

Fluctuation strength of tremolo played on the mandolin: How is tremolo evaluated as good?

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The tremolo played on the mandolin is a continuous sound produced by the repetition of attenuating sounds. The amount of acoustic amplitude of tremolo is usually fluctuated in terms of time. Therefore, the tremolo is assumed to give a listener the feeling of fluctuation, which is thought to be concerned with subjective evaluation for performance proficiency. Introduced here is an evaluation method that strongly depends on the “fluctuation strength” (FS), which has been suggested as an index for evaluating the feeling of fluctuation for fluctuating sounds at low frequencies. Past studies have investigated the index for modulated pure tones and broadband noise. In this study, tremolo fluctuations are described by FS, and the relation between FS and tremolo proficiency was investigated through evaluation experiments. Specifically, we conducted four studies using performance sounds and two kinds of synthesized sounds. As a result, highly rated tremolos had a relatively low physical FS and were correlated with highly subjective evaluations. Therefore, we confirmed that skilled tremolos satisfied both playing restrictions and psychoacoustical criteria.

Keywords: mandolin; tremolo; feeling of fluctuation; fluctuation strength; subjective evaluation

The tremolo is one of the popular ways of playing the mandolin (Fujita 2005). Though there is almost no agreement concerning the physical characteristics of tremolo played by experts, the feeling of fluctuation on tremolo is thought to be concerned with subjective evaluation for performance proficiency. The “fluctuation strength” (FS) has been suggested as an index for evaluating hearing sensation in fluctuating sounds at low frequencies, and past studies have investigated that of modulated pure tones and broadband noise (Ter-

hardt 1968, Fastl 1982, Fastl and Zwicker 1990). However, few have reported on the FS of fluctuating musical sounds produced by musical instruments and proficiency. In addition, there are no suggestions for an index corresponding to their proficiency.

Therefore, tremolo fluctuations are described by FS, and the relation between FS and tremolo proficiency was investigated through evaluation experiments. The plucking rate, onset deviation, and amplitude deviation are set on the basis of our assumption that they affect the hearing sensation and subjective evaluation for tremolo more strongly than the other factors. Here, both onset and amplitude deviation are called “irregularity on tremolo.” Aesthetic performances of tremolo are said to be “smooth” or “not fluctuating” by trained players, so the amount of FS for tremolo is originally calculated by extracting a fluctuation component of about 4–8 Hz from acoustic data. The procedure for objectively calculating the amount of FS is designed based on facts reported by past studies (Terhardt 1968, Fastl 1982, Fastl and Zwicker 1990) and an assumption that the characteristics of the tremolo are somewhat similar to the AM SIN at slow speeds (Roads 2001).

Therefore, we hypothesized that the fluctuation components extracted originally from a tremolo influences the feeling of fluctuation (or an aesthetic evaluation). Here, the calculated FS is called “physical FS,” while the FS proposed by Fastl *et al.* is called “psychological FS.” We conducted four studies using performance sounds and two kinds of synthesized sounds. In Study 1, the region of plucking rates used in actual tremolo performance was investigated. In Study 2, in order to describe tremolo fluctuation by FS, the relation between feeling of fluctuation, and physical FS was investigated using synthesized sounds that have just a feeling of fluctuation without tremolo proficiency, played at several plucking rates (2–16 Hz). In Study 3, the relation between physical FS and tremolo proficiency was investigated using performance sounds played at three plucking rates (6, 8, and 9 Hz). However, factors that affect the feeling of fluctuation and subjective evaluation for tremolo proficiency are not only plucking rate but also onset deviation and amplitude deviation. The unified irregularity on tremolo is rarely found by simply observing actual performance. So, in Study 4, the relation between physical FS and tremolo proficiency was investigated using other synthesized sounds by controlling three parameters that have both tremolo proficiency and feeling of fluctuation. Here, synthesized sound used in Study 2 is called “imitated sound,” while the sound used in Study 4 is called “simulated sound.”

METHOD

Participants

In Study 1, four mandolin players with over two years of experience were used as listeners. In Study 2, two of the listeners were mandolin players, and three of the listeners had no experience of playing the mandolin. In Study 3, seven mandolin players (P1-P7) with over three years experience were used as mandolin players. Six other mandolin players with over a half year of experience were used as listeners. In Study 4, five other mandolin players with over a year of experience were used as listeners.

Materials

In Study 1, simulated tremolo sounds with onset deviations and amplitude deviations on each plucking were used, 60 in total (3 deviation patterns and 20 plucking rate patterns). In Study 2, imitated tremolo sounds with onset deviations and amplitude deviations on each plucking were used, 45 in total (3 deviation patterns and 15 plucking rate patterns). Those sounds have just a feeling of fluctuation without tremolo proficiency. In Study 3, 21 tremolo sounds played by 7 players were used (i.e. 3 plucking patterns times 7 players). In Study 4, simulated tremolo sounds with onset deviations and amplitude deviations on each plucking were used, 27 in total (3 deviation patterns and 9 plucking rate patterns).

Procedure

In Study 1, participants were asked to evaluate whether or not stimuli were significantly perceived as tremolo sounds. In Study 2, an experiment using the method of magnitude estimation was conducted to subjectively evaluate the magnitude of fluctuation for imitated sounds synthesized at several plucking rates (2-16 Hz) under three deviation patterns by five listeners. In Studies 3 and 4, the two tremolo sounds were presented one immediately after the other, and listeners were asked to subjectively select the better one.

RESULTS

The result of Study 1 is shown in Figure 1; it was found that simulated sounds synthesized at plucking rate of 6-13 Hz were evaluated as tremolo sounds. The result that compared FS with amplitude-modulated pure tone (Terhardt 1968, Fastl 1982, Fastl and Zwicker 1990), as well as comparing to physical FS, is shown Figure 2. The magnitude of fluctuation for imitated sounds in

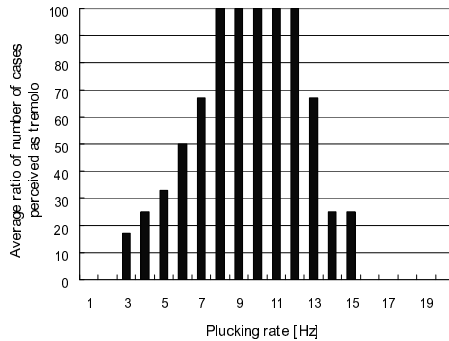


Figure 1. Results of investigation of the region of plucking rates.

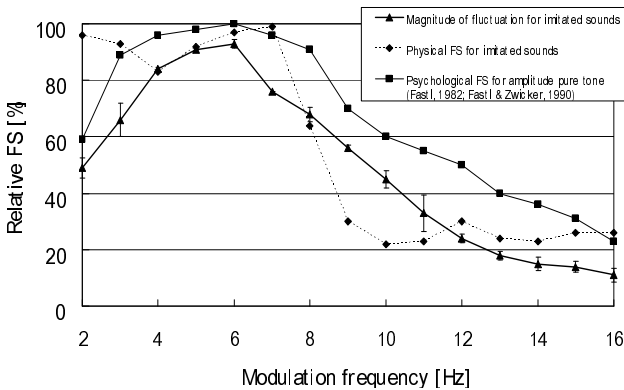


Figure 2. Results of investigation of feeling of fluctuation.

Figure 2 is the average of all results, represented as a percentage. Percentages were obtained by assigning the number 100 to the maximum value of each listener’s answer. As can be seen in Figure 2, it was confirmed that magnitude of fluctuation for imitated sounds is high at plucking rate of 4-8 Hz and low at plucking rate of 10-16 Hz. It revealed that the feeling of fluctuation for simulated sounds has a strong positive correlation with a high FS of amplitude-modulated pure tone and physical FS ($0.81 \leq r \leq 0.98$, $n=15$).

As a result of Study 3, it is confirmed that tremolos performed at plucking rates of 8 or 9 Hz were evaluated as good. Also, it is confirmed that faster rates correspond to smaller amounts of physical FS.

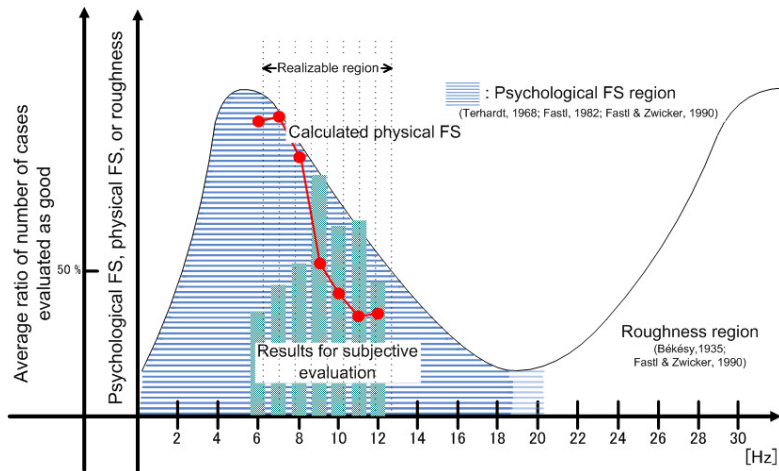


Figure 3. Relation between our results and psychological FS. (See full color version at www.performancescience.org.)

As a result of Study 4, it was found that the tremolos synthesized at plucking rates of 8-11 Hz were evaluated as good. Also, it was found that a plucking rate of 7 Hz corresponds to larger amounts of physical FS, and one after 7 Hz corresponds exponentially to smaller amounts of physical FS.

DISCUSSION

As seen from Study 4, highly rated tremolos had a relatively low physical FS. Furthermore, the physical FS has a strong negative correlation with a high subjective evaluation ($r=-0.60$, $n=27$). Therefore, this shows that physical FS can be used as an evaluation index of the tremolo performance proficiency played on the mandolin.

The relation between results obtained in this study and psychological FS is shown in Figure 3. The “realizable region” is obtained from the results of Study 1. As can be seen in Figure 3, two strong relations were confirmed among the calculated physical FS: the subjective evaluation results and the psychological FS.

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References

- Békésy G. (1935). Über akustische Rauigkeit. *Zeitschrift für technische Physik*, 16, pp. 276-282.
- Fastl H. (1982). Fluctuation strength and temporal masking patterns of amplitude-modulated broadband noise. *Hearing Research*, 8, pp. 56-69.
- Fastl H. and Zwicker E. (1990). *Psychoacoustics Facts and Models*. Berlin: Springer-Verlag.
- Fujisawa N., Yamada M., and Nakayama I. (2000). Fluctuation in frequency of Japanese pressed voice, Dami-Goe. *Journal of the Acoustical Society of Japan*, 21, pp. 365-367.
- Fujita O. (2005). *The Correct Way to Play Mandolin: Illustrated for Beginners to Instructors with Concert Repertories*. Tokyo: Zen-On Music Company Ltd.
- Kurakata K., Kuwano S., and Namba S. (1993). Factors determining the impression of the equality of intensity in piano performance. *Journal of the Acoustical Society of Japan*, 14, pp. 441-447.
- Rauber A., Pampalk E., and Merkl D. (2002). Using psycho-acoustic models and self-organizing maps to create a hierarchical structuring of music by sound similarity. Paper presented at the *Third International Conference on Music Information Retrieval*, Paris.
- Roads C. (2001). *The Computer Music Tutorial*. Cambridge, Massachusetts, USA: MIT Press.
- Terhardt E. (1968). Über akustische rauigkeit und schwankungsstärke. *Acustica*, 20, pp. 215-224.