JTML, Vol.3, 2-14

IMPROVING PIANISTS' RHYTHMIC PERFORMANCES IN SCORE READING THROUGH IMITATION AND FEEDBACK

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This research explored the applicability of an aural/visual imitation feedback technique to enhance learning to imitate recorded performances of piano melodies by piano students. In particular, it examined more closely the role of piano roll "performance score" visual feedback in improving less advanced students' understandings of rhythmic notation. A comparison was made between two imitation approaches. One consisted of aural presentations of expressive models played on a Disklavier with simultaneous visual display of the data as a scrolling piano roll on a computer screen. Aural/piano roll score feedback was followed by aural-plus-visual feedback of how well a student's imitation attempts matched the models. The other approach used aural presentation of models with notated score followed by aural-only feedback of the imitation attempts. Students achieved better imitation of the time dimensions of expressive models with aural/piano roll feedback than with aural/notated score feedback alone.

One of the most important concepts to be transmitted to students in music learning is that of notation being symbols for sounds. But no notated score can explicitly provide all the indications that must be observed for the performance of a piano piece to be musically satisfactory. Then how is this done? Research on music performance often assumes that the interpretive decisions arise naturally and consciously out of what the specifics in the score imply (Palmer, 1996). However, there is a problem with this assumption. A theme that has emerged from Woody's research (2000) on the acquisition of performance skills is the disagreement about the level of consciousness involved in expressive performances and the explicitness (or lack thereof) with which music teachers address student learning of expressivity.

The meaning of notes and rests lies in the quality of the sounds and silences. The exact rendering of the notes, the nuances, the inflection, the intensity and the energy with which notes are performed become their musical meaning (Lewers, 1980). Accepting this as truth, should we not be insuring that students develop musical skills to hear the sounds the symbols represent? Learning to become musically literate involves more than linking visual cues with instrumental fingerings (McPherson & Gabrielsson, 2002).

Thus once again, how does one effectively teach the nuances of sounds and silences that are implied by notes and rests on a score, helping students to not read note by note, but to shape the phrase by emphasizing patterns (Aiello, 1994)? Bamberger (1996, 1999) concluded that students must first experience playing musical patterns before they can learn to separate these patterns into individual notes. Imitating minute timing variations makes for performing expertise but first requires analytic listening powers to hear and understand them.

This study's evaluation of imitation as a teaching tool in piano instruction was inspired by the reputation of imitation for communicating style and technique to jazz musicians, composers, and visual artists. That reputation has been supported by Clarke's 1993 investigation of pianists' ability to perceive expression through imitation of the expressive piano performance of others.

The present study also examines the importance of feedback type in the pedagogical effectiveness of imitation. Feedback can improve expressive skills of music performance (Juslin, 2001; Juslin & Laukka, 2000). Several studies have measured the effectiveness of aural and visual feedback on musical learning. In particular, the results of Paladino's 1991 study, designed to determine the effect of aural feedback on children's melodic perception, indicate that feedback significantly improved melodic perception. Robinson (1994) examined the influence of visual and aural feedback on the pitch and duration characteristics of students' musical compositions. Results showed that the children in the study chose to utilize both visual and aural feedback, as well as time for reflection, to review and revise their compositions.

Johnson (1998) demonstrated that, given specific information on rhythm emphasizing rubato as noted in professional performances, musicians are able to modify their own performances and perform more musically. A study by Tucker, et. al. (1977) showed that augmented visual feedback can have striking effects on the acquisition and improvement of technical skills. With the aid of feedback displayed visually in modified notation that reflects the exact duration of the notes played, a concert level pianist dramatically improved his performance of a trill within minutes.

Technology

It is of historical interest that a technology employed by Carl Seashore in his groundbreaking studies (1936, 1938) of those aspects of music performance not ordinarily notated on the printed page resulted in a type of visual representation similar to that used in this study. Through the use of a special camera mechanism to record precisely on film the sequence, velocity, and duration with which the hammers of the 88 piano keys contacted their corresponding strings, Seashore made a photographic record of the beginning, duration and relative intensity of all the notes of a given piano piece. Using this record he derived what he termed the "performance score" of that piece.

Seashore's pedagogical purpose for study of the performance score was threefold: (a) to gain visual familiarity with the relation of performance scores to notated scores, (b) to compare performances of different pianists in terms of technical skill and individual interpretation, and (c) to examine elements of performance in detail. Training students to perform a piece involves combining their mental plan for how it should be interpreted with a physical motor control plan for carrying it out. Discrepancies between the two often arise. Knowing this, Seashore intended for the reader of one of his performance scores to attempt to replicate the score on the piano, stopping at different points to "hear out" the significance of a particular nuance in phrasing.

In the face of the widespread lack of agreement as to what comprises the interpretive implications of a score, it is the working hypothesis of the research reported here that many of these elements can be best understood and mastered through repeated efforts on the part of a student pianist to imitate exactly model performances of professionals that illustrate what the score inadequately communicates. These efforts at imitation generally should yield the best gains when interspersed with immediate followup analyses of the discrepancies between the model and the imitation attempt. The focus of these analyses should be the identification of motor skill adjustments that are necessary to close the discrepancy gap in terms of specific musical elements (timing and dynamics). The analyses require (a) the model to be imitated must be a good one, indicating what the notated score is inadequate of indicating; and (b) the student should be provided immediate feedback on how successfully his or her imitations match the model and what can yet be done to improve the match. A technology is required whereby both the professional example to be modeled and the student pianist's own efforts at imitation can be represented. The technology should allow the student to clearly apprehend how the imitation does and does not match the model.

A previous study (Riley-Butler, 2001) using eight college level piano majors explored the ability of aural/visual feedback as a tool in a comparative performance analysis of three performances of *Chopin Nocturne, Opus 15, No. 1,* by well-known artists. The findings confirmed Palmer's (1996) and Todd's (1992) documentation on several general characteristics.

1. Large amounts of slowing of tempo often occur at phrase boundaries.

2. The more the tempo slows down, the quieter the notes are played.

3. There are greater intensities at melodic contour peaks and lower in tensities at contour valleys.

4. The major source of timing variations was varying degrees of empha sis on expected locations (Repp, 1992).

In the same study, aural/piano roll feedback also was used for imitation of the artists' models by the piano majors in order to enhance their perceptual and technical mastery of interpretive nuances implicit in a score. The results suggested that aural/piano roll feedback has a much more pronounced and immediate effect on student understanding than the traditional method of listening to performances with notated score feedback.

In the present study, a somewhat more sophisticated design was used to determine if the findings from the first study could be generalized to a population of less advanced, younger piano students. The study's main research question seeks to evaluate the relationship of the type of feedback pianists receive after imitating a model to their ability to improve subsequently in their imitations. Specifically,

1. Are there differences in the accuracy of pianists' rhythmic imitation of a model melody when they view recorded performances in scrolling piano roll notation as opposed to traditional printed notation?

2. Are these differences consistent across repeated treatments?

The Technology Instrument

The Yamaha Disklavier piano used in the study is an acoustic instrument equipped with optical laser sensors. The MIDI (Musical Instrument Digital Interface) function of the Disklavier continuously measures the mechanical velocity of each key's hammer, registering the speed of its down-stroke. The sustain and shift pedals also are equipped with these continuous-position sensors. This equipment immediately converts these mechanical parameters into their piano sound aural equivalents.

The parameters of the time intervals elapsing between key strikes, the velocity of each strike, and the release time of each note, are recorded digitally on a floppy disc for possible data analysis and/or playback. The playback feature ensures exact mechanical replication of the sounds produced in the original performance and thus also ensures that tonal irregularities, noise and distortion, typically found in audio recordings of a piano, are avoided.

Music Sequencer

By utilizing high quality music sequencing software to read the floppy disc, the performance information can be displayed on a computer screen as a scrolling piano roll, to be read from left to right (Figure 1). Horizontal bars of various lengths indicate which keys are depressed (see the keyboard aligned vertically to the left), in what sequence, and for how long. Dynamics can also be interpreted visually from the piano roll. Emagic's Logic software, which was used in the study, displays the note bars in colors (not shown here) that varied from blue (soft) to red (loud) to represent dynamic levels.

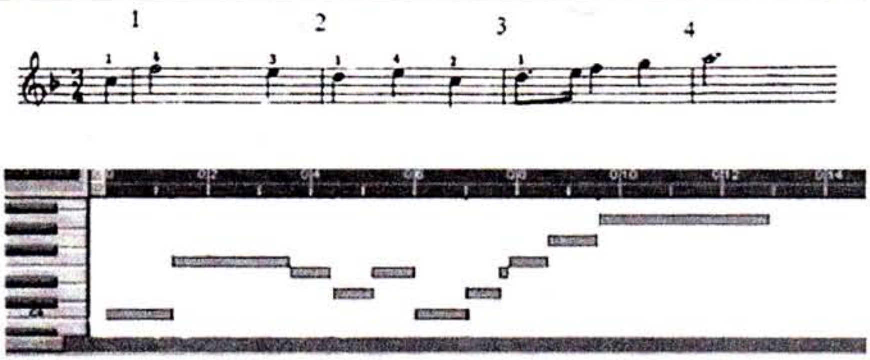

Figure 1. Notated and piano roll scores of Chopin melody, measures 1-4.

Feedback

The visual feedback of the piano roll can be viewed on the computer screen simultaneously while hearing playback through the Disklavier that offers a performance score of the performance. This performance score assists students in understanding the executed timing of the music example through the visualization of the length and juxtaposition of the horizontal bars that represent notes. This simultaneous playback on the Disklavier while viewing the piano roll permits one to compare performances in terms of technical skills and personal interpretation, and to examine difficult-to-notate elements of timing and dynamics in detail, such as specifically where and to what extent to ritard or accelerate the tempo.

Method

Materials

Three musical examples from the piano literature served as the models to be imitated. Melody lines only, as displayed in notation in the upper portions for Figures 1, 2 and 3, were taken, respectively, from the *Chopin Nocturne Opus 15, No. 1,* measures 1 through 4, *Beethoven Sonata Opus 7, Largo,* measures 1 through 4, and *Rachmaninoff Concerto No. 2, third movement,* measures 1 through 8. These performances, by the first author (a professional pianist) were recorded on floppy disc and played back using the Yamaha Disklavier technology. The melodies were chosen with the intention of presenting different rhythmic notation: quarter note/half note, (Rachmaninoff), dotted eighth/sixteenth and rests (Beethoven), and quarter note/half note rhythm with dotted eighth/sixteenth (Chopin).

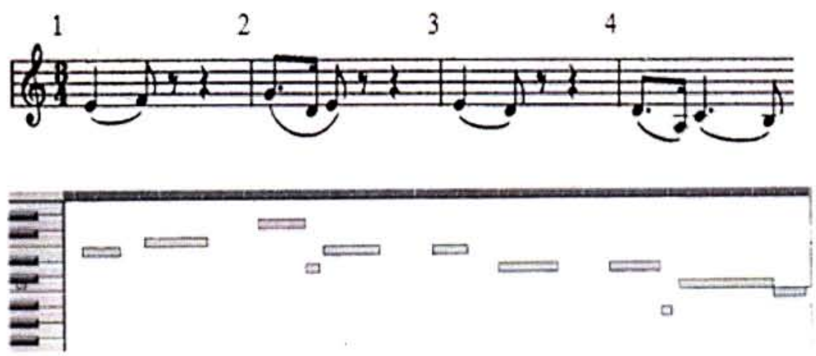

Figure 2. Notated and piano roll scores of Beethoven melody, measures 1-4.

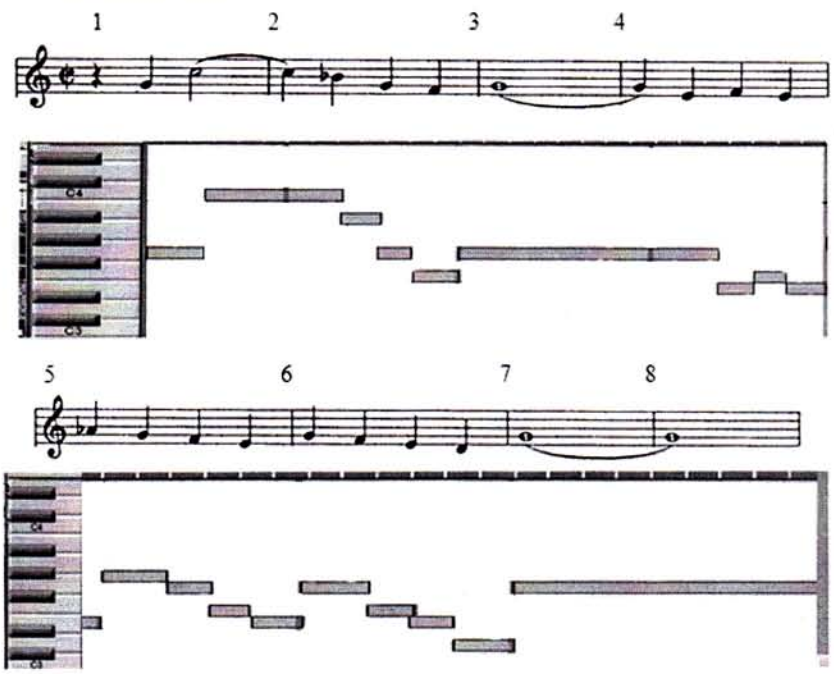

Figure 3. Notated and piano roll scores of Rachmaninoff melody, measures 1-7.

The reason for choosing different rhythmic notation was to study and compare students' perception of the written notation with their perception of the piano roll notation in listening and imitation. One can observe by the length of the note bars on the piano roll score in Figure 3 that the quarter notes in measures 5 and 6 were not played evenly. The quarter notes on the first beats of measures 5 and 6 were held longer than the other three quarter notes in the measures. In measure 6, the second and third notes were played closer together and the fourth note was held longer. The piano roll indicates the liberties taken by the pianist in performance.

Participants. Twenty early intermediate level piano students, ages 10 to 17, from The New School for Music Study in Princeton, New Jersey, participated. The average length of piano study was 5.25 years. All students were selected by their teachers and volunteered for the study.

Pre-selection Procedure

Based on a questionnaire regarding years of piano study, grade level, and family musical background, as well as a musical pretest, students were matched in pairs for age, years of study and teacher rating of each student's musical skills. The musical pretest consisted of sight reading three pre-selection melodies, comparable in level of difficulty to the examples chosen for the experiment. Skills rated by teachers were sight reading, musicianship and technique. Musical skills were rated on a scale of 1 through 5: 1 = poor, 2 = fair, 3 = satisfactory, 4 = very good, and 5 = excellent. After the students were matched into pairs based on the above criteria, within each matched pair they were randomly assigned to the aural-notation (AN) group or the aural-piano roll (AP) group. The matched pair design was chosen to account for extraneous variables of performance ability.

Experimental Session Procedures

In the experiment proper each participant had two 45-minute sessions, two weeks apart. Participants were told before the experiment began that they would be required to play the three melodies, listen to a performance of each melody played on the Disklavier, and imitate the model melodies as accurately as possible. The lid of the piano was shut to eliminate visual feedback from the piano hammers striking the strings as the keys were depressed. In the first session, all students were given 15 minutes to practice the melodies before recording them on the Disklavier. After the initial recording, students listened to one of the melodies. The AN model for presentation consisted of the model being played back on the Disklavier interfaced to the Logic software while the student viewed the printed notated score. The AP model for presentation consisted of the model being played on the Disklavier interfaced to the Logic software while the student viewed the piano roll scrolling on the computer screen.

The scheduling of AN and AP imitation and feedback procedures on the first of the two experimental sessions were as follows:

1. *Initial playing.* All participants practiced the melodies for 15 minutes and were then required to record the three melodies on the Disklavier. They read from a printed notated score (see the upper portions of Figures 1, 2, and 3).

2. *Listening to the model performances.* The AN group listened to these melodies while following each on a printed notated score. The AP group listened to these melodies while following the piano roll score of each scroll on the computer screen. The order of the melodies was counterbalanced across the sample.

3. *Practicing to imitate one of the models.* The model melody was played five times. The AN group listened to it while following it each time on the notated score and trying to play along with it an octave lower on the Disklavier. The AP group each time listened to it while following it on the performance score and trying to play along with it.

4. *Imitation.* Immediately after practicing the melody, each student was tested on how well he or she could exactly imitate it on the Disklavier. For the students in the AN group, this was done while they were reading from the notated score. For those in the AP group, this was done while they were following the performance score on the screen.

5. *Immediate Feedback.* For the AN group, feedback consisted of playback on the Disklavier of their imitative attempts. They were instructed that during this playback they were to listen critically for deviations in their playing both from the model they had just attempted to imitate and from the notated score. For the AP group, feedback consisted of playback on the Disklavier of their imitative attempts while following a cursor line sweep over the performance score of the imitated model. They were instructed to look and listen critically for deviations at that time in their playing from the model.

6. Steps 3 through 5 were repeated for each remaining melody in the session.

The second experimental session included an initial playing of the melodies by students to measure levels of retention. Following the initial playing, the listening, imitation, and feedback procedures from Session 1 were repeated using the counterbalanced design. Students in both groups heard the playback of their imitations and were allowed up to five trials to optimally imitate each melody. All imitations were played and recorded on the *Disklavier.*

Collection of Data

The timing of each key played and its release was recorded in SMPTE (Sound and Motion Picture Television Engineering) time code, which records hours, minutes, seconds, and frames at a rate of 25 frames per second. From these timed events Inter-onset Interval (IOI) measurements of the notes for each melody in the imitative model and/or the imitative attempt were calculated by subtracting the onset of each note in seconds and frames from the onset of the previous note. In order to adjust for any offset of beginning notes in imitative attempts, timings for each model and imitation were set to 00:00. IOI discrepancies between imitative model and imitative attempt thus were deduced by subtracting the onsets of each note in the model from the onsets of the corresponding note in the attempt. Mean onset difference scores were calculated for each student by adjusting all negative onsets to positive.

Results

Session 1

Each student's initial playing of the melodies in comparison to the model was assessed preliminary to the use of feedback. Timing deviation was highest in the Beethoven sight reading ($M = .52$, $SD = .2$); slightly less in reading the Chopin ($M = .4$, $SD = .2$) and less again in the Rachmaninoff ($M = .31$, $SD = .22$).

After feedback in Session 1, the imitation attempts by the AP group and the AN group were analyzed in comparison to the model. The AP group ($M = .1066$, $SD = .018$) produced significantly better melodic imitation ($t[9] = 5.22, p < .001$) in terms of less IOI discrepancy, than did the AN group ($M = .1977$, $SD = .05$). In followup matched t tests for each melody the AP group mean performance was significantly better for each melody. The comparison for the Beethoven melody was $t(9) = 3.456, p < .01$ (AP $M = .174$, $SD = .04$; AN $M = .267$, $SD = .08$), the comparison for the Chopin melody was $t(9) = 4.798, p = .001$ (AP $M = .08$, $SD = .02$; AN $M = .168$, $SD = .06$), , and the Rachmaninoff was $t(9) = 2.843, p = .01$ (AP $M = .06$, $SD = .02$; AN $M = .16$, $SD = .09$).

Session 2

In Session 2 students in the AP group ($M = .07$, $SD = .003$) were able to imitate the models significantly better ($t[9] = 10.309, p = .000$) than the AN group (M = .1755, $SD = .01$). As Figure 4 indicates, the AP group significantly improved from Session 1 to Session 2, ($M = .03$, $SD = .02$) $t(9) = 4.378$, p = .002, while AN improvement was nonsignificant ($M = .02$, $SD = .07$) $t[9] = .983$, p = .352. Improvement for 5 of the 10 AN students decreased. By contrast, all 10 of the AP students improved ($p < .002$, using a Sign Test). A comparison of the two groups (Fisher's Exact Test) showed that the AP group improved significantly from Session 1 to Session 2 than the AN group ($p = .032$, 2-tailed).

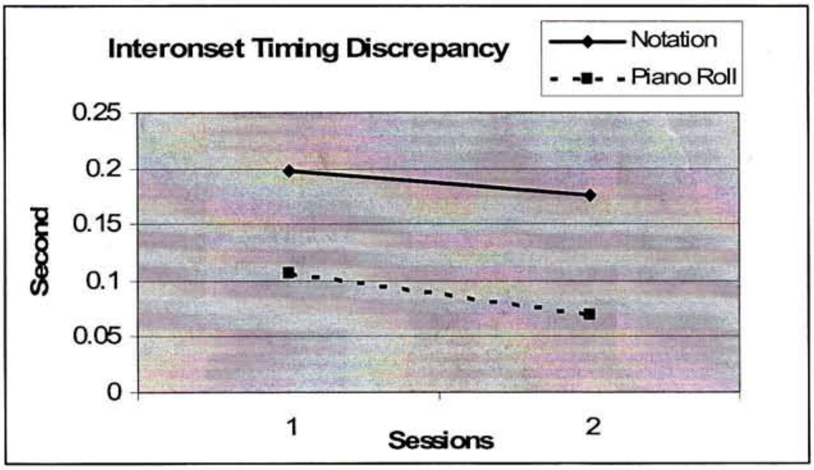

Figure 4. Effects of type of feedback and repeated sessions on Imitation.

The AP group performed significantly better on each of the melodies: Beethoven, $t(9) = 3.2$, $p = .01$ (AP $M = .13$, $SD = .02$; AN $M = .248$, $SD = .12$); Chopin, $t(9) = 2.57$, $p = .03$ (AP $M = .05$, $SD = .02$; AN $M = .19$, $SD = .17$); Rachmaninoff, $t(9) = 4.65$, $p = .001$ (AP $M = .04$, $SD = .007$ AN $M = .12$, $SD = .05$).

Regardless of the type of feedback, rhythmic complexity appeared to affect IOI in both sessions: both groups had the highest mean deviation in replicating the Beethoven and the lowest mean deviation for the Rachmaninoff. The Beethoven excerpt was often sight read in 4/4 meter or a combination meter of 3/4 and 5/4. The dotted eighth/sixteenth note measure in the Chopin melody was played in 4/4 meter instead of 3/4 by most students.

Discussion

The present study examined differences between piano students' imitation of melodies with piano roll notation and with traditional notation. Imitation guided by scrolling piano roll notation was more successful than when guided only by aural feedback with traditional printed notation. Results suggest that the scrolling piano roll provided the student pianist with clearer feedback cues for improving accurate phrase imitation. IOI discrepancies between the model and its attempted imitation were more noticeable and correctable when students could match note-for-note the feedback sounds of their own playing with the piano roll score presented in parallel on a computer screen. The AP group followed the piano roll of the model on the screen while listening to playback of their imitative attempts. Results of the

AN group suggest that these discrepancies were less noticeable when the students could only match up the feedback sounds of their own playing by comparing the progression with a printed score–even though backed by the aural memory of the model just recently played. Without the benefit of piano roll feedback, there was a tendency among many of the control group students to replicate their own timing, even after listening to the model performance.

Johnson (1998) suggests that people can hear if rubato is being used in performance, although they cannot pinpoint where or define exactly what is happening. As evident in the Rachmaninoff example (Figure 3), the simultaneous display of piano roll score coupled with Disklavier playback helps identify nuances in timing, such as rubato, that are not indicated on the notated score.

The experiment reported here examined the importance of feedback type in the pedagogical effectiveness of imitation. Results suggest that with the aid of feedback displayed visually in a modified notation that reflects the exact onset of the notes played, and when coupled with aural feedback, students were able to understand timing relationships of rhythmic subdivisions on the notated score (i.e., dotted eighth, sixteenth, quarter, and half notes) and to perceive them as patterns. Imitation of note duration was not emphasized to the students. However, when watching the piano roll, many students began to replicate note release.

But are these the most immediate, compelling feedback signals that the student can use to help correct errors in imitative performances in the future? Does this type of feedback help students learn not only how to listen as they play but what to listen for (Sloboda, 1999)? Comments made by the students who followed the piano roll seem to suggest that they received a clearer understanding of how the music should sound.

During the initial student readings, several students asked if they could hear the melodies played before they attempted to play them. Several students were unsure how to play the measures in the Beethoven and Chopin with the dotted eighth/sixteenth note figure. They were not certain how to count the rhythm. Observation of students practicing the melodies indicated that the majority spent most of the time trying to learn the notes and then attempting to add the rhythm. Those who received AP feedback commented that hearing the notes while watching the piano roll clarified the dotted eighth/sixteenth note rhythm on the notated score. Comments from AN students who did improve imitation indicated that, when correcting timing by ear, they did not pay as much attention to the score.

Long term improvement of student performance along with the coordination of motor skills requires continuous training in linking sound with symbols and action. As this link becomes sufficiently strong, the ability to "think in sound" becomes possible when merely reading the notation. It is this ability to translate symbols into sound before playing that greatly enhances the ability to successfully reproduce these sounds on the instrument

(Mainwaring, 1941). However, all of this cannot be accomplished in only two sessions of training. Further work that is planned in an expanded study will examine whether piano roll feedback coupled with aural feedback can improve listening awareness and concentration as well as increase understanding of technical production of interpretive nuances.

At the heart of these results is an important principle. As research (Miller & Bunuazizi, 1968) has shown, to gain fine control of subtle motor responses one clearly must be able to discern through feedback the signals that arise from error variations in these responses–in this case, discrepancies in IOI. Only then will one properly be able to recognize success when intentions aimed at reducing the discrepancies in fact succeed, and then to use that success to identify and encourage the sought-for perceptions and behaviors responsible . . . a principle as important to piano pedagogy as it is elsewhere.

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