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Creativity, Music and Computers: Guidelines for Computer-Based Instrumental Music Support Tools

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Abstract

This paper examines requirements for computer-based tools intended to support creative development in musicians. Approaches to instrumental music pedagogy are presented and implications for those seeking to support musical skill development with computers are discussed. A pedagogical philosophy based on the "natural learning process" is combined with recommendations from creativity researchers to build a set of suggested features and guidelines for developing instrumental music support tools which facilitate creative development. A prototype application illustrating our approach is described.

Keywords (Heading – minor)

Creativity, music, learning, supporting creativity.

INTRODUCTION

Some areas of the music industry now use computers routinely. Recording studios for example often use digital technology to encode live performances and then use sophisticated digital editing techniques to remove blemishes, add effects and so on. Similarly, many electronic instruments – particularly keyboard instruments – incorporate sophisticated computer technology to provide the ability to play and manipulate a huge range of sampled sounds. Mirroring these developments, music classrooms often make use of advanced audio editing tools, digital keyboard instruments and, sometimes, 'ear-training' computer programs which aim to develop students' aural skills. However, there are relatively few of these tools aimed at developing *instrumental* skills in musicians. Thus the approach that instrumentalists (at all levels) take to learning and practice remains relatively untouched by technology, with few tools other than the metronome and perhaps the electronic tuner seeing regular use in the practice room.

This, perhaps, is as it should be. Presumably, musicians would welcome any tools which made a significant contribution to the development of their craft and we therefore could conclude that no significantly compelling technology has yet been produced. However, computer technology in recent years has made advanced digital signal processing available on entry level personal computers and it is perhaps timely to consider whether intelligent use of this technology, based on sound pedagogical principles, could make a contribution.

In this paper therefore, we present a set of guidelines for those who wish to develop computer-based tools to support the development of musical skills. We first outline the pedagogical foundations of our approach and show that these have significant implications for those seeking to develop such tools. In particular we outline potentially serious pitfalls that may await those who take an overly simplistic, technology-driven approach. In addition, there has been significant research into supporting creativity both within the domain of computing and outside it and we show how this work suggests some specific requirements for tools to support instrumental musicians.

Finally, we discuss the development of a prototype 'Virtual Musical Environment' (VME) which illustrates our approach.

PEDAGOGICAL APPROACHES

The early stages of instrumental music learning are often focussed on gaining the physical skills necessary for producing controlled sound on the instrument. That is, trombonists learn to control their embouchure and slide arm, pianists learn finger coordination, etc. Broadly speaking, pedagogical approaches can be divided into two camps. The first emphasises the need to understand the physiology of instrumental technique in order to facilitate conscious control of the various muscles involved so that "correct" technique can be used. Perhaps due to a desire to approach instrumental music in a more 'scientific' way, there is often a tendency for musicians to attempt to take a reductionist approach to improving their playing. For example, singers may attempt to support their sounds by attempting to consciously control their diaphragm in some way in order to improve their range, volume or tone.

Kohut describes this approach as the "physiological-analysis-conscious-control" method (Kohut 1992, p.109), in which musicians attempt to understand the physical actions involved in music-making in detail and exert control over them consciously while playing. The key assumptions here are that

- complex involuntary muscle manoeuvres can be controlled consciously;
- conscious control will lead to improved performance;
- conscious control is best achieved by attempting to control the individual muscles/organs involved;
- a detailed intellectual understanding of the physical actions involved in playing is the key to improving performance.

The second approach, dubbed the "imitation method" (Kohut 1992, p.113), rejects these assumptions, arguing that

- the muscle manoeuvres involved are too complex and subtle to be meaningfully controlled by the conscious mind and that many muscles (such as the diaphragm) can not be controlled directly anyway. Recent studies of the physiology of memory seem to indicate that different regions of the brain are responsible for what is termed *implicit* and *explicit* memory and that motor skills are a form of the non-conscious implicit memory. Experiments with amnesiac patients for example show that patients who have no conscious recollection of learning a skill (ie. they forget the training sessions during which the skill was learned) still demonstrate normal motor-skill learning ability (Schacter 1999);
- attempting to consciously control the minutiae of physical actions that take place while playing a musical instrument is at best likely to lead to a tense, mechanical-sounding musical outcome and at worst to "paralysis by analysis" (Stewart 1987, Frederiksen 1996, Kohut 1992), where the musician becomes overwhelmed by the complexity of detailed muscle control and loses the ability to play even simple tunes on their instrument;
- improved performance results from setting and refining specific musical goals rather than consciously attempting to control physical actions at a low level;
- a detailed intellectual understanding of the physical actions involved in playing is not necessary.

For these reasons the trend in music pedagogy has been towards an approach based on the "natural learning process" (NLP) (Gallwey 1974) which emphasises the importance of leaving the complexities of muscle control to the subconscious so that the conscious mind remains free to set high-level musical goals. The technique for developing new skills is based on imitation, with a strong emphasis on mental musical goal-setting and excellence of role-models. Teachers taking this approach for example, would tend to spend more time on playing for students during lessons and encouraging them to try to copy aspects of the teacher's sound, instrumental technique or musical phrasing and would discourage discussion of physical aspects of instrumental technique.

Of course, the use of imitation to develop physical and musical skills does not preclude development of an individual style. An individual musician's mental image of musical ideals for given situations develops as they learn of different approaches through listening and watching performances by musicians on their instrument and others. Thus the musician may in effect choose a sound for a particular section of music which has characteristics of several other musicians but which is nevertheless unique. That is to say, the musical approach is influenced by many role models but retains qualities unique to the individual musician.

In this approach then, the musician gradually develops physical skills and an individual style as they build up a mental library of "target sounds" which trigger the appropriate physical responses. This mental library is reflected upon and refined through experience and exposure to new ideas, both musical and extra-musical. Thus regardless of the style of music performed, creativity is a fundamental part of musical skill development, as musicians constantly work towards an ideal sound which itself is being constantly refined. Even when musicians are playing music composed by someone else, creativity is required in the interpretation of the music notation chosen by the composer. The subtleties of musical phrasing - including tempo, articulation and dynamics – cannot be adequately represented by musical notation and thus the interpreting musician has a significant influence on the final musical result (Friberg and Battel 2002). It could be said that in effect the performance is a collaboration between composer and musician.

SUPPORTING CREATIVITY

If the development of musical skill is driven by the creative development and refinement of mental musical models, then the design of computerised tools to support musicians should take this into account. It can be seen that the NLP advocated in the previous section has significant implications for those seeking to support musical skill development with computers. Firstly, while it may not be technically difficult to build tools which measure a musician's physical movements while playing and display this data in real-time, this is unlikely to be helpful. In fact, such feedback is very likely to lead to "paralysis by analysis" as the musician is swamped with data regarding their physical actions and tries to consciously process this information and modify their behaviour. Depending on which movements are measured, it is possible that conscious control by the musician may not be possible anyway. For example, an interesting experiment was conducted by Watson and Hixon (1991) in which highly trained, experienced opera singers were asked to describe their breathing technique and these descriptions were then compared to detailed measurements taken when they actually sang. It was found that in general, what they thought they were doing and what they were actually doing were two different things, which would tend to support the arguments in favour of the imitation method. Namely, that detailed understanding of the mechanics of sound production is unnecessary.

However, while the NLP would seem to discourage efforts to provide detailed feedback on precise physical actions to musicians we believe there remains significant scope for computer-based tools to help musicians develop and extend their mental library of target sounds. For example, it might be that computers could be used to help stimulate musicians' imagination by encouraging them to consider different approaches to sound and music in the same way that tools for supporting graphic designers for example often allow the designer to apply different filters to an image to see what the effect will be.

Before considering likely features of such tools however, some consideration of the nature of creativity is needed. That is, what is creativity exactly and what does supporting creativity entail?

There is general agreement in creativity literature that creative ideas are novel and fit for their purpose (eg. Amabile 1996, Boden 1992, Csikzentmihalyi 1996, John-Steiner 2000, Sternberg and Lubart 1995). In the musical domain, defining the purpose is sometimes difficult. The purpose may be clearly defined in one sense – "the sound must not make the conductor angry with me" for example – but in other aspects the musician must discover or invent the purpose and then solve the musical problem themselves. To illustrate, perhaps a musician must play a phrase of notated music. At a high level this goal is clear enough, but the musician must still decide the purpose of the phrase itself. Should it evoke a sense of melancholy or happiness or torpor or some kind of combination for example? What should the phrase sound like? What articulations should be used? The answers to these questions (and many others) define the characteristics of the goal-sound that the musician will have in mind when they play this phrase. Thus it could be argued that creativity is involved in setting the goals and the musician's level of skill determines their ability to achieve these goals.

While it may be possible to quantify some aspects of musical performance practice, such as common techniques for signifying ends of phrases for example, careful thought is required when deciding how (or if) to incorporate this knowledge into music-learning support tools. If we wish to encourage a creative approach, it is important that tools designed to support music-practice and music-learning have an inbuilt flexibility that precludes overly simplistic, judgemental feedback. For example, a computer program that analyses a musical performance and then reports on how successful the performer was at shaping phrases is likely to encourage a conservative approach rather than a creative one.

Csikzentmihalyi (1996) puts the view that we are born with an innate curiosity and tendency towards creativity, but that this tendency to explore and discover new ideas may be easily discouraged. Just as bad teachers may (unwittingly?) discourage creativity in their students (Sternberg and Lubart 1995), it could be argued that badly designed support tools may do more harm than good. Tools that limit the user's options and/or impose rigidly defined measures of what constitutes creativity are likely to have a detrimental effect on the creativity they are attempting to support.

Nickerson (1999) has made a set of recommendations, based on creativity research literature, for those seeking to support and enhance creativity. These are comprehensive general recommendations which are not aimed specifically at those designing computer-based tools, but rather are intended to inform all manner of support for creativity. Along with developing skills and domain knowledge and building motivation and confidence, Nickerson emphasises the importance of fostering curiosity and exploration, noting that there is a 'playful' element to creativity.

Applying the principles of the NLP to Nickerson's recommendations, we now outline how these broad guidelines may be applied to the development of a creative approach in musicians and music students (Table 1).

Nickerson's recommendations	**Application to creative development in musicians**
Establish purpose and intention	Make the goal of building creativity explicit. Make it clear that instrumental music is more than a physical skill. That is, physical skill development occurs as a result of pursuing creative, musical goals and is not an end in itself.
Build basic skills	Support and encourage development of instrumental technique to facilitate creativity. ie. Help improve technical proficiency.
Encourage acquisition of domain-specific knowledge	Provide facilities for listening to 'expert' performances. As the NLP emphasises imitation as a strategy for developing musical and physical skills, it is important that musicians are given opportunities to build up their mental library of musical role-models and target sounds/styles.
Stimulate and reward curiosity and exploration	Encourage musicians to take risks and explore new approaches to music-making on their instrument. Provide facilities for discovering aspects of their playing they were unaware of.
Build motivation (especially internal motivation)	Be wary of 'psuedo-objective' evaluations of sound and other qualitative aspects. Encourage focus on musical end results and avoid triggering 'paralysis by analysis'. Encourage participation in 'communities of practice'.
Encourage confidence and a willingness to take risks	Avoid overly-judgemental feedback. Allow/encourage experimentation in a socially supportive environment.
Focus on mastery and self-competition	Encourage a reflective approach by facilitating retrieval of previous performances in order to demonstrate and track progress.
Promote supportable beliefs about creativity	Encourage realistic expectations. Don't gloss over the fact that musical creativity requires commitment.
Provide opportunities for choice and discovery	Allow musicians to discover their own personal preferences. Avoid inflexible assumptions about what constitutes 'great music' or 'great sound'.
Develop self-management (metacognitive) skills	Provide facilities for keeping practice diaries or similar tools.
Teach techniques and strategies for facilitating creative performance	Provide support for considering problems (musical and physical) in a different light. Encourage playfulness and considered work at the edges or extremes of technique.
Provide balance	Provide structure without stifling innovation and spontaneity.

Table 1 - Application of Nickerson's recommendations to creative development in musicians

While several of these recommendations appear to provide opportunities for intelligent use of computer technology, they are still quite general. Recent work in the field of human-computer interaction (HCI) has turned towards improving the support of creative work with IT, or perhaps more accurately, to removing impediments to creativity unfortunately often embedded in software tools. An approach which, like Nickerson's, emphasises the 'playful' aspect of creative work is Shneiderman's 'genex' (generator of excellence) framework (Shneiderman 2000, Shneiderman 2002). Designed as a broad set of guidelines for those developing computer software to support creative work, the genex framework is both a theory of the nature of creativity as well as a framework for improving current IT based support for creative work.

The genex framework comprises four phases:

Collect Gather information relevant to the task at hand.

Relate Consult with peers, experts.

Create Explore possible solutions in an iterative fashion. Evaluate various possibilities.

Donate Share results, display artwork, contribute to libraries.

It can be seen that genex leans heavily towards the systems view of Csikszentmihalyi (1999), that creative acts are fundamentally tied to the social system in which they take place. Thus, social events such as consulting with peers and sharing results are an integral part of the creative process.

Shneiderman suggests eight activities that take place within the four genex phases:

- Searching and browsing digital libraries
- Consulting with peers and mentors
- Visualizing data and processes
- Thinking by free associations
- Exploring solutions- what-if tools
- Composing artefacts and performances
- Reviewing and replaying session histories
- Disseminating results

The genex approach helps by making the higher-level goals of Nickerson more computer-specific as well as emphasising the social aspects of creativity. It can be seen that many of the activities are really more concrete instances of Nickerson's broader recommendations. For example, Nickerson's recommendation to 'Encourage acquisition of domain-specific knowledge' maps directly to the genex activities 'Searching and browsing digital libraries' and 'Consulting with peers and mentors'.

Taking the NLP approach and the recommendations presented in Table 1, we can now propose some possible features of a computer-based musical-creativity support tool (Table 2). Note that while a comprehensive, integrated tool for music learning would support all the genex activities, in practice some of these functions may be difficult to implement for various reasons such as problems with copyright laws for example. They are listed nonetheless to indicate the broad possibilities for tool design suggested by the genex framework.

Activity	Support
Searching and browsing digital libraries	Allow musician to search for and listen to samples of outstanding musicians on their instrument
Consulting with peers and mentors	Allow posting of practice sessions and trial performances for feedback.
Visualizing data and processes	Provide graphical representation of aspects of a performance, such as sound quality, in order that the performer might perceive patterns in, or qualities of, their playing that had previously gone unnoticed. Some interesting work in this area has been conducted by Nishimoto and Oshima (2001), who developed an application which displayed a jazz improvisation graphically, showing harmonic characteristics in a visual way.
Thinking by free associations	Provide access to a diverse range of performances, sounds and visual cues from within the performer's domain and outside it. For example, trumpeters should be able to listen to saxophone performances; jazz musicians can access classical recordings, etc.
Exploring solutions- what-if tools	Allow the musician to make audio/visual recordings of their performances. In addition to basic record/playback functions, these tools should allow the musician to manipulate and exaggerate aspects of their sound using digital audio techniques. For example, playback may be slowed to half-speed to highlight characteristics of the sound. Alternatively, the musician should be able to combine aspects of various recordings. Eg. Take a portion of one recording and overlay it with another to see what it would sound like.
Composing artefacts and performances	Allow musicians to record practice performances and to compare with previous recordings of their own playing and others.
Reviewing and replaying session histories	Keep a history of all performances for the purposes of tracking improvements or noticing 'blind alleys'. Allow comments on past recordings to be stored.
Disseminating results	Provide facilities for sharing recordings and practice histories with others. Support for communities of practice.

Table 2 - Creativity support for musicians based on the 'genex' framework

Having presented the three cornerstones of our approach to music-learning support tools – the NLP, Nickerson's guidelines for creativity support and Shneiderman's genex framework - we are now in a position to present them as a specific framework of guidelines and functional suggestions for those interested in developing computer-based music-learning support tools. We therefore present a summary of likely features of a comprehensive instrumental music-learning support tool that have been derived from the three approaches introduced in this paper. These features may of course be offered in separate modules, but are listed here together to give an indication of the integrated nature of the framework.

Features for building domain knowledge

- Provide facilities for listening to 'expert' performances;
- Allow musicians to record practice performances and to compare with previous recordings of their own playing and others;

Features for encouraging a creative approach

- Provide graphical representation of aspects of a performance, such as sound quality, in order that the performer might perceive patterns in, or qualities of, their playing that had previously gone unnoticed;
- Allow sharing of experiences with other users. Provide case-studies and background information on 'great performances';
- Provide facilities for customisation and discovery of personal preferences;
- Provide facilities for keeping practice diaries or similar tools;

- Keep a history of performances for the purposes of tracking improvements or noticing ‘blind alleys’. Allow comments on past recordings to be stored;
- Provide support for considering problems (musical and physical) in a different light. Encourage playfulness and considered work at the edges or extremes of technique;
- Provide access to a diverse range of performances, sounds and visual cues from within the performer’s domain and outside it;
- Allow the musician to make audio/visual recordings of their performances and allow them to experimentally manipulate aspects of various recordings. Eg. Take a portion of one recording and overlay it with another to ‘see what would happen’;

Features for sharing, collaboration and building motivation

- Allow posting of practice sessions and trial performances for feedback;
- Provide facilities for sharing recordings and practice histories with others. Support for communities of practice;
- Allow retrieval of previous performances to demonstrate progress;

Overarching goals

- Foster the desire to be creative. Make the goal of building creativity explicit;
- Support and encourage development of instrumental technique to facilitate creativity;
- Be wary of ‘psuedo-objective’ evaluations of sound and other qualitative aspects. Encourage focus on musical end results and avoid triggering ‘paralysis by analysis’;
- Avoid overly-judgemental feedback. Allow/encourage experimentation in a socially supportive environment;
- Encourage realistic expectations of the tool. Don’t gloss over the fact that musical creativity requires commitment;
- Provide structure without stifling innovation and spontaneity.

FUTURE DIRECTIONS: A PROTOTYPE ‘VIRTUAL MUSICAL ENVIRONMENT’

We have developed a prototype tool for encouraging an exploratory, creative approach to music-making which implements some of the recommendations in our framework. In particular, the ‘Virtual Musical Environment’ (VME) we developed:

- provides a graphical view of some of the musical aspects of performance;
- provides facilities for customisation and discovery of personal preferences;
- provides access to a diverse range of performances, sounds and visual cues from within the performer’s domain and outside it; and
- was designed in accordance with the ‘overarching goals’.

The VME has both audio and visual components. The visual component is dynamic and is affected by audio input. The visual display is broken up into a matrix of 36 squares, as shown in Figure 1. A cursor is constantly displayed on the screen in one of the 36 squares and moves from square to square in response to the musical input. The performer can move the cursor in the horizontal direction by varying the volume of sound, with louder notes moving the cursor to the right of screen and softer notes to the left. Different pitches move the cursor vertically, with higher pitches moving the cursor up the screen and lower pitches moving it down. Thus, the musician may move the cursor into desired positions on the screen by carefully choosing pitches and volumes. Figure 2 shows a screenshot of the VME while a (quite abstract) video is playing in response to musical input.

record live audio for 1 second (1)				stop recorded live audio 1	
	cursor	record live audio for 10 seconds (2)	play pre-recorded video 1		
play recorded live audio 1 (loop)			play pre-recorded audio 1 (loop)	play pre-recorded audio 2	
	play pre-recorded video 2				play recorded live audio 3 (loop)
		play recorded live audio 2 (loop)		record live audio for 3 seconds (3)	
stop recorded live audio 2	play pre-recorded audio 3		stop recorded live audio 3		play pre-recorded video 3

Figure 1: ‘Virtual Musical Environment’ (VME) visual display, indicating the behaviours triggered when the cursor moves to particular squares.

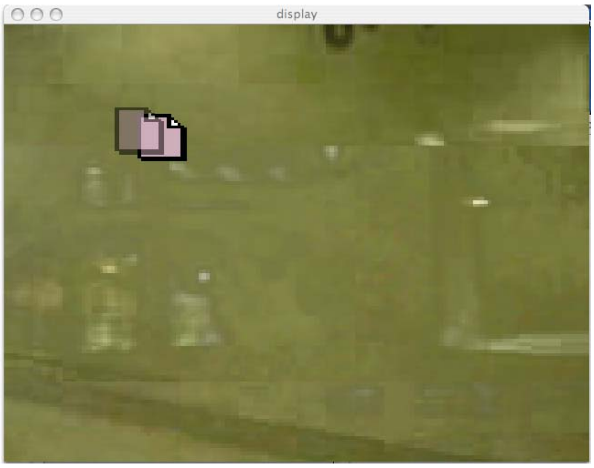

Figure 2: 'Virtual Musical Environment' screenshot

The program analyses MIDI (Musical Instrument Digital Interface) data which describes the pitch and onset velocity (roughly equivalent to loudness) of notes input to the computer. The program may be configured to respond to MIDI data created directly from a keyboard instrument or, in the case of acoustic instruments, input from a microphone can be converted to MIDI data via the Max object ‘fiddle~’ (Puckette et al. 1998).

This cursor control system provides the basic interface for human interaction with the virtual environment. This is achieved by mapping the cursor’s location on the screen to particular behaviours. For example, when the cursor occupies the square in the bottom right corner of the screen, the system begins playback of a pre-recorded video loop. When the cursor is moved to the top left of the screen, the system records live audio from the performer for one second and this audio will be played back when the cursor is moved to another square (row 3, column 4). As can be seen in Figure 1, moving the cursor to many of the squares in the display has some kind of effect on either the display itself or the audio being produced. All behaviours and the particular squares which trigger them may be changed relatively easily, allowing the environment to be customised for particular situations without changing the underlying method of controlling the cursor. If the environment is seeded with interesting content then this interaction method, while simple in concept, can lead to surprisingly rich interactive performances.

For an initial evaluation of the VME four different basic behaviours were triggered:

Video playback of pre-recorded video files	In the demonstration performance, three squares triggered playback of pre-recorded video. Any video files may be chosen, and three somewhat abstract video snippets were selected in this case.
Audio playback of pre-recorded audio files	As in the video playback, three screen icon positions triggered playback of pre-recorded audio. In this instance recordings of generative music by Dave Burraston were selected. This music was chosen partly because it was felt that it would compliment rather than distract from live instrumental music.
Audio recording of the performer in real-time	When the cursor was positioned on particular cells, recording was triggered. The computer recorded audio directly from the microphone input to a file for later playback. For our performance there were three squares which triggered recording of either one, three or ten seconds. Depending on circumstances and desired effect, longer or shorted durations may be selected.
Playback of audio previously recorded	Once real-time recording had occurred, other on-screen cells triggered playback of the recorded audio files.

The VME is still in the prototype stage, and careful evaluation is required before we can say whether it has characteristics that practicing musicians will find useful. We mention it here to demonstrate one possible approach to developing a creativity support tool for musicians in accordance with the guidelines presented in this paper and to indicate likely future work in this area.

CONCLUSION

The three key approaches discussed here – the NLP, Nickerson's twelve recommendations for creativity support and Shneiderman's *genex* approach to developing creativity support tools - form a powerful foundation upon which to build music learning support tools. Taken together, they may be considered a 'call to arms' for teachers and software developers to consider the pedagogical and psychological implications of the use of various computer-based tools carefully. Teachers may use the proposed framework to evaluate currently available tools and consider how they might best be incorporated into their teaching (if they are to be incorporated at all) and developers may use it as a basis for informing the design of future tools.

There is a considerable challenge before musicians, teachers and developers to devise and implement genuinely useful tools for creative development. We have mapped out some areas for future work in this paper and it is hoped that the framework presented here will be refined and extended as such tools emerge. Further empirical research on the development and use of music-learning support tools is required.

While new technologies for capturing and displaying audio data will no doubt continue to emerge, it is hoped that a framework such as the one proposed here will facilitate the production of genuinely helpful tools. An unfortunate consequence of a technology-driven approach is likely be the emergence of tools that encourage an overly mechanistic approach to music learning. A theoretical framework that encourages developers to give greater thought to both the pedagogical implications of tool design and the way in which the interaction between user and machine is structured may go some way towards mitigating this tendency.

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