Enabling physically disabled people to play and compose music

Tim Anderson, R&D Manager, Drake Music Project
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This article gives an overview of some of the ways that people with different types of disability can use a computer to enable them to make music. Computers can be used for musical purposes in many ways by disabled people: to write down musical ideas, to create, perform or print out a piece of music, to aid in playing an instrument, or to perform live using the computer itself as a musical instrument.

We first look at the equipment options for music making, and the different ways a user may operate the computer and music making devices. We then examine some of the software and techniques which people with a range of disabilities (even single-switch users) can use to compose and perform music. These are illustrated with some examples of people associated with the Drake Music Project - a charity which aims to facilitate disabled people in making music via technology. It has regular musical activities around the UK and Ireland for education, composition and group playing - see info box for contact details.

Equipment set-up

(a) Sound output from the computer

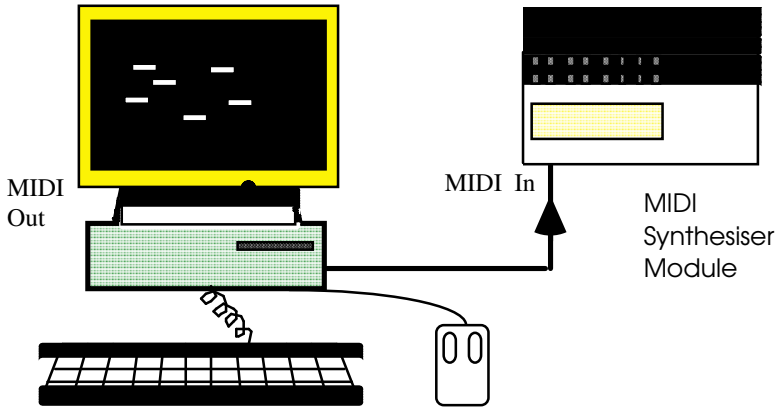
The computer can play back music in a number of ways, with a range of quality and cost:

• On a modern PC, there will often be a basic 'soundcard' installed which typically provides some instrumental sounds. With the appropriate software, this simple set-up alone can be used to compose by entering notes or arranging sounds with mouse etc or computer keyboard. It can also be used to perform, again using mouse or switches etc to generate music from the computer.

However, these PC soundcards are often more suited to games - perhaps adequate to audition a piece, but without the variety or quality of sounds needed for enjoyable music-making. A large increase in sound quality and variety can be achieved by upgrading the basic soundcard; this can be done in two ways: (1) add a new card which has higher quality sounds (eg the Yamaha SW60XG); (2) if the basic soundcard has a 'daughter board' socket, an additional 'daughter board' card can be plugged in, which again will have a far superior variety and quality of sounds (eg the Yamaha DB50XG has over 600 sounds). The Apple Macintosh can use built in ('QuickTime Instrument') sounds, which are also of sufficient quality to get an idea of how a piece will sound. As with the PC, add-on cards are available with higher quality sounds.

• A solution which can often be simpler and more flexible, is to add an external synthesiser (often called a 'module' if without a keyboard) connected via MIDI[1] - available from under £100 to several £1000s. A variety of options are available for connecting via MIDI: the Atari has MIDI connections as standard; some PC sound cards have a MIDI port built in; the Mac or PC can have a simple external converter added (£35-£50), or a more expensive device giving many more independent channels of sound. The MIDI OUT socket of the computer is connected to the MIDI IN of the synthesiser or module. Good quality MIDI modules can be bought for under £200 (eg the Yamaha MU10XG), or you can spend a lot more. Alternatively, many newer synthesisers (including this one) have a PC / Mac serial interface socket which directly connects to the computer via an 8 pin lead - obviating the need for a separate MIDI interface.

[1] MIDI is simply a standardised connection and set of messages for music equipment of different types to communicate.



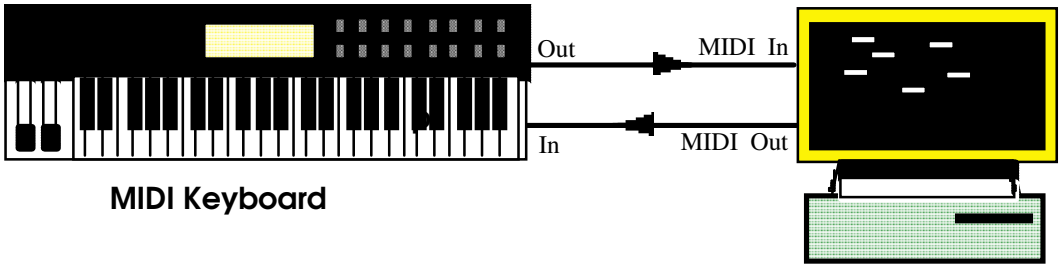
Digital audio sequencers require more involved consideration of hardware - beyond the scope of this article.

(b) Musical Input to the Computer

A variety of equipment can be used to enter music into the computer - connected via MIDI.

• **Keyboards.** MIDI keyboards come in a variety of sizes: small ones with miniature, light action keys are useful for people with limited reach or strength; full-sized keys are better for playing with hand, nose or foot; short 2 octave keyboards - which can be transposed - are useful across a wheelchair or if using a headpointer. Touch ('velocity') sensitivity is normally desirable, but a keyboard with an adjustable (fixed) 'velocity', or none at all, may be preferable for someone with a light or variable touch.

Keyboards can have sounds built in; others (known as 'master' or 'mother' keyboards) have no sounds themselves, and are designed to be connected to a computer via MIDI. If the keyboard does have sounds within it, then it can be used to play sounds in the same way as with the MIDI module above.



• **MidiCreator.** 'MidiCreator' is a box with a number of sockets to which multifarious sensors, switches, floor pads, and other 'gadgets' (eg. a ball of conductive foam) can be attached to sense position, pressure, light, angle in space etc. MidiCreator allows a wide variety of different movements or actions to be used to produce different notes, scales or chords (depending on the set-up). Many players can use it at once.

• **SoundBeam.** 'Soundbeam' is a dedicated device which senses a performer's position (using an ultrasonic beam) to play notes on a scale or a tune which has been stored. People can perform expressively on it using a solo instrument sound, or rich evolving 'soundscape'. It can be adjusted to respond to movements from a few cm to many metres - the latter allowing performance with a motorised wheelchair!

• **Drum pads and triggers.** MIDI drum pads are touch sensitive, and usually need to be hit hard with a stick. Some have additional 'trigger inputs' to which other pads or sensors can be connected; a dedicated 'trigger to MIDI' device can also be used.

• **Pitch converters (sound to MIDI).** Sound input to the computer can be used to enter notes, using software which analyses the pitch (eg 'Sound2MIDI', 'Logic Audio'). Singing can be an effective way of entering notes quickly; the software can correct any pitch inaccuracies if desired. Hardware devices to do the same thing are also available, which can also be used for performing (see below).

(c) Control

Physically interfacing switches into the computer can be done in a number of ways when using software which is designed for switch input:

• For the Mac or PC, an interface box (eg the Don Johnston 'Switch Interface') enables an external switch to 'press' certain characters or the mouse button. Switch systems such as 'Discover Switch' or 'Ke:nx' (Mac / PC during 97) may also be used.
• For the Atari, external switches can 'press' the mouse buttons or move the cursor by connecting them into the mouse port (eg via a customised interface, or a modified trackball).
• For software which uses MIDI notes to trigger events, switches can be connected using the MidiCreator box: a switch is connected into MidiCreator, and a MIDI note is sent into the computer.

There are a wide variety of ways that people operate equipment (computers, musical instruments, or other sensors). Some representative examples are listed below (with the exception of visually impaired users - this subject is too large to be included in this article):

[1] Operating computer by:
[a] mouse, trackball, trackpad or other direct mouse emulator - via head movement (eg HeadMouse) or direct joystick control. [b] emulating mouse control using *gliding*, for example: 'AccessWin', 'EasyAccess' (using computer keyboard perhaps with keyguard or head pointer), 'Ke:nx' using switches, joystick with glide control (perhaps using foot). [c] Using the computer keyboard only (eg using keyguard or head pointer), but *not* emulating mouse control as in [b].

[2] Operating a music keyboard or other MIDI musical instrument. Keyboards can be short, and have small keys with a very light action. Some people can press only one note at a time, or can only reach (eg with a head pointer, or foot) a restricted range of notes, or with restricted speed or accuracy. Some people can use a keyboard if a wrist rest (eg a long bar) is positioned above the keys.

[3] Operating equipment / computer via voice only

[4] Operating equipment / computer using multiple switches or sensors - moving various parts of the body (with a range from cm to metres).

[5] Operating equipment / computer using only a single switch.

A particular person may use several of these techniques (eg using a music keyboard as well as operating a computer via keyboard/keyguard), or may be restricted to just one. Sometime a user is faced with an either/or choice, eg is not able to simultaneously *reach* to a computer keyboard *and* a music keyboard (perhaps because using a head pointer or having a small range of arm movement). For example, where use [2] is indicated, use [4] (via MidiCreator or SoundBeam) or use [3] (via 'Pitch2MIDI' etc) can also be considered. NB. These numbers [1] - [5] will be used below to indicate types of ways people may operate.

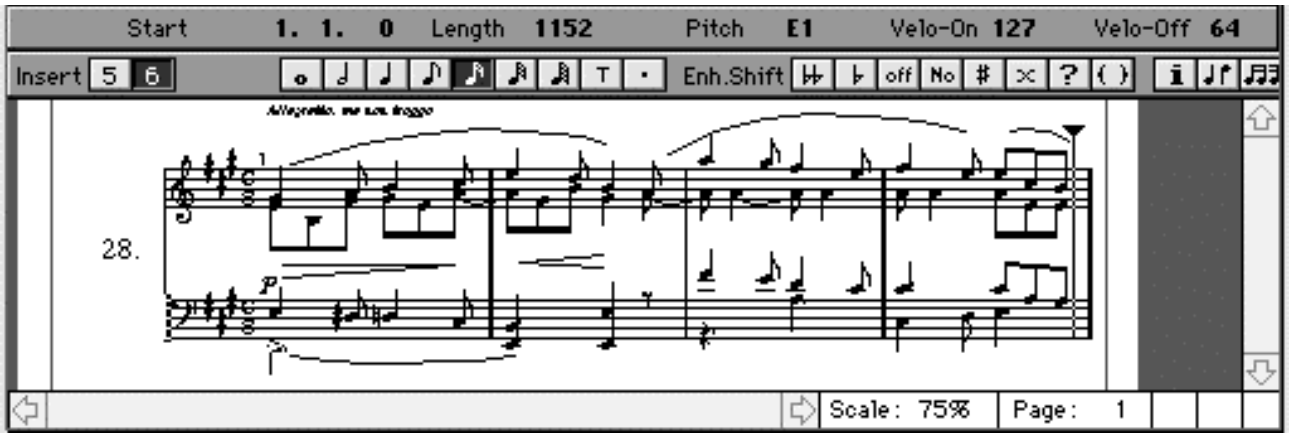
Composing - using 'sequencer' or 'scoring' software

Music can be conceived, organised, written down and played in a variety of ways with the help of a computer, using 'sequencer' software. These range widely in capability and complexity: from entry-level systems (eg 'Midi Workshop', 'Song Station' or 'Freestyle') to sophisticated ones (eg 'Cubase', 'Vision', 'Logic', 'Performer' and 'Cakewalk'). There is a wide choice available for PC, Macintosh, and Atari (although the latest versions are not usually available for the latter); a smaller range is available for the Archimedes.

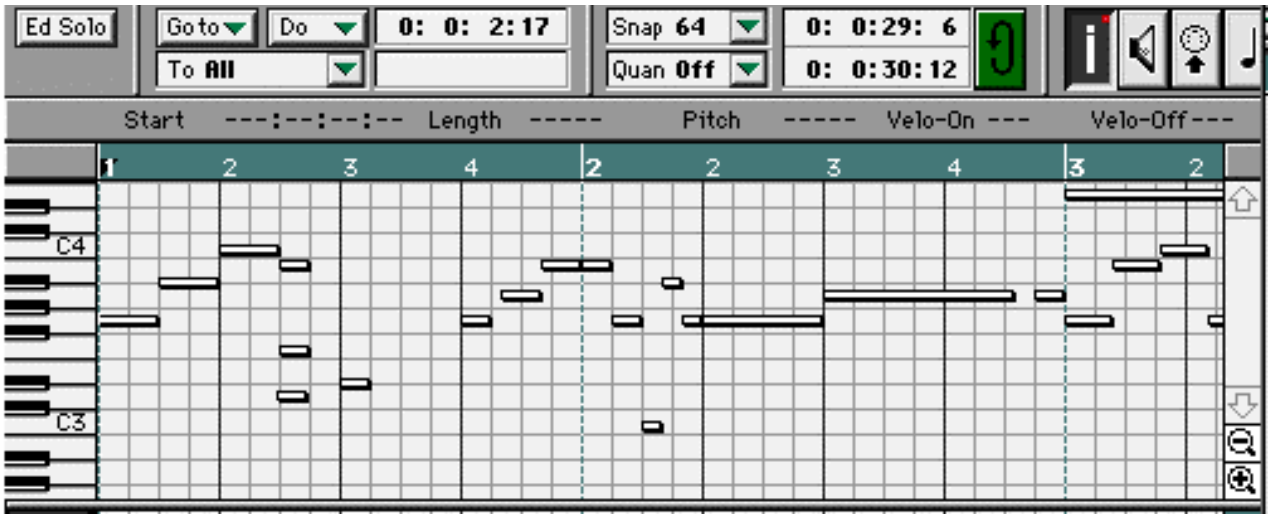
Sequencers allow notes to be entered on the screen using the computer keyboard or mouse, or can capture notes played on a connected MIDI instrument. Notes can then be edited, corrected or transformed, and organised and arranged to create a finished piece. Some sequencers can also create accompaniments for a tune in a user-defined manner.

If using a sequencer with 'digital audio' facilities - recorded sounds can also be integrated into the piece (see below). The piece can be printed out as a score manuscript (with lyrics) for performance by acoustic musicians, or can be played back by from the computer. More specialised 'scoring' software (e g Sibelius, Mosaic, Score) can also be used to create a score in a manuscript form - these systems may have more flexible facilities for drawing or typing in notes into the computer.

Sequencers provide various ways of viewing and editing notes: a score notation display (shown below) is useful if the user can read music, or wants to print it out.



Notes can also be displayed as a graphical 'pianola-style' grid (shown below), with time left to right, and pitch upwards. This can make editing easier, and is often preferred by beginners with music.



Notes can also be displayed as a list of numbers - useful for some users: the start time, duration, pitch and other parameters of each note can be altered precisely, often without requiring mouse operation.

Control of sequencer software

Most sequencers require extensive use of the mouse, although some do provide keyboard control of some operations. A few allow some editing operations to be controlled by notes played on a MIDI instrument. Two systems which are designed specifically for composition by disabled users (but which do not provide all the capabilities of sequencers) are VistaMusic and E-Scape. VistaMusic uses the computer keyboard and a MIDI instrument to enter and edit notes, with no use of the mouse. E-Scape can also be totally controlled via the keyboard, or via MIDI only, or via a single switch only - it is described in more detail below.

Composition can be divided into: (a) entering notes and rhythm, (b) editing notes, (c) constructing a piece by arranging and organising segments of music.

(a) Entering notes and rhythms

A variety of methods can then be used for the entering or recording of notes:

(i) Using a MIDI instrument (see 'Equipment Setup' section b) in various ways [2, 3, 4]:

• A note or chord can be entered with no regard to timing, using 'step time' entry. The length and position of a new note is set on the computer, then the desired note on the instrument is played to set the pitch. The *strength* (termed 'velocity') with which keys are hit can also be recorded - it can affect various

aspects of the sound, eg timbre, loudness, or attack. If the user has difficulty controlling it, a keyboard without touch sensitivity can be used (and expression then added on the computer), or one which allows the 'velocity' to be fixed. • Example user: Pat uses a headpointer, and operates the mouse cursor via keyboard and EasyAccess emulator. She then enters individual notes on a small MIDI keyboard nearby. [1 b + 2].

• Notes can be recorded in 'real time' - ie as played, but can later be corrected or altered - see below. A metronome click can be used, and may be set very slow, then sped up later. • Example user: Steve uses a single foot - he uses a trackball with locking button to operate the computer, and plays live with a toe. He can thus capture expression and feel, but is able to correct timing and any wrong notes as desired.

• A segment of music (initially empty!) can be repeatedly played. Each time round, a single note (or more) can be played on the instrument and added to the segment. Thus, the user can concentrate on getting the timing right. If desired, recorded notes may be instantly 'corrected' to be 'on the beat' - see below. • Example user: Mark uses his foot on a joystick (with external switches) to operate the computer's mouse. He uses the loop recording method to enter rhythm parts quickly by hitting keys on a MIDI keyboard or drum machine at the right time. [1b + 2]

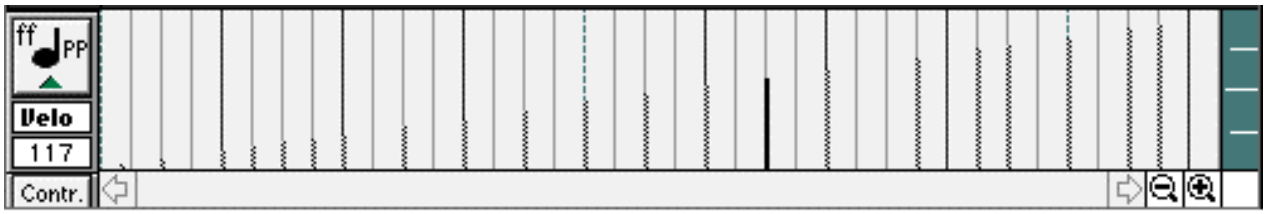
(ii) In scoring software, notes can be typed in directly from the computer keyboard [1c].

(iii) New notes can be drawn in an editing window by clicking and dragging with mouse etc on screen. Other parameters can also be drawn (eg for pitch bending, volume, panning, timbral aspects, vibrato etc). • Example user: Dave uses his nose to operate the mouse cursor via keyboard and EasyAccess. He draws all notes and expression parameters on screen using the mouse [1b]. His third album is now out on Stream Records - which specialised in promoting music by disabled artists or integrated groups.

(b) Editing notes

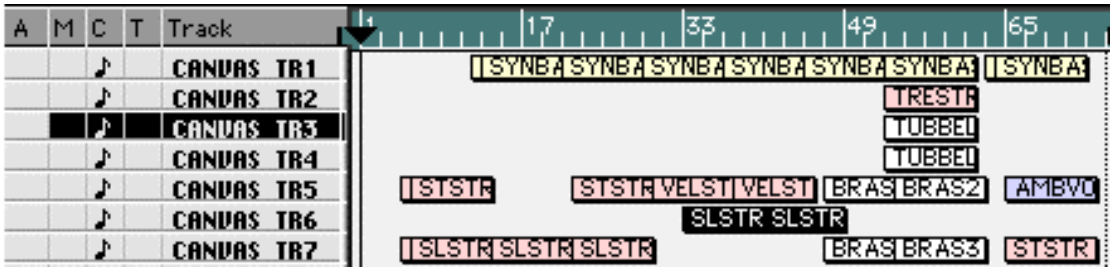
A variety of operations [using 1a / b, some via 1c, or even 2, 3 or 4] can be performed on notes:

• The tempo can be changed (eg speed up notes which were recorded slowly). Gradual changes can create accelerando or rallentando can also be created by changing the tempo gradually up or down.
• The timing of notes can be changed in many ways, eg can be 'quantised' to varying degrees (ie pulled more onto the 'on the beat' time) - can be useful with real-time recording
• A note or phrase can be repeated a specified number of times, eg to help create a repeated bass line.
• Notes can be removed with the delete key, the mouse, or via a menu option.
• The position, length or pitch of any note can be changed - by typing values, cursor keys, or mouse.
• Many other features can be altered: for example, the strength of playing ('velocity') can be changed (or values added) by drawing with the mouse, eg a crescendo can be drawn, as shown below.



Many sequencers have further, highly sophisticated facilities for arranging and transforming material.

(c) Constructing and arranging a piece



Many sequencers provide facilities to let the user organise music phrases and segments into a larger-scale piece of music. Notes, when entered in any of the above ways, can be grouped into segments (which may

be termed ‘tracks’, ‘parts’, ‘sequences’, ‘blocks’ or ‘chunks’). Most sequencers provide a display of the structure which enables it to be visualised easily, as shown above. The user can then organise, split, move, copy, delay, layer, repeat, change the sound, or transform these segments. Again, many arranging operations tend to be carried out via mouse actions.

Other tools for composing

• Using a sequencer with ‘digital audio’ facilities, sound samples (digital recordin gs stored on disk) can be assigned to play back within the piece. A piece then plays using both synthesised sounds and samples. Samples are displayed in a similar way to notes, as shown above. Samples can also be processed in many ways and changed radically. The art lies in creative editing, arranging and organising of samples.

• Software (eg Jazz Improviser, Band in a Box) allows the user to enter melodies or chords and create a range of accompanying music, according to specified ‘style’ rules and stored p atterns - which can be altered by the user. ‘Band in a Box’ is notable, as it can be almost completely operated from the computer keyboard.

Composition with a switch

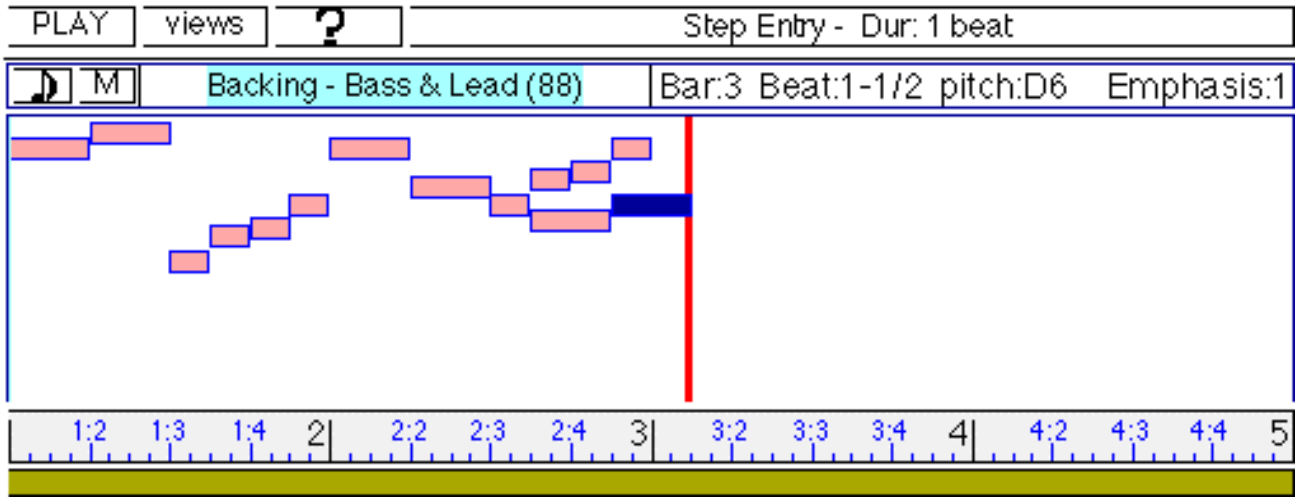
Switch users attempting to operate conventional mouse-driven sequencer software have to use a scanning menu overlay (eg ‘Ke:nx’) to emulate mouse operation. However, the processes involved in composing music are often more complex and repetitious than word processing etc, and the software is often highly demanding in the precision and number of mouse actions needed - switch users often find this laborious and fatiguing, leading to frustration and demotivation, especially when first starting.

This led the Drake Music Project to develop custom software (‘E-Scape’) which is designed from the outset to enable a person to control all aspects of the software easily using a single switch if necessary. It is also highly suitable for beginners, as the user is guided through musical and technical operations.

The ‘E-Scape’ system

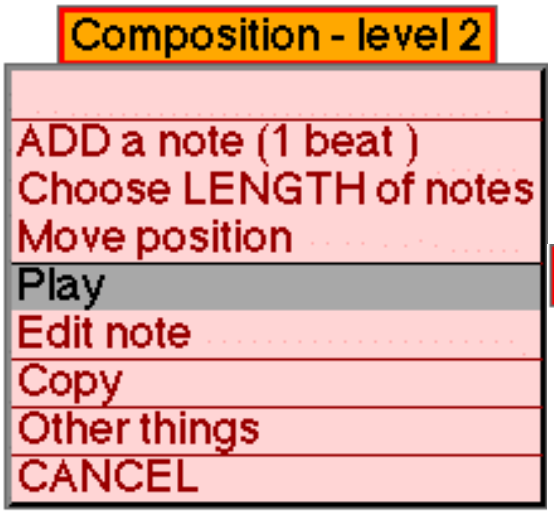
E-Scape is a composition software system created to facilitate severely disabled people in composing and playing music without any external help. *Every* aspect of E-Scape can be controlled by: the computer keyboard; one or more switches; any MIDI instrument, or mouse. Any *one* method can be used, or several together - useful if two different people are working together. All menus and alert boxes can speak, their text size can be increased to fill the screen, and colours of text and background can be altered - all by the user. Such features can enable people with some visual disabilities, or non-readers to use it.

The user creates a piece on a graphical page on the screen, on which notes can be entered and viewed as blocks having pitch, duration and time. The piece can have a number of different parts (‘tracks’), and the instrument sound for each track can be chosen. The example below has only a single track so far.

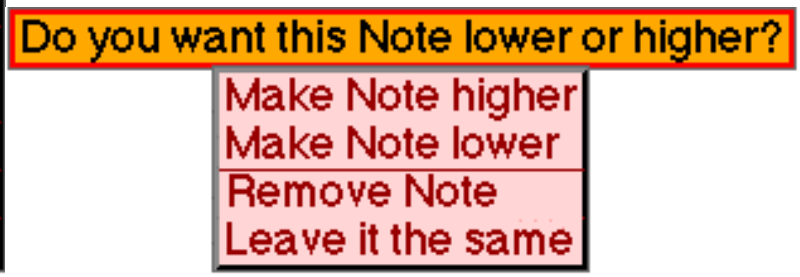


Notes can be edited (as for sequencers), and E-Scape tries to give the user as little physical work as possible by automating many operations. The user can select a ‘level’ to work at - lower levels have

fewer choices, simpler language, but more *guidance* through a process. Thus even complete beginners can start creating music immediately, by making decisions from a limited range. For example, pressing a switch (at 'user level' 2) brings up a top-level menu of choices - see [i] below. Note the attempt to keep the language simple at this level. An example will illustrate the assistance E-Scape gives in reducing switch fatigue.



[i]



[ii]

Example - Entering notes

At 'level 2' a user selects the menu option 'ADD a note'. A new note with the currently set note length (eg 1 beat) is written at the current position. With no further user intervention, E-Scape then starts playing this new note along with any other notes nearby, so the user can hear it in context. This is repeated until the user presses a switch, upon which he/she is asked whether to raise or lower the pitch of the new note - see [ii] above. The note is then automatically changed in pitch one semitone at a time, again each time played back 'in context'. The user only has to listen, and press the switch when the desired transposition has been reached. Thus a new note can be added at a chosen pitch and auditioned, using only four switch presses.

The 'beta' version of E-Scape is currently in use by the Drake Music Project and other institutions. It is under continual development, and is currently available free under beta licence. • Example users: Leon uses two switches with his head, and is a non-reader. He composes unaided using voice feedback and two-switches. Russell uses two switches with one foot - he is also composing unaided.

Performing

The computer can be used either (a) in conjunction with a MIDI instrument etc. to assist in playing it, ie to augment or improve the way it works, or (b) as an instrument itself - controlled via mouse, switches etc.

(a) Use in conjunction with a MIDI instrument

An 'instrument' is really anything which can capture the expressi ve movement of a performer and convey it to the computer. It might be a keyboard (eg hitting several keys with the foot), but could also be a set of pressure pads on the floor (stamped on, or run over with wheelchair!), an ultrasonic beam (eg moving part of the body to different places), or squeezing foam sensors.

The computer receives MIDI data from the instrument, performs some operations on it (via software such as Max, MidiGrid, Logic, MidiMap or Vision), and sends it out to a sound module. If the computer is set up by a collaborator, a person can use methods [2, 3, 4 or 5] to perform. For example:
• Changing the notes played - eg all the black notes could be a different scale. Certain keys on the keyboard could be made *silent* (useful if a performer finds it difficult to hit a *single* note), or several keys could be made to play the *same* note (useful if playing a keyboard with the foot).
• Triggering a musical phrase, chord or ornament etc, by playing a particular note on the instrument.

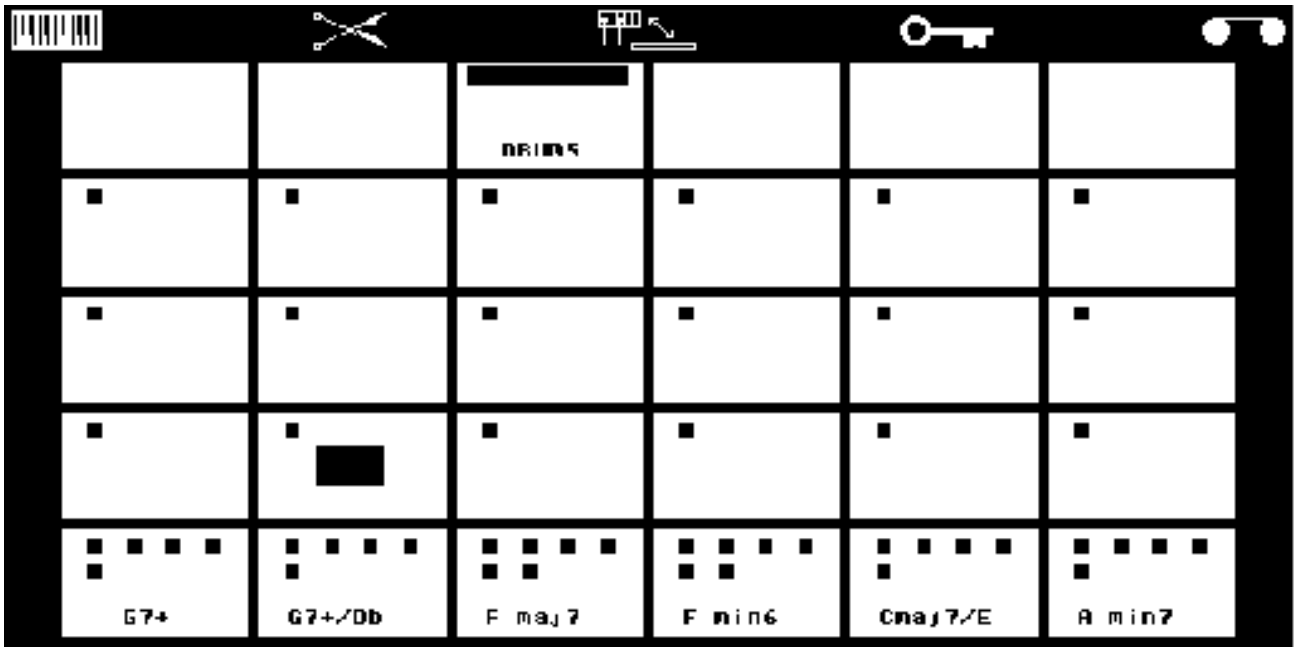
Software such as Max can be programmed to recognise when the performer has played a *particular* phrase.

• Enabling a person to play *chords* with a single finger, headpointer etc by storing each note as it is played. Alternatively, a chord can be assigned to a note (as above), but could *change* depending on the context.

(b) Using the computer itself as a performance instrument

A person can interact with the computer itself to create music in a variety of ways. An element of preparation is often involved, either by the performer, or a collaborator, or in a supplied file. The key is in this preparation of the musical elements which will be employed during the performance - the dividing line between composition and performance is a flexible one.

(i) The 'MidiGrid' software displays an on-screen grid of boxes, each of which can 'contain' a specified note, chord, or phrase (as shown below).



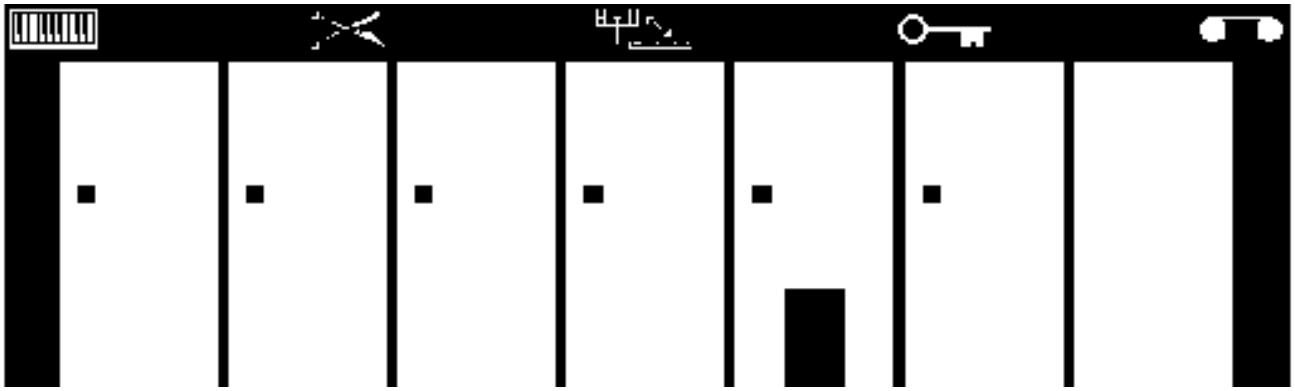
MidiGrid can be used in several ways by a disabled performer:

• The performer can 'conduct' phrases using the mouse [1a / b] - making them start and stop, together or separately. Phrases are created (in advance) which can combine with each other. The results can be recorded and thus used as part of the 'composition' of a piece of music - and can go on to be edited etc as described above.

• Collaborative performing: Some people can perform in collaboration with another player (or an assistant) who can use the mouse to select the appropriate box, and the switch-using performer then triggering it *at the appropriate time*. For a single-switch user playing in an ensemble, it may be satisfying to simply trigger a single sound at the right time. Example user: Leon uses two head switches to trigger two different chords.

• The contents of a box is played when the mouse moves over it and the button is pressed; or can be set so the mouse button need *not* be pressed [1a]. Thus, chords, arpeggios, or larger phrases can be played with a single movement of the mouse (or trackball, touch screen, HeadMouse etc). The computer is here acting as a genuine musical instrument - it can be played well or badly! A tracking mouse emulator [1b] could also be used if it is acceptable to have a fixed speed of mouse tracking across the boxes, but with the performer able to choose *when* and in what *direction* to move.

The grid can be varied in size; if it is made only one box wide or high, then a performer only needs to move a trackball etc in *one* dimension. • Example user: Stephen can move his head only a small distance; he uses a grid as shown below (a six note scale plus a silent box), with a saxophone sound, he can move his chin sideways on a trackball to trigger each note, and play jazz solos.



(ii) Using eg Vision or Logic sequencers, a segment of music (a phrase, note or chord) can be assigned to a key on the computer keyboard, which can triggered by a performer (eg using a headpointer or keyguard, [1c]). Other software lets a performer trigger or select segments of sampled sound or music.

(iii) Using eg E-Scape or MidiGrid, a switch-using performer can 'conduct' (ie step linearly through) a pre-composed piece: each switch press plays the next segment (note or chord) of the piece [eg users 4 or 5]. A performer is thus able to concentrate on the musical *timing*. If using E-Scape, switch-users can prepare this musical material themselves. • Example user: Baz uses a single switch with his knee to conduct through a sequence of chords in a group performance.

(iv) A piece consisting of several tracks can be prepared in a sequencer, then played. The performer can then selectively mute (make silent) different tracks or sections, or cycle round different parts of the piece - usually controlled with the mouse [eg users 1a/b]. • Example user: Dave uses his nose on cursor keys to operate the mouse cursor. He performs live using a set of prepared tracks, by playing them in a loop, then muting and un-muting different combinations to constantly change the piece.

(v) By varying various performance parameters and rules, a performer can control ('conduct') the algorithmic generation of music [eg users 1, 2, 3, 4, 5]. This is a subject worthy of an article itself.

(vi) Systems (Anderson, 94) can be created to interact with other players, eg a switch user can choose the time to play, but the notes played can be selected by other players in a sophisticated manner [eg 5+2,3+1].

Further reading

Anderson, T. M. and Hearn, D. (1994). 'Using Hyper-instruments for the re-distribution of the performance control interface'. Proc. ICMC, Aarhus.

Anderson, T. M. and Smith, C. (1996). 'Composability': widening participation in music making for people with disabilities via music software and controller solutions'. Proc. ACM Conference on Assistive Technologies, Vancouver.

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