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Writing apparatus controlled by head movements for motor handicapped people

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For a motor disabled person who cannot use his arms and hands we have constructed a device that enables him to operate a typewriter by means of head movements, via a forehead lamp. The text is first displayed on a picture screen and, after introducing any corrections, typed on a printer.

This writing apparatus has been used very intensively for one year now, and evaluation laid down by the user himself has been included in the present paper. Several factors relevant to a large-scale application of this apparatus are discussed.

The normal process of communication between people is a two-way traffic of spoken or written words, gestures or other acts. Typical of communication is its voluntariness: it proceeds from one's own choice or consent and one determines also its moment and duration.

In the case of certain forms of disability in which the patient cannot use his hands, arms and legs any more, the communication process is completely different. He is no longer able to write, make gestures or act in some way or another and his only mode of expression is the spoken word. In this respect he is, in addition, largely dependent on others for telephoning, writing letters or paying visits. This readily leads to a passive pastime, such as viewing TV programmes and talking to visitors who come and leave when they want to.

The dependence is nearly complete if the patient is unable to talk so that there is hardly any communication possible. Apart from communication, the patient's creativity is seriously affected. Creativity has many aspects in common with communication: it is a kind of self-communication of the person about a particular subject, in which, for instance, writing, drawing and many other activities are essential. With the majority of people the creative process involves a certain growth: notes develop into a letter or publication, a sketch into a drawing or design. Visual feedback is important to this process. An exclusively auditive feedback, as can be achieved by say a dictating machine is usually insufficient.

Communication and creativity are highly vital human needs, so that it is essential to develop aids for those whose normal communication and creativity channels are blocked. The present paper describes the successful application of such an aid to a patient whose normal communication abilities had completely disappeared.

The first mentioned author of this paper, P.H. van der Heijden, 53 years old, had suffered from amyotrophic lateral sclerosis since the early part of 1975. In the first year of his illness he was still able, be it with breaks, to perform his activities, namely the daily management of the newly established office of "External relations", of the Philips company, in a more or less normal way. From the beginning of 1976, when the functions of his arms, hands and legs had been largely diminished, this was no longer possible. His continuance in the office presented increasing difficulties so that his duties had to be taken over by a successor. From that time his activities were the presenting of written reports on various issues, the conducting of correspondence, and the like. Initially he was able to use an electric typewriter for this purpose, requiring only a minimal force for touching the keys, the hands and fore-arms resting on movable arm supports. In the middle of 1976, however, the use of these aids became more and more difficult, so that obviously this solution would not be a permanent one.

In an informative talk between Meyer and van der Heijden in August 1976, a radical solution was looked for, ie, a solution that was to anticipate the symptoms of his disease and would stay useful in a highly advanced stage of his disease. In addition his power of speech was affected somewhat and, although not urgent for the time being, the demand for finding a substitute for oral communication also had to be taken into account. Hence the user of the apparatus to be designed could acquire a proficiency in written communication before he was forced to resort to

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We regret to record that the user of the device, Mr van der Heijden, has died since the paper was submitted.

it for oral communication too. It was to be expected that, in addition to the movement of the eyes and the eyelids which are hardly or not affected by the illness, in the present instance the patient's capability of moving his head would be retained for a relatively long time too.

In finding an appropriate solution, attention was focused on this possibility. It envisaged specifically the use of a small lamp fastened to the patient's forehead whose light beam was to be directed to a 'key-board' with photosensitive cells by movements of the head. In so doing, the light signal would be converted into an electrical signal for operating an electronic typewriter. Such an apparatus had to be devised by the Philips Research Laboratories in cooperation with the Institute for Perception Research, both at Eindhoven. The idea turned out to be known in the literature (Soede, Stassen, van Lunteren and Luitse, 1973) and a few prototypes had already been built. Such a prototype, however, was not available within a short term and any delay was unacceptable. Accordingly it was decided to construct a similar apparatus quickly and without time-consuming development to a slightly modified design.

After a week of preliminary discussions work started in September 1976 with the construction of the apparatus, which was installed in van der Heijden's home a month later. The writing equipment operated by head movements has now been used by a single person for one year. Because in this year he had lost his power of speech, this writing equipment became his only means of communication. The user carried out most of the evaluation of the use of apparatus and hence it bears an individual character. Many aspects however are more generally valid.

Description of the apparatus

The writing equipment operated by head movements was made up from four matched components, as represented in Fig. 1.

- (a) A 'keyboard' or control panel containing photosensitive cells exposed by the light beam from a forehead lamp.
- (b) An interface which makes the information from the control panel suitable for being processed by the rest of the equipment.
- (c) An electronic typewriter with a store and a display, incorporating a so-called Super Bee, being an instrument that displays the chosen text on a picture screen and has a facility of introducing corrections

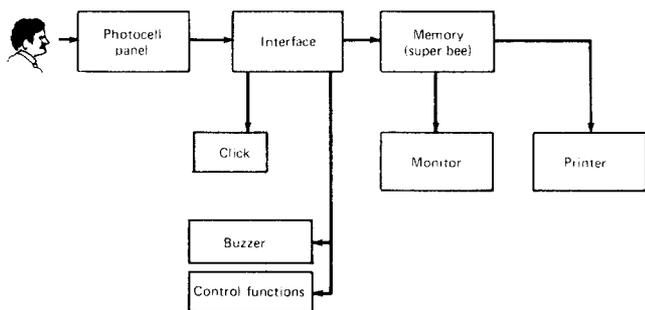


Fig. 1 Block diagram of the typewriter operated by head movements

such as removing text, inserting and shifting lines, etc.

- (d) The printer, which on an instruction of the preceding equipment prints the characters on a continuous paper strip.

Control panel and forehead lamp

On the basis of a few experimental results the control panel has been designed in such a way that the horizontal and vertical angular rotations of the head needed to direct the beam of light can be done with a modicum of effort, preferably no more than is required for normal reading.

Starting from a viewing distance variable between 50 and 100 cm from a roll-chair and allowing for the wish not to make the control panel unduly large, the panel dimensions were 40 x 18 cm, which complied with the following conditions:

- (i) a proper readability of the characters (selection of the size and type of letter).
- (ii) the requisite room for the photosensitive cells under the characters.
- (iii) the size of the light-spot from the forehead lamp (1.0 – 1.5 cm).
- (iv) the inter-character space required for compensating small involuntary head movements and any tremor. The space thus obtained, which is 2.5 cm in the horizontal direction, would also serve as the point of rest for the light spot.

The panel was provided with characters according to the QWERTY system because the user was accustomed to a normal typewriter. All the characters of the Super Bee including the upper case were rendered accessible. The characters were put on a reflective light-coloured background (Scotch light) which has the quality of reflecting incident light in the same directions to enhance the visibility of the light for the panel operator. The photocells were mounted in recessed holes in the panel to keep them inaccessible to directly incident intense sunlight. The photocells on the panel were exposed by a parallel light beam from a 6 W low-voltage lamp and an appropriate optical system. Placed at a distance of 50 cm this light source produced an illumination of 1500 lux for a light spot of 1 cm diameter, which was found to be more than sufficient to put the photocells in operation.

The lamp and the optics were accommodated in a light-weight (25 g) lamp holder which could be fastened in the middle of the forehead above the eyebrows by means of a headband. This position allowed the light beam to be moved over the control panel in the most natural way. In addition it enables the user to wear spectacles without interfering with the field of view. A clear picture of the lamp and the control panel is given in Fig. 2.

Interface

The interface converts the signal from the control panel to a form suitable for being processed by the electronic typewriter. In so doing it is essential that a 'touch' of a key only takes place if the light beam is intentionally directed to a photocell on the panel for a short time (about 1 s) and that the apparatus does not respond to light signals of short duration produced by moving the light spot over

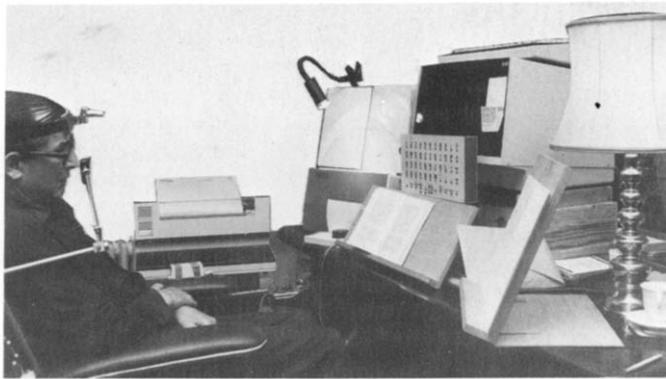


Fig. 2 General view of the apparatus in use

the control panel from one character to another and thus passing undesired characters.

The operation of the interface is diagrammatically represented in Fig. 3. The 54 photosensitive resistors (LDR) of the panel are mounted in a bridge circuit with a single central LDR, thus compensating for the effect of the ambient light and temperature on the photosensitive cells. When the light beam is directed to an LDR, an electrical signal is generated in the bridge circuit, which is amplified and integrated. A Schmitt-trigger changes state at a certain level of the signal from the integrator corresponding with a certain exposure time variable between 0.5 and 5 s. The output of this comparison circuit is supplied to the relay engaging the associated key of the Super Bee.

This output is also passed to a circuit which after a delay of 0.15 s blocks all the 54 relays by interrupting the common feed contact. At the same time an audible (click) signal is generated indicating that the next character can be selected. When the light beam leaves the relevant photocell, in 0.15 s the residual charge in the integration will be removed enough for the Schmitt trigger output to drop to zero, so that the blocking of the characters via the central feed contact can be cancelled.

Electronic typewriter

In this case use is made of a commercially available apparatus, a Super Bee, made up of a normal key panel, a store and a picture screen. Mounted below the key panel and parallel to the key contacts are 54 reed relays which are controlled by the Schmitt triggers in the interface. Under a continuous exposure of the relevant photocells most of the characters are printed only once, but a few correction keys were made repetitive, with the result that a permanent exposure rendered it possible to make many 'touches' in succession.

Printer

A normal commercially available printer was used. When the text is completely reproduced on the picture screen, it can be printed on a continuous paper strip by giving the instruction 'print' on the control panel.

Experiences of the user during one year of active use of the apparatus

If a handicapped person is supplied a typewriter that can be controlled by head movements, he has to go through a phase of adaptation in which he learns to operate the apparatus and subsequently to use it. This overall process

is highly individual because the desired activities, communication or leisure employment, depend on the person involved and his individual circumstances.

This section covers a report on such a process written by the user himself in the form of a diary. In reading it, the following should be remembered.

1. By education, sphere of interest and scope of activities the author was already accustomed to expressing himself by writing and felt the disappearance of this capacity as a great deficiency.
2. In the case reported here, the apparatus was a prototype of which the potentialities had not yet been fully investigated. Learning to use this apparatus without guidance was a kind of 'journey of exploration' to the author.
3. The forced period of the user's inactivity lasted for merely two months and he was highly motivated in learning to operate and to use the apparatus. In the case of longer periods of inactivity one may become apathetic and it may be very difficult for a user to start his work again. In general it seems favourable to provide the facilities referred to above as soon as possible.
4. The apparatus was continuously available at the user's home so that he was entirely free in selecting the times of usage. This is certain to be more stimulating than the obligation to work at fixed times settled by others.

These four aspects have decidedly added to the positive experiences with the apparatus.

In what follows the relevant sections from van der Heijden's report are presented.

22 October 1976

Today the apparatus was installed.

24 October 1976

First general impressions

I have the apparatus available at home for more than two days now. In my first enthusiasm, the day before yesterday I used it from 12 to 3 pm and then from 7 to 10 pm. Yesterday I took a holiday and today I'm working again from 4 to 6 pm and from 7 to 11 pm, which is a conclusive evidence for the fatigue factor being quite insignificant. On the contrary, the activity sets one's mind at ease: sitting quietly at home and calmly placing on record one's thoughts. This has something to do with the satisfaction of being able after many months to commit something to paper without

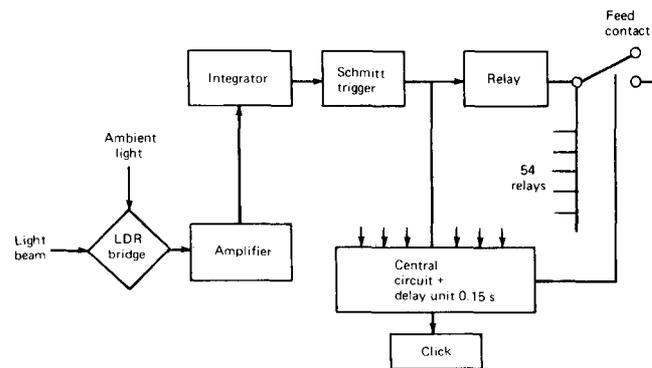


Fig. 3 Schematic arrangement of the interface

assistance and also that this, unlike other passive occupations like reading and TV viewing, is a genuine activity.

So far the head movements are not sensibly fatiguing and directing the light beam to the photocells presents no problems: it is possible to hold it quietly in position for the requisite half second and then pass it on to the next character, thus achieving a quiet, regular pace in which the ticking of the relays is something like the noise of a Frisian clock.

After two days the number of wrong touches has decreased to an acceptable level (I consider one error in every two lines a bit of a poor score; which is due to carelessness or fatigue or both). Hence I wonder whether it might be possible to reduce the time of illumination without detracting from the quality of the present results.

25 October 1976

Arrangement of the apparatus

At the moment the panel is situated above the monitor and even overhangs it a little so that its lower side just leaves the upper line on the monitor screen visible: thus a small head movement is sufficient for reading the results. The distance between my eyes and the panel/monitor is about 1 m, but thanks to my super-annuated reading spectacles, some deviation from this value is allowed. The advantage of a larger distance is that the head movements can be smaller, but a smaller distance entails a smaller light spot and hence a lower probability of striking the neighbouring photocell.

Forehead lamp

Its weight is so low as not to be annoying. The headband need not be tightened to hold it in place.

Panel

This is logically and practically arranged; I only want to make the following comment.

Double characters present a small problem because they make the quiet rhythm of 'keep the head still/touch the photocell/move the beam to the next character' simply impossible. When I am seated near the panel and hence the light spot is small, I am able to create a point of rest in the quadrangle between four neighbouring photocells.

Practical solutions:

- (a) a larger space between the photocells by situating them not straight but obliquely below one another,
- (b) the use of a (still) smaller light spot,
- (c) employing 1 or 2 blank cells as a neutral point of rest anywhere in the centre of the panel.

26 October 1976

I will return to my remarks about the double characters: I now have discovered that they do not present problems at all. After 'touching' the first character I fly to a neighbouring photocell, until I hear the next click of the relay, after which I simply touch the first character for the second time. In this way the rhythm is not interrupted.

29 October 1976

Panel neck pain

Since the day before yesterday I have felt a weak pain in my neck, which is likely to be vertebra pain. During my

illness I had neck pain before, but each time it disappeared after a few days. I have worked a good deal this week. The panel is still situated above the monitor. I shall place it alternatively at a lower level, ie, next to the monitor and replace it, also on medical advice, in order to find out whether this is an effective remedy. I now have gained so much experience that I need not view the monitor after each word. Accordingly, the change in panel arrangement may be satisfactory.

Memorandum

In writing a text from notes, eg, an excerpt of a book, the apparatus can be exploited to the full as follows.

The monitor line (ML) contains 80 characters and the capacity of a paper line (PL) is 114 characters: the difference is 34 characters. First put down the notes in the first 34 positions of the even lines and terminate them at all times with 'new line', ie, the instruction for the printer to start a new line (Note: always go down two lines in order to use the even lines only). The notes are now available on the panel so that the text can be prepared on the odd lines, which now must not be terminated with 'new line'. Do not type further than roughly the position 75 of ML, and then use the advance key to reach the odd line. The printer types alternatively odd and even ML's as single PL's. The text appears on the left of a PL (positions 1–75) and the notes which can be cut off if desired on the right (positions 81–114). It seems rather complicated, but when I read a book in my 'leaf-turning apparatus', I must lay down my notes before I turn a leaf, because it is not capable of turning leaves back.

3 November 1976

My experiences after 12 days are still favourable. Fatigue is immaterial to me (last Saturday I even worked for 4 h on end), which is certainly due to the enormous stimulus of being able to communicate, to act from my own initiative, in short, a kind of tonic.

The neck pain to which I referred a few days ago has vanished, although I did not change the location of the panel: obviously I am adapted to this arrangement.

As for the panel I still involuntarily tend not to direct the light spot to the photocells but to the characters above them. This raises the error rate, particularly at a larger distance, ie, a large light spot. Maybe it is possible to find transparent but yet clearly readable characters that could be glued on the photocells?

6 November 1976

Spectacles

There is a problem of reading at a distance: the panel should be read as well as the monitor, the printer and the documents I have to use for my work. I think 1 m for me to be a pleasant distance to the panel (smaller head movements and panel not too close), but this implies that the distance to the other texts is at least equally large and in my case even larger. As said, I use unduly old reading spectacles. The optician told me that measuring a pair of reading glasses for a large distance is by no means difficult: it is a critical point affecting comfort and success.

12 November 1976

Paper

Use is made of a special kind of paper for typewriting:

it is too broad and has perforated edges. Initially my documents were neatly trimmed off. I do not do this any longer, so that even letters also leave my home perforated. Usually I briefly explain the typewriting process, so that the receiver need not be too astonished.

I would not like to switch over to sheets of paper to be fed into the machine by others. The continuous paper strip has the advantage of enabling me to work several hours on end without being assisted by another.

I make mention of this because I believe that one's independence of other people, wherever it may be attained, is a crucial factor to those who must resort to help in any trifling matter. Accordingly, as there arise areas to be conquered in which he is self-sufficient, his feeling of functioning like the others — although in special way — will become more likely.

This may be an entirely uncalled for observation, which in addition is not applicable to the apparatus in question, which just makes its user quite independent. Yet I made it for its central position in conceiving aids for handicapped persons.

2 December 1976

After 6 weeks my experience with typewriting is still unchanged; I work very hard for hours on end without becoming too tired (although usually I am quickly tired; notably I cannot persevere communicating with people for long, also because speaking is fatiguing to me).

I make only a slight number of typewriting errors, namely one in ten lines. I practically never type wrong letters or figures. My most frequently occurring mistake is forgetting to type a space between two words, or a 'new line' after a break. It should be remembered that my pace of typing is fairly low, much lower than that of an average typist. After all, I am fully aware that errors can always be corrected in time and this may slightly affect my subconscious attitude towards my work.

13 March 1977

After five months, I am still using the apparatus regularly, at least a few hours every day with relatively great ease. It is of course important to note that it is the only means for me to express myself in writing (the more so as it is becoming increasingly difficult for me to talk). I allude here to the fact that an outsider accustomed to normal written and oral communication cannot form an accurate idea of any ease and unease in my using the apparatus, for he is always inclined to compare it with a fountain pen or a normal typewriter. Such a comparison is pointless to me and hence I never made it. To me it is only relevant whether, given my circumstances, the time I have available and the work I want to do, I can use the apparatus and I may say that this is the case indeed.

6 September 1977

Having employed the apparatus for more than ten months now, I still have not changed my views about its usefulness. That is to say that, for me, it is the ideal solution to my communication problems and I am unable to mention — apart from the points I referred to above, which do not involve the principle — in which aspects the apparatus could be improved.

Accordingly, the present evaluation rather aims at giving

an idea of certain developments in my illness as far as it is related to the use of the apparatus: recently my neck muscles began to fail considerably, while I can hardly speak now, this having been a problem since May 1976.

It has only recently become clear to me that the change in the arrangement of the apparatus with the panel being placed 10 cm lower so that the monitor had to be situated above it, was induced by an incipient failure of the neck muscles. By that time I have tilted the back of my roll-chair by 10 or 15 degrees because my head tended to bend. Hence, during my work, my head is now more forward and down with respect to my body than it was before. Since then my head is apt to incline much more frequently giving rise to increasing complaints. This inclination seems to depend upon my general physical and in particular my mental condition at a given moment.

The result is remarkable: sometimes it is quite impossible for me to direct the light beam to the letters, but if my condition is satisfactory, I fortunately am still able to use the apparatus for hours on end.

I felt much hesitation before using the apparatus not only as a typewriter but also as a talking instrument. Until last June I managed to talk a little, although this was already tiring and also painful. Then talking went quickly from bad to worse, so that even my wife was sometimes unable to hear me. This implied a growing isolation with its associated problems and frustration. Yet it seemed as if I had definitely given up the use of the spoken word by resorting to the apparatus for talking. I mention this because I have repeatedly experienced my persisting in the use of a fading function to the utmost. Maybe handicapped persons generally act in this way, and if so, this should be taken into account when they have to become accustomed to such aids as this writing (and talking) machine.

Anyway, my resistance has ultimately been broken down and I have regularly used the machine also for conversation. In the normal arrangement my partner is seated beside me and reads the text together with me from the picture screen, while I am writing; he renders me a valuable service when he completes a word or a sentence, so that I can stop writing it.

I must not create the impression that talking in this way does not present problems: the typing rate is 55 or 60 touches/min, ie, 10 words/min, a really slow pace which requires much patience particularly of the partner (this factor of patience is not essential to the handicapped person himself, because he had already learned to exercise patience for a long period). Depending on the nature of the conversation, the atmosphere in which it was held and the understanding existing between the partners, I was able to conduct many satisfactory conversations. I have noticed that it is important to avoid verbosity, but that a telegram style of conversation is not appropriate either because in this way the conversation gets no chance and keeps on the level of an exchange of information. On account of the special character this kind of conversation has for both partners, the atmosphere in which it is made is much more important than for a normal conversation. For example, somebody recently told me that he found that his conversation with me set his mind at ease because we did not skip from one subject to another and that it left far more time for reflection than would be possible under normal circumstances. Thus the process in question offers an unthought of advantage. Only a partner who does not 'listen', ie, who goes on talking when I am

writing, presents me with a real problem. I believe this to have a variety of causes; first there arises a great difference in pace between his share in the conversation and mine, which spoils the homogeneity of our conversation, second I am forced to divide my attention between writing and listening, and finally my observations have become obsolete once they are displayed on the screen: my partner has advanced so far as to misinterpret or even entirely misunderstand them.

I also wished to have an opportunity of talking where the apparatus is not at my disposal (eg, other sites in my home, outside the home). for this purpose I use a piece of cardboard on which the panel is copied and I form words with my head lamp in a similar way to that of the apparatus, and while my partner is spelling the letters of the words together with me, he 'hears' what I am saying. This is a very useful alternative, but it is no compensation for machine talking.

Discussion

The above evaluation reveals that the writing apparatus controlled by head motions can be an essential aid in the communication and the creativity of a handicapped person. There are a number of factors that become relevant in the case of a wider application of the apparatus described in the present paper. These factors concern the potential user as well as the further development of the apparatus.

Potential users

Potential users are those who cannot use, permanently or temporarily, their two hands in a normal manner, but do control their head movements and have a sufficiently high power of seeing. The apparatus could also be used successfully in cases of patients being strictly confined to bed and who are hardly able to write.

Introduction of the typewriter

When a handicapped person takes the typewriter into use, he must learn to control it and to explore its potentialities. The time of each of these two processes depends very much on the user in question and his individual circumstances. It goes without saying that his need and will of expressing himself by writing is decisive.

As regards control, a previous experience with a typewriter will lower the pupil's threshold and shorten the training period. After two weeks, van de Heijden reached a typewriting rate of 50–60 touches/min with an error percentage of 10%. The large number of correction possibilities are essential both in the initial stage and later on, because they enable the user to make mistakes without serious consequences. Most handicapped persons will therefore not experience learning to *control* the apparatus as their main problem.

Learning to use the apparatus is a much longer process for the patient because he must proceed on entirely new lines to lead a useful existence from which new stimuli are received. Hence any guidance of the user during the introduction of the apparatus should make allowance for its psychological rather than its technical aspects.

Use of the typewriter

Van der Heijden has chosen a set-up in which he

arranged not only the typewriter but also a page-turning device and a few notice-boards for affixing letters and newspaper articles around the panel and the monitor. His daily activities comprise the conversations by means of the apparatus, writing private and business letters as well as notes concerning books or articles in papers.

In general, the typewriter can be used for many purposes including leisure activities. The 2-dimensional overall picture on the monitor screen and the facility of a fast access of any point on this screen are essential in this respect. It is not only possible to make normal corrections in a written text but also to display and perform simple mathematical manipulations, while solo chess, cross-word puzzles, etc, for dull days can be played after some exercise. For the future, it will be a real creative activity to exploit to the full all the possibilities of such a typewriter.

Further development

The present typewriter is built to be used as a prototype adapted to the demands of the user. These demands, however, may differ from user to user and can mostly be adequately specified only if the person involved has gained experience with the apparatus. Consequently it seems desirable for it to be made as versatile as possible by incorporating many applications because additional adaptations will be fairly difficult and expensive. Moreover, the choice from various facilities can be very stimulating.

The above demands are largely satisfied in the current set-up by the use of standard equipment like a Super Bee and a printer.

Furthermore, a photocell is provided on the control panel which operates a buzzer warning other inmates of the house. Alternative control functions are the automatic dialling of a telephone number, switching on and off a TV or a radio receiver, and the like. Recently, a survey of commercially available aids of this kind has been published by the Department of Health and Social Security (DHSS, 1977) from which the user can make an appropriate choice.

To set up a batch production of typewriters controlled by head movements it is necessary to overcome several problems concerning effort and cost of development and production, installation and service. The problems encountered in developing a successful prototype to a type suitable have been previously described by Bouma, Engel and Melotte (1972) for the production of a technological device for the visually handicapped. A relevant evaluation, however, falls beyond the scope of the present article.

Conclusion

1. The typewriter described above is a satisfactory means of communication and provides creative possibilities for motor handicapped people who cannot use their arms and hands or cannot speak.
2. Learning to control the device is a fairly quick process, but learning to use it requires more effort of the handicapped. In the case under discussion the user pursued the whole procedure without any guidance.
3. The use of the device depends on the individual interest of the user. It is therefore recommended for economic reasons to maintain the versatility of the current apparatus, because individual adaptations for each

apparatus are labour-intensive and expensive. It is advantageous to construct the aid with commercially available apparatus (Super Bee, printer).

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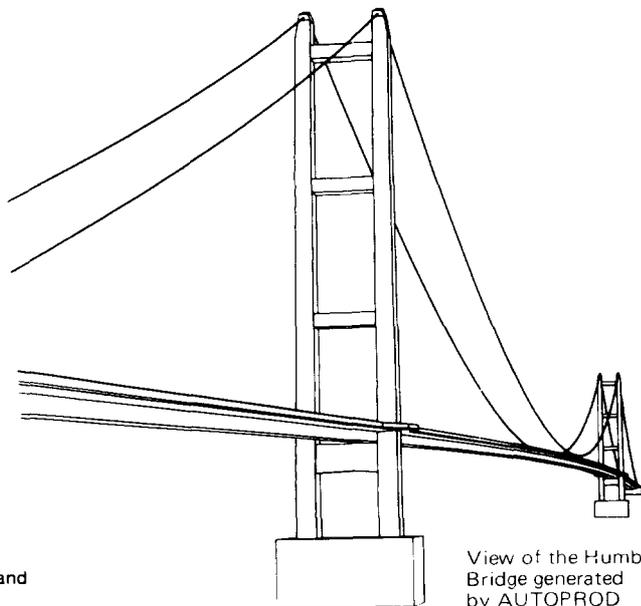
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View of the Humber
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