Selective attention in uncertain frequency detection¹

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Uncertain frequency detection of brief sinusoids in noise was studied in a special Yes-No paradigm that included single-frequency trials randomly interleaved with trials on which either of two frequencies could be presented. Contrary to implications from previous studies, and to sensory filter models of attention, the Os' deliberate attempts to impose narrow- or wide-band listening had only a small effect on the relative detectability of signals at 500 Hz and at 1100 Hz. If frequency selectivity is to be understood as sensitivity adjustment (rather than as a recognition process), the relevant parameters may be entirely stimulus determined.

The role of selective perception in signal detection is far from clear, but it is often linked to the concept of an auditory critical band (Fletcher, 1940; Scharf, 1961; Swets, 1963; Green & Swets, 1966; Sorkin, Pastore, & Gilliom, 1968). The critical band is often thought of as representing a relatively peripheral filtering process that can limit the effective bandwidth for sensory inputs; an appealing idea because of its possible connection with the neural inhibitory interaction that seems to underlie sensation in most modalities (von Békésy, 1967). One of the more puzzling questions about the perceptual selection process is the extent to which the listener can control its parameters. If the width, position, or frequency stability of the band of frequencies selected, or the number of bands simultaneously available are subject to the listener's control, then we must investigate *listening strategies*, not simply the fixed transducing properties of the auditory system. To the extent that such strategies are effective, it may be useful to adopt the concept of a *listening band* (Sorkin et al, 1968) for the perceptual selection process. In the experiments reported here we explore the degree to which the listener can adjust the listening band to different requirements, and the degree to which the listening-band concept may account for his relative inability to detect signals with wide frequency separation.

Two findings led to the present experiments. One is that listeners detect noise-masked tonal signals better when the signal frequency is held fixed than when there are two (or more) possible

frequencies, one of which is selected at random for each presentation. This performance decrement in the "uncertain frequency" condition was reported by Tanner, Swets, and Green (1956), who proposed a "single band" theory to account for it. According to this theory, the listener can attend to only one frequency band at a given time, and the band attended cannot be changed efficiently within the short duration of a signal presentation. When listening for two widely separated brief sinusoids, say at 500 Hz and 1100 Hz, the single-band listener can get sensory information from a band centered near 500 Hz, or from one centered near 1100 Hz, but not from both simultaneously. Thus, if the two signal frequencies are equally likely, the listener will be able to detect on half the trials as he would if he knew the frequency in advance, and on the other trials as he would if he were simply guessing, or not listening. The overall performance, reflecting these two detection levels combined, generally will be lower than it is when the signal has just one frequency. This theory received support from experiments by Swets, Shipley, McKey, and Green (1959). Other experiments were more consistent with multiple-band versions of the theory (Creelman, 1960; Green, 1961), or with Shipley's (1960) choice-theory analysis, which predicts the performance decrement without the listening band hypothesis. Although the data are inconclusive with respect to the various theories, the performance decrement is a consistent outcome of uncertain frequency tasks. (See Green & Swets, 1966, for a general review of the experiments.)

A second finding relevant to the present experiments is that listeners who have been trained to detect single-frequency signals apparently do not distinguish other tonal signals (probe signals) from Gaussian background noise, provided there is sufficient frequency separation between the probe signals and the signal to be detected. This finding was explored systematically by Greenberg and Larkin (1968), after others had reported that changing the frequency of the signal to be detected led to an abrupt initial drop in detection performance (Tanner, Swets, & Green, 1956; Greenberg, 1962). In the probe-signal procedure used by Greenberg and Larkin, the listener is instructed to

listen for a specific tonal signal, but other signal frequencies (probe signals) are occasionally introduced in lieu of the specified one. The probe-signal frequencies usually are chosen to represent a frequency band centered on the signal to be detected. In the two-observations forced-choice version of the procedure, one signal—either the specified signal or a probe—is presented on every trial in one of two listening intervals. The interval is randomly selected, and it is the listener's task to decide which contained a signal and which contained only background noise. These decisions are most accurate when the specified signal is presented, slightly less accurate when probe signals close to the specified frequency are presented, and at the chance level for all frequencies outside a band. Plots of response accuracy against signal frequency are sharply peaked and roughly symmetric, in the manner of a filter characteristic. Approximate determinations of "bandwidth" for these plots are within the range of most critical band estimates for the frequency ranges studied. The pattern of differential responding is invariant under many procedural variations, e.g., the set of probe-signal frequencies presented, the presence or absence of response feedback, and, to a great extent, the kind of information given in instructions. The data do not seem to depend simply upon the listener's lack of "awareness" of probe signals, as they respond in the same way when forewarned, and most listeners claim not to have heard signals other than that of the specified frequency.

The probe-signal results support the interpretation of frequency-selective listening as a filtering or attenuation of sensory input, although it is still conceivable that the attenuation operates at the level of the responses, rather than at the level of sensory information. Experiments that bear on this issue will be reported separately by Greenberg. In any case, the experimental instruction to listen for a single frequency produces data that are clearly consistent with the single-band theory.

Suppose, now, that the listener is confronted with the uncertain frequency task. Normally, he is instructed to listen simultaneously for both of the two possible signal frequencies. One question we deal with in the present study is whether or not instructions of this sort can

effect real changes in the pattern of listening. If, contrary to the usual instruction, the O can choose a relatively narrow listening band in the uncertain frequency task, then the data should reflect the probe-signal results: Overall uncertain-frequency performance should exceed performance on the unattended frequency, but should be lower than performance on the attended frequency. We attempt to control attentional bias through instructions and differential response outcomes (payoffs). This aspect of the study may be considered parallel to the experiments of Sorkin et al (1968), in which the relative probabilities of the signal frequencies were systematically varied. Both are attempts to induce differential sensitivity at different frequencies. Whether or not the effects are parallel, we consider later.

A second problem we deal with is that of measuring the performance difference between tasks with one vs two signals to be detected. Past experimental work has compared results in the uncertain frequency task with results from separate single-frequency sessions, usually run in advance of the uncertain frequency sessions. Aside from difficulties inherent in "repeated measurements" comparisons, there are two special reasons to devise procedures for simultaneous measurement of both kinds of performance. First, it is difficult to separate the effects of listening strategies from the effects of stimulus variability if, as Swets and Sewall (1961) showed, both may contribute to the performance difference. In their experiment, preobservation cues to signal frequency were used to remove all uncertainty from the one-of-two-frequencies presentation schedule. A small performance decrement remained, indicating that the randomly changing frequency alone causes the O some difficulty. Second, because there is little hope of ensuring that an O will adopt exactly the same listening strategy on two different occasions, the effects of a listening strategy on different tasks need to be examined in the same experimental context. This is done in the present study by interleaving trials from the single-frequency experiment and from the one-of-two-frequencies experiment in the same listening period.

The following section outlines the experimental method, which is based upon the single-observation, "Yes-No" detection paradigm. The experiments were performed in two variations of the basic procedure (Experiments 1 and 2), details of which are described separately.

GENERAL METHOD

Observers

Six Os, two men and four women, ages 18 to 25, were chosen from 24 applicants, for their ability to detect 1100-Hz signals in noise, and for their apparent ability to heed instructions. They were tested simultaneously in daily 2-h sessions.

Apparatus

The Os were seated at individual listening booths in an acoustic chamber. Each booth was equipped with event indicator lamps, three pairs of "Yes" and "No" response push-buttons, and binaural headsets with Permoflux PDR-10 earphones wired in parallel and in phase. The several headsets were wired in parallel. A background of wideband Gaussian noise was continuously present in the headphones at a constant level, approximately 55 dB above absolute threshold. Signals were added to the noise by simply gating the outputs of Hewlett-Packard 200 ABR oscillators without regard to phase, for 100-msec durations. Two signal frequencies were used: 500 Hz and 1100 Hz. In Experiment 1 the signal intensities were such that $10 \log E/N_0 = 7.6$ for the 500 Hz signal and 8.7 for the 1100-Hz signal. In Experiment 2, the signal intensities produced $10 \log E/N_0 = 8.6$ and 9.7, for the 500-Hz and the 1100-Hz signals, respectively. The 500-Hz signal was attenuated 1.1 dB with respect to the 1100-Hz signal to equalize their detectability. This adjustment, made after inspecting data from single-frequency practice sessions, agrees with the 0.2 dB per 100-Hz relation that Green, McKey, and Licklider (1959) reported. In the following, the 1100-Hz signal and the 500-Hz signal will be referred to as the "high" and "low" signals, or as "H" and "L," respectively.

Procedure

The experimental trials followed the standard single-observation detection paradigm: A 100-msec signal (S) was added to the background noise (N) on a randomly-selected half of the trials, and each O indicated whether he thought S had been presented by pressing a "Yes" or a "No" button. The events on each trial, and their durations in msec, were: warning light, 1200; space, 750; listening interval, 150; space, 100; and response interval, 4000. When a signal occurred, it was added to the noise in the final 100 msec of the listening interval. The 50-msec lag between the light and the sound was necessary to make them appear simultaneous. The 100-msec "waiting period" before the response interval prevented anticipatory activation of the push-buttons. The push-buttons were illuminated during the response interval by

indicator lamps that went off as soon as a response was registered.

Trials were run in succession, in "blocks" of 80, each block followed by a 2-min rest period. A 15-min rest period divided each 2-h session into equal periods of five blocks each. The first block of each period was a practice block, during which the signal level was decreased systematically from 100% detectability to the fixed level used in the experimental blocks. Response feedback was provided in all practice blocks by an indicator lamp over the correct response push-button. This lamp went on when the O responded, and went off at the end of the response interval. All practice trials were "uncertain frequency" trials, in which either signal, H, or L, could occur. To insure adequate exposure, H and L were each presented on about 1/3 of the practice trials.

Three types of trials were included in each experimental block. Some were trials on which only H or N were possible, and the O was asked if H occurred; some were trials on which only L or N were possible, and the O was asked if L occurred; and some were trials on which H, L, or N were possible, and the O was asked if any signal occurred. For brevity, we label them H-trials, L-trials, and HL-trials, respectively. The three types of trials were presented equally often, in random order. The nominal probability of S was 0.50 on all trials, and on HL-trials, H and L were equally often presented. For each trial type the O used a separate pair of "Yes" and "No" push buttons, the pairs arranged in order for H-, HL-, and L-trials on the response panel. The trial type, and thus the question the O was to answer, was not indicated to the O until *after* the stimulus presentation, when, during the response interval, the appropriate push-button pair was illuminated. Only the illuminated push-buttons could register a response. Thus, it was not possible for an O to know the trial type in advance, or to be unaware of the trial type information in making his response.

Preliminary Data

Before the main experiments, there were five practice sessions. In the first four of these, only a single type of trial was presented in any given block of trials. The trial types were interleaved in the last practice session. Thus, the first four preliminary data on the detectability of single-frequency and uncertain-frequency signals. Unfortunately, not all practice blocks were run at the signal levels used in Experiment 1. Data from the scattered blocks that were run at the same signal levels are summarized in Table 1. Every O shows a performance decrement in the

Table 1
Preliminary Data: Per Cent Correct Responses for Single-Frequency and One-of-Two Frequency Sessions, Conducted Before the Main Experiments. Numbers in parentheses indicate number of trials in each condition.

S	500 Hz (L-Trials)	1100 Hz (H-Trials)	Uncertain Frequency (HL-Trials)
1	79.1	75.0	69.6
2	72.5	74.3	59.2
3	77.5	73.0	60.8
4	76.6	76.0	58.9
5	72.9	67.3	58.0
6	77.9	77.6	72.7
	(240)	(300)	(319)

HL-trials condition, relative to either the H-trials or L-trials condition. For the group, the overall percent correct on single-frequency trials is 75. The corresponding single-band prediction for uncertain-frequency trials is 62.5%, which is very close to the obtained 63%. For individual Os, the single-band model does not fit quite so impressively.

EXPERIMENT 1

Procedure

The Os were instructed to adopt a specific mode of attention in each session; either to concentrate on just one of the signal frequencies, H, or L, or to listen for both. Two practice sessions and six data sessions were run with these explicit listening instructions. Denoting the listening conditions by symbols for the frequencies to be attended, the order of conditions was: l, hl, h, l, hl, and h.

Aside from the explicit listening instruction (instructions repeated twice each session, before the practice blocks), a wage system was used to encourage detection of the frequency, or frequencies, designated for listening concentration. The wage was based upon trial-by-trial payoff points. These points were small (± 1 point) on two of the three types of trials and large (± 10 points, or ± 15 points) on trials of the third type. Which type of trial was assigned large payoffs depended on the listening condition. For example, if the Os were to concentrate on the 500-Hz signal (listening condition l) correct responses would earn 10 points on L-trials, but only 1 point on HL- or H-trials. Correspondingly, incorrect responses would cost an O 15 points on L-trials, but only 1 point on HL- or H-trials. Thus, each listening condition was associated with a payoff scheme that made responses on one type of trial much more consequential than responses on the others. The payoff points were linearly convertible to money such that a change of 10% in response accuracy on high-pay trials was worth \$1.00 per session. On low-pay trials, a 10% change in accuracy was worth 16c per session. Os commonly

earned about \$2.80 in wages. They were paid an additional \$1.00 per session for consistent attendance and were in competition for two \$10.00 prizes for the best performance over all sessions.

Although this payoff scheme was not expected to motivate the Os greatly beyond what could be achieved by instructions alone, it served as a translation of the instructions into an explicit task with tangible outcomes. The two practice sessions were used to demonstrate the relation between performance and monetary return, but the earnings in data sessions were not revealed until all sessions were complete. Response feedback, used in all data trials, allows each O to monitor his own performance.

Results

Numerical data of Experiment 1 are given in Table 2. Compared to the preliminary data, the interleaved trials had no general effect on response accuracy. Only O 6 shows an overall drop in performance (about 8%); and O 4 was unable to maintain performance on the 500-Hz signal. We were not able to isolate the reasons for these shifts.

The small differences in response accuracy among the three listening conditions indicate that the Os' attentional biases were insufficient to produce major changes in the performance pattern. In most cases, the accuracy differences among the H- and L-trials are not statistically significant. Few of them, for example, exceed 95% confidence limits based upon binomial sampling. Nevertheless, accuracy of H- and L-trials is ordered in a pattern

that is consistent with the listening conditions. A measure of the effectiveness of these conditions that is independent of the absolute performance levels at specific frequencies is easily found by combining data for h and l listening conditions across H and L trials. Symbolically, we compute $[(l_L + h_H) - (l_H + h_L)]/2$ for each O. The resulting values are percentage accuracy differences induced by the listening conditions, for one-frequency trials. For Os 1 through 6, respectively, we get percentage values: 2.80, 5.59, 2.59, 1.30, 3.12, and 4.93. The mean accuracy difference is 3.39%, which is only slightly greater than the standard error (about 2.2% for individual data).

The effect of frequency uncertainty may be evaluated by comparing accuracy on HL-trials with the combined accuracy on H- and L-trials. Data for the combined trials are given in the right-hand column of Table 2. Considering the three listening conditions and six Os separately, there are 18 cases for comparison; in three of these accuracy on HL-trials falls below a 95% confidence band around the value for combined one-frequency trials. Assuming independence, the probability of three or more such occurrences is about 0.06, under the hypothesis that HL accuracy reflects a mixture of performance on H and L trials. A sign-test calculation for the same data indicates an overall accuracy difference significant at the $P = 0.05$ level. When data are combined for all Os, the difference between HL and combined one-frequency accuracy is: 1.8% in condition l; 3.5% in condition h; and 3.0% in condition hl. Thus, the measured decrement due to

Table 2
Per Cent Correct Responses for Experiment 1. Each entry is based upon approximately 425 trials, except the "combined H and L" entries, which are based upon approximately 850 trials. Asterisks between two entries indicate that the accuracy difference is statistically significant at the $P = 0.05$ level.

	Subject	Trial Type			Combined H and L
		L	H	HL	
Listening Condition L	1	74.26	70.77	71.44	72.63
	2	74.71	* 67.44	70.02	71.31
	3	69.98	68.46	66.44	69.27
	4	59.37	* 72.31	64.88	65.43
	5	67.27	63.85	63.53	65.67
	6	70.43	69.49	67.34	69.99
	Mean	69.34	68.72	67.28	69.05
Listening Condition H	1	73.18	75.28	70.29	74.23
	2	70.68	74.59	73.20	72.63
	3	67.50	71.16	69.80	69.32
	4	63.86	* 79.40	61.38	* 71.60
	5	66.29	69.11	62.87	67.69
	6	66.14	* 75.06	68.07	70.58
	Mean	67.94	74.10	67.60	71.01
Listening Condition HL	1	74.22	74.11	70.14	74.16
	2	73.70	73.60	71.09	73.65
	3	67.96	69.76	71.32	68.89
	4	60.67	* 75.63	69.19	68.25
	5	70.05	64.23	61.84	* 67.35
	6	69.27	73.60	62.23	* 71.46
	Mean	69.31	71.82	67.64	70.63

"uncertain frequency" is almost negligibly small: It is not the approximately 10% change that would be predicted by a "narrow band" listening hypothesis.

EXPERIMENT 2

If narrow-band listening was induced at all in Experiment 1, it was not sufficiently consistent or stable to produce the kind of differential responding found in the probe-signal experiments (Greenberg & Larkin, 1968). Because the listening conditions were instructionally defined, we could not be certain that the Os' attempts to heed them were not abated by some other arbitrary aspect of the procedure. We therefore repeated the basic experiment with modifications to check the adequacy of the procedure.

Three aspects of Experiment 1 seemed questionable and led to changes used in Experiment 2. First, the trial-by-trial information feedback, while useful in developing and maintaining high performance levels, may also allow Os to "balance" their performance among the three kinds of trials. Poor performance, even on small-payoff trials, may be unacceptable to Os who may shift their attention in order to prevent it. As performance generally drops somewhat when feedback is removed from signal-detection tasks, the signal intensities were raised a small amount for Experiment 2. This adjustment was also expected to provide somewhat better "cueing" for the signal frequencies.

Second, we noticed that while ostensibly listening for one of the frequencies, Os would sometimes detect the other with greater success. The assignment of listening conditions, it seemed, might better be determined by the individual O, rather than by an arbitrary experimental schedule.

A third aspect was changed, although it was not considered necessary to do so. In Experiment 1, while the large and small payoffs were associated with different trial types, the instructions emphasized the differential importance of signal frequencies. To be more consistent, the large-payoff trials were redefined as those on which the emphasized signal frequency *could occur*, and the small-payoff trials were those on which the emphasized frequency *could not occur*. For example, in listening condition h, all H-trials, and roughly half of the HL-trials were associated with large payoffs; the L-trials and the remaining HL-trials were associated with small payoffs. The associations were reversed in listening condition l. In condition hl, only HL-trials could lead to large payoffs.

Procedure

Experiment 2 followed Experiment 1 in

six sessions with the same Os. Each O was given a blank schedule sheet divided into 12 experimental periods, two periods for each session. After the practice block that began every period, each O assigned to himself a listening condition (and the associated payoff scheme), with the constraint that each listening condition, h, l, and hl, had to be chosen four times. The schedule sheets were collected before the first data block, and changes were not permitted during an experimental period. Response information feedback, present during practice blocks, was removed during all data blocks. The amplitude of the 500-Hz and 1100-Hz signals was raised 1 dB above the level used in Experiment 1. All other details of procedure were the same as in Experiment 1.

Results

Numerical data for Experiment 2 are given in Table 3. The overall level of accuracy is about 5% higher than in the first experiment, with better performance almost uniformly across conditions and Os, but with a distinct performance bias favoring the 1100-Hz signal. Comparison with the preliminary data (Table 1) and with data from Experiment 1 (Table 2) suggests that there may have been a shift in relative detectability of the two signals with practice. Highly practiced Os may not need the 0.2-dB per 100 Hz intensity adjustment reported by Green, McKey, and Licklider (1959) to make signals equally detectable. For the Experiment 2 data, rough calculations indicate that detectability declines at about half this rate as signal frequency is increased.

If we again compute accuracy

differences associated with the listening conditions h, and l, we find no discernable effect. The percentage differences are 0.74, -1.74, -1.58, 1.16, -0.35, and 1.78 for Os 1 through 6, respectively. The mean accuracy difference is essentially zero.

The frequency-uncertainty effect is somewhat stronger than in Experiment 1. The mean difference between combined one-frequency accuracy (combined H and L trials) and the accuracy on uncertain-frequency trials (HL trials) is 4.81% in condition l; 4.86% in condition h; and 1.25% in condition hl. Unlike the first experiment, the relative size of the difference across conditions is quite consistent among the individual Os. Again, however, the uncertain-frequency decrement is less than half the value that would be predicted from a single-band hypothesis.

DISCUSSION

One implication we draw from these data is that the listener—at least the novice listener, with signals of relatively low detectability—does not readily impose narrow-band frequency selectivity in a task that involves widely separate stimulus frequencies. In this sense, the concept of a *listening strategy*, as distinct from an adaptation to the stimulus situation, is brought into question. The instructions and incentives used in these experiments were insufficient to produce any major shifts in detection accuracy; and it is doubtful that any such scheme could be devised to further "motivate" frequency-selective listening. That it is not simply a motivation problem seems clear, because the Os were less able to achieve

Table 3
Per Cent Correct Responses for Experiment 2. Each entry is based upon approximately 425 trials, except the "combined H and L" entries, which are based upon approximately 850 trials. Asterisks between two entries indicate that the accuracy difference is statistically significant at the $P = 0.05$ level.

		Trial Type				
	Subject	L	H	HL		Combined H and L
Listening Condition L	1	83.80	82.62	77.10	*	83.22
	2	75.05	* 84.74	72.51	*	79.88
	3	74.15	78.26	72.63		76.29
	4	67.87	* 81.65	73.38		75.03
	5	73.52	70.77	68.32		72.20
	6	72.79	* 79.67	70.11	*	76.34
	Mean	74.53	79.62	72.34		77.16
Listening Condition H	1	81.70	82.00	75.00	*	81.85
	2	76.20	* 82.42	71.07	*	79.35
	3	76.44	77.39	73.74		76.90
	4	65.54	* 81.84	70.52		73.56
	5	73.04	69.70	72.37		71.43
	6	70.82	* 81.25	67.15	*	75.92
	Mean	73.95	79.10	71.64		76.50
Listening Condition HL	1	78.11	78.85	75.47		78.48
	2	73.96	* 79.50	75.57		76.64
	3	70.38	* 77.18	74.64		73.68
	4	67.43	* 81.59	73.46		74.22
	5	72.58	74.93	73.13		73.81
	6	74.88	* 80.28	74.57		77.49
	Mean	72.89	78.72	74.47		75.72

differential response accuracy when they could choose their own listening assignments (Experiment 2) than when the conditions were assigned arbitrarily (Experiment 1). We suspect that the role of instructions or incentives in these experiments is quite different than it is in a single-frequency task. In the latter case, it is reasonable to suppose that Os can freely adjust levels of concentration or effort to achieve a desired level of performance (as in an experiment by Clopton & Watson, 1969). In our experiments, it is not the level of concentration, but the allotment of attention or sensitivity that is at issue. If the single-band hypothesis, or any similar hypothesis that permits free adjustment of the listening band is correct, then the effects of differential listening should parallel the effects of differential signal intensities or presentation probabilities. The suggestion from our data is that the effects are not parallel: Rather, the listener's performance seems to be quite severely stimulus-determined. As Sorkin et al (1969) observed, the effective listening band may be a relatively long-term adaptation to a stimulus context. A short-term change in the band may be possible only if there is an appropriate change in stimulation. For example, differential sensitivity in the uncertain-frequency experiment might be achieved by repeatedly presenting one of the signals as a "sample tone" on each trial, or by practice listening with the emphasized frequency. These procedures were used in the probe-signal study (Greenberg & Larkin, 1968), and may be responsible for the stable narrow-band response functions found in those experiments.

The narrow-band hypothesis is also inconsistent with our measurements of the uncertain frequency decrement. As in previous studies, the decrement is variable across Os, but it is consistently smaller than the amount predicted by a single-band hypothesis. The data we used to make this comparison are (1) results from HL trials, on which either of the signals were possible, and (2) combined results from H and L trials, on which only one signal was possible. Because these three kinds of trials were interleaved, the a priori stimulus uncertainty was the same for each of them. Thus, to have an uncertainty difference, the uncertainty must be computed for the poststimulus period of each trial, e.g., for the period during which the available response alternatives were indicated to the Os. This period began 100 msec after the signal presentation. All other sources of differential effects were equated; the amount of stimulus variability, the mean interpresentation time for the signals, the Os' concentration level, and the listening

instructions. For most Os, performance on HL trials was below both values for the one-frequency trials, i.e., HL accuracy was not predicted by any weighted combination of the one-frequency data. For these Os, it might be claimed that the only possible source of the decrement is poststimulus processing of the sensory input, cued by the trial identification lamps. In this sense, one-frequency performance reflects an improvement due to poststimulus uncertainty reduction.

A more adequate comparison for the single-band theory could be made by comparing HL performance in the hl listening condition with mean one-frequency performance calculated only from the corresponding listening conditions, h and l. This comparison assumes that the three listening conditions can be treated as independent experiments, in which conditions h and l represent single-frequency narrow-band listening, and condition hl represents only the uncertain-frequency task. Again, the results are variable across Os, with an average decrement of 3% in Experiment 1 and 4% in Experiment 2. However, in view of the apparent failure of narrow-band listening, this comparison represents single-band theory less well than would be desirable.

If perceptual filtering or attenuation of input is the mechanism for selective attention, then these results seem especially anomalous, and some speculation seems appropriate. We found that the degree to which deliberate attending can alter performance in the uncertain frequency task is meager compared to (1) results of previous studies in which the apparent span of frequency sensitivity was quite narrow, and (2) the well-established ability of listeners to extract desired information selectively from complex patterns (see Neisser, 1967). Current views of perceptual attention regard it as a more complicated system than one that affects only the effective energy, or loudness of a signal. In particular, a nonselective analysis of the codable features of sensory input is presumed to take place *prior* to any further processing that may be selective (see Neisser, 1967 or Norman, 1969). In a sense, then, selective attention may be a phenomenon of recognition, rather than of detection.³ If so, no amount of training or experience in the uncertain frequency task should be able to alter the relative detectability of the two signals. However, any differential experience, whether provided by practice listening, a "sample tone," or biased presentation probabilities, may enable the listener to become a more efficient recognizer of one signal than of the other. The challenge, of course, is to devise procedures to separate the effects.

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NOTES

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3. Shipley (1965) studied the role of recognition in the uncertain frequency task from the point of view of choice theory. Her analysis assumed covert recognition responses prior to the detection decision. If such covert responses occur

in the present experiment, they provide a possible account of the difference between one- and two-frequency performance. When two frequencies are possible, the detection decision may simply mirror the covert recognition response, except, perhaps, for response bias. However, on one-frequency trials, the information

provided by the response indicator lamps makes greater decision accuracy possible. The improvement could occur in a variety of ways; by a Bayesian rule, a constant-ratio rule, or a deterministic scheme for collapsing three response categories into two. While such a strategy is possible in the present experiments, it seems unlikely as a

general explanation, because it would imply that performance differences across separated one- and two-frequency experiments result from covert recognition in the simple one-frequency detection task.

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