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Abstract

In an investigation of interactions between scales intervals in music cognition, melodic intervals were judged in three preceding scale contexts: (a) diatonic, (b) chromatic, and (c) no scale. Musically less trained and highly trained subjects compared standard and comparison intervals using three response categories, "smaller," "equal," and "larger". Standard intervals began with notes B or C and ascended by 100, 150, or 200 cents. A discriminal dispersion was estimated for each combination of standard and comparison intervals, which assumed that the bandwidth of subjective equality was constant. The dispersion width and the modal dispersion corresponded to the equality-related and size-related aspects of interval judgments, respectively. The size-related aspect was strongly influenced by the size of standard intervals. The point of balance, which corresponds to the traditional point of subjective equality (PSE), tended to be smaller as the standard interval became larger. It was, however, anchored to the point of musical equality when the standard interval began with the tonic. The equality-related aspect was influenced by the relationship between the preceding scale and the intervals to be judged. The diatonic preceding scale differentiated the intervals by their positions along the scale, that is, a sharp discriminal dispersion was estimated when the judged intervals were congruent with the diatonic scale. Such differentiation was not clearly observed in the chromatic condition. The relationship between these two aspects of interval judgment and the subject's musical ability is discussed.

Introduction

One of the most prominent characteristics of melody is "transposability," that is, transposed melodies are heard as having the same patterns as the originals (at least in Western tonal music). They differ from the originals in terms of the pitches of which they are composed, but are equal to the originals in terms of their constituent intervals. It is therefore quite reasonable to assume that listeners encode melodies in terms of pitch intervals.

Much research, however, has indicated that non-musicians are unable to judge the sizes of intervals precisely or consistently enough to explain transposability. Siegel and Siegel (1977a) reported that non-musicians could not consistently identify intervals except for unisons. Burns and Ward (1978) found that the average discrimination threshold for intervals among non-musicians was 36.8 cents higher than among musicians.

Considering that we develop the ability to identify a transposed melody without intensive training in music, these experimental results seem to refute the assumption that melodies are encoded in terms of intervals. In fact, Burns and Ward (1982) warned against hastily connecting the perception of individual intervals with the perception of music. As they argued, melodies are perceived as Gestalts rather than as a succession of individual intervals. Therefore, it becomes important to investigate the effects of contextual musical events.

In order to investigate the effects of musical contexts, recent studies have been concerned with the psychological significance of tonality (Dowling, 1986; Hoshino & Abe, 1984; Bartlett & Dowling, 1980; Krumhansl, Bharucha & Castellano, 1982). Tonality is a musicological concept that implies the tendency of a musical segment to center on a particular pitch class. Although some music theorists argue against a notion that tonality is imposed mainly by a tonal hierarchy within a key (Narmour, 1977), most melodies in Western tonal music consist of pitch classes which are members of a diatonic scale. Within the diatonic scale one pitch class, the tonic, functions as the melodic center. Besides the tonic, the diatonic scale has other prominent pitch classes, such as the dominant and subdominant. In other words, the pitch classes in the diatonic scale are hierarchically structured according to many music theorists (Meyer, 1973; Lerdahl & Jackendoff, 1983). Such a hierarchical structure is not only asserted in much music theory, but has also been the subject of psychological experiments (Krumhansl, 1979, 1990; but see also Butler, 1989, 1990).

Since each pitch has its own position in the musical scale, each interval must be regarded in relation to the scale system. Unfortunately, most of the preceding studies on interval perception did not use a rich musical context. Therefore, it is important to investigate the influence of scale systems on interval perception .

The purpose of the present research was to investigate such an influence. Subjects were required to judge the relationship between two successive intervals under conditions in which the preceding scale was either diatonic or chromatic.

Balzano (1982) has pointed to three characteristics of the diatonic scale: uniqueness, coherence, and simplicity. "Uniqueness" means that each of the scalar elements has a unique set of relationships to the others. The chromatic scale, in contrast, lacks "uniqueness." A scale composed of equal divisions, such as the chromatic scale and the whole tone scale, cannot satisfy this requirement.

It is assumed that the diatonic scale might contain, because of its "uniqueness," more psychological reference or anchoring points than the chromatic scale. If these reference points function for any interval or pitch class, comparative judgments concerning intervals will be more finely tuned in a diatonic context than in a chromatic context. However, if there is an interval or a pitch class which conflict with a diatonic context, these reference points will not function as such. In this case, pitch interval judgments in the diatonic context will be more confused than those in the chromatic context because a step in the diatonic scale does not always correspond to the identical interval size in cents.

Before discussing interval judgments, we must carefully consider two aspects of such judgments: the size-related aspect, and the equality-related aspect. When two intervals are presented, we can judge which one is the larger. This kind of judgment is assumed to reflect the size aspect. On the other hand, we know that listeners perceive intervals categorically in musical situations (Siegel & Siegel, 1977b). In Western tonal music, all possible intervals (i.e., microtones) do not necessarily have musical meaning. Thirteen discrete pitch intervals are selected from within the octave. Listeners often either cannot detect, or are able to ignore slight deviations from the ideal value of musical interval although they can detect the same degree of the deviation from the value of a non-musical interval. In such a situation, people would be more sensitive to the equality aspect than to the size aspect of interval judgment. In order to separate the two aspects, a new method of analysis is proposed in Results Section of Experiment 1.

Experiment 1

Subjects with less musical training were tested in the pitch interval discrimination task to investigate what effects the preceding scale had on the size and equality aspects of interval judgment.

Method

Subjects

Thirty undergraduates from Konan Women's College and Osaka University participated in the experiment. All had normal hearing. None majored in music. Although they had taken piano or organ lessons for an average 8.9 years according to their answers to questions about their musical experience, they could not be regarded as eager trainees.

Stimulus

On each trial subjects listened to a sequence consisting of (a) a preceding scale, (b) a standard interval, and (c) a comparison interval. The preceding scale was either diatonic or chromatic. The diatonic preceding scale began with C4 (261.6 Hz), and proceeded upward one octave. It consisted of eight notes (C4, D4, E4, F4, G4, A4, B4, and C5). The intervals between two contiguous notes in this scale were therefore 200, 200, 100, 200, 200, 200 and 100 cents, respectively. The chromatic preceding scale began with F4 (349.2 Hz). It also consisted of eight notes (F4, F#4, G4, G#4, A4, A#4, B4, and C5). All the intervals between contiguous notes in the chromatic scale were 100 cents. In addition to the two preceding scale conditions, a no-scale condition, (i.e., no preceding scale) was also prepared.

The standard intervals were composed of two successive tones. The first tone was either B4 or C5. The second tone was higher than the first by 100, 150, or 200 cents. Thus, six standard intervals were presented altogether.

The comparison intervals also consisted of two successive tones. The first tone always had the same pitch as the second tone of the standard interval. Nine intervals were prepared for each standard interval. They ranged in 20-cent steps from -80 cents to +80 cents relative to their standard intervals. Figure 1 shows a schematic representation of the stimuli.

Insert Figure 1 around here

When the 200-cent standard interval began with C5, it ends with D5, which is an element of the diatonic scale. When, however, it began with B4, it ended with C#5, which is not an element of the diatonic scale. In the case of the 100-cent standard interval, the relationship between the starting tone and the diatonic membership was reversed. The second pitch was not a diatonic element when the standard interval began with C5, but is a diatonic element when the standard interval began with B4.

Both the 100- and 200-cent intervals exist as musical intervals in Western tonal music (i.e., minor second and major second, respectively). Thus, whatever the identity of the first tones was, the second tones of both intervals were included in the chromatic scale. The second tones of the 150-cent interval, however, was included in neither the diatonic nor the chromatic scale.

Each tone had a 5-ms rise time, a 95-ms steady state potion, and a 5-ms decay time. Each tone rose and decayed linearly. The tones consisted of the first six harmonics, the amplitudes of which declined in inverse proportion to their harmonic numbers. The inter-onset intervals between tones were 200 ms in the preceding scale, the standard interval, and the comparison interval. They were set at 400 ms between the preceding scale and the standard interval, and between the standard interval and the comparison interval. The sound level of the tones averaged 65 dBA, measured through an earphone (STAX Λ Pro driven by STAX SRM/MK-2) coupled with an artificial ear (B&K, Type 4153) and a precision sound level meter (B&K, Type 2231).

Procedure

Ten subjects were randomly assigned to each of three groups (a) the diatonic, (b) the chromatic, and (c) the no-scale condition. The results of an ad hoc ANOVA for the period of musical training did not show a significant difference between the groups.

Each subject participated in two experimental sessions, which were held on separate days. Within a session, the starting pitch of the standard interval was fixed at either B4 or C5. Half of the subjects received first B4 and then C5. For the remaining half the starting pitches were reversed.

Twenty-seven combinations of the standard and comparison intervals were presented 20 times in each session. The order of presentation was random.

On each trial, subjects were required to judge the size of the comparison interval relative to that of the standard, using three response categories, "smaller," "equal," and "larger." They were instructed to judge based on an equal tuning, in which intervals having the same size in cents were regarded as identical to each other[1]. There might have been cases when subjects could not distinguish "smaller" or "larger," but thought that the intervals were not equal. They were instructed not to answer "equal" in this case. After each response, subjects were given oral feedback in which the sizes of the standard and the comparison intervals were given in cents. They first received 27 practice trials in each experimental session.

The experimental sequence was controlled by a personal computer (Apple Macintosh SE) and a MIDI system. The pitch sequence was generated by a YAMAHA TX-802 FM Tone Generator. The deviation from the required pitch was within ± 0.5859 cents, and was negligible for the present purpose. The feedback was stored in, and played back by, a MIDI sampling machine (AKAI S-1000). The audio signals were mixed by a YAMAHA DMP 7 and presented to the subjects' left ears through earphones (STAX Λ Pro driven by STAX SRM/MK-2).

Results

The number of responses in each category, pooled over subjects, was calculated. Figure 2 shows the scores for the 200-cent standard in the diatonic condition as a function of the comparison interval. The panel on the left shows the results from the B4-starting condition, and the panel on the right side shows the results from the C5-starting condition.

Insert Figure 2 around here

When it began with C5, the 200-cent standard interval had an "equal" response peak around its musically equivalent counterpart. Most of the residual responses, however, belonged to the “larger” category, that is, the number of “larger” and “smaller” responses were not balanced at the point of musical equality. However, when the 200-cent standard interval began with B4, there was no clear "equal" response peak.

The peak of the "equal" response is assumed to indicate the point of subjective equality (PSE). The traditional definition of PSE requires that "smaller" and "larger" responses be balanced at the PSE. This requirement, however, was not satisfied by the data from the C5-starting 200-cent standard in the diatonic condition. This implies that the traditional psychophysical model should be revised.

In the psychophysical model, the discriminal process is assumed to be a stochastic dispersion along a psychological continuum. This discriminal dispersion is assumed to be normally distributed. There is a point of subjective equality (PSE) along the psychological continuum which becomes the reference point. Thus, the discriminal dispersion is divided into two portions by the PSE. The negative portion represents the probability of a judgment such as "The comparison stimulus is smaller than the standard," and the positive portion represents the probability of the opposite judgment, "The comparison stimulus is larger than the standard." Because subjective equality is assumed to be a point, there is no room for an "equal" judgment. To allow the existence of an "equal" judgment, a "band" of subjective equality must be assumed rather than a point.

To estimate the positions of band edges along the psychological continuum, a Z-score was calculated using the proportions of the "smaller" or "larger" response categories for each standard-comparison pair. The Z-score gave the distance from the center of distribution in terms of the standard deviation. If homogeneity of dispersion is assumed, as in Thurstone's Case IV, the results from the C5-starting 200-cent standard in the diatonic condition would lead to the conclusion that the bandwidth of subjective equality should vary with the standard-comparison pair, as depicted in Fig. 3. A change in the bandwidth indicates a change in judgment criterion . To change criterion from one trial to another, the subjects must be informed of what was coming in the next trial. However, no information about such a criterion change was given.

Insert Figure 3 around here

Insert Figure 4 around here

Therefore, it is logical to assume that the bandwidth of subjective equality is constant and that the discriminal dispersion itself should vary in width. To obtain the variation in discriminal dispersion, first, the bandwidth of subjective equality was estimated on the assumption of a homogeneous dispersion. Then, its reciprocal value was defined as the standard deviation of the discriminal dispersion. Figure 4 shows the estimated results of applying the "constant-bandwidth" assumption to the data in Fig. 3. The wider the bandwidth in Fig. 3, the sharper the discriminal dispersion in Fig. 4. In addition to the variation among dispersion widths, the position of dispersion center would be modified by applying the “constant-bandwidth” assumption. When a dispersion was sharp, the center of the dispersion moved close to the reference level, where the “smaller” and “larger” responses were balanced. When a dispersion was flat, the center became moved away from the reference level.

Generally, if subjects produce more “equal” responses and fewer “larger” or “smaller” responses, the dispersion width becomes smaller. This can be regarded as an indicator of the equality aspect of judgment. On the other hand, if subjects produce the same number of “smaller” and “larger” responses, the modal dispersion score becomes zero. This can be regarded as an indicator of the size aspect of judgment.

The dispersion width and modal dispersion were estimated for each subject and for each combination of preceding scale, starting tone, standard interval, and comparison interval condition. Because a Z-score cannot be obtained for zero probability, when there was no occurrence of a particular response, that occurrence was assigned 0.5, which slightly distorts the total proportions.

<u>Dispersion Width</u>

A three-way (starting tone × standard interval × comparison interval) ANOVA was performed for the dispersion width score in each preceding scale condition. No significant effect was observed in either of the preceding conditions. Although it did not reach significance, a trend in the effect of the starting tone and its dependency upon the preceding scale condition can be observed, especially for the 200-cent standard. Figure 5 indicates the average dispersion width, pooled over subjects, for the 200-cent standard in the three preceding conditions as a function of the comparison interval.

Insert Figure 5 around here

In the diatonic condition, the value of the dispersion width for the 200-cent standard interval was minimal at its musically equal counterpart when the interval began with C5. When it began with B4, the value of the dispersion width was not minimal at the musically equal counterpart. In addition, the dispersion widths did not differ among the comparison intervals so distinctively as when it began with C5.

The trend towards an effect of the starting tone was not clear in the chromatic condition although it was observed in the no-scale condition as well as in the diatonic condition.

Modal Dispersion

A three-way (starting tone × standard interval × comparison interval) ANOVA was also performed for the modal dispersion score in each preceding scale condition.

In the diatonic condition, three main effects were significant: that of the starting tone, $F(1, 486) = 56.98$, $p < .001$; of the standard interval, $F(2, 486) = 352.3$, $p < .001$; and of the comparison interval, $F(8, 486) = 639. 6$, $p < .001$. The interaction between the starting tone and the standard interval was also significant [$F(2, 486) = 42.83$, $p < .001$]. In the chromatic condition, the effects of the standard interval and the comparison interval were significant [$F(2, 486) = 69.76$, $p < .001$; $F(8, 486) = 115.4$, $p < .001$, respectively]. In the no-scale condition, the effects of the standard interval and the comparison interval were significant [$F(2, 486) = 86.71$, $p < .001$; $F(8, 486) = 101.2$, $p < .001$, respectively]. The interaction between the starting tone and the standard interval was also significant [$F(2, 486) = 6.572$, $p < .002$].

Insert Figure 6 around here

The average modal dispersion, pooled over subjects, is plotted against the comparison interval in Fig. 6. Each line in the figure depicts the results from a combination of the starting tone and the standard interval. The point at which each line crosses the reference level, the horizontal dot-and-dash line in the figure, corresponds to the point of balance between the "larger" and "smaller" responses. There was a tendency for the point of balance to shift toward a smaller comparison interval as the standard interval became larger in all the preceding conditions. The main effect of the standard interval reflects this tendency. Such a tendency is more prominent for the standard which began with B4 than for the standard which began with C5 both in the diatonic and no-scale condition, as is shown by the significant interaction between the starting tone and the standard interval.

Discussion

As the modal dispersion scores indicate, the point of balance shifted to the smaller comparison interval as the standard interval became larger. The direction appears opposite to that of the general tendency found by the adjustment of isolated intervals, that is, the smaller interval is apt to become compressed and the larger interval is apt to be stretched (Burns & Ward, 1982). The task in the present experiment, however, was quite different from the adjustment task. Whereas in the adjustment task, subjects compared the presented interval to their internal standard, in the present experiment they made comparison between two presented intervals.

The effect of the standard interval on the size aspect is assumed to be an artifact of the experiment. Because the standard interval began with a constant pitch in one session and the comparison interval began with the pitch of the second tone of the standard intervals, the second pitch of the comparison interval was, on the average, considerably higher for the larger standard interval. If one assumes that subjects' responses depended partly on the pitch of the second tone in the comparison interval, it would be predicted that they should produce more "larger" responses in the trials with the larger standard interval.

It is interesting that the standard interval factor interacted with the starting tone factor in the diatonic condition. The second pitch of the comparison interval influenced the size aspect of interval judgment so that the point of balance tended to "drift" away from the point of musical equality. However, the degree of drift was less for the standard interval starting on C5 than for the standard interval starting on B4. Because C5 was the tonic in the diatonic context, it can be expected to have functioned as a better reference point than B4. Thus, the interaction indicates that the good reference point anchored the drifting tendency to the point of musical equality.

This explanation is also supported by the fact that no significant interaction between the starting tone and the standard interval was found in the chromatic condition. Because the chromatic context gives no, or a very weak, impression of the tonal center, it is reasonable that there should have been no clear differentiation by starting tone. It is, however, surprising that the interaction between the starting tone and the standard interval was also significant in the no-scale condition because the only cue for the subjects to differentiate between the two starting tone conditions was the absolute pitch of the stimuli.

Although it did not result in statistically significant effects, the tendency to differentiate according to the starting tone was observed in the equality aspect of judgment in the diatonic and the no-scale conditions also. The 200-cent standard interval starting on C5 had a sharper discriminal dispersion with its musical counterpart than the 200-cent standard interval starting on B4. Here again, the note C5 appears to have functioned as a good perceptual anchor.

Because the subjects were not well trained musically, their performance tended to be unstable. One could argue that because this lack of stability caused errors to increase, statistically significant results could not be obtained. In Experiment 2, highly trained musicians served as subjects in order to obtain more stable performance as well as to investigate how training affects the two aspects of interval judgment.

Experiment 2

In Experiment 2, highly-trained musicians were tested in the pitch interval discrimination task. To investigate more precisely the effects of musical abilities on the comparative judgment between two intervals, they were also tested on both absolute pitch identification and relative pitch identification.

Method

Subjects

Thirty-five undergraduates from Kyoto City University of Arts and Osaka University of Arts took part in the experiment. All had normal hearing. Most of them claimed to possess absolute pitch.

Absolute Pitch Identification

Stimulus

In the absolute pitch identification task (AP task), an isolated tone was presented in each trial. Its pitch was selected from all the possible pitch classes from the equal tempered scale in 7 pitch registers [C1(32.7 Hz)~B7(3951.1 Hz)].

Each pitch was presented once. Thus a subject received 84 trials in the AP task. The trials were given in 12 blocks. Each block consisted of 7 trials. Within each block, at least one pitch from each register was presented, and a tone belonging to the same pitch class never occurred twice. Except for those constraints, the order of presentation was random. The timbre of the tone was the preset timbre labeled "piano 1" on the YAMAHA TX 801 FM Tone Generator.

Procedure

Subjects were required to supply the pitch name of each tone by using the labels: C, D, E, F, G, A, B, and #. They were not required to identify the register in which the tone occurred.

Relative Pitch Identification

Stimuli

In the relative pitch identification task (RP task), a pair of tones which comprised an isolated interval was presented in each trial. Each tone was tuned 50 cents off the equal tempered scale in an attempt to prevent subjects from utilizing their absolute pitch.

Twenty-five melodic pitch intervals were generated. They ranged in steps of 100 cents from -1200 cents (the descending octave) to 1200 cents (the ascending octave) including 0 cents (the unison). Each interval was presented 3 times. Thus, a subject received 75 trials in the RP task. The trials were given in 3 blocks. Each block consisted of 25 trials. Within each block, each type of interval was presented once in a random order.

To minimize the development of a tonal center, the intervals in two consecutive trials were composed of four pitch classes which did not come from any single diatonic scale except for the succession of (a) unison (0 cents) and octave (±1200 cents); (b) unison and tritone (±600); and (c) tritone and octave.

The timbres of the tones were the same as in the AP task. The inter-onset interval between tone pairs was 500 ms.

Procedure

Subjects were required to identify the interval by marking the corresponding 25 positions on the response sheet. The center position corresponded to unison, the left end to the descending octave, and the right end to the ascending octave.

Pitch Interval Discrimination

Stimulus

The same stimulus sequence as used in Experiment 1 was used in the pitch interval discrimination task in Experiment 2.

Procedure

Subjects were randomly assigned to each of three preceding conditions: (a) diatonic, (b) chromatic, and (c) no-scale. The number of subjects was 12, 12, and 11 for the diatonic, chromatic, and no-scale group, respectively. The subjects' performance scores in the AP task and RP task were not significantly different among the three groups.

All other details of the experimental procedure were similar to those in Experiment 1, except that the subjects participated in two interval discrimination sessions the same day as they participated in the AP and RP sessions.

Results

For the interval discrimination task, the dispersion width and modal dispersion were estimated for each subject and for each combination of preceding scale, starting tone, standard interval, and comparison interval as in Experiment 1.

Dispersion Width

A three-way (starting tone × standard interval × comparison interval) ANOVA was performed for each preceding scale condition. In the diatonic condition, the main effect of the starting tone was significant [$F(1, 594) = 12.182$, $p < .001$]. The interactions between the standard and comparison interval, and among all three factors, the starting tone, standard interval, and comparison interval, were also significant [$F (16, 594) = 2.121, p < .007$; $F (16, 594) = 2.656, p < .001$]. Figure 7 show the average dispersion width, pooled over subjects in the diatonic condition, plotted against the comparison interval. In the chromatic condition, the effect of the comparison interval was significant [$F (8, 594) = 3.149, p < .002$]. It interacted with the effect of the standard interval [$F (16, 594) = 3.881, p < .001$] In the no-scale condition, only the interaction between the standard and comparison interval was significant [$F (16, 540) = 2.516, p < .001$].

Insert Figure 7 around here

In all the preceding scale conditions, an interaction between the standard and comparison interval was observed. This interaction means that the dispersion width was differentiated along the comparison interval continuum, and that the profile of the differentiation varied with the standard interval. The differentiation was not clear for the 150-cent standard condition but was prominent for the 200-cent standard. With a preceding diatonic scale, except for the 150-cent standard, the differentiation became clearer in the condition starting on C5 than in the condition starting on B4.

A significant effect of the starting tone was observed only in the diatonic condition. In Fig. 8, the scores for the average dispersion width for the 200-cent standard in each preceding condition are plotted against the comparison interval.

Insert Figure 8 around here

Modal Dispersion

A three-way (starting tone × standard interval × comparison interval) ANOVA was performed for each preceding scale condition. In the diatonic condition, three main effects were significant [starting tone, $F(1, 594) = 32.33$, $p < .001$; standard interval, $F(2, 594) = 12.13$, $p < .001$; and comparison interval, $F(8, 594) = 68.76$, $p < .001$]. The interaction between the starting tone and the comparison interval was also significant [$F(8, 594) = 3.541$, $p < .001$]. In the chromatic condition, the the effects of standard and comparison intervals and their interaction were significant [$F(2, 594) = 48.72$, $p < .001$; $F(8, 594) = 194.8$, $p < .001$; $F(16, 594) = 4.312$, $p < .001$, respectively]. In the no-scale condition, three main effects were significant [starting tone, $F(1, 540) = 7.734$, $p < .006$; standard interval, $F(2, 540) = 109.7$, $p < .001$; and comparison interval, $F(8, 540) = 140.5$, $p < .001$]. The effect of the standard interval interacted significantly with the effect of the starting tone [$F(2, 540) = 12.00$, $p < .001$], and with the effect of the comparison interval [$F(16, 540) = 15.55$, $p < .001$].

Figure 9 depicts the average modal dispersion as a function of the comparison interval. In the diatonic condition, the modal dispersion of the condition with C5 as the starting tone was almost always more positive than that of the condition with B4 as the starting tone for the same comparison interval. In the chromatic condition, however, the effect of the starting tone was not clear. In the no-scale condition, it interacted with the standard interval, and a tendency similar to that observed for less trained subjects in Experiment 1 was found.

Insert Figure 9 around here

Generally, in all the three preceding conditions, there was a tendency for the larger standard interval to produce a smaller estimate for the point of balance.

<u>Correlation between AP, RP and Pitch Interval Discrimination tasks.</u>

To investigate the relationship between these experimental tasks and subjects' musical abilities, Pearson's correlation coefficients were calculated for each combination of hit rates for the AP and RP tasks and dispersion width estimates for all the six standards paired with their musically equivalent comparisons. In the AP task, most of the subjects performed badly for tones in the highest register, from C8 to B8, and trials for those stimuli were excluded in the calculation of the hit rate.

If a subject could judge the relationship between two intervals in any context exactly, the dispersion width estimate for its musical counterpart was necessarily very small. Such a musically highly trained subject should also have achieved high scores in the AP and RP tasks. Thus, these correlation coefficients were predicted to be negative. Table 1 displays the results. Coefficients whose absolute values exceeded .40 are asterisked. When the standard interval was 150 cents, that is, a non-musical interval, the correlation was low. The RP scores had more high correlations than the AP scores when a preceding scale was presented.

Insert Table 1 around here

Discussion

The significant effect of the starting tone in the diatonic condition suggests that the presentation of the diatonic scale might have imposed a strong anchoring point, (i.e., the note C; in this case the tonic). When the intervals to be judged were based on this anchor tone, the discriminal process for the musically equal intervals was sharply distributed. This sharp distribution means that a salient point of equality exists. In such a case, the modal dispersion is also anchored to the musical point of equality.

However, when the standard interval began with B4 in the diatonic condition, the discriminal dispersion was relatively flat and the mode shifted in the direction of overestimation of the standard interval. This direction would be expected assuming that the subjects compare the pitch of the last tone in a trial to the internal representation made incorrectly with C5 as the reference. For example, when a 220-cent comparison interval was paired with a 200-cent standard starting on B4, the pitch of the last tone was 20 cents higher than D#5 (which will be denoted as D#'5 from now on) because the comparison interval begins with the second pitch of the standard interval (C#5 in this case). If a subject happens to err in his internal target by assuming that the standard interval begins with C5, his internal target for the second pitch of the musically equivalent comparison will be E5. D#'5 is still lower than E5. Thus, he would be expected to respond with "smaller" even when the comparison was really larger. As a result, the standard interval would appear to be overestimated.

By presenting a chromatic scale, however, the tone with which the standard interval begins does not matter. The scale imposed by the chromatic context is assumed to be homogeneous and to improve the size-related aspect of the pitch interval judgment.

In the no-scale condition, only when the judged interval was 200 cents, was the discriminal dispersion differentiated along the comparison interval continuum. In this condition, although no significant effect of the starting tone could be found in the dispersion width scores, it was found in the modal dispersion scores. This effect interacted with the effect of the standard interval which was also observed in the other two preceding scale conditions. A tendency for the larger standard interval to be matched with the smaller comparison interval in the size relationship was less common in the C5-starting condition than in the B4-starting condition. In the no-scale condition, anchoring by starting with C was not strong enough to affect the equality differentiation, but was sufficient to anchor the drifting of the point of balance to the point of musical equality.

General Discussion

Tests using highly trained musicians showed a statistically significant effect of the starting tone on the equality aspect of judgment which did not reach the significance in Experiment 1. Although we need to consider carefully the difference in the musical ability between the different groups of subjects in the two experiments, the starting tone can be regarded as having an effect on the equality aspect of the judgments of the less trained subjects in the same direction as those of the highly trained subjects.

The effect of the starting tone can be explained in terms of the short term memory trace as reported by Deutsch (1972, 1973). According to her findings, the repetition of a pitch class produces memory consolidation. In the present experiments, the relation among the pitch classes composing the preceding scale, the standard and comparison interval differed depending on the starting tone. Because the preceding diatonic scale proceeded by one octave, the inclusion of a pitch class to the diatonic scale indicates that it was repeated.

Insert Figure 10 around here

In order to argue about the effect of repetition, it is meaningful to examine the interaction between the effect of the starting tone and the effect of the standard interval in the diatonic condition. Figure 10 depicts the mean of the dispersion width at the point of musical equality as a function of the standard interval for each combination of the preceding scale and the starting tone. In the diatonic condition, when the standard interval was 200 cents, the discriminal dispersion at the point of musical equality was sharper in the condition starting on C5 than in the condition starting on B4. Although such a tendency was also observed for the 100-cent standard, it was not observed for the 150-cent standard. The second tone of the 200-cent standard starting on C5 was D5 which was a member of the diatonic set while that of the 200-cent standard starting on B4 was C#5 which was not a member of the diatonic set. Therefore, one might explain that the effect of the starting tone as resulting from membership of the second tone of the standard interval in the diatonic set. Such an explanation becomes difficult if we consider the case of the 100-cent standard, where the relationship between the starting tone and the diatonicity of the second tone was inverted. The results for that standard interval, however, did not show the reverse tendency.

The second tone of the comparison interval can explain the effect of the starting tone. For the 100-cent and 200 cent standard interval, the second tone of the musically equal comparison interval was included in the diatonic scale when the starting tone was C5, but it was not when the starting tone was B4. For the 150-cent standard interval, it was included in the diatonic scale when the starting tone was B4, but it was not when the starting tone was C5. As Fig. 10 shows, for the highly-trained subjects, the width scores for the sequence where the second tone of the comparison interval was included in the diatonic scale were less than those for their counterparts where the second tone of the comparison is not included in the diatonic scale.

The second tone of the comparison interval was the last tone of the whole sequence in the trial, and is supposed to have a more dominant anchoring effect than the second tone of the standard interval, as reported by Bharucha (1984). The diatonicity of the last tone in the sequence, however, is not sufficient to explain the low dispersion width score, not only because the dispersion width scores were relatively high for the B4-starting 150-cent standard with highly-trained musicians, but also because no starting tone effect was observed for the 150-cent standard with the less trained musicians. For example, in terms of the repetition of the composing tones, there was no difference in the diatonic condition between the sequence of 100-cent standard and 100-cent comparison starting on C5 and the sequence of 150-cent standard and 150-cent comparison starting on B4. The dispersion width, however, was more for the latter case than for the former case as shown in Fig. 10.

Further, the explanation only in terms of short term memory trace is not sufficient when the results in the chromatic and no-scale condition are considered. Because the chromatic scale began on the F4, the second tone of either the 200-cent standard or the 200-cent comparison did not appear in the preceding chromatic scale. These cases can be considered equivalent to the case of the 200-cent standard starting on B4 in the diatonic condition in terms of the repetition of the composing tones. According to the explanation in terms of short term memory trace, the dispersion width would have been rather large. However, the results of the highly trained subjects indicates that the scores for the 200-cent standard interval in the chromatic condition were even smaller than the score for the 200-cent standard starting on B4 in the diatonic condition. Although the results of the less trained subjects indicates that they were larger than the score for the 200-cent standard starting on C5 in the diatonic condition, they were still smaller than the score for the 200-cent standard starting on B4 in the diatonic condition.

In the diatonic condition, the starting tone also had effects on the size-related aspect of the judgment. In both Experiments 1 and 2, the point of balance was anchored to the point of musical equality when the standard interval began with C5. When it began with B4, the appearance of the effect of the starting tone was different for the highly trained and less trained subjects.

As Fig. 9 depicts, with the highly trained subjects, the modal dispersion in the B4 condition shifted in the direction of overestimation of the standard. As discussed earlier, the direction of shift may be explained by assuming that the subjects judged with the incorrect point of reference, C5, which was the tonic of the preceding diatonic scale. The musical training that the subjects had taken would have enabled them to retain the preceding musical context a little longer against the appearance of the conflicting event. Such ability is assumed to be necessary to process "accidentals" in music.

On the other hand, we can hypothesize that less trained subjects had not had enough training to retain the preceding context against the conflicting event. Thus, as shown in Fig. 6, they seemed to lose the anchoring point, and their point of balance drifted away from the point of musical equality under the influence of the effect of the standard interval.

The chromatic condition did not produce any striking effect of the starting tone on either the size or equality aspect of judgment. In this condition, the highly trained subjects seemed to find the salient point of equality in both starting tone conditions when the standard interval was 100 or 200 cents as shown in Fig. 10. Although the effect of the standard interval was significant, the degree of deviation of the point of balance from the point of musical equality was less than in the diatonic and no-scale condition. And the effect of the starting tone was not clear. Thus, the point of balance anchored to the point of musical equality in the chromatic condition for the highly trained subjects. The untrained subjects seemed unable to find the point of equality in the chromatic condition for either of the standard intervals. Their points of balance were more influenced by the standard interval than those of highly trained subjects and they were not influenced by the starting note.

The results in the no-scale condition resembled those in the diatonic condition. While the effect of starting tone on the equality aspect of judgment was not statistically significant either for the less trained or for the highly trained subjects, the effect of starting tone (or its interaction with other factors) on the size aspect was observed for both groups of subjects. It may be suggested that the subjects had a "default" context for judging intervals, and that such a default context was not chromatic but diatonic. It is surprising that even the less trained subjects tended to differentiate by starting tone. In the no-scale condition, the only cue to the difference between the two starting tone conditions was the absolute pitches of the tones.

Recent studies of Miyazaki (1988, 1989) have shown that the absolute pitch is not as rare as had previously been thought. Although the subjects in Experiment 1 were not highly trained, they did have some musical experience. Therefore, one can surmise that they possessed absolute pitch to some degree.

It is unlikely, however, that the subjects based their judgments completely on absolute pitch. If had they done so, those subjects with better absolute pitch should have performed better. As Table 1 shows, a relatively high correlation coefficient between the dispersion widths and the AP test scores was only observed for the 200-cent standard starting on B4 in the chromatic condition and for the 200-cent standard starting on C5 in the no-scale condition. When the preceding scale was presented, there were many cases in which the correlation coefficient between the dispersion widths and the RP test scores became relatively high. This suggests that the subjects utilized relative pitch more than absolute pitch in comparing the two intervals.

The present results show an interaction between the preceding scale, the size of the standard interval and the starting tone of the standard interval. In the chromatic context, the effect of the starting tone was not significant. In the diatonic context, both the starting tone and the interval were critical. In that sense, one must also consider the starting tone and the second tone of the comparison interval which were not included in the independent variables in the present experiments. There also remains the open of question whether in any scale system other than the diatonic an interval can be differentiated by its position on the scale.

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Table 1.
Correlation between dispersion width, AP and RP scores. Values below -.400 are marked with an asterisk.

Scale \ Task		B-start Standard 100	B-start Standard 150	B-start Standard 200	C-start Standard 100	C-start Standard 150	C-start Standard 200
Dia-tonic	AP	-.318	.074	-.159	-.240	.078	-.073
	RP	-.302	.110	-.524*	-.719*	.181	-.578*
Chro-matic	AP	-.132	.147	-.615*	-.489*	.263	-.295
	RP	-.600*	.036	-.663*	-.604*	-.167	-.589*
No-Scale	AP	.097	-.102	-.152	-.024	-.264	-.447*
	RP	.229	-.142	.145	-.253	.172	-.374

Figure Captions

Figure 1. Schematic representation of the sequence of stimuli; (a) preceding scale, (b) standard interval, (c) comparison interval. The lables in the boxes indicate the pitch classes of tones which composed the musically equivalent pairs. From the top to the bottom, each row corresponds, respectively, to each case of 200-, 150-, and 100-cent standard interval. The label hatched and marked with a prime (') depicts a tone which is 50-cent higher than the pitch class without a prime mark.

Figure 2. The percentage of each response category, vs. the comparison interval for the 200-cent standard in the diatonic condition of Experiment 1, pooled over subjects.

Figure 3. The discriminal dispersions estimated on the "homogeneous dispersion" assumption for the 200-cent standard interval starting on C5 in the diatonic condition. The number on the left indicates in cents the size of the comparison interval relative to that of the standard.

Figure 4. The discriminal dispersions estimated on the "constant bandwidth of equality" assumption for the 200-cent standard interval starting on C5 in the diatonic condition. The number on the left indicates in cents the size of the comparison interval relative to that of the standard.

Figure 5. The average dispersion width for the 200-cent standard interval vs. the comparison interval, pooled over subjects. These subjects were less trained.

Figure 6. The average modal dispersion vs. the comparison interval, pooled over subjects. The subjects were less trained. Each line corresponds to a combination of standard interval and starting tone: (a) --------, B100; (b) — — —, B150; (c) ———, B200; (d) --------, C100; (e) — — —, C150; (f) ———, C200.

Figure 7. The average dispersion width in the diatonic condition vs. the comparison interval, pooled over subjects. The subjects were highly trained.

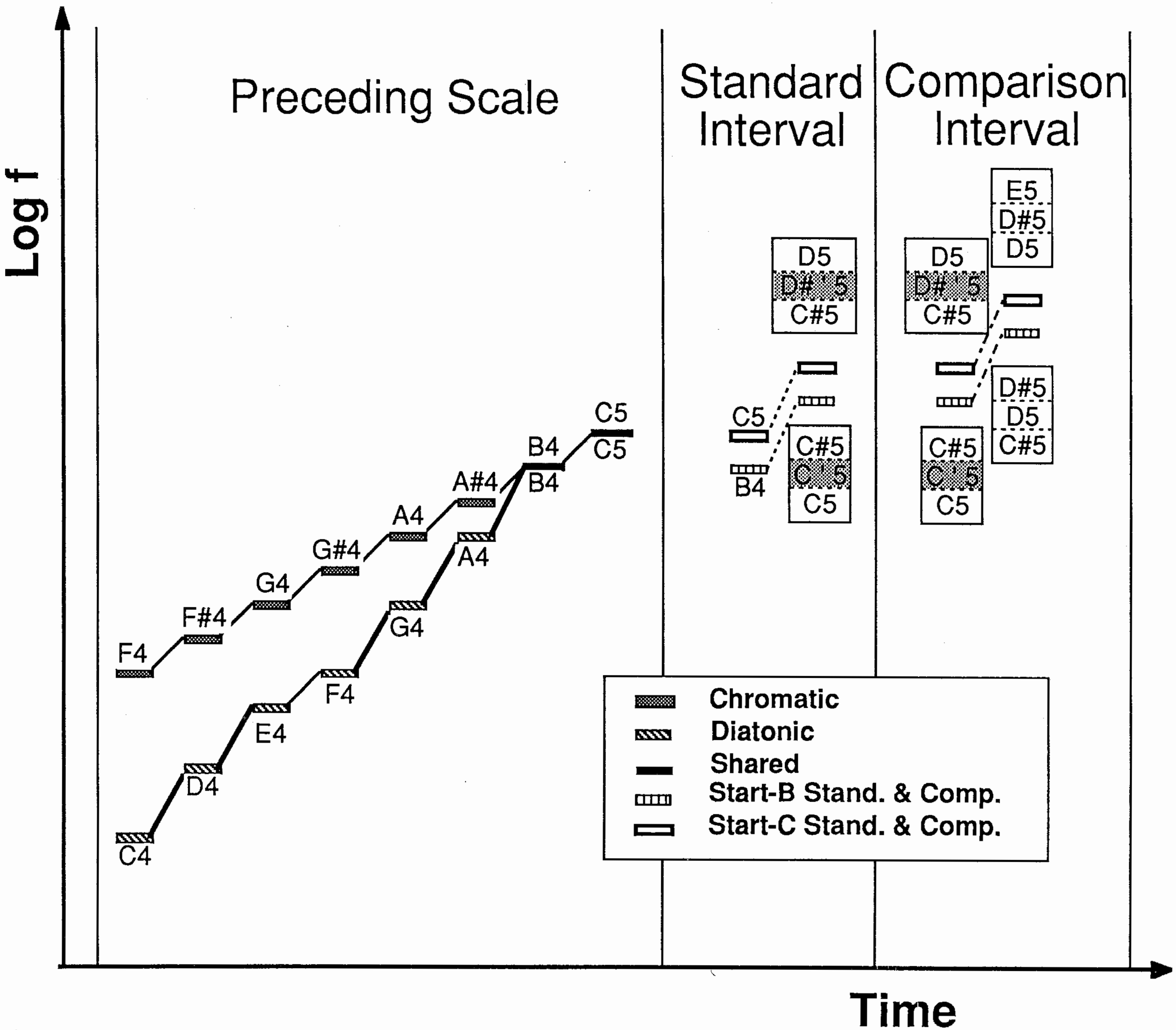
Figure 8. The average dispersion width for the 200-cent standard interval vs. the comparison interval, pooled over subjects. The top panel is the same as in Fig. 7.

Figure 9. The average modal dispersion vs. the comparison interval, pooled over subjects. The subjects were highly trained. Each line corresponds to a combination of standard interval and starting tone: (a) --------, B100; (b) — — —, B150; (c) ———, B200; (d) --------, C100; (e) — — —, C150; (f) ———, C200.

Figure 10. The average dispersion width at the point of musical equality vs. the size of the standard interval, pooled over subjects. The upper and lower panel displays the results of the highly and less trained subjects, respectively.

Footnotes

1 Tuning for each pitch class in a diatonic scale differs among tuning systems such as Pythagorean tuning, just tuning, mean tone tuning, or eqaul tuning. For example, in just tuning, an interval between C and D is 203.910 cents while an interval between D and E is 182.404 cents. These two intervals are both 200 cents in an equal tuning (Blackwood, 1985).



Log f
Preceding Scale
Standard Interval
Comparison Interval
F4
F#4
G4
G#4
A4
A#4
B4
C5
C4
D4
E4
F4
G4
A4
B4
C5
C5
B4
D5
D# 5
C#5
C#5
C5
D5
D# 5
C#5
E5
D#5
D5
D#5
D5
C#5
C#5
C5
Chromatic
Diatonic
Shared
Start-B Stand. & Comp.
Start-C Stand. & Comp.
Time

Figure 1

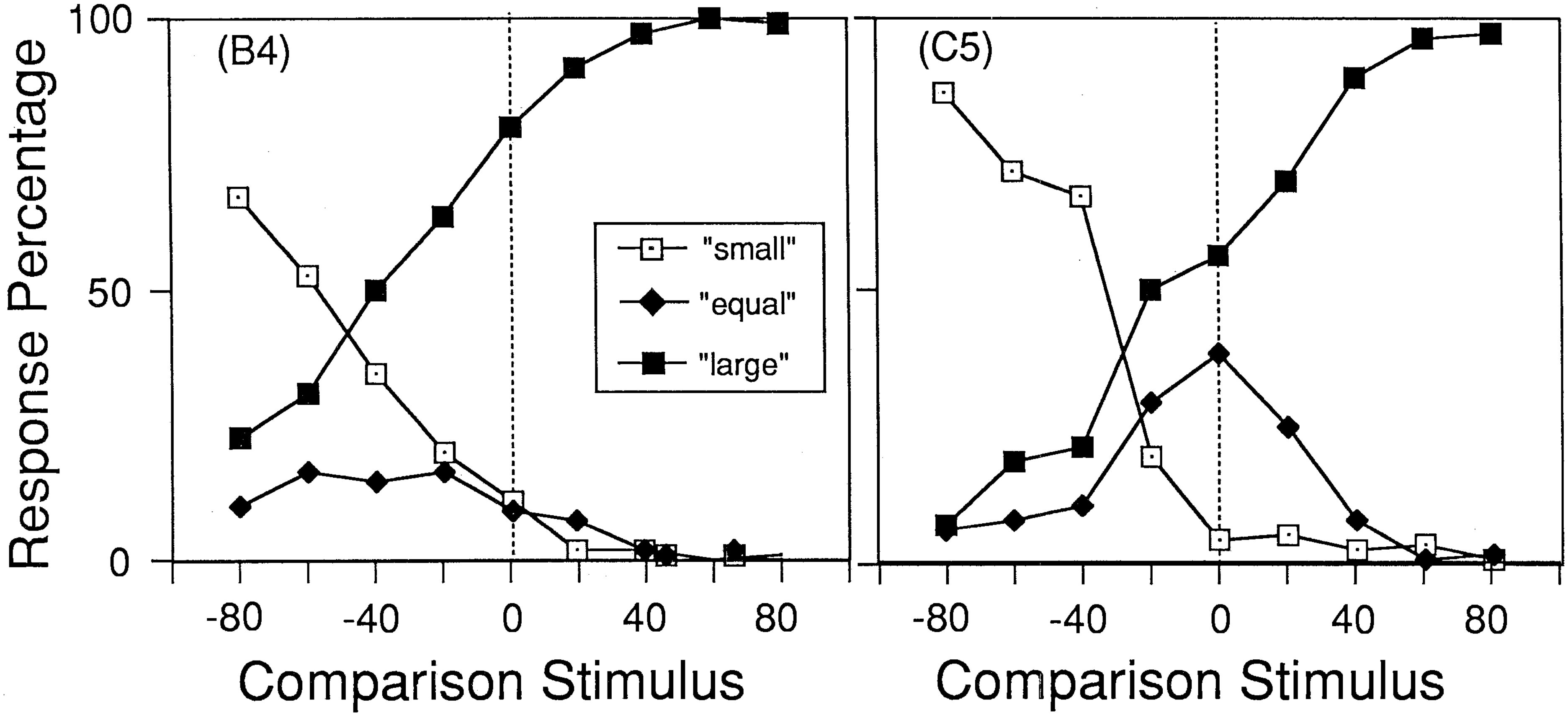

(B4)
(C5)
"small"
"equal"
"large"
Response Percentage
100
50
0
-80
-40
0
40
80
Comparison Stimulus
Comparison Stimulus

Figure. 2

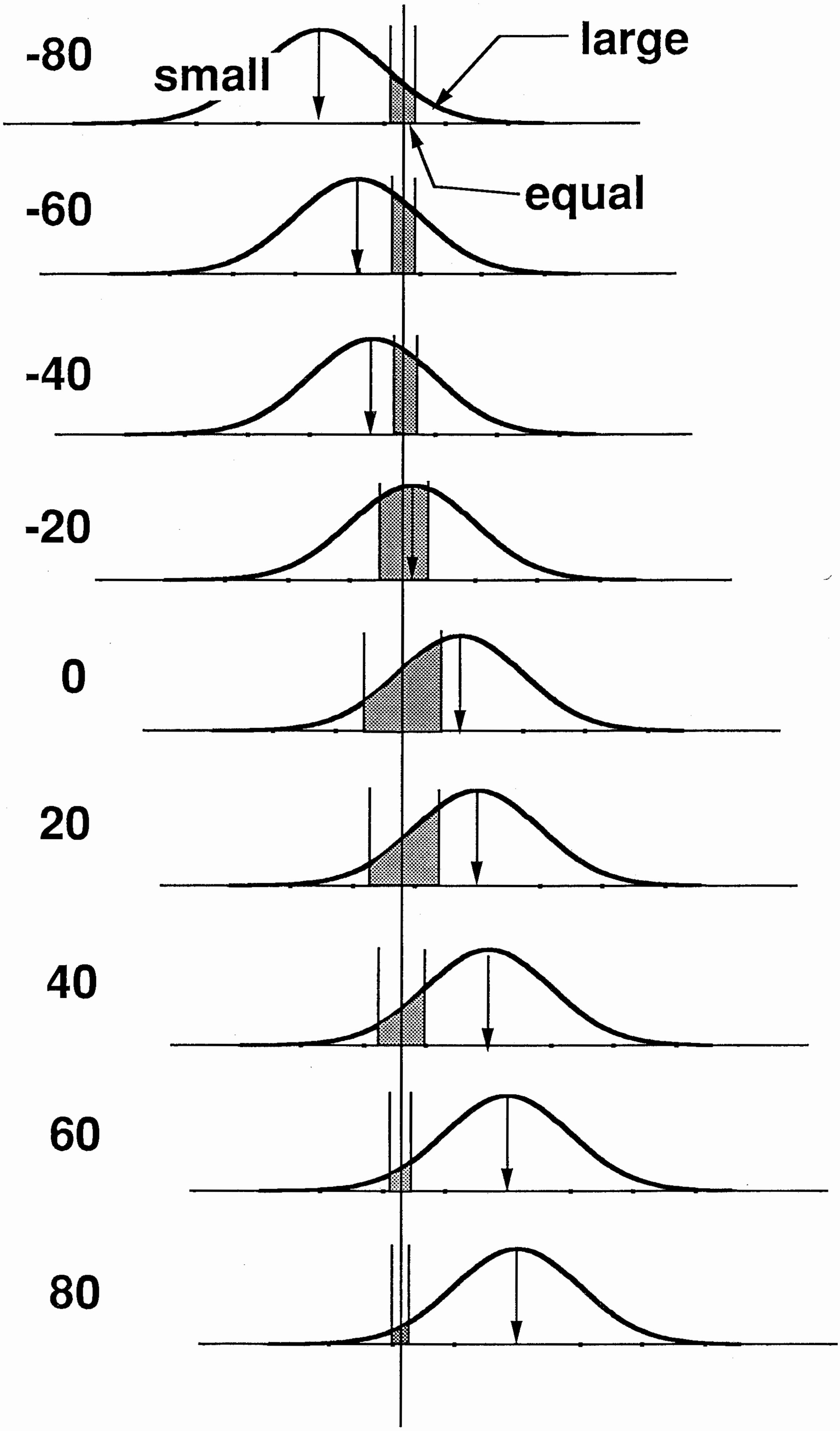


Figure. 3

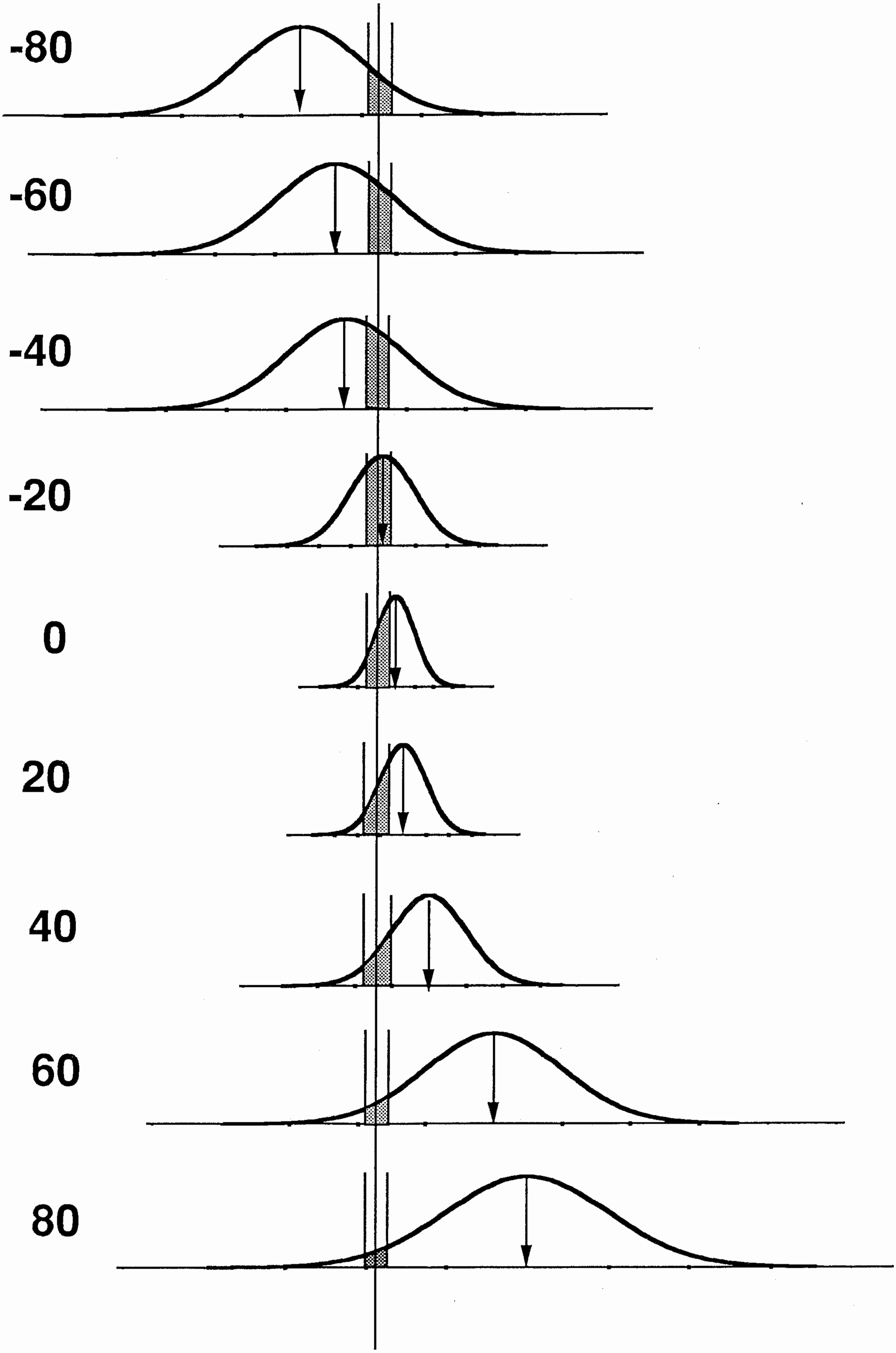
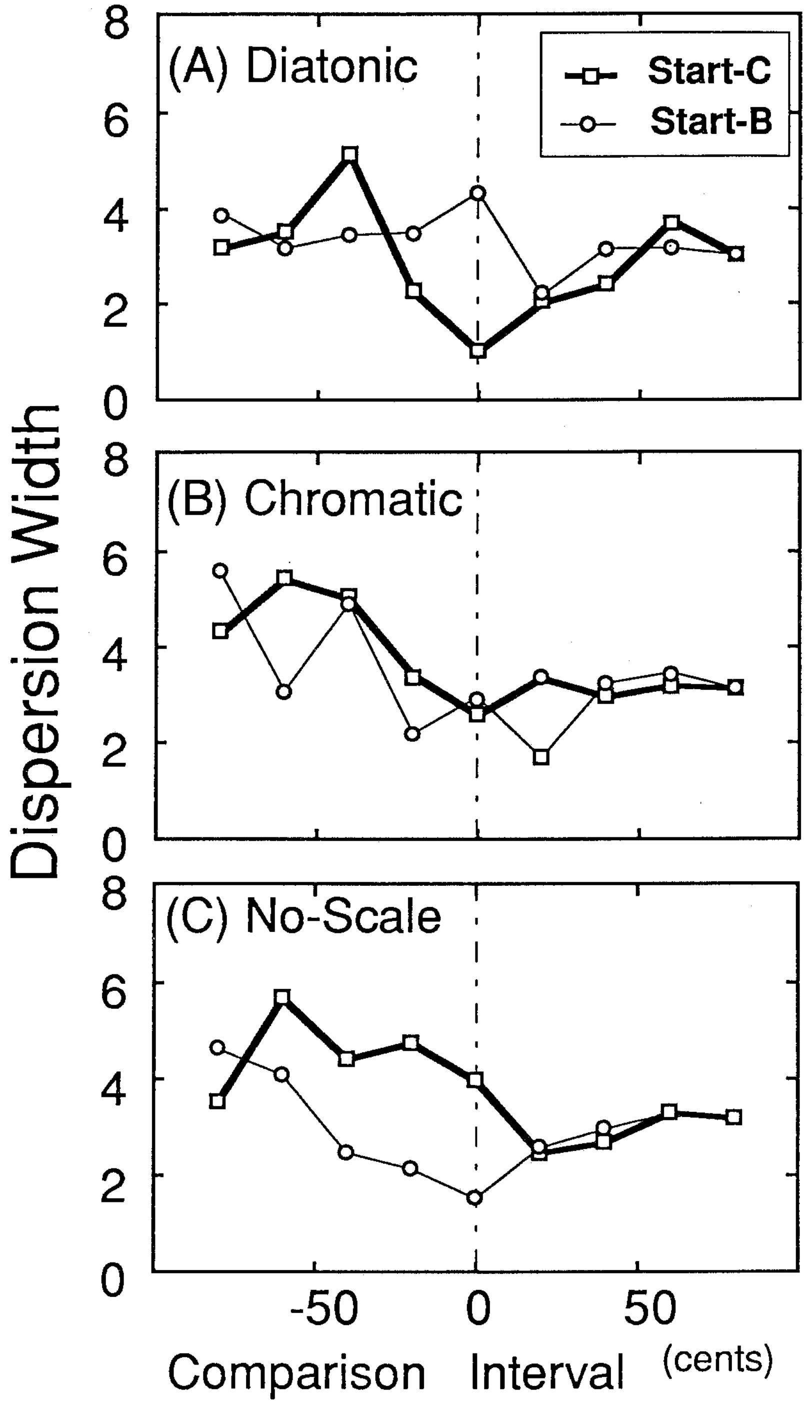
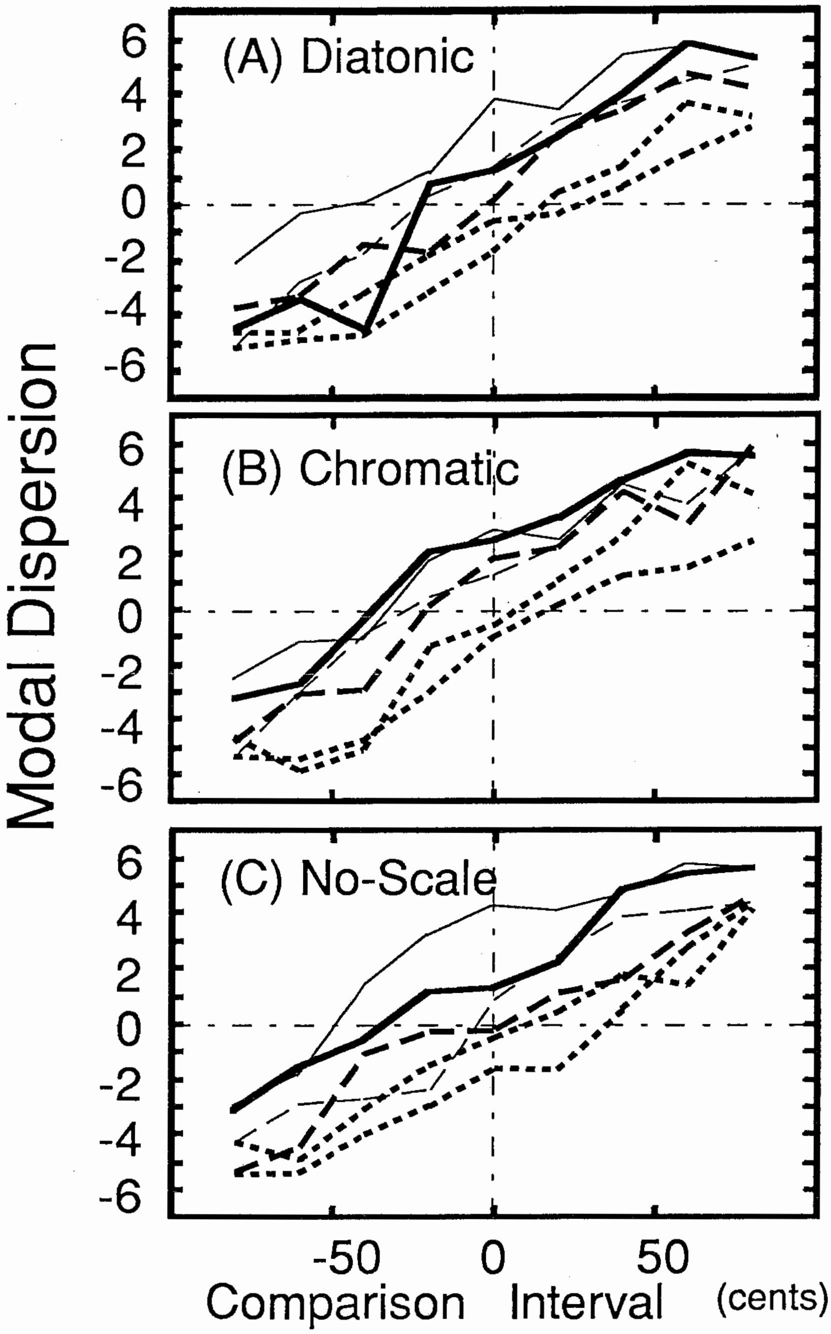


Figure. 4



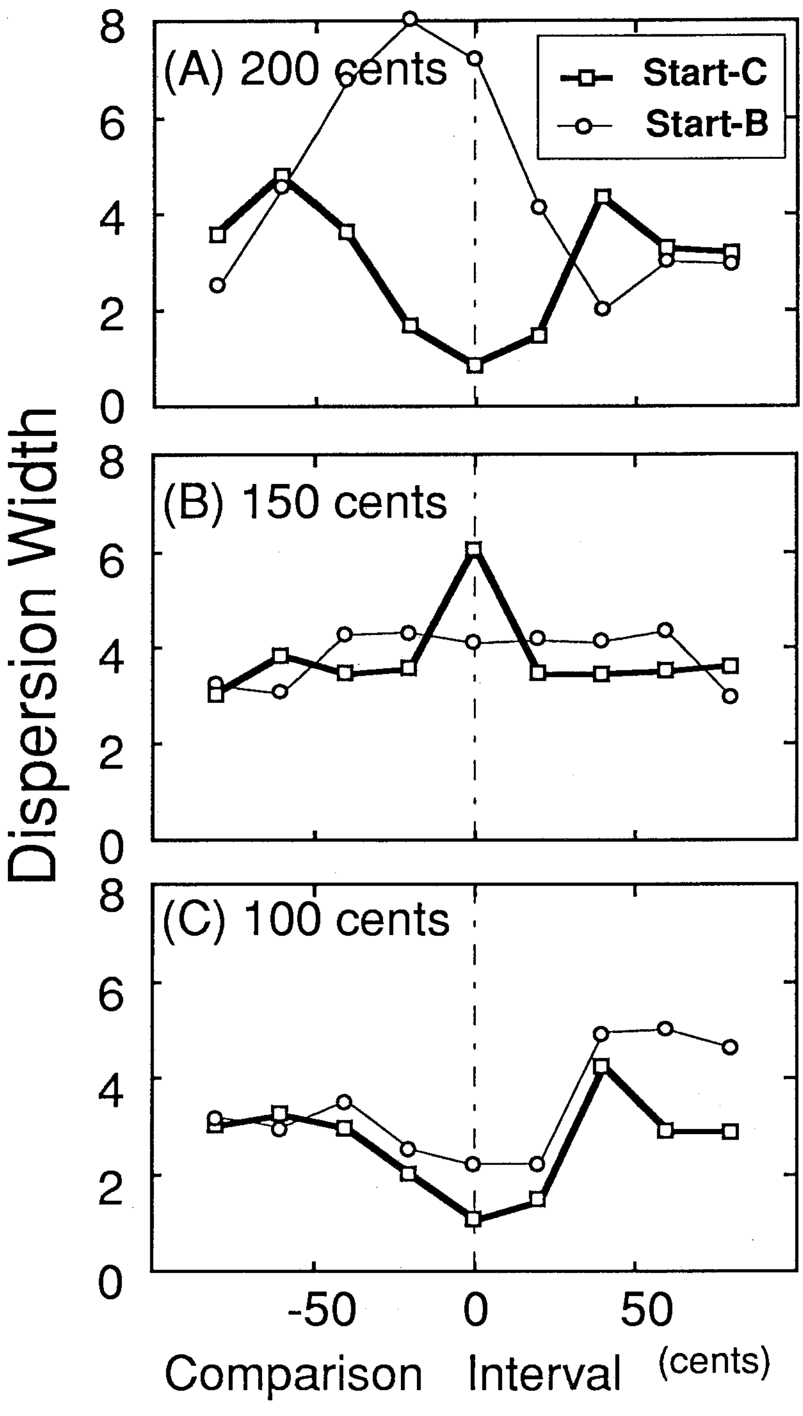
(A) Diatonic
Start-C
Start-B
(B) Chromatic
(C) No-Scale
Dispersion Width
8
6
4
2
0
-50
0
50
Comparison Interval (cents)

Figure. 5



Modal Dispersion
(A) Diatonic
(B) Chromatic
(C) No-Scale
6
4
2
0
-2
-4
-6
-50
0
50
Comparison Interval (cents)

Figure 6



(A) 200 cents
Start-C
Start-B
(B) 150 cents
(C) 100 cents
Dispersion Width
8
6
4
2
0
-50
0
50
Comparison Interval
(cents)

Figure 7

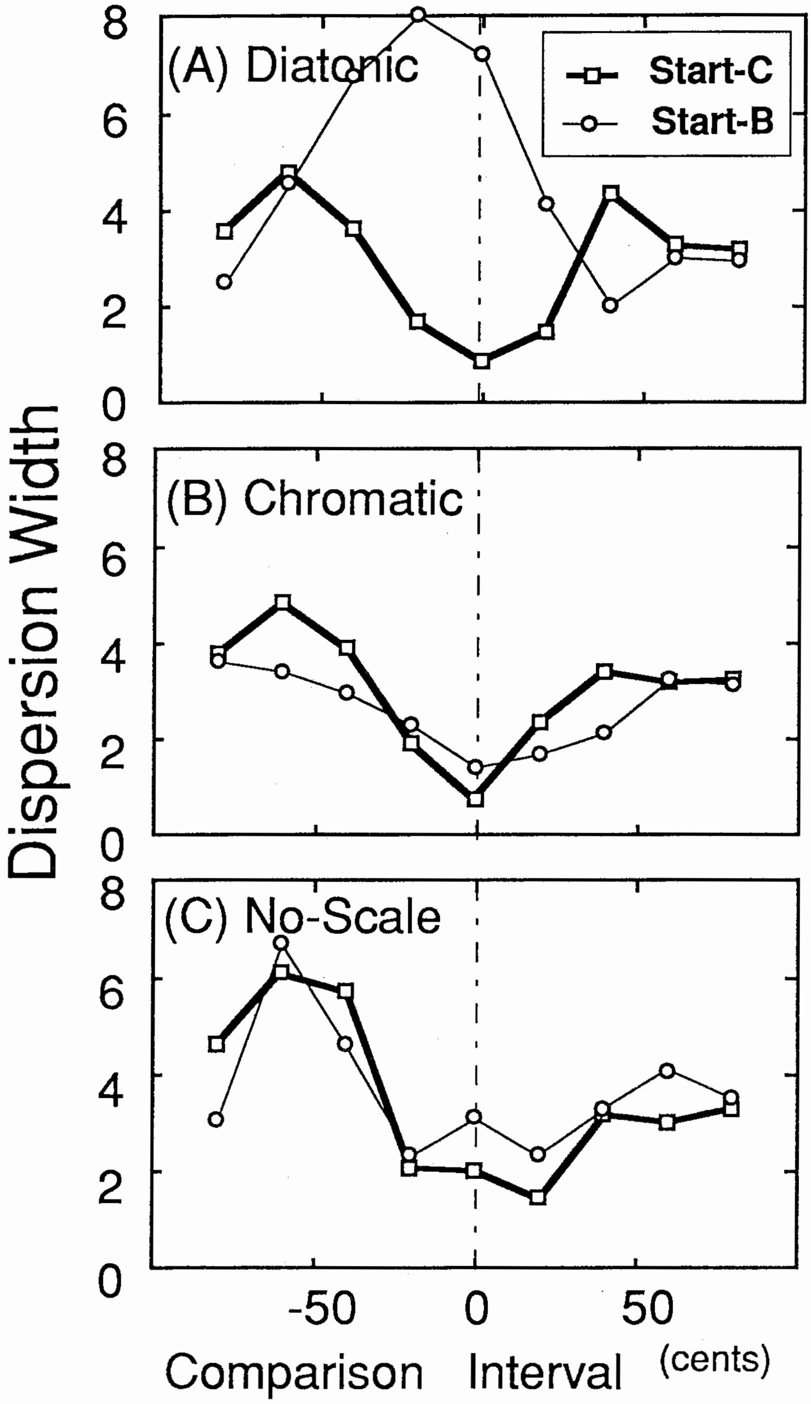
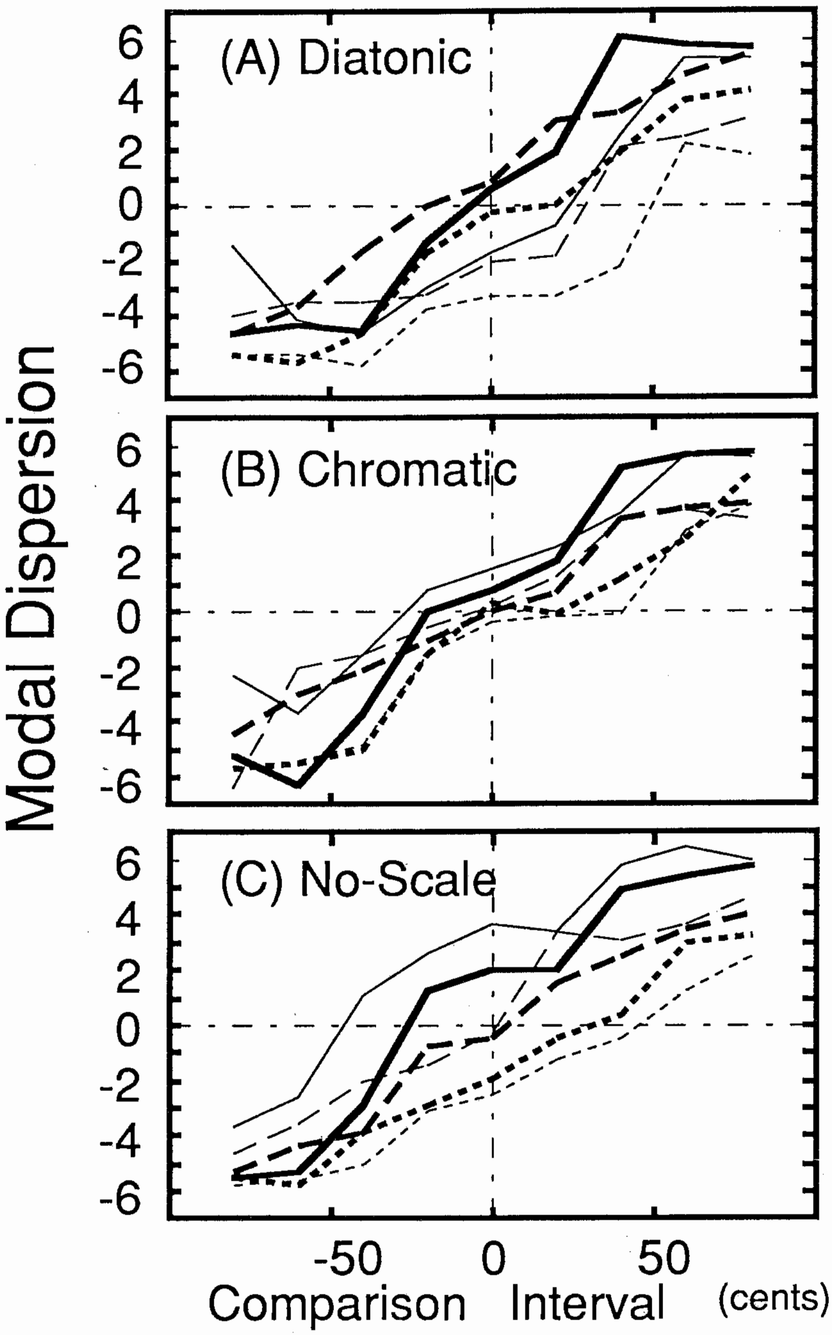
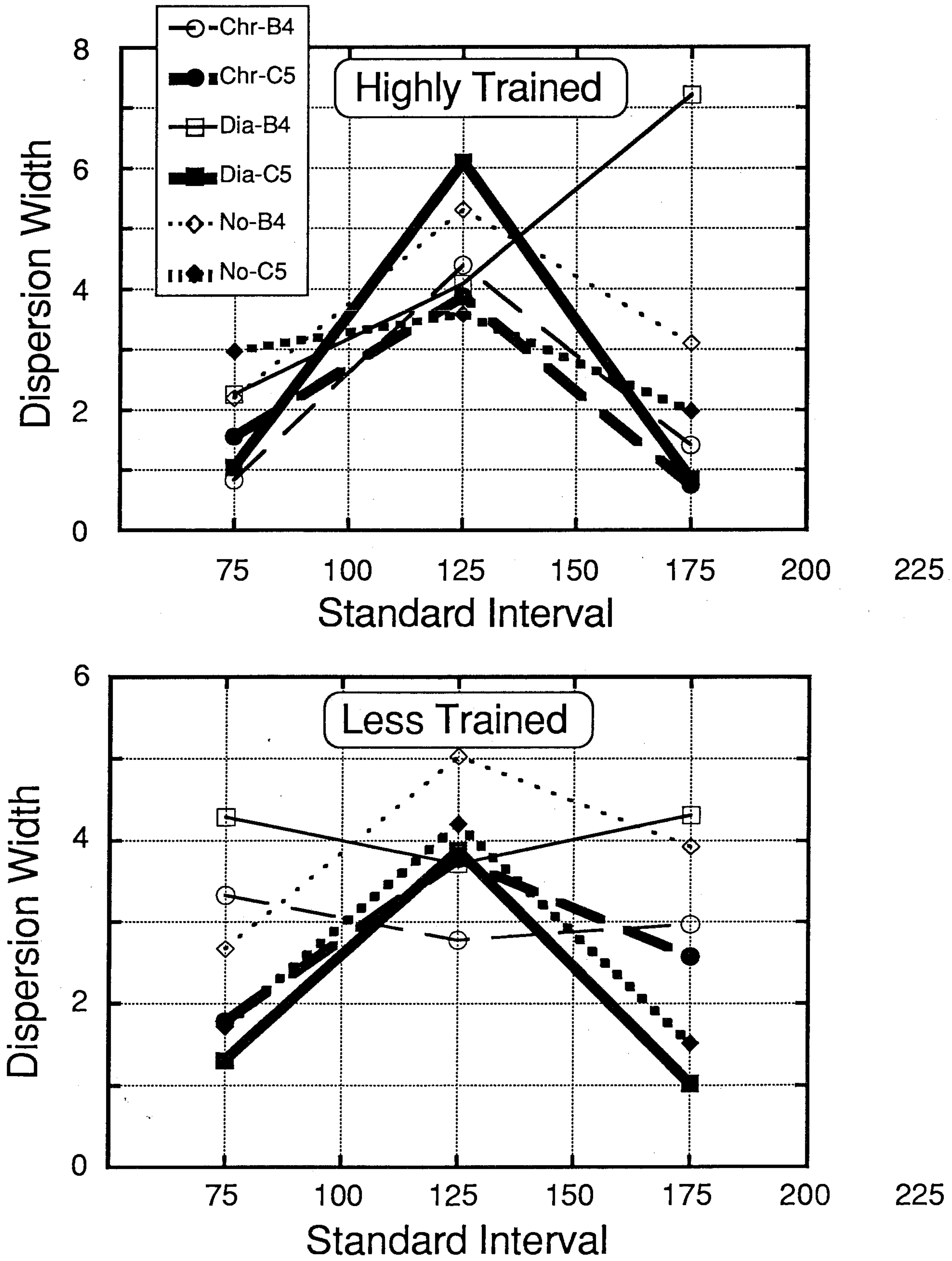

(A) Diatonic
Start-C
Start-B
(B) Chromatic
(C) No-Scale
Dispersion Width
8
6
4
2
0
-50
0
50
Comparison Interval (cents)

Figure 8



Modal Dispersion
(A) Diatonic
(B) Chromatic
(C) No-Scale
6
4
2
0
-2
-4
-6
-50
0
50
Comparison Interval
(cents)

Figure 9



Chr-B4
Chr-C5
Dia-B4
Dia-C5
No-B4
No-C5
Highly Trained
Dispersion Width
0
2
4
6
8
75
100
125
150
175
200
225
Standard Interval
Less Trained
Dispersion Width
0
2
4
6
75
100
125
150
175
200
225
Standard Interval

Figure 10