An Investigation of Perceived and Performed Sound Durations

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Abstract

The aims of this study were to describe the way in which sound durations are perceived, and to attempt to explain the hidden mechanisms of the duration perception in music performances. Three experiments were carried out to determine the difference limen for the perception of sound duration and to find the effects of frequency and intensity on duration discrimination. For short duration tones ranging from 25 to 100 msec, a linear improvement in discrimination judgements was found with increasing duration of signal. The JND was constant for durations between 100 msec and 2 sec. However, for extended stimulus durations (more than 2 sec) the JND was again linearly improved. Subjects were also presented with a pair of stimuli, composed of high and low frequency pure tones, and asked to discriminate differences in duration of the two tones and ignore differences in the frequency of the tones. It was found that subjects perceived the higher frequency to be longer in duration. When an experiment was carried out to investigate the effect of intensity on duration discrimination it was found that a 20 phon difference makes subjects perceive the louder stimulus as longer than the quieter stimulus. Finally, in a performance study, an analysis of musical performances revealed the effect of frequency. It was found that the musicians played the higher notes shorter than the lower notes. This agrees with what was previously found in the work on the perception of tones.

Ⅰ. Introduction

Most measurements of discrimination have focused on the smallest difference between two sounds that a subject can detect. Having examined the lower and upper bounds of hearing, the smallest perceivable difference between two sounds could be sought. This quantity is called either the just noticeable difference (JND) or the difference limen (DL). The JND is the smallest perceivable difference in dB between two intensities or the smallest perceivable change in Hz between two frequencies or the smallest perceivable difference in msec between two durations. The JND for a given continuum varies with the stimulus condition and with factors unrelated to the basic resolving power of the auditory system. Some of these factors [1] are: (i) the percentage of correct responses required to call the difference just noticeable, and (ii) the method by which the stimulus difference is introduced e.g., by modulating a continuous sound or by presenting separate, slightly different sounds.

In this context, studies of auditory perception have been carried out with an overwhelming concern for the frequency and intensity discrimination. For frequency discrimination in particular we know, fairly well, the factors concerning the limits of discrimination with respect to the method of stimulus presentation, the dependence on intensity, the masking effect, and even the duration effect. Although much work has been undertaken on factors affecting pitch and intensity perception, little work has been undertaken on the factors affecting duration perception. In particular there is a paucity of information on whether or not there is any effect of frequency difference on sound duration judgements. In this study, an experiment was first undertaken to confirm the previous studies of duration discrimination. Then, in the second and third experiments, the effects of frequency and intensity on duration discrimination were investigated.

Music is described as a "language" [2] whose acoustic perception usually is prescribed more precisely than is the case with other auditory signals, including speech. Actually, the frequencies of musical tones and the time signatures in which they are realized are most important factors for carrying information. However, it is not the physical sound parameters as such (e.g., frequency and temporal envelope of tones) that are the decisive criteria of musical performance, but the corresponding auditory qualities (e.g., subjective duration, rhythm, timbre, roughness, pitch, harmony) to the human auditory system.

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Hence, the quantitative relations between stimulus parameters and auditory sensations are of particular importance in the theory as well as the realization of music. When an interpretation is made as a compact coding of expressive forms [3], the only parameter variable over which the performer has almost complete control, regardless of which instrument he uses, is the duration of the sound events [4]. The manipulation of various durations might be the most important tool available to the performer. As Gabrielsson [4] mentioned, it is evident that timing has a connection with rhythm and also with melody, harmony and even a single chord. Actually, timing, in one way or another, influences every aspect of the music. Therefore, a sense of time is one of the most valuable determinants of what a person can hear in music and hence of a persons ability to perform. Based on the theoretical development, the last experiment reported in this study was planned to investigate whether there is a link between the duration perception and music performances.

Because detection test results for the smallest difference between two sounds are not typically stated in terms of objective correct or incorrect responses, subjective evaluation methods are generally used in experiments that require duration comparisons, loudness balances, pitch matches, or other judgments that are inherently subjective, *i.e.*, for which there is no objective criterion for the "correctness" of a response. This is unfortunate, since tasks that involve subjective judgments often have greater problems concerning signal detection tasks and subject training than those that involve objective judgments. They are difficult for both the experimenter and the subject and could benefit greatly from the advantages associated with forced-choice adaptive procedures. This paper describes one approach to the use of such procedures in subjective judgment tasks.

Ⅱ. Perception of Sound Duration

Studies of duration discrimination [e.g., 5-7] have been reported which employed a forced-choice procedure. In these studies, the durations used were less than 2 sec. In contrast, temporal intervals ranging from 25 msec to 8 sec have been used in this experiment. The experiment reported here employed a recognition paradigm; a pair of the different-duration signals was presented on each trial and the subject attempted to discern which one was the longer in the pair.

If a person is asked to compare the durations of stimuli which are several seconds long, he may subdivide the interval into a sequence of short durations which he can count rhythmically. This type of counting strategy has been frequently attempted in duration experiments and, as Getty [8] indicated, it is to a subjects advantage, when perceiving a long duration, to subdivide into a number of shorter durations. The subjects in this experiment were not given any instruction about using a counting strategy.

A. Experimental Method

There were two female subjects (N.J. and K.C.) and two male subjects (H.J. and S.K.), all of whom had normal audiograms. The subject N.J. had had experience in other experiments on auditory duration assessments. The other subjects were experimentally naive. The subjects ranged in age from 20-30 years, with most being university students. The subjects were paid for their services.

The subjects were tested individually in an anechoic room. Each received the schedule of stimulus presentations via a microcomputer (KAYPRO 286i) speaker. Computer code, written in C language, was written for this work. Each pair of sounds was comprised of two pure tones. The experiment was programmed to start presenting signal pairs of 10% difference in length and then vary this value depending on the subjects responses. The JND was determined as the ability to discriminate between the duration of the two signals in the pair using 75% correct scores. Responses of the subjects were interpolated to produce the JND for each standard duration.

The subjects were assessed by the two-alternative adaptive staircase procedure in this experiment. The subjects were required to select the sound they believed to be the longer one. The interstimulus interval (ISI) for each pair of sounds was one second and the next pair of sounds was followed one second after answering on a keyboard. The subjects listened to pairs of sounds which had standard durations ranging from 25 msec to 8 sec. The experiment was repeated three times and the average value was taken as a JND for the standard duration.

The frequency and intensity of the bursts were fixed at 1 kHz and 70 dB SPL, respectively. The rise and decay of the stimulus were steep so that a 'click' occurred at the beginning and the end of the signal. The clicks were about 1 to 1.5 msec, which is in total around 10% of the shortest (25 msec) stimulus. The clicks might help the subjects perceive the beginning and the end of the stimulus (and hence the duration of the signal).

B. Results and Discussion

The results of the experiment are presented in Fig. 1, which presents the Just Noticeable Differences (JND), obtained from four subjects, using standard stimuli durations from 25 to 8,000 msec, as a function of standard stimulus duration, Ts. From Fig. 1, the JND, for the whole range of stimuli durations, can be seen to vary from 2.7 to 28.7%.

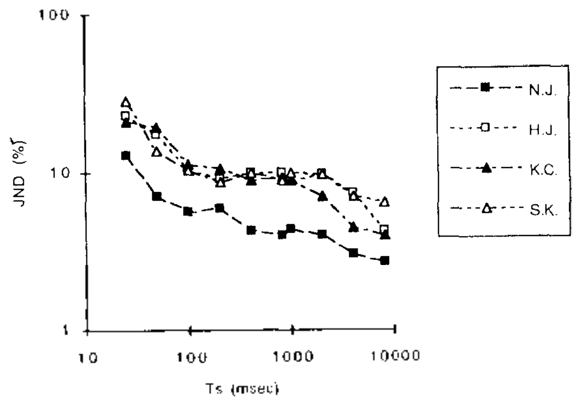

Figure 1. Just Noticeable Differences, JND (%), obtained for four subjects, as a function of standard stimulus duration, Ts (msec).

From the results of the experiment it is obvious that, for short duration tones ranging from 25 to 100 msec, a linear improvement in discrimination judgements was found with increasing duration of signal. The JND was constant for durations between 100 msec and 2 sec. However, for extended stimulus durations (2 to 8 sec) the JND was again linearly improved. All the subjects reported that they counted to help them discriminate between stimuli of longer durations. The results show that the subjects appear to accurately perceive the difference in duration between the two sounds when the standard stimuli durations are above 2 sec.

In the present experiment the untrained subjects, H.J., K.C. and S.K., produced low correctness scores in their duration judgements. For durations from 100 to 2,000 msec, their JNDs are approximately 10% and nearly independent of the stimulus duration. Fig. 1 also shows the individual differences of duration discrimination ability to judge relatively small duration differences. The trained subjects attain low thresholds for shorter stimuli durations (Ts = 25-50 msec).

However, the two breakpoints of 100 msec and 2,000 msec were common for all the subjects. These breakpoints are likely to be important in understanding how people perceive differences of sound duration. The reason for the first breakpoint is considered to be because of a change of auditory discrimination technique/mechanism in short duration stimuli. It appears that subjects use an 'energy' or 'loudness' strategy below 100 msec [5]. The second breakpoint is again thought to be due to a change in auditory discrimination technique (a counting strategy seems to be instinctively used above 2,000 msec). In the duration range between 100 and 2,000 msec the JND was approximately constant.

Ⅲ. The Effect of Frequency on Duration Discrimination

In one of Burghardts [9] experiments, a 1 kHz tone and a 200 Hz tone were presented in succession, and the subjects were made to adjust the physical duration of one of the tones in such a way that successive tones were perceived as having the same apparent duration. The relation between the physical durations of the two tones under the condition of equal subjective durations was investigated and it was found that the 200 Hz tone has to be presented with a greater physical duration than the 1000 Hz tone to be perceived with the same apparent duration. In another experiment, Burghardt matched in duration a 1000 Hz tone with a 3200 Hz tone in the same way and found that the subjective duration of pure tones depends not only on physical duration but also on frequency. Burghardt also found that when the physical duration of a pure tone is held constant its subjective duration is distinctly diminished by decreasing frequency. In Burghardts experimental results the range of duration in which the effect is significant is almost identical with the range of durations covered by the majority of musical tones (durations less than about 800 msec). The present work extends Burghardts experiments: different psychoacoustical methodologies are used, the range of frequencies extended (up to 8000 Hz), closer frequency intervals than a 1000 Hz tone and a 200 Hz tone used, and varied frequency in a pair of stimulus signals investigated.

In the current experiment musician subjects were presented with pairs of equal frequency stimuli and pairs of stimuli composed of high and low frequency pure tones. The task of the subjects was to discriminate differences in duration of the two tones. It is to investigate how duration discrimination depended on the difference of tone frequencies in each pair of stimuli. As the loudness of the generated sound could be controlled by the amplitude of the sound in the computer system and as equal amplitude tones, with different frequencies, would not sound equally loud [10], the subjects were given a control to adjust the amplitude of a second tone, of different frequency, to match the standard tone in loudness. This process continued until the range of frequencies (250 Hz-8 kHz) was covered for each subject. The equal loudness settings of the standard and comparison stimuli for each subject, as determined in the pre-test, were fixed for the experiment.

A. Experimental Method

There were two female subjects. Subjects N.J. and S.L. had had 15 and 13 years of musical experience, respectively. N.J. had previously taken part in other experiments on auditory duration assessments. The subjects were paid for their services.

A Macintosh IIci computer controlled the experiments. The MacRecorder sound system with its application, SoundEdit, enabled the recording, editing, playing and storing of sounds. The generated pure tone stimuli were saved in a range of file formats and presented by the other application, MacroMind Director. MacroMind Director was originally used as computer animation and presentation package, but the control for presentation of audio only was used in this experiment. Stimuli were presented through headphones and responses of the subjects were recorded on answer sheets by the subjects themselves who were located in a separate room. The rise/fall time for each stimulus was 5 msec which prevented audible clicks.

Pairs of standard (S) and comparison (C) tones (where S was 50, 100, 200, 400 or 800 msec and the values of C/S were 1.04, 1.08, 1.12, 1.16, and 1.2) were presented. The interstimulus interval (ISI) for each pair of sounds was 1,040-1,600 msec while the time between pairs of sounds was fixed at 4 sec. The data for the experiment were collected using a two-alternative forced-choice procedure (2AFC).

In the present work, stimulus pairs were used with frequencies; 0.25, 0.5, 1, 2, 4 and 8 kHz. It was designed to investigate the duration discrimination only when the comparison signal, C (which was of an equal or lower frequency than the standard stimulus) was the longer duration stimulus. Therefore, if S was 50 msec at 8 kHz, C would be 52 (C/S = 1.04) to 60 msec (C/S = 1.2) at frequencies of 0.25, 0.5, 1, 2, 4 and 8 kHz. If S was 100 msec at 4 kHz, C would be 104 (C/S = 1.04) to 120 msec (C/S = 1.2) at frequencies of 250, 500 Hz, 1, 2 and 4 kHz, and so forth.

All the stimuli pairs were presented 20 times. The order of the longer and shorter duration stimuli was equally distributed. Each subject served two hours a day and completed the experiment over two weeks.

B. Results and Discussion

The proportion of correct responses obtained in an investigation of frequency difference effects on duration judgements is shown in Fig. 2. The standard stimulus durations are from 50 to 800 msec and the standard stimulus frequencies are from 0.25 to 8 kHz. The trend of the frequency effect was similar for all the durations. Therefore, the results from each stimulus duration were averaged and compared at each stimulus frequency.

As shown in Fig. 2, when the tone frequencies were the same, duration discrimination performance was described well by a simple model of duration discrimination. When the frequency was varied for the comparison tone of each sound pair, but fixed for the standard stimulus within a pair, duration discrimination performance was poorer than for equal frequencies in most cases. The larger the frequency difference between the two tones within a pair, the worse the duration judgements.

Both subjects showed that frequency affected duration judgements except in the case of the 8 kHz tone pairs (not shown in Fig. 2). The effect of frequency on duration discrimination is strong in the case of a large frequency difference pair, but an 8 kHz tone does not seem to have an effect on duration judgements when compa-

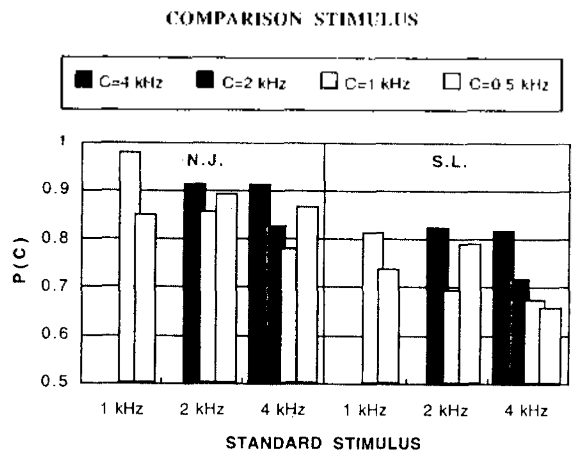

Figure 2. Comparison of proportions of correct responses, P(C), obtained from two subjects, in nine cases of frequency difference in sound pairs, using standard stimulus durations of 50, 100, 200, 400 and 800 msec. The standard stimulus frequencies (S) are from 1 kHz to 4 kHz and the comparison stimulus frequencies (C) are from 0.5 kHz to 4 kHz.

risons are made with lower tones from 250 Hz to 4 kHz. This is possibly because 8 kHz is outside the music and speech frequency range, and large pitch changes made a more disruptive effect on timing discrimination than did small ones [11].

A further explanation for the observed failure of the frequency effect in the 8 kHz tones is as follows: Above 6 kHz, the ability to distinguish between two tones on the basis of frequency becomes very poor. In fact, above 6 kHz, the sense that tones have a musical pitch is rather weak, and this may explain why the musical scale does not go above 4-5 kHz [10]. It is probably the reason why the two subjects, in the 8 kHz case, did not apparently respond to the frequency difference in the way they responded to the 0.5-4 kHz cases.

Ⅳ. The Effect of Intensity on Duration Discrimination

It has been known that both absolute thresholds and the loudness of sounds depend on duration [12-14]. For durations exceeding about 500 msec the threshold is independent of duration, however, for durations less than about 200 msec the sound intensity necessary for detection increases as duration decreases [15]. This means that absolute sensitivity decreases when the duration of a stimulus becomes much shorter than a second. The nature of this phenomenon reveals an interesting property of the auditory system, called *temporal integration*. Over a certain range of durations (about 15-150 msec) the ear appears to integrate sound energy for the purpose of detection. The additional energy contributed by signals of more than 200 msec in duration does not help in the detection of the sound so that the threshold does not change [16].

How then is intensity related to the threshold of duration? From Abels study [7] it can be seen that, for signals of 3.5 kHz frequency, a change in intensity from 85 to 65 dB did not affect discrimination performance when the standard stimulus duration, T, was 5, 40 and 320 msec. Creelman [5] also examined the effect of signal level on duration discrimination in the presence of noise. In his first experiment (*Effects of signal voltage on duration discrimination*), he found duration discrimination improved with an increase in signal voltage only at low signal-to-noise ratios, the dependence becoming negligible as the signals were made loud and clear above the noise background. In another study Creelman used two levels and varied T from 40 to 640 msec (Experiment 4: *Discrimination as a function of standard duration and signal voltage*). He found an interaction between signal level and T. The difference in duration discrimination, as a function of tone level, was greater as the value of T became shorter. Carbotte and Kristofferson [17] showed that for T equal to 50, 200 and 250 msec, changing the intensity by 37 dB (which was larger than the 17 dB in Abels study) resulted in the same small change in performance at 50 msec as that obtained at 250 msec, *i.e.*, there is a discrepancy between the results of Creelman and Carbotte and Kristofferson.

A. Experimental Design

There were two female subjects (N.J. and K.C.) and two male subjects (H.J. and S.K.), all with normal audiograms. The subjects ranged in age from 20-30 years, with most being university students. They had previously taken part in other experiments on auditory duration assessments, for at least 20 hours. The subjects were tested individually in an anechoic room. Each received the same schedule of stimulus presentations from the Macintosh computer through headphones. The rise/fall time for each stimulus was 5 msec.

Stimulus pairs were used with four different intensities. For the condition in which pairs had 0, 3, 6 and 10 dB differences in intensity, the amplitudes of stimuli were maintained at 100, 71, 50 and 32%, respectively. The 1 kHz frequency and 200 msec tone was maintained for the four sound pressure levels.

The subject N.J. was presented with C/S = 1.025, 1.075 and 1.125, and, for the other subjects, the values were 1.05, 1.1 and 1.15. The ISI and the time between pairs of sounds were the same as in the second experiment. The 2AFC method was employed in this experiment. Subjects were presented with a pair of stimuli composed of high and low intensity pure tones and asked to discriminate differences in duration between the two tones, ignoring differences in the intensity of the tones. All the stimuli pairs were presented 40 times. The order of the longer and shorter duration stimuli was equally distributed. Responses of the subjects were recorded on answer sheets by the subjects themselves.

B. Results and Discussion

As shown in Fig. 3, when C was lower intensity than S (Cases II, IV and VI), duration judgements were poorer than for equal intensities (Cases I and VIII). In cases II and III there was little difference in the correct responses because the sound level difference of two signals was only just perceptible (3 dB). When comparing Case VI with Case I, the difference of correct responses, with a 10 dB difference in intensity, was as large as 0.15. However, even though the intensity of S became lower than C (from Case I to Cases III, V and VII), the proportion of correct responses was almost constant at 0.79 to 0.82.

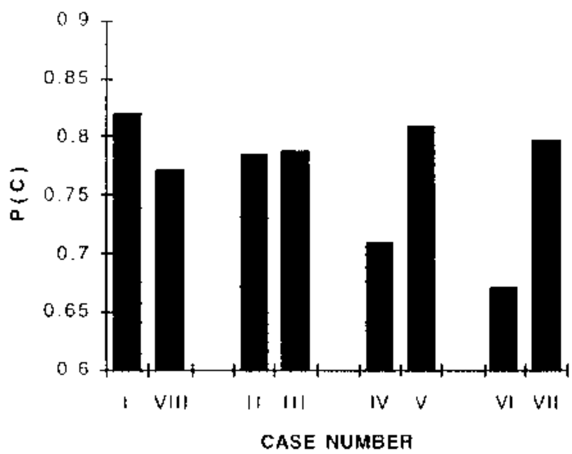

Figure 3. Proportions of correct responses, P(C), averaged from four subjects, in eight cases of amplitude differences from 32 to 100% of the standard stimulus amplitude (As) and the comparison stimulus amplitude (Ac), using a standard stimulus duration of 200 msec. Case I As:Ac = 100%:100%, Case II As:Ac = 100%:71%, Case III As:Ac = 71%:100%, Case IV As:Ac = 100%:50%, Case V As:Ac = 50%:100%, Case VI As:Ac = 100%:32%, Case VII As:Ac = 32%:100% and Case VIII As:Ac = 32%:32%.

From the comparison of Case I with Case VIII, it can be seen that the difference in performance as a function of tone amplitude is not great, even though there is large variation in amplitude (100-32%, 10 dB difference). There is a difference (as small as 0.05 in the P(C) value) between Case I and Case VIII which suggests that detectability has little importance. The result again supports Abels [7] data and does not support Creelmans [5] or Carbotte and Kristofferson [17] researches. The subjects discriminations were more likely to be affected by the amplitude of signals than detectability or intensity bias. If the subjects mainly based their judgements on detectability (*i.e.*, a high intensity), Case VIII should have had much lower P(C)s than Case VII.

The result suggests that duration discrimination of tone pairs is affected by variations in amplitude as by the apparent duration difference in the signals, even though reducing the duration of a tone burst has been believed to reduce sensitivity of intensity to some degree [13-14, 18-20]. This hypothesis might be further tested by investigating the thresholds on duration judgements (the duration JNDs) but for the same intensity range in the variable intensity case.

V. An Analysis of The Duration of Notes in Recorded Musical Performances

It has been known that music sounds unacceptable when performed by a digital computer in agreement with what is written in the music score. This discrepancy constitutes an essential part of music communication [21]. As Sundberg [21] mentioned, the discrepancy is not random and must be meaningful, that is, it carries information which the listener needs to enjoy the performance. What is this information? How is the acoustic code chosen when used by the musician for conveying it? Is this code used in music only or is part of it borrowed from extramusical communication? It seems a reasonable hypothesis that variations in the length of notes may contribute to the musicality of performances. What is being investigated in this section of the present work is whether the length of performed notes depends on the pitch of the notes *i.e.*, whether there is a link between the results of the previous experiments and music performances. More specifically the hypothesis is that higher pitched notes, of a given nominal length, will be played shorter than lower pitched notes of the same nominal length.

Despite the high accuracy of the computerized equipment there are still problems in certain cases, especially regarding physical and perceptual tone onsets as well as decays. The registered acoustical events are often complex. Tones appearing after another in the score overlap each other in the acoustical reality. This is why performance studies have to be supplemented by studies of the experimenter's (listener's) experience. Accordingly most of the present performance study was carried out by a musician N.J. having 15 years of musical experience, who has absolute pitch and served as a volunteer subject showing lower JNDs than the other subjects. For most of the experiments the performances were stored on sound files in the Macintosh computer. They were analysed by means of the sound system used in the previous experiments, which simultaneously displays the variations of total amplitude (intensity) and fundamental frequency or lapse of time (duration). By adequate filtering (low/high band pass filter) and calibrations it was possible to get very accurate representations of monophonic performances and in many cases also of polyphonic music.

A. Experimental Method

The performances of four contemporary flutists, Baron, Blau, Schulz and Beaucoudray, were analysed and compared by measuring durations (the flute part only) of their tone interpretations. The first three artists' recordings of the Mozart Flute Quartet in A-major, K. 298 and the Beaucoudray recording of the Bach Flute Sonata in E-minor were analysed. For the Quartet (first three repeated lines in Andante), the crotchets, which were performed at least six times for each note, were selected and their durations measured. The performance durations of semiquavers were measured in the sonata (first 10 lines in Adagio ma non tanto), to compare the duration interpretation in a piece of music.

The duration-measured notes for the Mozart and the Bach were E4, F#4, G4, G#4, A4, A#4, B4, C5, C#5, D5, D#5, E5, F#5, G5, G#5 and A5. The duration of each tone was measured from its onset to the onset of the next note with an accuracy of msec [4]. The very last notes, the very first notes in an incomplete bar, and the notes followed by a rest were omitted, since their durations could not be measured accurately. Each duration measurement of the notes was normalized as a proportion of performance duration of the bar to which the crotchet or the semiquaver belonged. The normalized duration for each performance was averaged and compared by pitch to find any trend which depended on pitch. Both the normalized and raw data were presented for comparison (See Figs. 4 and 5).

B. Results and Discussion

In Fig. 4, Figs. 5(a) and (b), the order of the polynomial regression was five. From the results shown in Fig. 5(a), the (normalized) mean durations of the crotchets show that the musicians performed the higher tone with shorter duration. The polynomial regression lines also reveal that there are periodical variations with a period of approximately one octave, although, in Fig. 5 (b), the correlations are poor and the polynomial fit is hardly justified.

The durations of the crotchets in the Mozart quartet and the semiquavers in the Bach sonata were 500-700 msec and 380-450 msec, respectively. In the Bach piece, the trend was observed in the performers duration interpretation of the semiquavers. As shown in Fig. 5(b), the normalized durations of the semiquavers in the Bach piece were mostly below '1', whereas, the normalized durations of the crotchets in the Mozart piece were evenly spread around '1'.

The reason for the larger variation in duration performances of the Bach than in the Mozart is probably because significant changes in music expression are led by the flute in the Sonata, which could be interpreted as the musician trying to make the music less 'mechanical'. In sonata music like the Bach it seems to be the flutist or the pianist who varies the expressive parameters [22] when they are in the leading part of the Sonata. Therefore there

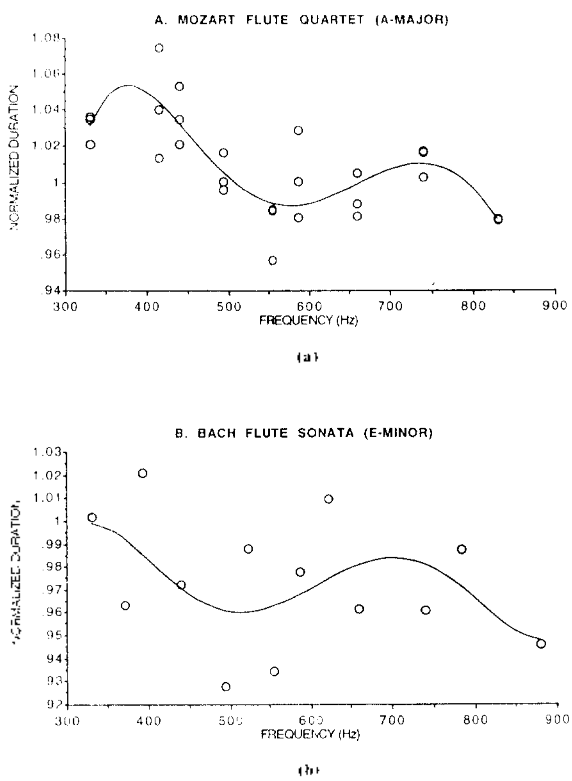

Figure 5. Comparison of the normalized note performance durations obtained from three performances (Baron, Blau, Schulz) of the Mozart Flute Quartet in A-major, K.298 (a) and Beaucoudray's recording of the Bach Flute Sonata in E-minor (b).

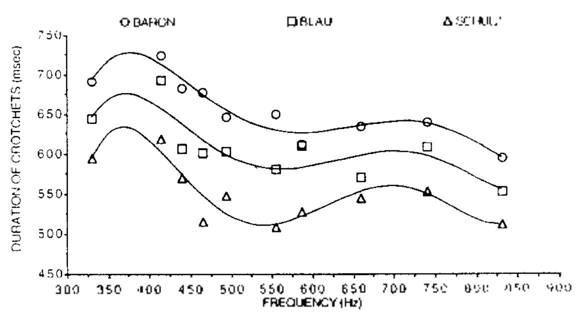

Figure 4. Comparison of the performed note durations obtained from three performances (Baron, Blau, Schulz) of the Mozart Flute Quartet in A-major, K.298.

may be variation among different performers interpretations of a musical work and intra-individual variations as well. However, from the Mozart, the periodic trend was obvious for the three performers, *i.e.*, it can at least be mentioned that the trend is not performer specific. The influence of instrument and key signature should be further investigated.

Ⅵ. Conclusions

The result in the first experiment shows an interesting tendency in the variation of individual threshold of sound duration. There are two breakpoints of 100 msec and 2 sec. For short duration tones ranging from 25 to 100 msec, a linear improvement in discrimination judgements was found with increasing duration of signal. Then it is constant for durations between 100 msec and 2 sec. For extended stimulus durations (2 to 8 sec) the JND was again linearly improved [23].

So far it has been found that duration discrimination is worse when there are frequency differences. For different frequency sound pairs subjects perceive the higher frequency sound to be longer in duration [23]. The effect of frequency on duration discrimination is strong in cases where the pair of tones has a larger frequency difference. However, when the higher tone frequency was above 4 kHz, the effect of a large frequency difference (0.25 to 4 kHz) on duration judgements with lower tones disappeared. From the results of experiments to investigate the effect of intensity on duration discrimination, it was found that the duration discrimination tasks are affected by an intensity difference of 20 phons [24].

The last experiment reported in this paper attempt to account for duration fluctuation at the note level. It has been found that high tones are played shorter and such practice has been justified in terms of previous results which demonstrate that high tones are perceived as longer than lower tones of the same physical duration [23]. It seems that musicians change their performance deliberately and sometimes unconsciously: the musicians played the higher notes shorter than the lower notes. The performers perceive higher tones longer as a listener of their performance and they are likely to perform higher tones shorter. There is also some evidence for periodic variation over an octave in the duration of performed notes though this is not significant in most of the performances studied.

Possible applications of the present perception study might be areas like signalling codes or speech coding scheme for a speech processor, speeded up speech in advertisements, safety devices and warning signals. Finally, it is worth commenting that duration discrimination testing is potentially a valuable tool to investigate the perception of sound and hearing disorders. It is surprising that so little attention has been paid to it especially as it is fundamental to the performance and perception of music.

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