on a visual display screen; direct to a computer: even if they use an adding machine or calculator they are still keyboard operators. Futurologists predict that the number of people who use keyboards will increase quite dramatically in the next few decades. More and more information is being fed into computer store. Here in Britain the Post Office is currently considering a scheme for putting one whole encyclopaedia into computer store for reference through code dialling. Before the year 2000 AD children at school may well learn to type before they learn to write. The advantages for children have already been proved (Wood and Freeman[4]: Moore and Anderson[5]).

If more and more people use keyboards and if they start to use them at an earlier age when physical defects may be more readily induced, the cost in terms of human suffering will increase unless the design of the keyboard is changed.

3 Direct costs

The most direct cost is seen in low rates of production and inaccuracy. Training costs are higher than they need be because of the time required to gain proficiency and the complexity of the training programmes which alone produce high speed, accurate operators.

The story is told that at least one publisher anticipated keyboard input speed equal to the kps capacity of the equipment that had been purchased for his newspaper. At 18 kps this would be 180 wpm or 64800 kph.

The 'bottleneck' of keyboard input is readily apparent in figures quoted for a variety of keyboard operations:

a
average production for newspaper production on hot metal Linotype machines was 3 lines of 31 characters per minute. Currently in the industry using qwerty layout machines a figure of 7000-10 000 kph is quoted.

b
in offices in England, 15 wpm, 5400 kph is given as an average for transcripton from shorthand notes to typescript (Whittle[6]).

c
in America a conducted cyclometer measure of typing output in terms of keystrokes recorded that so-called full-time typists produced less than two hours of typing per eight-hour day, against a measure of 83 kpm, ie 13.83 wpm, 4 980 kph (Lannon[7]).

In the newspaper industry attempts to break the keyboard input 'bottleneck' have mainly been concentrated on eliminating tasks and so reducing the requirement for keyboarding. This has been done through the use of Optical Character Recognition (OCR) systems for wire services and classified advertising: front desk systems for editorial: and computer store and retrieval for repeat and updating. All these methods have involved high capital investment in electronic equipment and change of skill and tasks for many of the people involved. These expensive and extensive innovations have been implemented whilst the qwerty keyboard with its inhibiting design and layout have been retained.

However many tasks are eliminated, and it does make sense to eliminate re-keyboarding of any kind, there remains the initial keyboard input which is still subject to the 'bottleneck' caused not only by low operating speeds but by the high error rate inherent in the qwerty keyboard.

The fact that almost anyone can learn to type at up to 20 wpm (7200 kph) by almost any method, obscures the fact that it takes skilled training and high dedication on the part of operators to reach speeds of over 80 wpm (28 800 kph), which alone make sense of the high capital investment in keyboard systems both in newspapers and print and in offices generally.

The uneven stretches caused by the diagonal slope of the rows of keys on qwerty result in uneven reach and distance movements, and this together with the letter layout which reinforces language confusions and induces errors, adds to learning difficulties and training time. Of course there are many highly skilled and accurate keyboard operators. They are only a small proportion of the total number of people who learn to use a keyboard and their skill has taken longer to achieve and required greater effort. These difficulties all add to the cost of providing training both in our educational and training establishments, and in industry.

'All plans come apart at the seams unless input problems are resolved by operators whose native talents are not restrained or limited by the keyboard systems. When planning a system, give at least as much consideration to the selection of the keyboards and training of the operators as to the processing rate capabilities of the phototypesetter and the computer' (Kneller[8]). This was written in 1971 and the advice still holds true.

4 Effect of keyboard design

If we accept the evidence that the Sholes keyboard design forces fingers into such unnatural positions that physical malformations are caused, it is obvious that keying speeds cannot be optimal.

One simple way of assessing the effect of fingers having to make unnatural stretches to fit a flat horizontal home row is to compare the speed of two fingered lateral keying with two fingered contra-lateral keying. Table 1 shows average kps rates for 10 experienced operators, five keying on electric and five on mechanical keyboards, for two-fingered adjacent lateral keying.

The losses in speed from fastest to slowest are: 42.36% on electrical and 39.78% on mechanical.

Table 2 gives average kps rates for the same operators for two-fingered contra-lateral keying.

The losses in speed from fastest to slowest are: 3.91% on electrical and 11.83% on mechanical.

It has been fairly generally accepted that the reason for such differences in lateral keying speed was the relative strengths and weaknesses of fingers. But this