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Dichotic recognition of musical canons: Effects of leading ear and time lag between ears

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A musical canon consists of two melodic lines with the second part copying the first exactly after some time delay. Right-handed adults listened to canons presented dichotically at time delays between the ears of 2, 4, and 8 sec. Presentation rate varied from 1.0 to 4.4 notes/sec in one part. Different groups of subjects heard the canons with the left or the right ear leading. The subject's task was to tell whether a given stimulus was a canon or not. Control stimuli were noncanons by the same composer. Musically experienced subjects performed better at the task than inexperienced subjects. Short time lags were easier than long, and the effect of lag was more pronounced with the right ear leading. In the light of previous evidence of functional ear asymmetry in music perception, these results suggest that whenever possible subjects use a strategy of selecting out small chunks of the lead-ear melody for short-term memory storage and later comparison with the trailing melody. The auditory system processing information from the right ear is especially good at focusing on small chunks. But this strategy is particularly vulnerable to time lag; hence the interaction of lead ear and time lag.

In a musical canon, the melodic line of one voice is copied exactly by a second voice following the first at some time interval. This is the general rule followed by the familiar rounds "Row, Row, Row Your Boat" and "Frère Jacques." These rounds illustrate the special case of a canon in which several parts enter at regular intervals of time and the first part starts again from the beginning at the same time interval after the entry of the last part (Tovey, 1956, pp. 19-25). The present experiment deals with two-part canons in which the second part follows the leading part at the same pitch level at time lags of 2, 4, and 8 sec. Each canon stimulus was a passage approximately 20 sec long from one of Telemann's (N.D.) *Canonical Sonatas, Op. 5*, which were first published in 1738. Right-handed adults listened to these canons dichotically, with either the right or the left ear leading. The listener's task was to say whether or not each musical fragment was or was not a canon. On certain trials, control stimuli were presented. These were drawn from noncanonical sonatas by Telemann (N.D.), and were of similar musical style to the canons. Each subject listened to all the canons with the leading part in the same ear, and each was told which ear that would be.

The task of identifying a dichotic tonal sequence as a canon is one of recognizing that two melodies are identical, when the melodies are presented overlapping in time and in the two separate ears. The listener knows to which ear the leading part will be presented, and he can try to remember features of that part for later comparison with the trailing part. This task is quite easy when the canons are presented as they are in performance, with the leading part starting out alone and the trailing part entering after the specified time delay playing exactly the same melody.[1] In this study, all the canons started at the point where the trailing part entered. This made the task much more difficult, since the listener had no obvious cue as to the time delay at which he should listen for the repetition of the leading melody in the trailing part. The time during which the trailing part contained a melody identical to that presented in the leading part was kept constant at 15 sec. Therefore the stimuli were of varying lengths, depending on the time lag between the parts. The leading part consisted of 15 sec of melody to be copied in the trailing part, plus new material (of duration equal to the time lag) presented while the trailing part finished its 15 sec of copying. The trailing part started with material not previously heard for the duration of the time lag, followed by 15 sec of copying the leading part. The verbal analog of this presentation method would be if the lead ear received: "*Gently down the stream, Merrily, merrily, merrily, merrily*, Life is but a dream;" while the trailing ear received: "Row, row, row your boat, *Gently down the stream, Merrily, merrily, merrily, merrily*." [The copied material is italicized. This

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verbal analog is similar to Treisman's (1964) dichotic listening task, with the difference that there the listener's attention was concentrated on one ear by shadowing.] The canon stimuli were thus of 17, 19, and 23 sec duration for time lags of 2, 4, and 8 sec. Noncanon stimuli were randomly assigned durations to match.

There is considerable evidence that the two ears perform differently on melody recognition tasks. Early results (Kimura, 1964) showed an advantage of the left ear over the right in melody recognition. More recently, Bever and Chiarello (1974) found better performance in melody recognition to be associated with right-ear superiority. Bever and Chiarello interpreted their results as illustrating the functional asymmetry of the two hemispheres of the cerebral cortex. It seems well established that the two sides of the cortex are functionally more closely related to the contralateral ear than to the ipsilateral one (Darwin, 1974). Bever and Chiarello theorized that the right-ear/left-hemisphere system should be better at recognizing fragments of melodies, as an aspect of the purported superior analytic abilities of the left hemisphere. The left-ear/right-hemisphere system should be better at processing whole melodies. They argued that the more musically experienced the listener, the more he will use an analytic strategy in recognizing melodies. That is, he will excerpt fragments of the melody to hold in memory for later comparison. Bever and Chiarello attributed the right-ear superiority of their experienced subjects to their use of an analytic strategy. A major difficulty with this interpretation is that the right-ear advantage of experienced subjects is just as pronounced with whole melodies as with fragment recognition. As Bever and Chiarello suggested, this may have been due to the difficulty level of the task.

One possible source of the failure of Bever and Chiarello's task to disclose different functional asymmetries between whole melodies and parts with their experienced subjects may have been their reliance on monaural presentation. Darwin (1974) points out that asymmetrical performance is most often observed with tasks in which competing stimuli are presented to the two ears. The present experiment uses dichotic presentation in an attempt to bring out differences between the performance of the two ear-hemisphere systems. Subjects could be expected to use different strategies depending on which ear receives the leading and which the trailing stimulus. The ear-hemisphere system receiving the leading stimulus should process it in a way that facilitates comparison with the trailing stimulus. If it is the case that the right-ear/left-hemisphere system is good at remembering melodic fragments, then it will follow a strategy of excerpting a salient chunk of the lead melody, storing it in memory, and waiting for a similar fragment to occur in the trailing part (Strategy A). The left-ear/right-hemisphere system, not being as good at fragment recognition, should rely on a strategy of using overall features of the whole melody for its comparison—general pitch range, timbre, tempo, rhythmic regularity, etc. (Strategy B).

With both strategies, the task should become easier with shorter time lags between the stimuli in the two ears. That would agree with Treisman's (1964) result that as the time lag between dichotic messages was shortened, more subjects realized that the messages were identical. But Strategy A should be more affected by time lag than Strategy B, since Strategy A depends on the recognition of specific chunks of the stimulus. Dowling (1973) showed that short-term memory for five-note chunks of melodies follows the usual J-shaped serial position curve for melodies 5 to 10 sec in length. This means that intervening to-be-remembered material interferes with memory for previously presented chunks. In the present task, as in Dowling (1973), interfering material follows the initial chunks the subject selects for storage. The longer the subject has to wait before recognizing them, the more interfering material he will hear, and the worse will be his performance. It may also be that, faced with the difficulty of remembering a chunk for longer periods of time, the subject may concentrate his search on that part of the trailing melody immediately following the stored chunk in the leading melody. This should have the same deleterious effect on performance at longer time lags. Strategy B should not show as great a dependence on time lag, since the features used for comparison change much less rapidly in the music itself than do the pitch patterns used by Strategy A. These features do not need to be stored in memory, since they are continuously available in the lead melody itself. Strategy B relies mainly on simultaneous matches between the leading and trailing stimuli, depending very little either on memory or on finding the right search window. Since the broad, overall features used by Strategy B change slowly over time, there should be a slight effect of time lag when it is used. If the right-ear/left-hemisphere system uses Strategy A and the left-ear/right-hemisphere system Strategy B, a Lead Ear by Time Lag interaction should result.

In addition to the variables of lead ear and time lag, the stimuli were also categorized according to tempo: Fast (4.0 to 4.4 notes/sec in one of the parts), medium (2.2 to 3.5 notes/sec), and slow (1.0 to 1.6 notes/second). Since Telemann did not write a fast canon with an 8-sec time lag, only eight of the nine possible stimulus types appear in the experiment. Table 1 shows the source and categorization of the 17 canons used in the experiment. Since these, with the sample canon presented with the instructions, comprise all of the canons Telemann wrote for flute,

Table 1
Musical Selections by Teleman Used in the Experiment

	Sonata	Movement	Time Lag (sec)	Tempo (notes/sec)	Tempo Category
			Canons (from Op. 5)		
	2	3	2	4.4	F
	2	1	2	4.3	F
	3	3	2	3.1	M
	6	3	2	3.0	M
	1	3	2	1.6	S
	5	2	2	1.5	S
	5	3	4	4.4	F
	6	1	4	3.5	M
	5	1	4	3.1	M
	1	1	4	1.6	S
	1	2	4	1.6	S
	2	2	4	1.0	S
	3	1	8	2.6	M
	4	1	8	2.2	M
	4	2	8	1.6	S
	3	2	8	1.3	S
	6	2	8	1.2	S
			Sample Canon		
	4	3	2	3.8	F
			Control Stimuli		
Dresden	1	1		4.0	F
Dresden	3	2		4.2	F
Op. 2	2	2		3.0	M
Op. 2	2	4		2.6	M
Dresden	1	2		2.3	M
Op. 2	1	3		1.4	S
Op. 2	2	1		1.4	S
Op. 2	2	3		1.4	S
Op. 2	3	3		1.0	S
			Sample Control Stimulus		
Op. 2	1	1		2.4	M

Note–F = fast tempo; M = medium tempo; S = slow tempo.

there were necessarily different numbers of stimuli in the different categories. The nine noncanon stimuli (Table 1) were selected to reflect the overall proportion of control stimuli of approximately .33 within each tempo category, but with the addition of a second fast stimulus to give more stable data points. Each subject heard all the stimuli with the same ear leading on the canons. Lead ear was controlled by orientation of the headphones, so that both conditions used exactly the same stimuli. The stimuli were recorded in one random order which was the same for all subjects.

METHOD

Stimuli

The stimuli were played on an alto recorder and tape-recorded. Both parts of both the canons and the control stimuli were played by the same musician and recorded successively on separate tape channels. Timing of presentation was controlled by a Davis timer functioning as a metronome, which was barely audible on the tape. Stimuli were presented to subjects dichotically via earphones over high-quality sound-reproduction equipment. The range of fundamental frequencies of the stimuli was 350 to 1,400 Hz.

Subjects

Twenty-four California State University, Los Angeles, undergraduates served in individual sessions for course credit in introductory psychology (5 males and 19 females). The subjects were recruited with the stipulation that they be right-handed, and were given a brief questionnaire concerning handedness upon their arrival at the laboratory. [The emphasis on handedness is due to the theorized functional asymmetry of the brain. Right-handed subjects would very probably have analytic language functions located in the left hemisphere (Milner, 1974).] The subjects also completed a brief musical autobiography. The subjects were blindly assigned to conditions with left or right ear leading, and were assigned to groups on the basis of musical experience. The inexperienced group had never had any music lessons on any instrument or voice. Subjects in the experienced group had had at least 2 years of musical training, including lessons on an instrument or voice or playing in an ensemble, but not including singing in choirs or music appreciation classes. The experienced group had a mean of 5.1 years' experience and a median of 4.8 years. Eight prospective subjects who reported to the laboratory were not used in the experiment on the basis of questionnaire or autobiography responses. There were six subjects in each of the four Lead Ear by Experience groups, with no more than two males in a group.

Procedure

After completing the questionnaires, the subject received instructions. The experimenter explained the concept of a musical canon or round as involving two parts, one of which copies the other exactly after some time lag. The subject listened to the round "Frère Jacques" presented with two parts dichotically via the earphones. The experimenter explained that the same ear (right or left, depending on condition) would always lead and the other ear follow if the stimulus was a canon. The experimenter explained that the stimuli in the experiment would be different from the "Frère Jacques" the subject had just heard in that they would plunge right into the middle of the music with both parts playing at once, but that if the stimulus was a canon the second ear would still be copying the first exactly. The subject then listened to the sample Telemann canon. If the subject was puzzled by the example, it was repeated until he reported hearing the second part copy the first. Three out of the 24 subjects required repetition of the sample. The sample noncanon was then played. The experimenter explained the confidence-level response system and noted that, of the 26 stimuli, 17 would actually be canons and 9 would not. The subject responded with pen on a single sheet of paper with a numbered blank for each response, using a four-level confidence rating scale of "Sure Canon," "Canon," "Not Canon," and "Sure Not Canon." After each stimulus, there was 10 sec in which to respond. A warning beep preceded the onset of the next trial by 2 sec.

RESULTS

Areas under the memory operating characteristic (MOC) were calculated for each subject for each of the eight stimulus categories. False-alarm rates were based on responses to control stimuli in the same tempo category as the canon stimulus in question. Area under the MOC approximates a bias-free estimate of correct response rate where chance is .50 (Swets, 1972). Three analyses of variance were run on the areas under the MOC. First was an overall analysis of 8 Stimuli by 2 Conditions (right or left ear leading) by 2 Groups (experienced or inexperienced). Table 2 shows the cell means for this analysis. The effect of Experience was significant [$F(1,20) = 16.92$, $p < .01$], with experienced subjects performing better. The only other significant effects were those of Stimuli [$F(7,140) = 2.34$, $p < .05$] and the Conditions by Stimuli interaction [$F(7,140) = 2.09$, $p < .05$].

Because of the significant results of the overall analysis, the planned analysis of variance to test for the hypothesized Conditions by Time Lag interaction was carried out. The data were collapsed across tempos for each subject to give 3 Time Lags by 2 Conditions by 2 Groups. The results are shown in Figure 1. The effects of Experience [$F(1,20) = 16.40$, $p < .01$] and of Time Lag [$F(2,40) = 6.67$, $p < .01$] were significant. The only other significant effect was the Conditions by Time Lag interaction [$F(2,40) = 4.12$, $p < .05$].

As a check on possible effects of tempo, a similar analysis was run for Tempos by Conditions by Groups. The only significant effect was that of Experience [$F(1,20) = 16.40$, $p < .01$].

DISCUSSION

Differences in performance, depending on which ear receives the leading part in a dichotic canon, seem well substantiated by these results (Figure 1). Subjects for whom the right ear led followed a strategy which was markedly affected by time lag between parts. It seems reasonable to suppose that this strategy is one of excerpting chunks of the lead melody, storing them in memory, and then searching for them in the trailing melody. Whether the time-lag dependence is due to memory processes (decay or disappearance of the chunk) or to perceptual processes (time span of the search window in the trailing part), it strongly suggests a strategy based on chunk storage. This is in contrast to the strategies followed when the left ear was leading, which were not nearly so time-dependent. Moreover, both musically experienced and inexperienced subjects show the same pattern of results. This is in contrast to the results of Bever and Chiarello (1974), suggesting qualitative differences in listening strategies between experienced and inexperienced subjects. On the present task, at least, the effect of musical experience seems to be simply to enhance overall performance rather than change basic cognitive strategies. The same kind of functional asymmetry of the brain for listening strategies appears to hold for persons at both levels of experience.

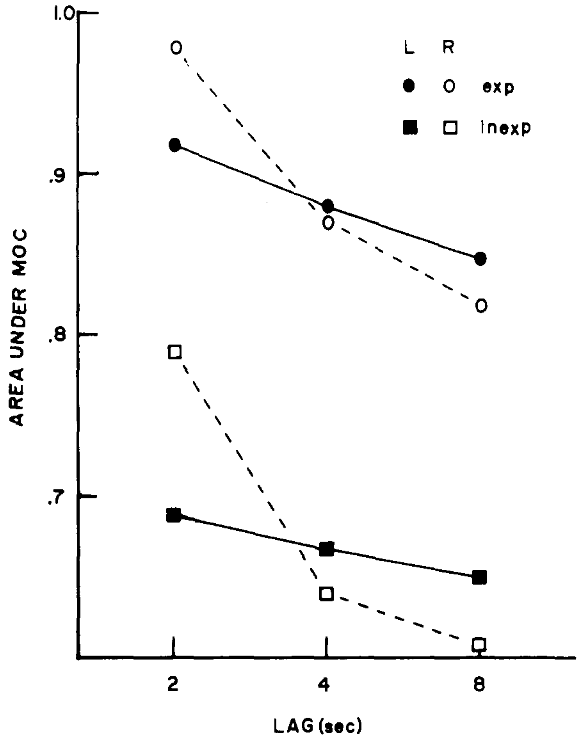

Figure 1. Mean areas under MOC for experienced (circles) and inexperienced subjects (squares) listening with either the left (filled symbols) or right (open symbols) ear leading, as a function of time lag between ears. Data have been collapsed across tempo categories. (N = 6 for each point.)

Table 2
Mean Areas Under MOC for Experienced (E) and Inexperienced (I) Subjects Listening with Either Left or Right Ear Leading

Lag	Tempo	Lead Ear: Left E	Left I	Right E	Right I
2	F	.92	.65	.96	.81
	M	.92	.72	1.00	.71
	S	.89	.70	.97	.86
4	F	.88	.71	.83	.58
	M	.96	.57	.85	.63
	S	.82	.72	.94	.72
8	M	.88	.68	.81	.43
	S	.80	.61	.83	.78

Note—Stimuli had time lags between parts of 2, 4, and 8 sec, and had fast (F), medium (M), or slow (S) tempos (N = 6).

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NOTE

1. Subjects in a pilot study made almost no errors when the stimuli began with one part playing alone. This agrees with previous results on melody recognition (Dowling & Fujitani, 1971). This is not surprising since the presentation is exactly like the standard recognition-memory paradigm except for the addition of the distracting presence of the continuation of the standard stimulus during the presentation of the comparison.

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