. The far condition gives performance for the right test tone given the left masking tone and the left test tone given the right masking tone. Average performance given the middle masking tone is represented by the middle condition. The masking functions are plotted across stimulus onset asynchrony (SOA which is equal to the time between the onset of the test and masking tones. Given that both the test and maskin tones were 20 msec, the SOA is equal to the intertone negative SOA values.

The relationship between the test and masking tones had the largest effect on performance at the shorter SOA's. The backward-masking functions replicated those found in Experiment I with the exception that performance remained somewhat better at the longest SOA's with the near masking tone than with the far masking tone. In forward masking, the masking tone directed to the same side of the head as the test tone produced significantly less interference than the masking tone to the middle of the head at SOA's of 60 msec or less. Test-tone identification was poorest at these same intervals when the masking tone was presented to the opposite side of the test-tone presentation. The interaction of the direction of the test tone and masking tones was statistically significant, $F(2, 20) = 34.5$, $p < 0.001$. In contrast to the large effect of the direction of the masking tone on identification of each of the two test tones, masking tone location had no effect on average identification performance, $F(2, 20) \approx 1$.

The results showed significantly less forward than backward masking. Judging the direction of the test tone improved with increases of the silent intertone interval out to 80 msec in forward masking and 180 msec in backward masking. Subjects tended to judge the direction of the test tone in the direction of the masking tone in both the forward and backward masking conditions at short SOA intervals. This tendency was present in backward masking even at the longest SOA's when the masking tone no longer interfered with identification of the test tones as measured in average percentage correct or d'. This result appears to be consistent with the idea that the tendency of the subject to respond toward or away from the direction of the masking tone might be due to a decision bias at the longest SOA's.

EXPERIMENT III

Given the interaction between the direction of the test and masking tones in lateralization judgments, we wondered whether similar results would be observed on other dimensions of tonal recognition. Pilot data reported by Hawkins, Thomas, Presson, Cozic, and Brookmire (1974) shows that pitch judgments may also be influenced by the frequency of the masking tone. Two intertone intervals were employed in a backward recognition masking task. The test tones were 800 and 850 Hz and the masking tones were 775 and 875 Hz. When either of the masking tones could occur on each trial, performance on the low (high) test tone was much better when the masking tone was also low (high). For example, at the zero intertone interval, the percentage of correct low recognitions was 87% given the low masking tone and only 38% given the high masking tone. With a 250-msec silent intertone interval, there was very little difference in identification performance as a function of the relationship between the test and masking tones. Given that Hawkins *et al.* tested performance at just these two intertone intervals, the present experiment examined performance with high and low masking tones under both forward and backward masking.

A. Method

Eight subjects were tested for five consecutive days Four students chose this option to fulfill an introductoı psychology course requirement and the other four wer paid $1.50 an hour for participation.

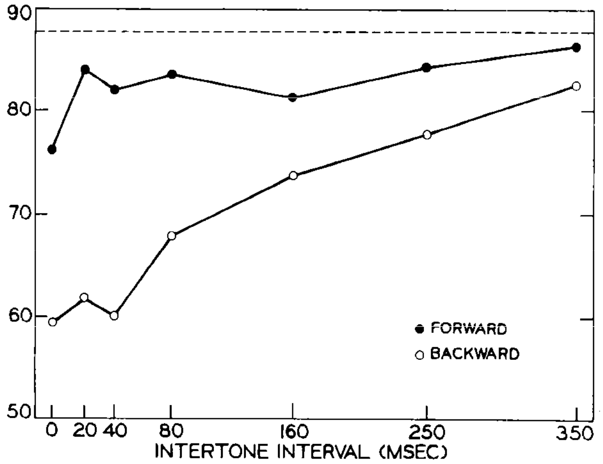
On each trial, the subject was required to identify a sine wave test tone as high or low. The test tone w preceded or followed, on $\frac{7}{8}$ of the trials, by a masking tone. The high and low test tones were 860 and 79 Hz, respectively. The masking tone was either high (900 Hz), middle (825 Hz), or low (750 Hz). The tone were generated by a digitally controlled oscillator (Wavetek model 155) and played over matched headphones (Grason–Stadler TDH-49). The intensity of th tones was 80-dB SPL. Both the test and masking tone lasted 20 msec. The tones began at the zero crossing and reached maximal intensity in $\frac{1}{4}$ of the cycle.

Each trial began with the visual presentation of a cu 1 or 2 signifying whether the test tone would be presented first or second. The cue lasted 200 msec and was presented 1 sec before the onset of the test-tone presentation. On masking trials, the test tone was preceded or followed by a masking tone with a 0, 20, 40, 80, 160, 250, or 350 msec silent interval between the test and masking tones. On $\frac{1}{8}$ of the trials no masking tone was presented. These trials were cued with the digit 1 indicating to the subject to identify the first tone. This means that subjects given the cue to identify the first tone were not able to predict when, i fact, no-masking tone would be presented. This situation is analogous to the typical backward-masking ex periment in which no-mask trials are randomly intermixed with masking trials (cf. Experiment I). All otl er experimental conditions were the same as in Exper ment II.

On day 1, two sessions of 305 trials each were give without a masking tone present. On days 2–5, the ex periment proper was carried out. For four of the sub jects, only one session was carried out on days 2 and Therefore, the results were pooled over only the last two days of the experiment.

B. Results

Figure 5 presents the forward- and backward-masking functions. The figure shows significant backward masking out to an interval of 350 msec whereas no for ward masking occurred at intervals of 20 msec or greater. This interpretation is substantiated by the statistically significant effect of forward vs backward masking, $F(1, 7) = 23$, $p < 0.005$, and the interaction be tween forward vs backward masking and the intertone interval, $F(7, 49) = 8.8$, $p < 0.001$. Asymptotic performance under forward and backward masking was sligh ly poorer than performance under the no-mask condition. This result contrasts with previous results show



IG. 5. Percentage of correct recognitions of the frequency : the test tone as a function of the silent intertone interval ıder the forward- and backward-masking conditions in Ex- ›riment III. Performance under the no-mask condition is in- cated by the dotted line.

ress; Massaro and Kahn, 1973; Massaro and Cohen, 975; Watson, Wroton, Kelly, and Benbassat, 1975). is possible that the observers missed or forgot the ue on a small proportion of trials and categorized the ıasking tone instead of the test tone. The no mask ɔndition might show a slight advantage, therefore, ince this mixup could not occur given only one tone in ıe no-mask condition.

Figure 6 plots the percentage of correct identifica- ons under forward and backward masking as a function ' the frequency relationship between the test and mask- g tones. Identification of the high test tone given the gh masking tone and the low test tone given the low asking tone is called the near condition. The far con- tion represents performance when the test and mask- g tones are high and low or low and high, respectively. he middle condition represents average performance ı the high and low test tones given the middle masking ne. In contrast to the relatively large effect of the ›lationship between the test and masking tones in the teralization experiments, a much smaller effect is und in pitch judgments. The interaction between the equency of the test tone and the frequency of the mask- g tone was not significant. At SOA's larger than 40 sec, in forward masking, performance was essentially symptotic regardless of the relationship between the equency of the test and masking tones. In backward asking, the far masking tone produced somewhat ore interference than the near masking tone out to ıd including an SOA of 100 msec.

The frequency of the masking tone did influence av- rage identification performance, $F(2,14)=5.7$, $p<0.025$. he middle frequency masking tone produced about 4% ss masking than the higher or lower frequency tones both forward and backward masking. One possibility r this slight advantage might be that observers used e middle-frequency masker as an anchor for rela- ve judgments. If observers sometimes recognized

to determine whether the test was higher or lower. If they recognized the test as higher than the mask, they would then know that it was the high tone. Two other results argue against this interpretation. If observers were simply making relative judgments, we would expect forward masking to be symmetrical with backward masking and this did not occur. If subjects did sometimes make relative judgments and these were easier than absolute judgments, performance should have been easier under the masking conditions at long SOA's than unde the no-mask condition. This was not the case; therefore, subjects did not appear to make relative judgments in the pitch identification task and the reason for the slightly reduced masking with the middle-frequency masker must be found elsewhere.

C. General discussion

The results of this series of backward- and forward-masking experiments demonstrate that judging the direction and pitch of a 20-msec tone requires perceptual processing time after the tone is presented. Three quantitative differences between lateralization and pitch judgments may show that lateralization occurs at a different level in the processing sequence than pitch resolution. The backward-masking functions appear to asymptote somewhat sooner for lateralization than for pitch judgments. This result indicates that the time for lateralizing a sound may be somewhat less than that needed to determine a sound's pitch. Second there appears to be significantly more forward masking of lateralization than of pitch judgments. The phenomenon of precedence in which the first sound preempts the perception of direction may account for more forward masking in lateralization than in pitch judgments. Third observers are much more likely to judge the test tone as having the value of the masking tone in a lateralization than in a pitch judgment task. Given that these differences were observed between experiments, it is necessary to ask observers both to lateralize and judge

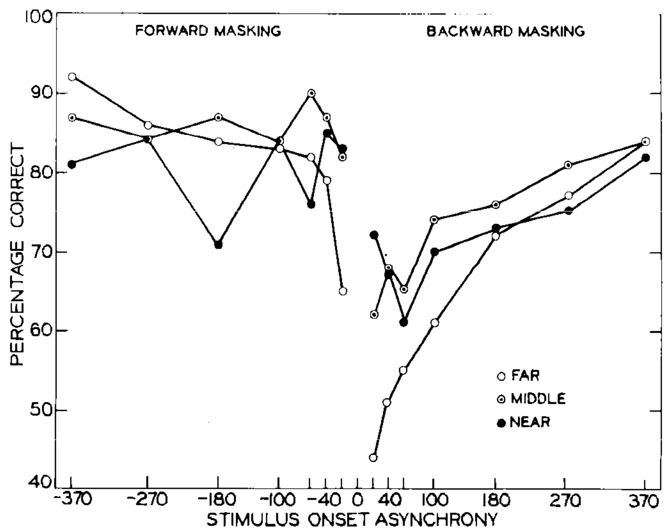


FIG. 6. Percentage of correct recognitions of the test tone as a function of stimulus onset asynchrony in Experiment III. The

the pitch of the test tone on each trial. The results should provide a more valid and reliable measure of the differences in the two judgments.

On the other hand, it may be that the lateralization results were different than the pitch judgments, not because of judging different attributes of sound, but because of the nature of the two tasks. The lateralization judgment did not require a long-term memory comparison in the same way as the pitch judgment. In order to perform the pitch recognition task, observers had to remember the absolute pitches of the high and low tones. However, subjects did not have to remember the exact direction of the test tones in the lateralization task. Subjects could lateralize the test sound by observing whether the test sound presented on each trial was to the right or left of the middle of the head. No standard sound(s) had to be maintained in memory as in the pitch recognition task. Therefore, a more direct comparison of pitch and lateralization judgments would have test tones arriving to only one side of the subject's head but varying in their exact direction. In this case it would be necessary to remember the exact direction of the test tones in order to lateralize the test tones accurately. We plan to compare lateralization and pitch judgments including this modification of the lateralization task.

Any serious theoretical interpretation of the results of the present experiments must await a good deal of parametric research utilizing the recognition masking paradigm. Factors that must be explored in future work include the psychophysical task, the randomization procedure, and the psychophysical similarity between the test and masking sounds. The present task required an absolute judgment of the direction of the test tone. It may be the case that relative direction judgments such as in a same–different task may not be as susceptible to recognition masking. Given that recognition masking of pitch judgments has been found in both same–different tasks and two-interval forced-choice tasks (Massaro, 1975b), one might expect the same generality to hold in lateralization masking.

Although the experiments reported here used an absolute judgment task subjects might have used the masking tone as a standard for a relative judgment. In fact, some of the subjects reported utilizing the masking tones as a reference on some of the trials. However, performance was always better under the no-mask condition than when a masking tone followed the test-tone presentation. This means that subjects were able to make an absolute judgment in the task, and according to questionnaire data, this was their typical strategy. However, if the masking tone direction were held constant across a series of trials, it is possible that subjects might be able to make a relative judgment between the test and masking tones at the same level of accuracy as the no-mask condition. The caveat is that backward masking of lateralization may be limited to tasks that randomize test and masking stimuli directions within an experimental session. This result would provide a basic difference between lateralization and pitch judg- the frequency of the masking tone and/or the intertone interval is fixed across a block of trials.

All experimental conditions were randomized within a given session in the present studies. This procedur is used so that subjects cannot adopt different process ing strategies under the different experimental conditions and, also, to control for other variables such as memory and motivation across the different experimei tal conditions. [See Massaro (1975a, 1975b) for a mo: detailed discussion of the advantages of the randomiza tion procedure and the pitfalls involved when condition are blocked across sessions.] Given the possible con· founding of psychological processes in the blocked pro cedure, the results of the present experiments cannot be generalized to experiments in which the masking conditions are blocked across experimental sessions.

The frequency and duration of the masking tone was always equal to the test tone in the present lateralization experiments. As noted in the introduction, Békés (1971) and Tolkmitt (1974) reported backward masking when a pure tone was followed by a tone of another fre quency or by white noise. Future research will need to determine what effect the psychophysical similarity of the test and masking sounds will have on lateraliza· tion and spatial location masking. It is possible that subjects tended to lateralize the test sound in the direction of the masking sound because they were, in fact, the same sound and normally would have come from the same source. Forward masking at short intervals may be related to the phenomenon of preceden which is a fusion of spatially separated signals into a single percept directed at the position of the first signal (Gardner, 1969). Precedence might account for th actual enhancement in test-tone lateralization when the near forward-masking tone preceded the test tone by less than 60 msec (cf. Fig. 4). If it does, then decreasing the similarity between the first and second sounds should reduce the suppression of the second sound reducing the amount of forward masking.

*This research was supported by U. S. Public Health Servic Grant MH-19399.

Békésy, G. von. (1971). "Auditory inhibition in concert hall Science 171, 529–536.

Gardner, M. B. (1969). "Image fusion, broadening, and dis placement in sound location," J. Acoust. Soc. Am. 46, 339 349.

Hawkins, H. L., and Presson, J. C. (in press). "Masking and perceptual selectivity in auditory recognition," in *Attentic and performance VI*, edited by S. Dornic (Academic, New York).

Hawkins, H. L., Thomas, G. B., Presson, J. C., Cozic, A and Brookmire, D. (1974). "Precategorical selective atten tion and tonal specificity in auditory recognition," J. Exp. Psychol. 103, 530–538.

Massaro, D. W. (1970). "Preperceptual auditory images," J. Exp. Psychol. 85, 411–417.

Massaro, D. W. (1973). "A Comparison of forward versus backward recognition masking," J. Exp. Psychol. 100, 434 436.

Massaro, D. W. (1975a). *Experimental Psychology and Infor*

Massaro, D. W. (1975b). "Backward recognition masking." J. Acoust. Soc. Am. **58**, 1059–1065.

Massaro, D. W., and Cohen, M. M. (1975). "Preperceptual auditory storage in speech recognition," in *Structure and process in speech perception*, edited by A. Cohen and S. G. Nooteboon (Springer-Verlag, Heidelberg).

Massaro, D. W., and Kahn, B. J. (1973). "Effects of central processing on auditory recognition" J. Exp. Psychol. **97**, 51–58.

Miller, G. A. (1956). "The magical number seven, plus or minus two. Some limits on our capacity for processing information," Psychol. Rev. **63**, 81–87.

Mills, A. W. (1960). "Lateralization of high-frequency tones," J. Acoust. Soc. Am. **32**, 132–134.

Mills, A. W. (1972). "Auditory localization," J. V. Tobias *Foundations of modern auditory theory* (Academic, New York), Vol. 2.

Tolkmitt, F. J. (1974). "Latency of sound localization as a function of aximuth and frequency," J. Exp. Psychol. **103**, 310–316.

Watson, C. S., Wroton, H. W., Kelly, W. J., Benbassat, C. A. (1975). "Factors in the discrimination of tonal patterns. I. Component frequency, temporal position, and silent intervals," J. Acoust. Soc. Am. **57**, 1175–1185.

Woodworth, R. S. (1938). "Exp. Psychol. (Holt, New York).

Yost, W. A., Turner, R., and Bergert, B. (1974). "Comparison among four psychophysical procedures used in lateralization," Perception Psychophys. **15**, 483–487.