The Use of Musically Relevant Vibrational Stimuli in Improving Children's' Musical Learning

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December, 1997

Introduction

The art of music is one that is steeped in tradition. From techniques of composition and performance to methods of music theory, learning musical skills have typically been based on historically accepted procedures passed on from one generation to the next. In the fifteenth century, early theorists such as Gaffurio produced written works with the purpose of transmitting ancient Greek ideas of music to their contemporary musical societies. Soon after, figures such as Guido and Zarlino built upon these collections of knowledge and developed their own procedures of teaching music to students of music. Even today, much education in music is based on traditional lesson plans and pedagogical techniques that have a strong historical foundation.

However, simply because there exists a strong tradition for a teaching technique does not mean that the particular technique is the best or most effective way of teaching music to children. In the current half of this century, much research has been performed in the fields of cognitive development and music education that might lead one to believe that vast improvements can be made in the way that children are taught musical skills. Additionally, the rapid growth of technology has provided new methods of utilizing computers and electronics in the field of music. Although the initial tendencies were to use these technologies for compositional work, current trends point to research using computer resources in music performance, education, and cognition. As is often the case in new research, one sees work being performed that touches on multiple disciplines.

In music, the development of one's aural skills is a critical component of progress. Specifically, one's ability to take dictation by writing in musical notation a piece of music that is presented aurally is particularly important. The process of learning this skill is traditionally brute force repetition and practice. For the most part, this is probably the best way of learning this skill, or any skill for that matter. This does not mean, however, that there cannot be a better way of learning through repetition than the techniques currently in use. At the moment, a student learns aural skills in the classroom by hearing what the instructor plays and then attempting to write it down. In this situation, the stimulus is purely in the aural modality which is seemingly appropriate given that the student is practicing aural skills. However, research has shown that often, young children have preferred modalities and learn more effectively when those modalities are exploited (Persellin 1988 and Zikmund and Nierman 1992). Even though the end result should have the student capable of dictation of music presented aurally, it might be the case that children will learn this skill better and more quickly if they are allowed to use other modalities in assisting the learning process.

By using knowledge culled from work in cognitive development, music education, and music technology, the following experiment proposal seeks to gain insight on whether or not a multi-modal method of teaching aural skills using both haptic and aural stimuli is more effective than the traditional means of teaching aural skills using only aural stimuli. Children of ages 7 years and 12 years will be tested to examine a possible critical age threshold for a child's ability to incorporate haptic information along with auditory

information. This proposal touches on numerous previous studies that involve using haptic stimuli in assisting a child's learning of aurally presented material. The main advancement of this proposed study, however, is that it will present musically relevant haptic stimuli along with musical auditory stimuli, a combination which has not been studied before.

Related Work

Temporal Structuring

The key to this study is the assumption that the cognitive processes of music are not limited to a single modality, namely the auditory one. If this is true, then the proposed study becomes a useful tool in examining musical learning as a potentially multi-modal activity. The results of Karma's study temporal structuring study (Karma, 1994) suggest that the auditory modality is not the only channel in which music may be learned, although it is probably the most common and most efficient. In this study, Karma redefined musical ability as a general temporal task in an effort to remove cultural biases from the concept of what music is or is not. In its revised form, musical ability was presented as the skill of grouping temporal events. The study used this definition and presented music aurally to one set of subjects and visually to another set of subjects before comparing their performances against each other.

The task itself consisted of the presentation of a pattern, either aurally or visually, that was repeated three times without indication of when the segment ended and the next repetition began. A fourth pattern was then presented and the subject judged whether it was the same or different from the previous pattern. The group of subjects tested on auditory patterns consisted of 203 students in Finland ranging from ages 9 to 14. However, in an attempt to truly test visual understanding of patterns, Karma used only congenitally deaf subjects for the visual portion of the study. This was necessary because it seems that people with hearing intact tend to audiate visual stimuli of this nature so that as they see the patterns, they form mental sounds to accompany them. By using deaf subjects, the potential of audiation, at least in the form common to people with hearing, was removed so that the test became a task completely dependent on the visual modality. Therefore, the subject group for the visual task consisted of only 23 adults at an educational institute for the deaf, also in Finland.

The results of this study showed that both groups, auditory and visual, performed roughly equally well in identifying temporal patterns . According to Karma, this means that musical thinking can exist in a non-aural modality. Still, there are several problems with this study. The first problem is the revised definition of musical ability. Attempts at defining music and musical skill are frequent throughout history and are always controversial. This particular definition is no different. By simplifying the concept of musical ability to this extent, many characteristics are removed that help define music not only in our culture, but also in many others. This is a critical problem because it forms the basis of his claim that sound is not necessary in musical thinking.

Another problem with Karma's study is the vastly different demographics of the subjects of each group. While the aural group consisted of over 200 school children, the visual group consisted of 23 adults. In addition to the considerably smaller sample size of the visual group, the fact that they are adults may have led to biased performance results due to better understanding of instructions or closer attention and more care during the trials. Despite these problems, however, Karma demonstrated an important finding in this study. Regardless of whether or not the stimuli were music and regardless

of performance biases between adults and children, the study still showed that temporal patterns can be accurately identified without the aid of one's hearing. What this means is that music, which is heavily dependent on temporal patterns, may be presented in non-aural ways and thus suggests that further study in the presentation of music through non-aural modalities may be quite beneficial to understanding new methods of teaching and learning music.

Motion-Based Learning

In a test of the above concept, Lewis' study of motion-based instruction of music listening skills (Lewis, 1988) hypothesized that a physically active lesson in music listening would be more effective than a plan based on just listening. Lewis states that this hypothesis is based on several beliefs. First, kinesthetic movement may be a more appropriate modality of learning for young children. Second, the inclusion of a second modality will enhance the learning process for the children. And third, the active movement will increase the child's general attention, thus leading to greater focus on the musical task.

For this study, 61 first-grade children and 52 third-grade children were used in testing for learning achievement in the musical areas of dynamics, tempo, melodic direction, meter, and rhythm. The movements incorporated into the lessons included conducting, body ostinati such as clapping, stamping, and snapping, eurythmics, and dance.

In the end, Lewis' results showed little difference in performance for most of the musical areas between groups that utilized movement-based instruction and groups that did not. Lewis offers two main explanations for why the results contradict the hypothesis. First, the training sessions used in this study were given in 12 half-hour lessons, definitely a short time period in which to improve one's musical ability. Second, the performances were rated based on written material provided by the children after each test. Given the age groups of first- and third-graders, a written response may not accurately reflect the child's understanding of the material due to insufficient writing skills. Despite these problems, the results showed that while the first-grade group showed improvement only in learning dynamics through motion-based instruction, the third-grade group showed improvement in dynamics and melodic direction as well as a standard Music Listening Composite measurement that incorporated performance results across all five musical categories. This suggests that there may be a difference in the effectiveness of motion-based instruction based on the children's age. A multi-modal form of music instruction may be beneficial to a third-grader, but not to a first-grader. Like the Karma study, this conclusion leads one to believe that further study into multi-modal instruction of music is necessary.

Multi-ModalInstruction

Another study examining the effect of multi-modal presentation of musical content to children is Standley's study involving preschoolers given auditory and vibroacoustic stimuli (Standley, 1992). In this case, preschoolers were presented aurally with a story, with and without musical elements, in two different environments. One setting involved using a Somatron Infant Mattress in which vibroacoustic stimuli was presented with the child on the mattress. The second condition was without vibroacoustic stimulus. Ninety-six children between the ages of 3 and 5 were used in this study and were divided into four groups corresponding to each of the above combinations of conditions. In each case, the child's on-task time was tracked to ensure that each subject was paying attention to the story for the equivalent lengths of time. After the presentation of the story, each child was asked ten questions regarding the content of the story and these

responses were then used to measure the child's performance of recalling details of the story.

In the end, this study showed that vibrotactile stimulation did not effect the children's attentiveness or preference of environment. However, it did reduce comprehension of the story. Standley offers several explanations for why the vibroacoustic stimulus did not improve performance. The most significant reason is that at age 5, children may not have developed the capacity to incorporate additional modalities into their learning processes in a useful manner.

The Lewis study suggested that movement-based instruction might be beneficial to third-graders, but not to first-graders. If this is the case, then the subjects in Standley's study were all younger than the threshold age required for kinesthetic information to be a valuable addition to the learning process. Additionally, the types of motion used in these two studies differ greatly. While Lewis utilized active motion requiring significant motor control initiated by the subject, Standley used passive kinesthetic vibrations applied to the subject that required no effort by the subject to produce. This could have had a great deal of impact on the results since an internally activated motion requires more involvement on the part of the subject than applied vibrations. An even greater problem may be that the kinesthetic stimuli used by Standley had no true relationship to the auditory stimuli. The Somatron simply provided vibrations intended to increase a child's attentiveness, but conveyed no meaningful information to enhance aural understanding. Still, the idea of applying kinesthetic stimulation instead of requiring the subject to initiate movement is intriguing because it reduces the cognitive load necessary in generating body movement. An improved test based on Standley's work should use kinesthetic stimuli that is closely related to musical stimuli as well as children from age groups both below and above the critical threshold for incorporating multi-modal information into musical learning.

Stimuli Relevance

In the Brooks et al. study (Brooks et al., 1987), relevant vibroacoustic stimuli is used to test for understanding of vocabulary words presented through the kinesthetic modality. Although understanding of words and music are significantly different, they are also somewhat similar in that they are auditory phenomena that require high levels of cognitive understanding. Thus, despite the lack of musical information, a study such as this will shed some insight on the effectiveness of the kinesthetic modality in conveying pertinent information for a given task.

For this study, two prelingually deaf teenagers were used as subjects. Each was submitted to a training period in which kinesthetic frequency information corresponding to specific words was presented to their fingers by means of a vocoder. After the training, they were tested on their ability to correctly identify words as they were presented. In this study, both subjects reached an 80% success rate on a 50-word vocabulary after 28.5 hours and 24.0 hours of training. What this shows is that the kinesthetic modality can be used effectively in processing high-level information that most people process through the auditory modality. Although this result is not directly related to the task of musical learning, it suggests that the kinesthetic modality could be useful in a high-level cognitive task such as musical learning. One problem with the Brooks study is the small sample size of two subjects. Additionally, these subjects are significantly older than 7 years and 12 years which are the ages of subjects to be used in the proposed study of this paper. Nevertheless, the result is interesting and raises questions as to whether a similar system of teaching is appropriate for learning music instead of words.

A more relevant study would focus on using appropriate kinesthetic activity along with musical samples. The study by Zikmund and Nierman (Zikmund and Nierman, 1992) examines children's' performance in melodic and rhythmic conservation tasks when assisted with reinforcement in their preferred modalities. It is believed that not all children learn most effectively in the same modality. One may respond best to visual information while others may prefer aural or kinesthetic information. Zikmund and Nierman tested this concept in relation to learning simple melodic and rhythmic musical samples.

In their study, Zikmund and Nierman used 149 students of ages 8 through 12 years. Each student was first tested to determine his or her preferred modality using the *Learning Style Inventory*. Next, each student was presented with a short melodic or rhythmic sample that was played twice. The students were then played 4 more samples for which they were asked to judge "same" or "different" in comparing each sample to the original sample. This procedure was performed on several groups of students. One group received only the aural presentation of musical samples. Other groups were allowed to reinforce each musical segment by means of their preferred modality. For example, the visual group would hear the sample, see a visual representation of the sample, and then hear and see the sample simultaneously before making "same" or "different" judgments on following samples. Likewise, the kinesthetic group would hear the sample, either shape the melody in the air or clap the rhythm depending on whether they were presented with a melody or rhythm, and then hear and shape or hear and clap the sample simultaneously before making judgments.

The results of this study showed that children had better performance at music conservation tasks when allowed to utilize reinforcement in their preferred modality than when they had to rely on hearing alone. The significance of this result is that a multi-modal method of teaching music, when presented appropriately, seems to be more effective than teaching music through only the auditory modality. There are several key factors that allowed this study to show success when the above studies failed. First, the non-aural information in this case was readily pertinent to the musical sample presented aurally. Specifically, the kinesthetic techniques of shaping melodies or clapping rhythms correspond closely with the test sample. This is in striking contrast to the Standley study in which there was no correlation between the kinesthetic stimuli and musical stimuli. Second, the ages of the students used in Zikmund and Nierman were appropriate in that they were above the critical threshold of multi-modal learning enhancement. This was a problem for Standley since it seemed that the children in that study were too young to be positively affected by non-aural stimuli. Likewise, the third-graders used in the Lewis study showed better performance than the first-graders, but not to a convincing degree. In this study, however, the children seem to be old enough that information presented in an additional modality seems clearly to be beneficial to their musical conservation. Furthermore, more fifth- and sixth-graders used in this study showed preference for the kinesthetic modality than third- and fourth-graders, suggesting that the critical threshold is near the fourth- to fifth-grade boundary.

Despite these successes, there are still problems with the Zikmund and Nierman study. Because of the way the procedure is structured, they do not rigorously examine whether or not the improved performance is modality specific. It is possible that any reinforcement, whether in the preferred modality or not, will improve performance. Also, the visual and kinesthetic methods of reinforcement are not entirely consistent with one another since one is a passive process (the visual) while the other is an active process (the kinesthetic). To truly test their hypothesis, a follow-up study should be

performed in which musically relevant kinesthetic stimulation is applied to the subject so that the active component in the modality is removed.

Study Proposal

Use of Haptic Feedback

In an effort to remedy the above problems, the proposed study of this paper addresses each of these factors and presents an alternate testing method to measure understanding of simple melodies. This study will utilize a new force-feedback technology that allows the experimenter to provide a tightly controlled computer-generated haptic stimulus. To the subject, this device resembles a smooth platform on which one rests his or her hand. Beneath the platform exist several motors and sensors that allow for computer-controlled movement such as angular tilting, up and down displacement, varying degrees of vibrational movement, or even the creation of different textures as one presses down on the platform. By using this device, an experiment can be performed in which various types of haptic stimulus are closely fitted to aurally presented musical samples.

Although different types of haptic stimuli are available, this experiment will use only vibrational stimuli. In Western music, there is traditionally a close correlation between the pitch of a note to the intensity of the music. As the pitch of a melody rises, the intensity of the music tends to rise also. Likewise, a pattern of descending pitches tends toward a decrease in musical intensity. Therefore, the haptic information will attempt to mirror the intensity of the melody by increasing its amplitude of vibration as pitch increases and by decreasing its vibrational amplitude as pitch decreases. At the same time, the vibrational stimuli can follow the rhythmic pattern of the melody by matching onset and release times with each note of the melody. This can done easily by using a single computer to control both the haptic platform as well as an electronic synthesizer that performs the melody, providing a closely correlated relationship between the haptic stimuli and the musical melody. Even though this study proposes the use of only one form of haptic stimuli, future studies may experiment with some of the other forms mentioned above.

Subjects

Another major problem with the above studies was the age of children used as subjects. Although it seems that a combination of kinesthetic and aural stimuli improves performance over trials using just aural stimuli, this improved performance is effective only if the children are older than a critical threshold around the ages of 9 or 10 years. This problem is addressed in this study by using children of ages 7 and 12 years, ages which are solidly below and above the threshold based on results of the previously mentioned studies.

The purpose of this study is to show that a passively applied haptic stimulus provided simultaneously with an aurally presented melodic sample, given that the haptic stimulus is musically relevant, will improve a child's ability to learn the melody in comparison to hearing the melody without information through the haptic modality. If this is true, then improved performance will appear in the trials involving the 12 year-olds, but not for the 7 year-olds.

In order to ensure that the platform mechanism itself is not affecting the children's performance, several control groups are required for this study. In addition to the two groups receiving simultaneous haptic and aural stimuli (one group of younger children and one group of older children), four additional groups are required as control groups.

For both ages, subjects are required to perform the task without any haptic stimuli. For these children, the platform will not be used and they will receive only the aural musical sample. Additionally, we must determine whether the physical act of placing one's hand on the platform affects performance even when no haptic stimuli is provided. Therefore, two more groups (one for each age group) must be tested in which they rest their hands on the platform during the trials but no haptic stimuli is actually presented through the platform. These four control groups in addition to the two experimental groups gives a total of six groups of children to be tested.

Musical Stimulus

The melody to be used in this study will be a simple, diatonic, tonal melody of eight measures in length. This style of melody is extremely common in traditional Western music and should not confuse the children by being unfamiliar or disorienting. The length of eight measures is a very common phrase length that should also be comfortable for the children to work with.

Procedure

The procedure for each child in this study will be the same. First, instructions will be given to the child explaining what to expect (e.g. - you will hear a melody, you will rest your hand on this platform while you hear a melody, or you will feel vibrations on this platform while you hear a melody). Next, the child will be taught a melody based on the system used in Gromko's study of invented notations for measuring musical understanding in children (Gromko, 1994). In this procedure, the child is played a melody and then asked to sing it back. This is repeated until the child is acceptably proficient at singing the melody. At this point, the child is asked to "write the way the song sounds so that you will remember the song tomorrow and so that a child who isn't even here today will know how the song sounds by looking at what you have written on your paper." A group of judges will then score each child's drawing for understanding of pitch content as well as rhythmic content.

Although this scoring method is somewhat subjective, it has many benefits. It is highly probably that previous musical training will lead to better performance for a child in this study. However, it is still possible to possess musical understanding without formal musical training. Asking verbal questions to measure performance requires a certain amount of musical vocabulary that is dependent on formal training. This would automatically create a bias against children with no formal musical background regardless of understanding of the presented melody. Likewise, asking the children to provide written representations of the melody using traditional notation faces the same problem. On the other hand, the effectiveness of one's invented system of communication often reflects the depth of one's understanding of the concepts to be communicated (Gromko, 1994). Therefore, asking the children to invent their own notation to express their understanding of the presented melody gives them an opportunity to display musical comprehension without the requirement of formal musical training.

Conclusion

Hopefully, the results of this study will show that a multi-modal presentation of musical information in both the haptic and aural modalities will lead to an improvement in musical learning and understanding. This study addresses previous problems of critical age threshold and musically appropriate haptic stimuli. If it turns out that the results show no improved performance, or even a degradation of performance, other conclusions must be drawn. In such a case, it could be that there is some sort of cross-

modal interference in either the perceptual process or in the higher cognitive processes that had not been examined in previous studies. If this occurs, further study is required to examine why there is a degradation in performance. On the other hand, if the above hypothesis is supported by the results, it will give new insight on how to improve the musical learning process of children by moving away from traditional single-modality methods of teaching aural skills. If the addition of pertinent haptic information improves a child's learning capabilities, then we could develop pedagogical techniques combining haptic and aural training before moving on to higher-level tasks involving only aural skills.

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