Matching to sample of three-tone simultaneous and successive sounds by musical and nonmusical subjects*

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Simultaneous and successive sounds composed of three pure tones were judged by a three-choice matching-to-sample procedure. Music students performed significantly better than nonmusic students, particularly under conditions where the choices involved successive sounds. Serial position effects among the three choices were analyzed in terms of signal detection theory. Nonmusic Ss showed a decrease in discriminability (d') from the first to third choice; music Ss were also best at discriminating the first choice but had the lowest d' for the second choice. These results were interpreted as indicating a qualitative difference in the manner in which music students respond to tonal sequences.

Students with formal music training can discriminate simultaneous and successive sounds composed of two pure tones better than can nonmusic students, but the differences between groups have appeared to be quantitative rather than qualitative (Doehring, 1971a). Qualitative differences might, however, emerge with listening tasks of greater complexity. In the present study we presented simultaneous and successive sounds composed of three pure tones to music and nonmusic Ss. Their task was to judge which of three simultaneous or successive sounds matched a simultaneous or successive sample sound. The use of three-choice matching to sample permitted assessment of serial position effects among the choices in terms of signal detection theory (Doehring, 1971b). Our purpose was to determine if music Ss might differ qualitatively from nonmusic Ss in their performance of the three-tone three-choice tasks, in the hope thereby of obtaining further insight into the perception and memory processes involved in responses to complex sounds.

METHOD

The Ss were 12 university music students with at least 8 years of formal training and 12 students with no formal music training. All had normal hearing and were right-handed in writing and throwing. Right-handed Ss were chosen in an effort to obtain homogeneity of the groups with respect to ear dominance (Kimura, 1967). None had participated in previous studies of this type. Tones were tape-recorded from a Johnson

Intonation Trainer that had been modified to produce pure tones of equal loudness. Tapes were played back from a Revox 77A tape recorder to Echo HS-606 earphones.

Simultaneous sounds were chords, namely, three tones played together for $\frac{1}{2}$ sec. *Successive sounds* were arpeggios, three $\frac{1}{2}$ -sec tones played in immediate succession. The interval between sounds, either simultaneous or successive, was always 1 sec. The matching-to-sample procedure required S to indicate which of three sounds following the sample sound contained the same notes as the sample. The judgments were made under four conditions: (1) *simultaneous-simultaneous*—sample chord followed by three test chords; (2) *successive-successive*—sample arpeggio followed by three test arpeggios; (3) *successive-simultaneous*—sample arpeggio followed by three test chords; (4) *simultaneous-successive*—sample

chord followed by three test arpeggios. Trial durations for the four conditions were 5, 9, 8, and 6 sec, respectively. Within a given trial, the successive tones were all played either from highest to lowest or from lowest to highest.

Tones were selected from the range of G3 (196 Hz) to C5 (523 Hz). In any given sound, the high and low notes could differ by 8 to 19 semitones, and the middle note was 3 or more semitones from either extreme. Only the middle note was varied within a trial, with 3 adjacent semitones used for the choice sounds. A series of 96 trials was prepared in which there were 12 trials to each ear under each condition. The order of conditions and ears was randomized.

The Ss were tested individually in a sound-treated room, with sounds presented monaurally at about 80 dB. Detailed instructions were given regarding the four conditions, but Ss were not informed that only the middle tone had been varied in the three-tone sounds. Responses were made by pushing an appropriately marked button, with immediate knowledge of correctness given by illumination of the pushbutton representing the correct choice.

RESULTS

Percent correct judgments by each group are shown in Table 1 as a function of conditions and ears. Results obtained for the four conditions by two-choice two-tone matching to sample in the previous study (Doehring, 1971a) are also given. A t test showed that the music group was significantly superior to the nonmusic group (.01 level). The results for each group were then analyzed separately by analysis of variance, with significant effects further assessed by the Newman-Keuls test where necessary.

Table 1
Percent Correct Judgments in Three-Choice Matching to Sample for Three-Tone Sounds, With Previous Results for Two-Choice Two-Tone Matching to Sample (Doehring, 1971a) Also Indicated

	Three-Choice, Three-Tone						Two-Choice Two-Tone	
	Music			Nonmusic			Music	Nonmusic
	(N = 12)			(N = 12)			(N = 8)	(N = 8)
	R	L	R + L	R	L	R + L	(Doehring, 1971a)	
1. Simultaneous-Simultaneous	83	78	81	60	60	60	93	96
2. Successive-Successive	82	86	84	54	57	56	95	88
3. Successive-Simultaneous	38	58	48	40	38	39	74	58
4. Simultaneous-Successive	47	42	45	35	25	34	84	56
Total	63	66	64	47	48	47	86	75

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For the music group, there was a significant difference among conditions (.01 level), with judgments under Conditions 1 and 2 significantly more accurate than those under Conditions 3 and 4 (.01 level). Ears did not differ significantly, but there was a significant interaction between series and ears (.01 level) which was attributable to a large left-ear superiority under Condition 3 in comparison to the small ear differences under other conditions.

For the nonmusic group, there was also a significant difference among conditions (.01 level), with no significant ear difference or Condition by Ear interaction. Further analysis showed that nonmusic Ss were significantly more accurate for Condition 1 than for Condition 2 (.05 level), for Condition 2 than for Condition 3 (.01 level), and for Condition 3 than for Condition 4 (.05 level).

The results for each group were pooled over conditions and ears for analysis of serial position effects in terms of signal detection theory (Doehring, 1971b). Hit rate was proportion of trials on which the matching sound was correctly detected at each position; false-alarm (FA) rate was the proportion of incorrect responses at each position relative to the total possible incorrect responses at that position; the relative discriminability (d') of each position was determined from tables prepared by Elliott (1964). Table 2 shows mean hit rate, FA rate, and d' at each position for each group. Differences in hit rate and d' among positions were assessed for each group by analysis of variance and the Newman-Keuls test. There was a significant difference among positions (.01 level) for both hit rate and d' . For the music group, hit rate for the first choice was significantly higher (.01 level) than that for the second and third choices, which did not differ, and FA rate decreased steadily from first to third choices. As a consequence, the first choice was significantly more discriminable than the second (.01 level), but not the third choice, with the second and third choices not differing significantly. For the nonmusic group, hit rate was significantly higher for the first than for the second (.05 level) and third (.01 level) choices, and the second was significantly higher than the third choice (.05 level). FA rate was identical for the first two choices and slightly lower for the third; and the first choice was more discriminable than the third (.05 level), but the second choice was not, with the second and third choices not differing significantly.

Table 2
Signal Detection Analysis of Serial Order Effects Among the Three Choice Sounds for Combined Conditions, Series, and Ears

	Serial Position of Choice Sounds		
	1	2	3
Music (N = 12)			
Hit Rate	.76	.58	.58
FA Rate	.22	.18	.14
d'	1.87	1.48	1.67
Nonmusic (N = 12)			
Hit Rate	.54	.48	.40
FA Rate	.27	.27	.25
d'	1.04	.86	.75

DISCUSSION

The main differences between the present study and two previous studies (Doehring, 1968, 1971a) were that sounds contained three notes instead of two, there were three instead of two choice sounds, and the four conditions were randomized from trial to trial instead of being presented in separate blocks. As before, neither group perceived simultaneous and successive sounds in a completely equivalent manner. This was indicated by the large decrease in accuracy from Conditions 1 and 2 to Conditions 3 and 4, which contained a mixture of simultaneous and successive sounds. Gibson's (1966) assertion that the span of perception of simultaneous stimuli is equivalent to the span of memory for successive stimuli should, therefore, be interpreted with some caution.

The original purpose of this series of studies was to determine how well Ss could "hear out," in the sense of Ohm's acoustical law, the components of simultaneous tones with reference to their responses to temporally discrete tonal sequences. The results for nonmusic Ss demonstrate the inappropriateness of such an approach, since they found the matching-to-sample task more difficult when the choice sounds were successive (Conditions 2 and 4) than when they were simultaneous (Conditions 1 and 3). Rather than pursue the testing of this perceptual model, it seems best to determine what parameters contribute to the relative difficulty of responding to simultaneous and successive tones.

The poorer performance of nonmusic Ss with successive sounds as choices is probably attributable to the greater demands on immediate memory associated with trials of longer duration, interference from temporally sequenced sounds, or both. In any case, music talent and experience can be said to facilitate immediate memory for three-tone sequences to an even greater extent

than it facilitates abstraction of the components of simultaneous tones.

The analyses of serial position effects also demonstrated differences in memory as a function of music background. For both groups, the first choice was by far the most easily detected as matching the sample. The further decrease in both hit rate and discriminability from the second to third choice for the nonmusic Ss might indicate that they did not wait until all sounds had been presented before making comparisons with the sample sound, but formed a judgment as each sound was presented. Such a relatively simple explanation would not, however, fit the results for music Ss, who showed an improvement in discriminability from the second to the third choice after adjustment for differences in FA rate. Since music Ss found the first and last choices most discriminable, they may have stored the series of four samples and choice sounds as a single tonal sequence before forming a judgment. In such a case, identity of the sample sound and the adjacent first choice sound would still be most easily compared, but the third and last choice should be more easily compared than the second choice because of its peripheral location in the sequence.

Ear differences were assessed because left-ear superiority indicative of right-hemisphere dominance for tonal perception might be expected in right-handed Ss (Kimura, 1967), and differences between groups in ear asymmetry could provide another indication of qualitative differences in the auditory processes of music and nonmusic Ss. The lack of significant ear differences for either group might be attributable to the relatively high intensity of the test sounds.¹ However, the significant interaction of ears and conditions for music Ss does suggest differences between groups in ear asymmetry. It is not obvious why only the successive-simultaneous condition should result in ear asymmetry for music Ss, but further study of ear asymmetry, using simultaneous and successive sounds of lower intensity and preferably dichotic presentation, should provide more information about hemispheric specialization for the processing of tonal stimuli in relation to music background.

In the present study, we have found qualitative differences in the manner in which Ss with music aptitude and experience respond to complex tones. The most important aspect of the observed differences seems to lie in the processing of tonal sequences in immediate memory. Although there are obvious problems in specifying the extent to which aptitude, training, and

experience contribute to differences between music and nonmusic Ss, the study of perception, memory, and decision processes in highly proficient, as compared with normal, listeners should add to our understanding of human audition in general and also contribute to a more valid description of musical ability.

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NOTE

1. Doehring, D. G. Ear asymmetry in the discrimination of monaural tonal sequences. Unpublished manuscript, 1971.