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Psychoacoustics and the Choice of Instrument Sound on Achievement in Music Instruction

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Abstract. The popularity of the piano as the preferred instrument used in music classrooms across the world is not for its psychoacoustic purity. Instruments such as guitar and harp which produce sound through single-string vibration are said to be "purer" than the piano which produces sound through multiple-string vibration. The increasing use of high fidelity sampled sound in the music world – instead of sound generated by a MIDI sound card – will continue to accentuate the psychoacoustics of instrument sound in music instruction. Do psychoacoustics of instruments, and therefore, choice of instruments, affect learning in music instruction?

This study investigated the effect of psychoacoustics of two instrument sounds (guitar and piano) on college music students' achievement in a Web-based music instruction. A Web-based ear training module for melodic pitch discrimination was developed for the purpose of the study using two psychoacoustically distinct instrument sounds. Both quantitative (participants' achievement scores) and qualitative data (practice records, users' feedback, and focus-group interviews) were collected for repeated measure analysis using *t*-test and analysis of variance. Result from the study showed that: (a) Web-based Music Instruction had a large positive effect on achievement in Web-based music instruction, and (b) psychoacoustically different instrument sounds do have a significant effect on Web-based music instruction. Further studies are recommended to better understand the effects of psychoacousticity of instrument sound and choice of instrument used on achievement in Web-based music instruction.

Introduction

Musicians, by nature of their professions, are required to distinguish "by ear" the various pitches that form the melody and harmony of a musical piece. People with no comprehension of what they hear will often have problems reproducing or distinguishing the differences in pitches. Hence, one integral part of music education and training for college music students is to learn to hear (Arnone & Small, 1999; Kraft, 1967). Ear training thus allows musicians to develop the aural skills needed to experience music more completely.

Pitch discrimination is an important learning task to college music students because higher-level music classes often require the students to have a firm foundation in basic listening skills. The improvement of pitch discrimination skill by way of ear training provides the means for first year college music students to learn the relationships of the musical pitches and to attain good listening skills.

1. Pitch Discrimination

Better listeners make better musicians (Worthington & Szabo, 1995); thus college music students who possess better listening skills are more likely to succeed as musicians. Successful musicians are usually well versed in identifying musical intervals, able to identify scores of intervals readily and accurately (Burns & Ward, 1982; Killiam, Lorton, & Schubert, 1975). Students who hope to improve their musical ability should therefore develop their musical pitch discrimination ability to become better listeners.

1.1 Computer-Based Music Instruction

Computer-based music instruction (CBMI) for ear training was regarded not only as a feasible substitute for classroom music instruction (Deihl, 1971; Killam, 1984; Kuhn & Allvin, 1967; Wittlich, 1987), but also a reasonable and effective "tutor" (Taylor, 1980) capable of assisting students' learning (Kemmis, Atkin, & Wright, 1997).

The first CBMI for aural training was introduced in the mid 1970s as the Graded Units for Interactive Dictation Operations (G.U.I.D.O.), a programmed instruction in ear training for college music students, offered via the PLATO mainframe to provide training for the recognition of musical intervals, melodies, chords harmonies and rhythms (Hofstetter, 1975; 1978; 1985; Peters & Beiley, 1995). Reports of the positive effects on the early use of CBMI for aural skills development eventually lead to a formalized incorporation of CBMI into college music theory curriculum (Davis, 2001; Eddins, 1981).

However, the advent of Internet and online learning in recent years has created a gap in the literature on the use and effects of Web-based music instruction (WBMI), particularly at the college level (Coffman, 2000). This study examined the effects of psychoacoustics and choice of instrument sound on pitch discrimination achievement of college students using an innovative WBMI developed by the researcher.

2. Sound

Sound is produced through vibration. The vibrating object causes air particles around it to go through a series of compressions and decompressions. When this "wave" of compressed and decompressed air particles reaches a person's ear, the vibration is interpreted and perceived by the human brain as sound. Music psychologists have ascertained that different types of sound assert different psychological effects on the hearers (Siegel & Siegel, 1977), meaning the choice of sound used is of importance in pitch discrimination training, and may affect outcomes.

2.1 "Pure" Tone

When a pure sine wave is electronically converted to audio with a tone-generator, a single steady pitch is produced. This is commonly known as a "pure tone" and is typically depicted in textbooks as a series of repeating peaks and grooves.

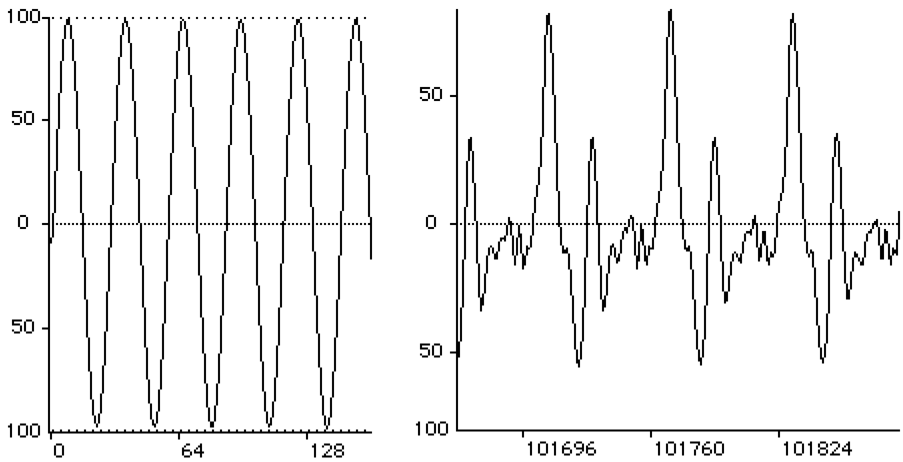

Figure 1. Sonograms of Pure Tone (Left) vs. Complex Tone (Right)

Researchers in the fields of psychoacoustics and music psychology generally prefer using pure tones in pitch discrimination studies to ensure the reproducibility, consistency, and validity of the research data. However, pure tones are physical anomalies because natural sounds, such as the sound of musical instruments, exist as complex tones. As shown in the following sonogram, the auditory signatures between an electrically generated pure tone and a naturally produced complex tone are very dissimilar (see Figure 1).

2.2 Complex Tone

Psychoacoustic findings have further confirmed that human ears perceive pure tones differently from complex tones (Walker, 1990). Sergeant (1973) concluded that a pure tone was not suitable for musical pitch discrimination in a learning situation because it was devoid of musical context.

Instead, Sergeant recommended the use of complex tones, such as the recorded sound of acoustic musical instruments, for music learning because "the stimuli used in the process of measurement must be compatible with the context in which the musical learning took place" (p. 15). Furthermore, since college music students are usually required to pick an acoustic instrument (including voice) as their major instrument, it makes good pedagogical sense to use the sounds of the student's acoustic instrument for pitch discrimination.

2.3 Piano and Classroom Music Instruction

While current classroom practice is an end result of what work in the classrooms over the years, advances in technology and development of new instructional tools and methods can often help to improve current practices. The piano has become the de facto instrument in the music classroom because it allows music instructors the liberty to produce a wide range of musical notes and styles. The widespread availability of the piano in the music classroom means it has also become a convenient instrument for ear training practice. However, from a pedagogic point of view, having the piano as the only instrument for sound production in ear training is of little practical value to players of other instruments. For example, it would be much better for the violin majors to practice pitch recognition using their primary instrument, the violin; and for the flautists, the flute, and so on.

Moreover, musical pitches produced by the acoustic piano are often considered impure from a psychoacoustic point of view. The impure sound of a piano note is the result of a group of (two, or three) vibrating strings culminating in a "composite sound" rich in harmonics and overtones. An acoustic guitar with a singly, freely vibrating string, would produce an acoustically purer sound in contrast to the acoustic piano. Psychoacoustics studies informed us that the harmonics and overtones found in composite sounds would often confound a person's aural perception, whereas an acoustically simpler or purer sound would facilitate higher accuracy in pitch discrimination.

2.4 Sampled Instrument Sound

The advent of Internet and the recent boom in online music delivery have brought about many advances in music technology, including large scale production of high fidelity sound samples of authentic and modern instruments. Nowadays, musicians can choose from a variety of "sound banks" available from music production software, studio-quality pre-recorded sound samples, engineered sound banks, and even virtual instruments.

With each passing years, these products are becoming not only more user-friendly but also affordable to the general consumers. The inclusion of high fidelity instrument sound in WBMI has gone from plausible to a reasonable expectation because of the availability of instrument sounds sampled using real instruments. Further, transcoding technology such as MP3 and OGG allow WMBI developers to reduce the size of these sound files for convenient online delivery to anywhere in the world, and to anyone with an Internet connection.

3. The Problems

Despite numerous studies on CBMI for aural training, the effects of psychoacoustics and choice of instrument sounds employed in CBMI were seldom explored. Until a few years ago, this assertion is hardly surprising considering the relatively low quality instrument sounds generated by the consumer-level computer sound card by way of FM-synthesis. Professional computer musicians looking to add high fidelity instrument sounds into their music would need to either call upon live performance, or additional hardware such as a high-quality synthesizer or sound sampler.

Since from a psychoacoustic point of view, acoustically less complex sound is easier to discriminate than acoustically complex sound, what is the effect of psychoacoustics on achievement in ear training? Does the choice of instrument sounds affect pitch discrimination achievement of college music students? Should an acoustically purer instrument sound (such as the guitar) be used in introductory ear training instead of the standard piano?

3.1 Research Questions

The first research question was, “What are the effects of psychoacoustically different instrument sound on achievement in pitch discrimination?” For this study, guitar and piano had been chosen to represent psychoacoustically pure and complex sound, respectively.

While environmental and instructional factors did not have much of an effect on the development of aural skills (Heritage, 1986), prior musical learning and instrument playing experience had been suggested to possibly influence musical achievement (Sloboda & Davidson, 1996). The second research question is therefore: “What are the effects of prior music learning and instrument playing experience on Web-based pitch discrimination training?”

4. Methodology

4.1. Research Materials

An online ear-training module was developed for this study with the dual purpose of pitch discrimination training and data collection. Sampled piano and guitar sound of high fidelity were incorporated as sound source to provide a better musical context, and to maximize the pedagogic values of ear training. In comparison, commercial CBMI for aural training commonly made use of instrument sounds generated by computer sound cards, which were lower in fidelity than the sampled instrument sounds used in this study.

The training modules required the participants to memorize, recall, and identify melodic intervals in both ascending and descending orders. Specifically, this study investigated the effects of (a) psychoacoustically-different instrument sound, and (b) prior music learning and instrument playing experience on first-year college music students’ achievement in pitch discrimination.

4.2 The Study

Permission to collect data from first year music majors at a major research university in the United States was obtained from the Institutional Review Board (IRB) at the host institution prior to the commencement of the study. The training module was subsequently field and pilot tested before the commencement of data collection. A total of 65 first year students completed both pretest and posttest; of which, 62 completed the follow-up posttest also. The follow-up posttest took placed one week after the conclusion of the online data collection, and was meant to measure the post-treatment retention of pitch discrimination skill of the participants in this study.

The test items used in the pretest, posttest and follow-up posttest were all drawn from a total of sixteen carefully counterbalanced items. These items consisted of melodic intervals in two instrument sounds (piano and guitar) in 4 interval classes (P5, P4, M6 and m3) and two play order (ascending and descending). Participants were randomly assigned to one of two counterbalanced groups for pitch discrimination training of melodic intervals at the point of online registration for the study.

5. Findings

A reliability coefficient of 0.906 attested to the high inter-item correlation among test items, measured using Cronbach alpha (α). Statistically significant differences in this study were generally reported at the a level of 0.05; and the effect sizes of repeated measure studies were reported as partial Eta squared (□p2) values (Thalheimer & Cook, 2002), in which case the values of 0.01, 0.06, and 0.14 represented small, medium and large effect sizes, respectively (Green, Salkind & Akey, 2000).

5.1 Research Question 1

Pitch discrimination training using melodic intervals recorded in guitar sound has a larger positive effect [$t (65) = 6.418$; $p < 0.001$; $Eta2 = 0.392$] than piano sound [$t (65) = 3.075$; $p < 0.005$; $Eta2 = 0.129$] on achievement of melodic intervals identification. Students trained with melodic intervals recorded in guitar sound attained higher achievement scores than students trained with melodic intervals recorded in piano sound. There was a large interaction effect among different Intervals [$F (9, 49) = 21.154$; $p < 0.001$; $Eta2 = 0.795$].

Guitar sound was found to have a larger positive effect on achievement than piano sound in pitch discrimination training. While pitch discrimination had traditionally been provided by the acoustic piano, the findings suggested a psychoacoustically purer instrument may be a better choice. Music educators might want to consider other instrument sounds that are psychoacoustically less complex in replacing the piano as instructional tool for pitch discrimination. Findings in this study appeared to suggest a psychoacoustically purer (or simpler) sound would be an easier (better?) instructional medium for learning pitch discrimination.

5.2 Research Question 2

Students with prior music training experience learned melodic interval discrimination at a faster rate [$F (1, 63) = 8.555$; $p < 0.005$; $Eta2 = 0.12$] than students without prior training. Web-based pitch discrimination training had an overall positive effect [$t (65) = 6.269$; $p < 0.001$; $Eta2 = 0.380$] on first year college music students’ achievement in melodic interval identification.

Participants who have had prior instrument playing experience before college, for example from a high school band or school orchestra, could possibly perform better in pitch discrimination tasks than participants with no prior instrument experience. However, analysis showed that prior instrument experience [$F (2, 59) = 2.218$; $p = 0.118$] and types of instruments played [$F (7, 57) = 1.638$; $p = 0.143$] were both not significant at the $p = 0.05$ level.

Results from this study indicated that music students with prior musical training learned pitch discrimination at a faster rate than students with no prior training. The prior musical training apparently laid a good foundation to provide support and scaffolding for subsequent pitch discrimination training. The WBMI developed for this study appeared to be a fairly effective learning tool. The first year college music majors were found to have improved significantly in pitch discrimination achievement.

6. Conclusions

Even though WBMI has many advantages over the older CBMI, there is currently a wide gap in the literature on the use and effects of innovative technology and WBMI at the college level. This study informed the literature by examining the effects of psychoacoustics and the choice of instrument sound on achievement in pitch discrimination. The Web-based aural training module developed for this study employed realistic instrument sound to provide not only the musical context for music learning, but also maximize the pedagogic values of ear training for music students other than piano and keyboard majors. Findings of the study suggested that psychoacousticity of instrument sound, and hence the choice of instrument used, can have an important role in aural training achievement.

The time has come for an update of pitch discrimination training using new technology. More importantly, more research is necessary for the re-evaluation and verification of pedagogic values of current music classroom practices. The development of new WBMI can help pave the way for other music courses geared towards online certification. There is also possibility for the WBMI to be marketed as a commercial product for self-directed learning.

WBMI liberates the music students from having to congregate at a music laboratory for “drill-and-practice” exercises in ear training. Because many college students now have easy access to the Internet and Web resources from campuses and dormitories, there will be more opportunity for music students to improve their ear training skill should online ear training become more readily available. The collaborative research endeavors in WBMI between instructional technologists and music educators will serve to benefit both academic fields and improve music education, at large.

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