

## **Chapter 3**

# **Accessing the Keyboard**

- 3.1 Introduction**
- 3.2 Keyboard Quick Assessment Guide**
- 3.3 Adapting the Keyboard**
- 3.4 Alternative Keyboards**
- 3.5 Further Information**

## 3.1 Introduction

The keyboard is the most common method of controlling the computer and for most people, it is also the fastest and easiest to use. Since almost all computers are supplied with a keyboard, it is also generally the cheapest access method. Therefore, it is usually worth exploring keyboard adaptations and different types of keyboard before turning to other methods of access.

If a pupil has difficulty in accessing a standard keyboard, extra demands are being placed on them. For some, adjusting seating, the position of the monitor, or providing an adjustable table are sufficient measures. Other pupils may have poor finger or hand control but can still target individual keys. Or keys are pressed unintentionally because of involuntary tremor. For those for whom a standard keyboard is almost, but not quite, appropriate, a range of adaptations is available. It is often surprising how fairly minimal adaptations can open up access opportunities for pupils who initially appear to require major and expensive adaptations.

As well as adaptations to standard keyboards, alternative keyboards are available. These include miniature and 'expanded' keyboards as well as devices designed from ergonomic principles. Pupils who use voice output communication aids may also be able to control the computer using the communication device in place of the computer keyboard.

This chapter discusses these adaptations and alternatives. The products mentioned are not necessarily recommendations or endorsements but rather examples of equipment and software.

The chart on the next page summarises common difficulties with keyboarding and suggests some tools and techniques that might help: refer to the text for further details.

## 3.2 Keyboard Quick Assessment Guide

Observation	Access tool
<b>The user can hit keys on the keyboard but...</b>	<b>Investigate...</b>
...often hits the wrong key	seating and positioning vision keyguard increasing input acceptance time expanded / overlay keyboard with big keys
...gets letters repeated by mistake	turn off key repeat, or increase repeat time and delay
...tremors or hits the key several times	increase post-acceptance delay
...can't hold two keys down at once	'Sticky' keys
...has difficulty knowing when a key has been pressed	'Key beeps'
...suffers pain when typing	seating and positioning wrist rests Dvorak/ergonomic layout ergonomic keyboard voice recognition 'word prediction' software to reduce keystrokes
...can't reach across the whole keyboard	seating and positioning arm supports small laptop-size keyboard miniature keyboard
...cannot see the keys clearly	seating and positioning lighting high-contrast key stickers expanded keyboard 'chording' or Braille keyboard on-screen keyboard voice recognition
...types very slowly	practice, using appropriate software to teach keyboard familiarity 'word prediction' or 'abbreviation expansion' software
...is not literate	overlay keyboard on-screen keyboard using a VOCA as a keyboard
<b>The user... cannot use fingers, hands or feet to operate the keyboard...</b>	<b>Investigate...</b>
	seating and positioning  vision hand/finger/wrist splint hand-held pointer head or chin pointer voice recognition expanded or overlay keyboard operated by knuckle or fist on-screen keyboard access by pointing device or switches Morse Code

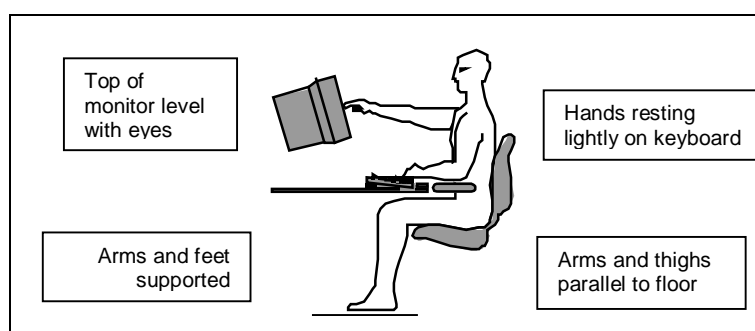
## 3.3 Adapting the Keyboard

### Equipment and Hardware Adaptations

#### Seating and positioning

If a pupil is having difficulty accessing a keyboard (or any other access device) the first thing to consider is seating and positioning. There is little point in investigating all sorts of adaptations unless the basic positioning of the keyboard, computer and screen are correct and the user is seated in a stable, comfortable position. Good seating and positioning is a pre-requisite for use of technology (Cook & Hussey, 1995, Gray, 1988). Chapter 2 summarises the basic requirements and references on seating and positioning; modern computer manuals have a section on ergonomics and good keyboarding technique; and if at all possible consult an occupational or physiotherapist.

Figure 3-1 Basic ergonomic position



The basic ergonomic position for keyboarding is given in Figure 3-1. If the user cannot maintain sitting balance then support must be provided at pelvis or trunk using cushions or straps.

#### Tables and furniture

A wide range of tables is available from school and office equipment suppliers such as Neat Ideas. Many schools buy a 'standard' type of computer trolley from educational suppliers and these are often unsuitable for users with special needs. If the pupil is in a wheelchair, the height of the keyboard and screen may be too high; or the wheelchair may not fit under it; and the surface area may be too small to take expanded or overlay (*Concept*) keyboards.

Some suppliers sell trolleys where the height can be set by inserting dowels or pins through the legs to hold the plinth at the correct height. These are satisfactory if the table does not need to be adjusted very often (for example, if the user is always seated in the same chair and always performing the same task), but they are difficult to adjust when fully loaded with equipment.

Specialist trolleys such as the *Varitech* (Figure 3-2) have a handle which lets you adjust the height easily and precisely even when the trolley is loaded with equipment. They also have plenty of space underneath to allow a wheelchair to be pushed in under it; and have a larger than standard top surface to accommodate special keyboards

The Disability Information Trust books on *Employment and the Workplace* and *Communication and Access to Computer Technology* (Barrett, & Herriotts, 1994, 1995) have detailed descriptions of adjustable tables, footrests, arm supports and other positioning equipment. These publications are inexpensive and comprehensive and anyone involved with special access should have copies. Office equipment suppliers such as Neat Ideas and HCS Global sell the more common ergonomic items such as wrist and foot rests and adjustable keyboard and monitor supports and the companies will provide catalogues on request.

Figure 3-2 Varitech adjustable trolley



Table 3-1 Adjustable workstations and tables

ADJUSTABLE WORKSTATIONS / TABLES	Description	Price Guide	Supplier
SIS workstations	Height adjustable in 3cm steps between 51 and 75 cm using pins – adjustment must be made before locating computer and equipment.	£99 to £199	RM
Varitech	Computer workstation with shelf unit. Height adjustable when fully loaded.	£460	Atkinson Eng.
Jenson	Adjustable single-level table – adjustable when fully loaded.	£540 - £870	Lacelink Ltd.

### Adjustable keyboard and monitor arms

Continuously adjustable tables are expensive. If space and funding is restricted, there may be no choice but to try and adapt a standard trolley. If the keyboard is too high or otherwise not accessible, one option is to locate it on the user's wheelchair tray (if there is one, and if it is big enough). Or, office equipment suppliers sell a range of keyboard shelves and monitor arms that can be attached to a table and then swung out and adjusted to the correct height for a wheelchair user.

Table 3-2 Monitor arms

ADJUSTABLE MONITOR ARMS	Description	Price Guide	Supplier
<b>Misco Arm</b>	Adjustable monitor arm and keyboard shelf	£55	Misco
<b>Monitor Float arms</b>	Pneumatic monitor arm with keyboard rack	From £99	HCS Global

## Footrests

If the user's feet are dangling down from a seat that is too high it will be hard to maintain sitting balance and achieve good hand control. Footrests with adjustable height and angle are available from computer and office equipment suppliers from around £20 upwards.

**Table 3-3 Footrests**

FOOTRESTS	Description	Price Guide	Supplier
<b>Comfort Footrest</b>	Adjustable non-slip footrest	£16	Misco
<b>EasyTilt Footrest</b>	Adjustable non-slip footrest	£24	HCS Global

## Wrist rests

Standard ergonomic wrist rests are suitable for users who require some support – perhaps to stabilise the arm – but do not need full arm support. Wrist rests are available for standard keyboards from many different distributors.

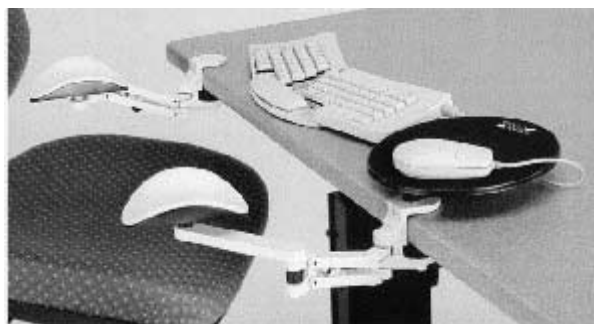
**Table 3-4 Wrist rests**

WRIST REST	Description	Price Guide	Supplier
<b>Fellowes Wristpad</b>	Basic foam wristrest	£5	Neat ideas
<b>SM Keyboard Wrist Rest</b>	Gel-filled wrist rest	£19	HCS Global
<b>Adjustable Wrist Rest</b>	Foam padded height adjustable wrist rest	£16	Misco
<b>SAS Padware Wrist Rest</b>	Pressure sensitive ergonomic wrist rest	£12	SAS

## Arm supports

Arm supports take the weight of the arm and let the user move across the keyboard to access the keys. They are useful for people with muscle weakness who get tired typing. The supports can be attached to a table, to a wheelchair or to a chair armrest and start at around £30.

**Figure 3-3 Ergo Rest arm supports**



**Table 3-5 Arm supports**

ARM SUPPORTS	Description	Price Guide	Supplier
<b>Ergo rest</b>	Forearm rest (800mm reach) which can be attached to table or chair	£140 - £205	QED
<b>Ergo Arm Rest</b>	Forearm rest with a smaller range (290mm)	£75	Data Sound
<b>MAG sliding support</b>	This gives support over the whole forearm and a 145mm range forwards and backwards	From £525	Rehability Ltd.

ARM SUPPORTS	Description	Price Guide	Supplier
The Arm Supporter	Lightweight arm support with 410mm reach	From £98	Spyder Engineering
Adjustable Armrests	Pair of adjustable armrests for attaching to typist's chair	£32	Neat Ideas

### Grab bars & restraints

Some pupils with athetoid cerebral palsy benefit from a grab bar fixed across the table or tray. When the bar is grasped using one hand, it stabilises and reduces uncontrollable movement and so improves control in the other. Grab bars can be bought from OT and therapy suppliers such as Nottingham Rehab, or home-made – the *Augmentative Communication Assessment Resource* (Goosens & Crain, 1986) gives advice and instructions for making grab bars.

### Typing Tools

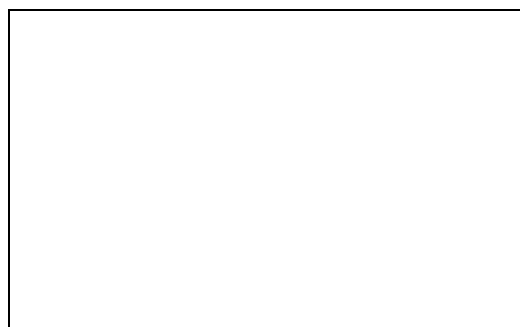
**“ The pupil doesn’t have sufficient finger or hand control to use the standard keyboard – can she use it in any other way? ”**

Some pupils have poorly coordinated finger movements or cannot extend a finger to target keys. They may find be able to grasp a round dowel, pencil, peg or a ‘T-bar’ to press the keys – the grasp action can prevent the fingers from hitting the keys and may increase overall hand control. Pupils who can point accurately with one finger but tend to hit keys with their other fingers could try using a mitten with a hole cut in it for the ‘good’ finger, while the other fingers are kept fistful by the glove. Occupational therapists can mould splints from low-temperature plastics, either to keep the wrist extended, or to keep the typing fingers straight. All of these tools can be used in conjunction with furniture and adaptations like keyguards.

### Mouthsticks and Headpointers

Those who have good head control but no usable hand function might be able to type using a *mouthstick* – a long rubber-tipped rod which is gripped in the mouth by means of a moulded dental plate. Alternatively they might be able to type using a *headpointer* in the form of a lightweight helmet with a rod projecting from the front. Both require careful adjustment to ensure a comfortable and secure fit, as well as to minimize neck strain over prolonged use. An important factor for pupils with speech is that the mouthstick prevents the user from speaking whereas the headpointer does not interfere with speech. In terms of using the device independently, a mouthstick may be stored in such a way that allows the pupil to use it without help, while the headpointer has to be strapped on by a helper.

**Figure 3-4 Chailey headpointer (chin version)**



Some users and parents may feel that these pointers are unsightly. It may be important to emphasize their advantages so that they are not immediately rejected on the basis of appearance. Reasonable typing speeds can be achieved with these direct selection methods, they are relatively inexpensive,

easily portable, and can be used with any computer with only minimal adaptation. We consider the Zygo item to be more attractive than the Chailey Heritage units, but at a considerably greater cost.

**Table 3-6 Mouthsticks and headpointers**

<b>MOUTHSTICKS / HEADPOINTERS</b>	<b>Description</b>	<b>Price Guide</b>	<b>Supplier</b>
<b>Mouthstick</b>	Plastic mouthpiece with different attachments	£6 - £10	Chailey Heritage
<b>Headpointer – Forehead</b>	Adjustable padded headframe with pointer on forehead strap	£40	Chailey Heritage
<b>Headpointer – Chin</b>	Adjustable padded headframe with pointer on chin strap	£62	Chailey Heritage
<b>Zygo Headpointer</b>	Adjustable padded headframe with pointer on chin strap	£145	QED

### Keyguards

*“ The pupil can manage a standard keyboard but often makes mistakes due to uncoordinated movements... ”*

A keyguard fitted over the keyboard can help to prevent unintentional keypresses for those who type with a finger, typing tool, mouthstick or headpointer. A keyguard is a metal or plastic plate with holes punched into its surface and secured over the keyboard with clips or strong Velcro. The keyguard helps to prevent keys from being accidentally pressed while the user’s hand moves over the keyboard to locate the desired key. It also allows the user to position their finger over the required hole, resting their hand on the keyguard’s surface if required, before pressing the key underneath.

**Figure 3-5 Special Access Systems Keyguard**



There are as many styles, shapes, and sizes of keyboards as there are models of computers. Some keyguards are designed for specific computers – in particular those made by Apple, Acorn and IBM – so when you order a keyguard for, say, an Acorn A4000 series computer, you know that it will be a good fit for that keyboard.

The situation is less straightforward if you are using a PC compatible computer because the size and shape of keyboards varies. If the fit of the keyguard is not precise, some holes may reveal part of an adjacent key, which increases the likelihood of inadvertently pressing two keys at once. If possible, try the guard before you buy it or send a full-size photocopy of the keyboard to the supplier who can then match it against the layout (but not the profile) of their keyguards. If you can’t find a keyguard that fits, consider replacing your keyboard with a keyguard/keyboard combination, that is, a keyboard that comes fitted with its own keyguard.

Hardly any keyguards are available for laptop computers because of problems of mounting the keyguard in a compact area, the proliferation of models, and the relatively small number of laptop users in education. However, the keyguard/keyboard combination mentioned above could be used if

the computer has a socket to enable an additional external keyboard to be connected. Compact keyboards and keyguards are also available; these keyboards are about half to two thirds full size, and are easier to store and to carry (page 41, *Expanded and Miniature Keyboards*).

If none of the off-the-shelf keyguards are suitable, you might be able to have one made by a specialist company, technical service or voluntary group such as REMAP.

Table 3-7 Keyguards

KEYGUARD	Description	Price Guide	Supplier
<b>PC &amp; Acorn Keyguards</b>	Good quality well-made steel keyguards for Acorn and PC standard and compact keyboards.	£39 - £52	SAS, Inclusive Technology, SEMERC
<b>PC Keyboard &amp; guard</b>	Keyboard with matching guard	£87	SAS
<b>Mac Keyguards</b>	Acrylic keyguard for Macintosh computer	£78	Don Johnston
<b>PC Keyguards</b>	Keyguards for PC and compact keyboard	£45 - £58	CAC
<b>Made to order</b>	Range of keyguards made to meet individual requirements – send photocopy of keyboard	varied	Interface Designs, REMAP

## Software Adaptations

### “ Are there any software adaptations that might help? ”

The keyboard can be adapted using software *Access Utilities* to help users who have motor problems and who type using a finger, headpointer, or mouthstick.

- **Filters to reduce mis-keying** – *Input Acceptance* and *Post Acceptance Filters* alter the response of the keyboard to eliminate unintentional and multiple keypresses, and a *Repeat Filter* slows down or stops the automatic repeating of characters.
- **Sticky Keys to hold down modifier keys** – allows shifted characters or commands to be typed without having to hold down a *modifier key* (Shift, Ctrl, Alt, Apple, Option) while pressing a second key.
- **Auditory or visual feedback** – informs the user when a keypress is accepted by the computer.
- **Mouse Control** – *MouseKeys* allows the keyboard to be used to move the mouse cursor and to perform clicking and dragging (see section 4.3 *Alternatives to the Mouse*)
- **Serial Keyboard and Mouse Emulation** – another computer or a communication aid can be connected to the serial port of the computer and the user can send keyboard characters/commands and control the mouse (see page 45, *Using a Communication Aid as a Keyboard*)

MacOS and Windows 95 computers have many of these access features built in to the computer's operating system. Acorn and Windows 3.1 users can add them with separate 'shareware' or 'freeware' utility software.

Other terms for:

<i>Filters</i>	<i>SlowKeys; BounceKeys; RepeatKeys; Keyboard Speed</i>
<i>Mouse Control</i>	<i>MouseKeys</i>
<i>Keyboard &amp; Mouse Emulation</i>	<i>SerialKeys</i>

## Filters

It can be hard to visualize the effect of *filters* from a description so you should refer to the companion interactive tutorial program on disc and on the CALL Web site (<http://call-centre.cogsci.ed.ac.uk/CallHome>) to try out the effect of different types of filter.

The filter settings will need to be carefully adjusted to suit individual users – this usually requires some trial and error. The physical condition, such as muscle tone and motor coordination, of some users may change from day-to-day or over a longer period of time, so it is important to monitor the user's use of the keyboard on regular basis and make adjustments to the filter and other settings accordingly.

The three types of filters – **Input Acceptance**, **Post Acceptance** and **Repeat** – are described below.

- **Input Acceptance Filter**

The **Input Acceptance Filter** slows down the response of the keyboard so that the user has to keep the key **continuously** pressed for a set time, called the *input acceptance time*, before it is accepted. If the pupil tends to 'knock' other keys when typing, increase the input acceptance time until the unintentional keypresses are filtered out.

*Other terms for:*

<i>Input Acceptance Filter</i>	<i>SlowKeys</i>
<i>Input Acceptance Time</i>	<i>Acceptance Time</i>

- **Post Acceptance Filter**

The **Post Acceptance Filter** should be used if the pupil tremors when trying to release a key, causing the key to be pressed a few more times. This filter slows down the response of the keyboard after a key has been released by ignoring **all** further keypresses for a certain time, called the *post acceptance delay*.

*Other terms for:*

<i>Post Acceptance Delay</i>	<i>Debounce Time</i>
<i>Post Acceptance Filter</i>	<i>BounceKeys (modified version of Post Acceptance Filter)</i>

- **Repeat Filter**

Some learners have difficulty releasing a key after they press it, and get several unwanted letters appearing on screen. Prevent this by increasing the **repeat acceptance delay** or turn the repeat off completely.

If a key is held down, it will start repeating once the **repeat acceptance delay** has finished. The interval between successive repeats is determined by the **repeat time**. Most operating systems have a built-in 'control panel' or configuration utility that allows these settings to be adjusted. You should first experiment with these built-in settings if you need to slow down or disable automatic repeat. However, if the control panel does not allow you to switch off the automatic repeat feature or to make fine adjustments to the settings you will need to use an access utility with a **Repeat Filter**. To minimize interactions between the built-in repeat filter and that provided by the access utility, you must set the built-in repeat acceptance delay setting to **minimum** delay ('short') and the repeat time to **maximum** ('slow').

*Other terms for:*

<i>Repeat Acceptance Delay</i>	<i>Delay Until Repeat</i>
<i>Repeat Filter</i>	<i>RepeatKeys, Keyboard Speed</i>
<i>Repeat Time</i>	<i>Key Repeat Rate</i>

**Case Box**

T. uses a chin pointer to access a standard keyboard with guard. She needs the repeat acceptance delay and time set to 0.3 seconds to avoid unwanted repeated letters; Post Acceptance Delay set to 0.1 seconds to filter out double hits; and Sticky Keys to generate shifted keys and control commands.

## Sticky Keys

Pupils who type using a single finger, mouthstick or headpointer are not be able to hold down the modifier keys – **abj** – in order to produce shifted characters and commands. The **Sticky Keys** feature overcomes this problem by allowing the user to tap **once** on one or more modifier keys to have them

*latched* (held down) for one keypress. For example, a capital 'S' can be typed by tapping **j** to latch it, and then pressing **S**; the Shift key is automatically unlatched after the letter is typed. If a modifier key needs to be held down for more than one keypress, choose an access utility that allows the user to *lock* down the modifier keys (usually by tapping the key **twice** in succession); when the modifier key is no longer required, it can be unlocked by pressing it again.

*Other terms for:*

*Sticky Keys*

*Automatic Shift*

## Auditory and Visual Feedback

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It can be helpful if the access utility generates **sounds**, in the form of clicks or different tones, to inform the user when a key has been pressed and accepted by the computer, or when the user latches the Shift key.

Users with hearing impairment may need a **ShowSounds** feature that provides **visual** feedback of keyboard events – some utilities do this by flashing the title-bar of the application currently in use or by flashing the whole screen. You should look for a utility that provides auditory and/or visual feedback for one or more of the following keyboard events:

- when a key is **pressed**
- if the Input Acceptance Filter is used, when a key is **accepted**
- if the Repeat Filter is used, when a key **repeats**
- if Sticky Keys is used, when a key is **latched, unlatched, locked** or **unlocked**

Users with visual impairment who are not able to see the status indicator light for the @][ keys will benefit from a *ToggleKeys* feature: when one of these keys is pressed, a high note is emitted if the indicator is lit or a low note if it is unlit.

## Access Utilities

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Access features with these filters are either built into the operating system or are available as 'shareware' or 'freeware' utility programs from Internet sites or resource centre (there may be a small charge to cover the cost of materials and postage). With shareware and freeware, the author retains the copyright to the software but permits you to make copies for yourself or someone else. If you decide to keep and use shareware software, you must send a licence fee to its author. You don't need to pay a fee to use freeware but you may be required to register your name and address with the author.

- **Acorn !Configure**

The Acorn *!Configure* utility contains programs to adjust keyboard and mouse response. It can be found in the 'Apps' folder in the taskbar at the bottom of the screen.

- **Mac Control Panels & Easy Access**

The Mac Control Panels (in the 'Apple' menu at the left hand side of the menu bar at the top of the screen) include a repeat filter in the Keyboard panel, mouse speed in the Mouse panel, and also *Easy Access*. If you cannot find *Easy Access* in the Control Panels, either use the 'Extension Manager' to make *Easy Access* active, or move *Easy Access* from the 'Control Panels (Disabled)' folder into the 'Control Panels' folder, which are both inside the 'System' folder.

- **Windows 3.1**

The Windows 3.1 Control Panels are accessed through the Main icon of the Program Manager. The Keyboard option can be used to set the speed at which keystrokes repeat and the delay time before they start to repeat. The Mouse option is used to change the speed of the mouse. *Access Pack for Windows* has utilities such as *Sticky* and *MouseKeys*.

- **Windows 95**

In Windows 95, the usual keyboard and mouse adjustments can be made from the standard Control Panels inside the ‘Settings’ folder on the Start Menu. There are also **Accessibility Options** within the Control Panel, which provide keyboard response adjustments, *MouseKeys*, and high-contrast colour options.

Figure 3-6 Windows 95 Keyboard and Accessibility Control Panels

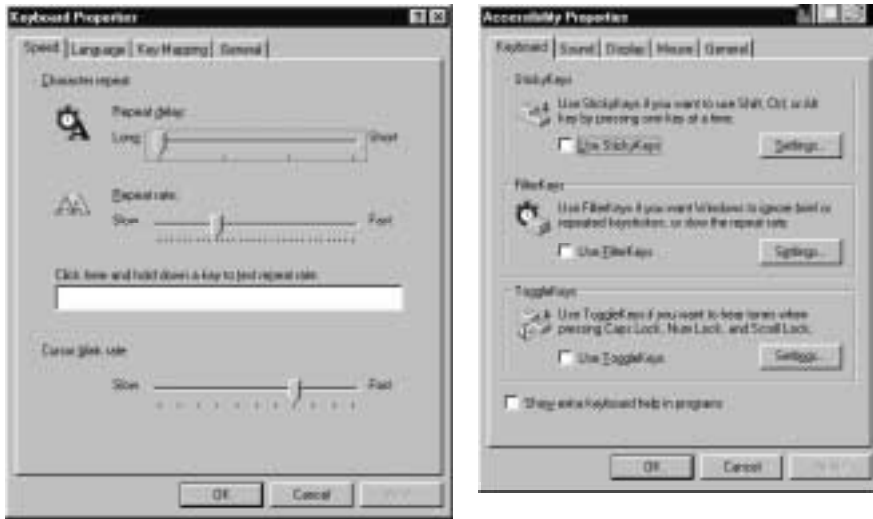


Table 3-8 Access Utilities<sup>1</sup>

ACCESS UTILITY	Supplied with Op. System	Input Acceptance Filter	Post Acceptance Filter	Repeat Filter	Sticky keys	Auditory Feedback	Visual Feedback	Mouse Control	Serial keybd/mouse emulation	Price Guide	Supplier
Acorn <b>!Configure (built-in)</b>	✓			✓						Free	supplied with Acorn
Acorn <b>!SpKbd (on Special Access utilities disc)</b>		✓	✓	✓	✓			✓		Cost of disc	Local or national centres eg. ACE, CALL
Macintosh <b>Control Panel (built-in)</b>	✓			✓						Free	supplied with Macintosh
Macintosh <b>Easy Access</b>	✓	✓			✓	✓	✓			Free	supplied with Macintosh
Macintosh <b>SerialKeys</b>									✓	Free	Trace Center
Windows 3.1 <b>Control Panel (built-in)</b>	✓			✓						Free	supplied with Windows 3.1

<sup>1</sup> You can download all the access utilities listed in Table 3- apart from those for Acorn computers, plus many more, from the Trace Center web site at <http://trace.wisc.edu/>.

ACCESS UTILITY	Supplied with Op. System	Input Acceptance Filter	Post Acceptance Filter	Repeat Filter	Sticky keys	Auditory Feedback	Visual Feedback	Mouse Control	Serial keybd/mouse emulation	Price Guide	Supplier
Windows 3.1 <b>Access Pack</b>		✓	✓	✓	✓	✓	✓	✓	✓	Free / cost of disc	Microsoft, CALL, SCET, ACE
Windows 95 <b>Control Panel (built-in)</b>	✓			✓						Free	supplied with Windows 95
Windows 95 <b>Accessibility Options (built-in)</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	Free	supplied with Windows 95

## 3.4 Alternative Keyboards

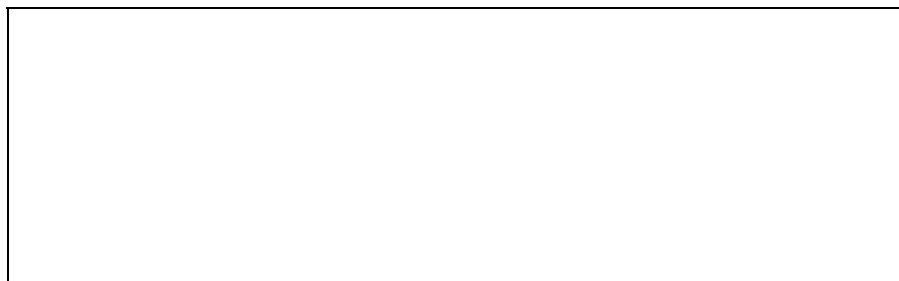
### Alternative Keyboard Layouts

The standard QWERTY keyboard layout was originally designed to slow typists down to avoid damage to the mechanisms of early mechanical typewriters. QWERTY is therefore physically inefficient, usually less familiar than alphabetic order (for example), and has no logical or perceptual advantages.

In the 1930s and 40s, August Dvorak designed ergonomic keyboard layouts which placed the most commonly used keys in the most easily accessible locations. There are Dvorak keyboards commercially available, or you can install a 'Dvorak keyboard driver' which re-maps the standard keyboard to the new layout. Dvorak keyboard drivers are available for PC and Mac computers, and can be downloaded from the Trace Center's web site at <http://trace.wisc.edu/> or from <http://www.acs.oakland.edu/oak.html> (Mac) and <http://www.microsoft.com/kb/softlib> (PC).

The one-handed Dvorak layouts can be helpful for users of headpointers, mouthsticks or typing tools because the most common keys are placed close together at either the left or right side of the keyboard.

Figure 3-7 Dvorak Keyboard Layout



Windows 95 users can also use the *ZDKeyMap* utility program (available from <http://www.hotfiles.com/demo/utilities.html>) to redefine the keyboard layout to suit their own preferences.

There are some things to consider before deciding on an alternative layout:

- once you get used to it you will find QWERTY more difficult;

- you need to stick new key labels to the keyboard to match the new layout (upper and lower keytop stickers in various colours are available from SEMERC and Inclusive Technology);
- if the computer is shared it would probably be worth buying another keyboard to adapt so that you still have a QWERTY one for other users.

Teachers and helpers often need the standard keyboard at the same time as the pupil is using the alternative keyboard, to help with editing or to start up applications. The *Co-Pilot* adapter for PC and A7000/RiscPC from KCS (£29.90) lets you connect the adapted and standard keyboards. Macintosh users can plug alternative and standard keyboards together without needing an extra interface box.

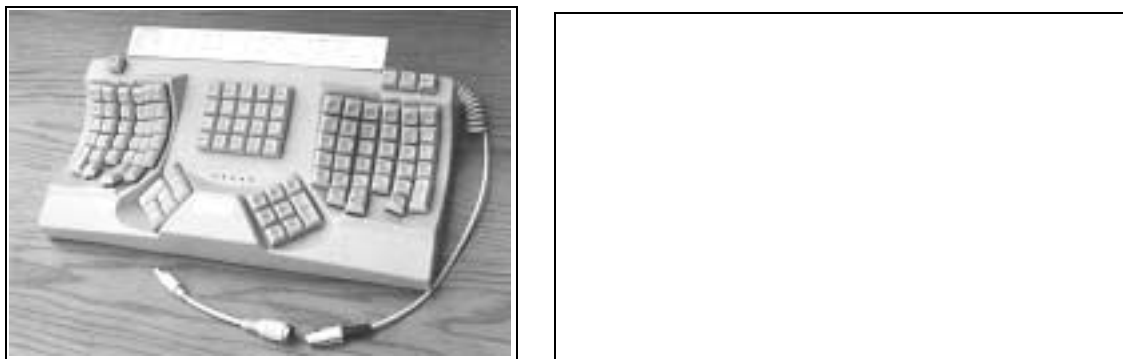
## Ergonomic Keyboards

With the recent increase in incidence and awareness of repetitive strain injury, carpal tunnel syndrome, and other injuries related to excessive keyboard use, there is a proliferation of 'ergonomic' keyboards.

Ergonomic keyboards do work: once you have got used to them, most people are loath to go back to the standard flat type. They cannot 'cure' RSI though – they may reduce the discomfort, but the best way to use an ergonomic keyboard is *before* you develop RSI so that you avoid getting it in the first place. School children are less likely to suffer from RSI because they do not generally spend long periods typing intensively, but ergonomic keyboards may still be helpful for those who have limited hand control or who suffer pain when typing (perhaps due to arthritis), because the hands are in a more relaxed position, less movement is required, and most keyboards support the wrist.

Some ergonomic keyboards, like the *Microsoft Natural Keyboard*, are QWERTY keyboards which are shaped to fit the dimensions of the body and the way most people sit at a desk (as opposed to a standard keyboard, which isn't). The basic principle is to split the keys into two halves and then angle them outwards towards your hands. Wrist rests are usually built in. More expensive keyboards allow you to adjust the angle of each half to the most comfortable position.

Figure 3-8 Maltron Keyboard (left) & Microsoft Natural Keyboard (right)



Some ergonomic keyboards are not only shaped to fit people but are also available with either QWERTY or ergonomic key layouts. The most popular specialist type in the UK is manufactured by Maltron.

### Case Box

A. is in second year at University and suffers from severe arthritis. She evaluated a *MS Natural* keyboard and immediately found an improvement. Her hands are supported in a more comfortable position and she experiences less pain and can type for longer periods. However, the biggest improvement in writing was achieved by using a voice recognition program which almost completely reduced the need to keyboard at all.

The table below lists some of the more common keyboards available in the UK. For a more comprehensive list, see the 'Typing Injury FAQ' at <http://www.tifaq.com/> and related web sites.

Table 3-9 Ergonomic Keyboards

ERGONOMIC KEYBOARD	Description	Price Guide	Supplier
Microsoft Natural	Moulded keyboard designed to encourage use of hands at appropriate angle	£55	PC World, Misco, etc.
Alps Natural	Moulded keyboard with integral wrist rest	£50	Misco, HCS Global
Maltron	Shaped two-handed keyboard with optimised key layout	£375	KCS, Maltron

## Chording Keyboards

Chording keyboards have a handful of keys (one per digit per hand) instead of the 100 or so on a standard keyboard. You type by playing different 'chords' which generate the different letters and keys on a standard keyboard. Chording keyboards are useful for:

- people with one hand;
- people with limited arm range and power (e.g. due to arthritis) – very little arm or wrist movement is needed to use them;
- visually impaired users – there is no need to hunt for keys;
- touch typing – Infogrip, manufacturers of the BAT keyboard, claim that the learning curve for their keyboard is shorter than that for a QWERTY keyboard.

Figure 3-9 Examples of Chording keyboards -- BAT (left) &amp; Twiddler (right)



Table 3-10 Chording keyboards

CHORDING KEYBOARD	Description	Price Guide	Supplier
BAT Personal Keyboard	Single handed keyboard with 7 keys, with software for macros and abbreviation expansion	£199 (PC) £235 (Mac)	KCS
Twiddler	Combination keyboard (12 keys) and mouse for PC that fits in the palm of the hand.	£199	The Keyboard Company

## Expanded Keyboards

The keys on an *expanded keyboard* are larger and more widely spaced than on standard keyboards, and are suitable for pupils who have difficulty with the small keys on the standard keyboard.

The specialised expanded keyboards are about a third larger than standard keyboards, and the keys are approximately 3cm in diameter with a gap of about 2.5cm between adjacent keys. The cases are

made of high impact plastic or heavy gauge steel for stability and to better withstand the thumps and bumps caused by heavy hand movements. The keys are usually recessed into the casing, allowing the user to rest or slide their hand on its surface during use. They have keys to control the mouse and access features like *Sticky Keys*.

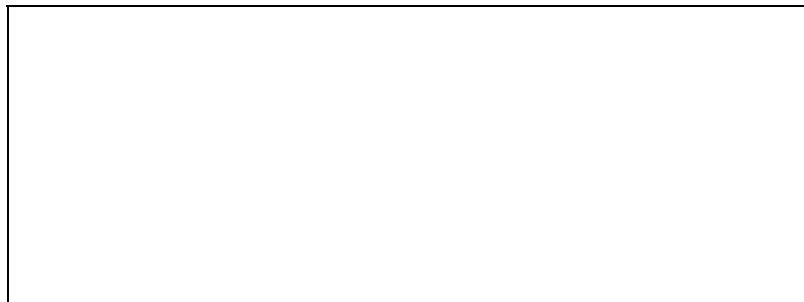
*Big Keys* is not an expanded keyboard as such, but is useful because the keys are larger than the standard keyboard. It is designed mainly for home use but is also popular in schools because of its low cost and simple and attractive design. Keys can be upper or lower case in a range of colours, a keyguard is available, and the *Co-Pilot* adapters allows you to connect *Big Keys* and the expanded keyboard at the same time. It is available for Mac, PC or Acorn A7000/RiscPC.

Case Study

'Mary' attends a mainstream P1 class. She has cerebral palsy, which effects her ability to hold and use a pencil: she can draw simple lines and shapes, but letter formation is difficult and slow. She can use a standard keyboard with guard, but types faster with *Big Keys* because the larger keys are easier to target. The specialised expanded keyboards are not suitable because she is a little person with little arms and she cannot reach across them – whereas *Big Keys* is smaller overall.

*Big Keys* has an alphabetic layout and does not have any punctuation, control or function keys so it is really only suitable for early learners tackling very simple writing tasks. There are also no mouse control keys. The new version - *Big Keys Plus* – which has punctuation, delete and function keys, with either alphabetic or qwerty layout, and so is a better device for general school use.

Figure 3-10 *Big Keys*



You can also use an overlay keyboard as an expanded keyboard – see chapter 5. Overlay keyboards are much cheaper than the specialist *King* or *Maltron* keyboards and they have the advantage that overlays can be designed for different tasks. The main advantage of the expanded keyboards is that the keys move when pressed so the user has some tactile feedback (the keys on overlay keyboards give no tactile feedback).

Figure 3-11 Mac King Keyboard



Table 3-11 Expanded Keyboards

EXPANDED KEYBOARDS	Overall size (cm)	Key size (mm)	Layout	Input Acceptance Filter	Post Acceptance Filter	Repeat Filter	Sticky keys	Auditory Feedback	Tactile Feedback	Mouse Control	Plugs into Keyboard Socket	Price Guide	Supplier
Macintosh, PC, A7000 <b>Mac/Win King</b>	54 x 28 x 6.3	31 (round)	Freq /qwerty	✓		✓	✓	✓	✓	✓ <sup>1</sup>	✓	£638	Don Johnston, CAC
Macintosh, PC, A7000 <b>Expanded keyboard</b>	62 x 23 x 7	20 (round)	Alpha /qwerty	✓		✓	✓	✓	✓	✓	✓	£545	PCD Maltron
Macintosh, PC, A7000 <b>Big-Keys</b>	48 x 17 x 3	20 (square)	alpha <sup>2</sup>	3	3	3		3	✓		✓	£85	KCS, Semerc, Don Johnston
Macintosh, PC, A7000 <b>Big-Keys Plus</b>	48 x 17 x 3	20 (square)	Alpha /qwerty	3	3	3		3	✓		✓	£99	KCS

Layout: **freq**=frequency of use; **alpha**=alphabetic

Notes: <sup>1</sup> In mouse emulation mode, the centre of the keyboard represents the current cursor position; pressing a key away from the centre position moves the cursor in that direction

<sup>2</sup> Big-Keys has a simplified alphabetic layout intended for early learners, without punctuation, control or function keys.

<sup>3</sup> Not supplied with keyboard – but standard keyboard adjustments and accessibility controls can be used.

## Compact and Miniature Keyboards

Young children or people with a limited range of hand movement who cannot reach across a standard keyboard may benefit from small keyboards.

The Cherry *G84 mini keyboard* for PC's is designed for laptops and industry but is also popular in primary schools and keyguards are available.

The TASH *Mini* keyboards are even smaller and are suitable for people with a very restricted range of movement (for example, due to muscular dystrophy or arthritis).

An alternative to a mini keyboard is to use a palmtop computer like the *Psion 3a* running a ‘terminal emulation’ program and connected to the desktop computer with a serial RS232 cable. When keys are pressed on the palmtop, they are sent to the desktop’s serial or COM port, and then *SerialKeys* software (Table 3-13 on p. 46) on the computer converts them into keypresses.

Figure 3-12 TASH Miniature keyboard

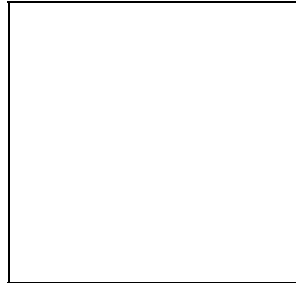


Table 3-12 Miniature keyboards

MINIATURE KEYBOARDS	Overall size (cm)	Key size (mm)	Layout	Input Acceptance Filter	Post Acceptance Filter	Repeat Filter	Sticky keys	Auditory Feedback	Tactile Feedback	Mouse Control	Use Standard Keyboard at the same time	Plugs into Keyboard Socket	Price Guide	Supplier
Acorn A4000 & earlier use a PC PS/2 keyboard with Keyboard Encoder adapter														
PC, A7000 <b>Compact keyboard (Keyguard)</b>	28 x 13	12 (square)	qwerty	1	1	1	1	1	✓	1	2	✓	£55 £39	Semerc, CAC, Inclusive Tech.
Macintosh, PC, A7000 <b>Mac/Win Mini (Keyguard)</b>	19 x 12	10 (square)	freq; qwerty	✓		✓	✓	✓		✓ <sup>3</sup>	✓	✓	£534	Don Johnston, CAC
Macintosh, PC <b>Mini Keyboard (Keyguard)</b>	19 x 12	10 (square)	freq; qwerty	✓		✓	✓	✓		✓ <sup>3</sup>	✓	4	£271 £53	Don Johnston, CAC
Acorn <b>MiniKeys</b> plus Psion 3/Acorn Pocket Book ~£250	16 x 7	8 (square)	Qwerty	1	1	1	1	1	✓	1	✓		£29 (+ £250)	Semerc
Macintosh, PC <b>SerialKeys</b> plus Psion/Acorn Pocket Book ~ £250	16 x 7	8 (square)	Qwerty	1	1	1	1	1	✓	1	✓		Free (+ £250)	Trace Center

Layout: **freq**=frequency of use; **alpha**=alphabetic

Notes: <sup>1</sup> These features are not provided by the keyboard itself, but can be added with Access Utilities (see *Software Adaptations*).

<sup>2</sup> The keyboard can be plugged alongside the standard keyboard with a Co-Pilot adapter.

<sup>3</sup> In mouse emulation mode, the centre of the keyboard represents the current cursor position; pressing a key away from the centre position moves the cursor in that direction

<sup>4</sup> Connects to Ke:nx (Mac - £554), Words+ (PC - £500) or DADAEntry (PC - £620) interface boxes; the Filter and other features are dependent on the software supplied with the interface box

## Special Keyboard Technology & Access Features

Depending on the model, expanded and mini keyboards may be available in the following layouts:

- **Qwerty.** This is the layout of standard keyboards.
- **Alphabetic.** Suitable for those not familiar with the *qwerty* layout. This may include early learners who have rote-learned the alphabet, or those with visual impairment who want to 'count through' the alphabet to locate specific keys. Some alphabetic keyboards (e.g. *Big-Keys*) have colour coded keys to help early learners to more easily distinguish the special keys and learn the position of the keys.
- **Frequency-of-Use.** The most frequently used keys (e.g. 'a', 'e', 't', 'i') are grouped around the centre of the keyboard to reduce physical effort and help increase typing speed (see *Alternative Layouts* and *Ergonomic Keyboards* above).

There are two distinct types of expanded and miniature keyboards: **Direct Replacement** and **Matrix**.

- **Direct Replacement** keyboards (Mac/Win *King/Mini*) can be plugged into the computer's keyboard socket and usually have *filters* to reduce accidental keypresses. This type of keyboard works with almost all application software because they directly replace the standard keyboard.
- **Matrix** keyboards (*Mini, King*) connect to the computer via an **interface box**, such as *Ke:nx* for the Macintosh and *DADA-Entry* or *EZ Keys* for PC's. Special *driver* software supplied with the interface box detects key activations and provides access features to alter the keyboard's response. Matrix-type keyboards are cheaper than direct replacement keyboards (but you have to buy the interface box as well, which is expensive). If your school already has a *Ke:nx* or *EZ Keys* access system, you can reduce the cost of adding an expanded or miniature keyboard by purchasing a matrix type. These access systems are also useful in situations where a computer is to be shared by pupils with different access needs, ranging from one switch scanning to matrix keyboards.

## Using a Communication Aid as a Keyboard

Most of the more expensive voice output communication aids (VOCAs) have a special connector (usually referred to as the *RS232, Serial* or *COM* port) which is used for communicating to computers, environmental control systems and other electronic devices. The VOCA can be set to send text messages (usually called 'ASCII') out the RS232 port instead of, or as well as, speaking them out. A special hardware interface or *SerialKeys* software on the computer is then used to convert the ASCII text from the VOCA into key-presses, mouse movements and other computer operations.

### Why use a voice output communication aid to control the computer?

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- **For Physical Access**

If the user already has an effective special access method for the VOCA it may be simpler and cheaper to continue using this than to provide an equivalent special access method to access the computer directly. For example, although someone using an optical headpointer with a *DeltaTalker* could purchase a head-controlled pointer plus on-screen keyboard for the computer, the cost would be over £1000 so it would be much cheaper to use the *DeltaTalker* as a keyboard. Or a *Lightwriter* user with limited finger range, who has difficulty reaching all the keys on a standard computer keyboard, can connect the *Lightwriter* to the computer and use it as a miniature keyboard instead of having to buy a miniature computer keyboard.

However, it is important that the access method suits the application on the computer. Some individuals tackling particular tasks may be more efficient using a specialised access method running on the computer, with a selection set matched to the particular application.

- **To capitalise on the language storage and retrieval strategies in the VOCA**

Many people who use a symbol-based VOCA are not readers. While symbol-based communication programs are available for computers, some users will be more effective using their communication devices. The language strategies and communication techniques in VOCAs have been designed to be as fast and efficient as possible, and an experienced user will be proficient at generating language using those strategies. Taking our two examples above: the *DeltaTalker* user will almost certainly be able to produce text more efficiently using the system they are familiar with, compared to another symbol-based communication system running on the computer. If the *LightWriter* user already uses acceleration techniques like *abbreviation expansion* and *word prediction* built into the Lightwriter, it may be more effective to carry on using them rather than purchase and set up similar programs to run on the computer.

- **For learning**

Writing using a VOCA symbol set can help with acquisition of literacy because the message is typed on screen as it is spoken. Conversely, composing text messages and stories using the symbol-based VOCA, editing them, adding pictures and symbols and printing them out give new opportunities for practice using the VOCA, which can complement, extend and reinforce symbol vocabulary.

- **For simplicity, independence and convenience**

Some people will simply find it more convenient and effective to use the VOCA to operate the computer.

### What are the disadvantages?

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These examples assume that the user is primarily using the computer for writing. If it is used for another purpose, such as computer-aided drawing, desktop publishing or multimedia access, where there is less need to generate text, then another type of computer access device may be better.

### How do I connect the VOCA to a computer?

---

The VOCA is usually plugged into the computer's own *serial* port using a cable; this is referred to as the 'Modem' or 'Printer' port on the Macintosh, and the 'COM' port on the PC/Acorn. There are several different types of serial connector so you need a cable with the correct type of connector at each end. Cables are available from the VOCA suppliers.

Some VOCAs (such as *DeltaTalker* and *DynaVox*) also have an infra-red transmitter so that the user does not need to physically connect a cable. Instead, an extra infra-red receiver unit is plugged into the computer's serial port or keyboard connector.

Once you have connected the communication device to the computer's serial port you need a software utility program (commonly referred to as *SerialKeys*) to convert the text from the VOCA into computer actions. SerialKeys software is free or low cost and works with most application programs running on the computer.

There are also some electronic interfaces which plug into the computer's keyboard and mouse connector so that SerialKeys software is not needed. The hardware interfaces are more expensive, should work with all applications, and can be transferred from one computer to another without having to install the SerialKeys software.

**Table 3-13 SerialKeys software and hardware**

SERIALKEYS SOFTWARE & HARDWARE	Description	Price Guide	Supplier
BBC & Acorn	SerialKeys software for BBC and Acorn	£120	Liberator

SERIALKEYS SOFTWARE & HARDWARE	Description	Price Guide	Supplier
<b>KeyEmu</b>	computers. Price includes cable.		
PC (DOS) <b>AccessDos</b>	SerialKeys software	Free / cost of disc	ACE, Trace web site
Windows 3.1 <b>Access Pack</b>	SerialKeys software	Free / cost of disc	ACE, Trace web site
Windows 95 <b>Accessibility Options</b>	SerialKeys software	Built-in to Windows 95	Microsoft
Macintosh <b>SerialKeys</b>	SerialKeys software	Free	Trace Center
<b>RS232 cables for VOCAs</b>	RS232 serial cables to connect VOCAs to computers for use with SerialKeys	£20 - £50	VOCA suppliers
<b>Discover:Kenx</b>	Multi-function serial access interface; no extra SerialKeys software is needed but requires RS232 serial cable	£554	Don Johnston
<b>T-TAM</b>	Accepts RS232 ASCII data and plugs into either Mac or PC keyboard/mouse ports; no SerialKeys software is required	£420	Liberator
<b>DeltaTalker Infra-red Receiver</b>	Infra-red receiver for DeltaTalker. Connects to PC keyboard/mouse port; no SerialKeys software is required	£375 - £495	Liberator
<b>Dynabeam</b>	Infra-red receiver for DynaVox. Connects to Mac or PC keyboard/mouse port; no SerialKeys software is required	£395	Dynamic Abilities

### Setting up the VOCA and computer

Before you try sending commands and text from the VOCA to the computer you must set them up so that they use the same:

- **Baud rate.** The speed at which information is sent. This can be 300, 600, 1200, 2400, 4800, 9600 or 19200 baud. The most common are 300, 1200 and 9600 baud.
- **Data bits.** Each character is sent as 7 or 8 'data bits'. 8 is the most common.
- **Start/stop bits.** A 'start' bit is sent before each character sent from VOCA to computer, and 'stop' bit(s) sent after it.
- **Parity.** An extra 'parity bit' may be added to the character for error-checking. Most VOCAs and systems have 'No Parity'.

### Programming the VOCA to send commands to the computer

Different VOCAs have different methods of sending text out the RS232 port and these are described in some detail in the VOCA manuals. With *Touch*, *Light* and *Delta Talkers*, for example, you can select 'Serial On' to send any text which appears on the Talker screen to the computer. With an *AlphaTalker* you have to go into a special 'keyboard emulation' overlay. For an *ORAC*, you either use Spell Mode to send text, or embed 'Note entry' ORacts into the message. There is a special overlay, manual and cable available for ORAC keyboard emulation, from Mardis. With a *DynaVox*, you can set output to the serial port so that anything in the Message Box is sent to the computer, or define a 'verbal cue' which only sends particular messages to the computer.

Any of the VOCAs can be used as a straightforward keyboard alternative for typing letters and most have overlays with letters and keys for computer control either built in, or available from the manufacturers. If you wish to send whole words and phrases to the computer as selections are made, the *Touch*, *Light* and *Delta Talkers* and *DynaVox* are easiest to set up for this purpose.

- **Sending text**

Once the VOCA and computer are connected and set up, text selected on the VOCA will appear on a wordprocessor screen.

- **Typing special keys**

If you want to emulate special keys on the keyboard like e, band ayou need to send a special message to the SerialKeys program or interface. Most of the SerialKeys programs and hardware use the same messages based upon the *General Input Device Emulating Interface (GIDEI)* proposal produced by the Trace Center.

All the special codes start with an 'escape' character and finish with a full stop. For example, to get the VOCA to press the Return key on the computer, you need to send `<ESCreturn.>`. If you want to hold down the shift key while you send a letter (e.g. j plus `<h>` to get H) you should either use *Sticky Keys* on the computer or send a code with the 'hold' command, like `<ESC,hold,shift.>`, and then send the letter `<h>`.

You have to program these codes into the VOCA in order to send them but most VOCAs apart from the *DynaVox* and *ORAC* do not have an ESC key on their spelling or fixed overlays. Refer to the VOCA and SerialKeys manuals for more information on codes and how to program them.

Most SerialKeys programs and interfaces offer several ways to control the mouse pointer. With some a command can be sent to move it directly (e.g. `<ESCmouseup.>`); or *MouseKeys* can be used (see *Chapter 4*) and codes sent to operate the numeric keypad keys (e.g. `<ESC,lock,kp8.>` will lock down 8 on the numeric keypad, which will start the mouse pointer moving upwards; or move it in steps (e.g. `<ESC,move,+10,-20.>`); or to a particular location (e.g. `<ESC,goto,20,25.>`). The mouse button(s) can be clicked, double clicked and dragged uses similar commands (eg. `<ESC,click.>`, `<ESC,moulock.>`).

## 3.5 Further Information

### Web sites

**Apple Disability Access** - <http://www2.apple.com/disability/default.html> - Information and software for Macintosh computers.

**CALL Centre** - <http://call-centre.cogsci.ed.ac.uk/CallHome> - Information and links to other sites.

**Inclusive Technology** - <http://www.inclusive.co.uk/default.htm> - An excellent practical introduction to the range of alternative keyboards and pointing devices available.

**KCS** - <http://www.keytools.com> - KCS web site.

**Microsoft Accessibility Site** - <http://www.microsoft.com/enable> - Microsoft accessibility information and programs which can be down-loaded.

**Microsoft Accessibility Software** - <http://www.microsoft.com/kb/softlib> - Downloadable software.

**PC Magazine** - <http://www.hotfiles.com/demo/utilities.html> - Various utilities including the ZDKeyMap utility.

**TASH** - <http://www.valleyweb.com/tash/index.html#1> - TASH web site: keyboards and switches.

**Trace Centre** - University of Wisconsin <http://trace.wisc.edu/> Information, lists of programs, links to other sites, downloadable freeware, shareware and demonstration versions of programs.

**Typing Injury Web site** - <http://www.tifaq.com/> - Excellent information about typing injury, keyboards, pointing devices, furniture, as well as list of products and links to manufacturers' web sites.

### Suppliers

**ACE Centre**, Ormerod School, Waynfilet Road, Headington, Oxford OX3 8DD, Tel. 01865 63508.

**Atkinson Engineering**, Unit 7, Premier Mill, Begonis Street, Darwen, Lancs. BB3 2DP. Tel. 01254 773524.

**Cambridge Adaptive Communication**, The Mount, Toft, Cambridge CB3 7RL. Tel. 01223 264224.

**CALL Centre**, 4 Buccleuch Place, Edinburgh EH8 9LW. Tel. 0131 667 1438.

**Dynamic Abilities**, The Coach House, 134 Purewell, Christchurch, Dorset BH23 1EU. Tel. 01202 479955.

**Chailey Heritage**, Rehabilitation Engineering Unit, North Chailey, Lewes, BN8 4EF. Tel. 01825 722112.

**Data Sound Ltd.**, Gates House, 111 / 113 Fortis Green, London N2 9HR.

**Electrone**, Unit 1 Central Park, Bellfield Road, High Wycombe, Bucks HP13 5HG, Tel. 01494 511999.

**Don Johnston Special Needs**, 18 Clarendon Court, Calver Road, Winwick Quay, Warrington WA2 8QP. Tel: 01925 241642.

**HCSGlobal**, 2 Cartsydyke Avenue, Greenock, Renfrewshire, PA15 1DT. Tel. 01475 500012.

**Inclusive Technology**, Saddleworth Business Centre, Huddersfield Road, Oldham OL3 5DF, Tel. 01457 819790.

**Interface Designs**, 12 East Meads, Onslow Village, Guildford, Surrey GU2 5SP. Tel. 01483 32909.

**Keyboard Company**, The Studio, Lypiatt, Stroud, Glocs. GL6 7LW. Tel. 01453 88522.

**KCS**, PO Box 700, Southampton SO17 1LQ. Tel. 01703 584314.

**LaceLink Ltd.**, 13 Pinehurst, Sevenoaks, Kent TN14 5AQ. Tel. 01732 763221.

**Liberator**, Whitegates, Swinstead, Lincs. NG33 4PA, Tel. 01476 550391.

**Microsoft**, Microsoft Campus, Thames Valley Park, Reading RG6 1WG. Tel. 0870 60 10 100.

**Misco**, Faraday Close, Park Farm Industrial Estate, Wellingborough, Northants. NN8 6XH. Tel. 01933 400400.

**Neat Ideas Ltd**, Sandall Stones Road, Kirk Sandall, Doncaster, DN3 1QU. Tel. 0800 500 192.

**Nottingham Rehab** Ludlow Hill Road, West Bridgford, Nottingham NG2 6HD. Tel. 0115 945 2345

**P.C.D. Maltron Ltd**, 15 Orchard Lane, East Molesey, Surrey KT8 0BN Tel. 0181 398 3265.

**QED Ltd.**, Ability House, 242 Gosport Road, Fareham, Hampshire PO16 0SS. Tel. 01329 828444.

**Rehability Ltd.**, 36 Station Road, Billingshurst, West Sussex RH14 9SE. 01403 786062.

**RM (Research Machines)** New Mill House, 183 Milton Park, Abingdon, Oxon OX14 4SE. Tel. 01235 826000

**REMAP**, c/o Mr J.J. Wright, 'Hazeldean', Ightham, Sevenoaks, Kent TN15 9AD Tel. 01732 883818.

**SCET**, 74 Victoria Crescent Road, Glasgow G12 9JN. Tel. 0141 337 5000.

**Semerc** 1 Broadbent Road, Watersheddings, Oldham OL1 4LB, Tel. 0161 627 2381.

**Special Access Systems**, 4 Benson Place, Oxford OX2 6QH. Tel. 01608 811909.

**Spyder Engineering**, Station Road Industrial Estate, Whittlesey, Peterborough, Cambridgeshire PE7 2EY. Tel. 01933 674340.

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