The Finger-Joint Gesture Wearable Keypad

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Abstract

A wearable, fragmentised, idiomatic, generic and mobile keypad concept, making use of well-established metaphors, is suggested for entering digits and characters. The “Finger-Joint Gesture Wearable Keypad” terminal utilises the inside of the phalanges of the fingers as a wearable telephone keypad. Negligible training time is required. By employing the thumb as an operator, depressing the insides of the finger’s phalanges, the familiar keypad digits and characters are created. By generating finger gestures by letting the operator depress the nail of a finger, different telephone functions are accomplished. The concept is generic and several other functions can easily be generated. The context as a necessary prerequisite for inducing restrictions is discussed as a viable way for creating support for suggesting new design approaches.

Introduction

The traditional mobile terminal is usually looked upon as one single unit. Practically all manufacturers chose to produce an integrated unit, containing batteries, keyboard, loudspeaker, antenna and display. This design approach requires a context where one hand is always free to hug the terminal. A contextual prerequisite is also that the monolith can be housed somewhere when it is not being used, preferably in a pocket. Many users prefer to host it in a leather compartment with a clip, which can be attached to the belt when not in use. By restricting the context to scenarios where portability issues (Rosenberg 1998) are considered of vital importance, it is possible to design a different type of interface more suitable for the mobile user. A user that has only one hand to spare for the interaction with the device and has no means or wish of hosting the device in a pocket. This scenario of the electronic future is also in accordance with that of T. G. Zimmerman (1996) who writes that “we are heading toward an electronic future where information will be accessible at our fingertips, whenever and wherever needed”. Whereas Zimmerman refers to the need of providing access to or retrieving information, this article will focus on the entering of it.

One-handed mobile text input paradigms for entering text and digits

The Chording Glove

The one-handed Chording Glove (Rosenberg 1998) text input paradigm is designed for scenarios where traditional input paradigms fail. The Chording Glove has micro switches attached to the glove fingertips that can detect if a finger depresses the flat surface of a table or not. By using only one hand and no keyboard, it is possible to enter the whole English alphabet by mapping each character to unique chords. A chord constitutes the simultaneous depression of more than one finger to generate one single character. Apart from that, the one-handed Chording Glove concept also incorporates the ability to switch mode (between digit and cursor mode) as well as between lower and upper case letters. Three mode switches were placed on the side of the phalanges of the index finger by Rosenberg (1998, page 58) on the prototype glove. By using only one hand, it is possible for the user to perform almost all-different kinds of functions normally needing two hands, a full-size QWERTY keyboard and a mouse to accomplish.
The Chording Glove thus features that finger depression combinations (chords) are mapped to characters in a many-to-one fashion. However, getting rid of the keyboard and restricting the operation to one hand takes its toll. Rosenberg (1998) had to introduce a learning period lasting several hours. After 11 hours of

training, word input speed reached app. 18 words per minute (wpm) whereas the character error rate amounted to 17%. No digit data was analysed.

The Half-QWERTY hard keyboard

Another one-handed input paradigm (which features a hard keyboard) that might suit the mobile user that has previously acquired the skill to touch-type is the half-QWERTY keyboard (Matias, MacKenzie and Buxton 1996). The non-dominant hand is used only. By employing the Space bar as a shift mode, it is possible to mirror the right-(hand) part of the QWERTY layout (TYUIOP). The same *finger* and the same *position* is used but by the opposite (left hand) when the Space bar is depressed to generate a letter previously typed by the right hand when touch-typing. The half-QWERTY features that half of the alphabet (the letters covered by the right hand when touch-typing) is matched to each finger in a two-to-one-fashion. However, input speed is not very high and ample training is needed. Using data not adjusted for neither cumulative (each out-of-sync character counted as an error) nor chunk error rate (consecutive errors are considered a single error) subjects reached 50% (half-QWERTY speed) of their two-handed typing speed after 8 hours of training. In extended testing subjects achieved average one-handed speeds a high as 60 wpm and 83% of their two-handed rate. A long training phase accompanied with chunk error rates varying between 12%-6% (1^{st} vs. 12^{th}-50 min training session) was the outcome of the experiment. No digit data was analysed.

The hard Telephone keypad

The traditional mobile telephone keypad dedicated to *digit* input also features *letter* input (see Figure 1). Holding the terminal in one hand while using the thumb as an operator to enter digits or letters.

The keypad features a digit layout where each digit is mapped to each key in a one-to-one fashion.

The keypad also features a character mode where several characters (between 1-4 or more) are mapped to each key (digit key 2-9, the Star key (*), digit key 0 and the Pound key (#) whereas digit key 1 is dedicated to Space).

By depressing each key the number of times that matches the rank order of the character mapped to the key, the character is selected. By depressing digit key #2 (A B C) successively three times, the letter C is selected. The mobile telephone keypad is used for sending SMS (Short Messaging Service) text messages or for entering names in the Address Book. Entering name information is frequently done whereas most mobile phone users hardly ever employ the SMS feature. The reason for this is probably that the procedure for entering characters is very cumbersome compared to using only one keystroke to represent each character. That is also why the text-input string is maximised to contain 160 characters, roughly equal to 32 words (including Space) in the English language (Matias, MacKenzie and Buxton 1996).

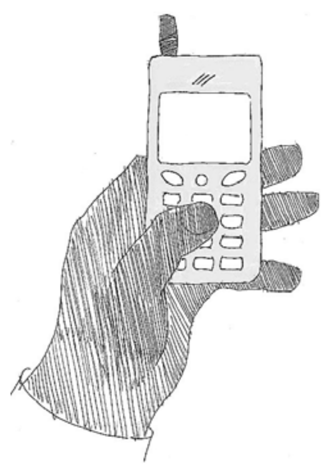

Figure 1. The traditional keypad of a cellular mobile terminal using the thumb as operator when engaged in one-handed input *(Copyright © 1999 Didier Chincholle).*

The typical MMI of an Ericsson cellular terminal (Ericsson 888) featuring the functions “YES”, “NO”, “CLR” and arrow keys (down/up) is depicted in Figure 2. Apart from the traditional keypad, the “YES” key is for Calling “a name or a number”, the “NO” key is for Hang up, the “CLR” key is for deleting a previously entered digit(s) and the arrow keys are for navigating in the menu.

Figure 2. The keypad and the various function keys (YES, NO, CLR and arrow keys (down/up) encountered on an Ericsson 888 cellular terminal.

Two-handed mobile input paradigms

The Optimal soft keyboard and other layouts using stylus for entering text
Using a touch-sensitive rectangular small screen and a stylus that taps on a soft keyboard is also suitable for the mobile user. The Optimal soft keyboard (MacKenzie and Zhang 1998), designed to minimise stylus travel distance, is regarded to fit the mobile user. Predicting the upper-bound text entry rate using Fitt's law generated a text entry rate of 58 wpm which is "35% faster than the prediction for the (soft) QWERTY layout" (MacKenzie and Zhang 1998).
However, in earlier research, MacKenzie, Soukoreff and Zhang (1997) predicted text entry rate utilising Fitt's model where visual scan time for novice users was set to 0.951 s (seconds) did not always match actual text entry rate. The 9-word sentence *"the quick brown fox jumped over the lazy dogs"* was used to predict target performance. Several different soft keyboard layouts were investigated: QWERTY, Dvorak, ABC, Fitality, Telephone keyboard (keypad) and JustType. It turned out that for novice users, *text* entry rate was fastest for the QWERTY layout (21 wpm), which was much higher than the predicted text entry rate according to Fitt's model (8.9 wpm). The experimentally obtained text entry rates for the remaining layouts amounted to 7-10.7 wpm. For the other layouts, the predicted and experimentally obtained wpm values agreed rather well for novice users. This outcome is due to the familiarity with the QWERTY layout that most users have. Thus, the soft Telephone keypad experimentally obtained *text* entry rate did not differ from the text entry rates obtained by using the other layouts. Although the Telephone keypad layout is assumed to be very familiar to users when it comes to entering *digits,* it appears less familiar regarding entering *text.*

The soft Telephone keypad layout using stylus for entering digits
In another experiment performed by MacKenzie et al. (1994) *digi*t input rate was assessed for a soft telephone keypad. The digit input was transformed into a wpm metric in order to make the results more comparable. The soft keypad *digit* input speed amounted to 30 wpm after some practice whereas

character error rate amounted to 1.2 %. The digits 0 and 5 had the highest error rates: 1.93% and 2.41% respectively. The improvement in speed over sessions amounted to 14% for the soft telephone keypad.

The Non-Keyboard QWERTY touch-typing paradigm

By restricting the user group to those who have acquired the skill of touch-typing it was possible to suggest the Non-Keyboard QWERTY touch typing paradigm (Goldstein et al., 1998, 1999). Here learning time was negligible, rendering an instant text entry rate of app. 44-wpm, or higher, and character error rate amounted to 12 %. This negligible training time should be compared to that of the half-QWERTY keyboard (Matias, MacKenzie and Buxton. 1996) where 50% of the two-handed touch-typing speed was reached after 8 hours' of practice. The rapid text entry pace is due to the fact that the user is using the same touch typing metaphors and skills previously learned when touch typing on an ordinary QWERTY full-size keyboard. No new re-learning has to take place.

Based on these findings, it is crucial that new learning has to be minimised to suit the novice user. At the same time, certain contextual constraints have to be set. The input paradigm must be one-handed and the input device has to be wearable to suit the mobile user.

Would it be possible to suggest a wearable keypad terminal optimised for entering digit information that would suit the mobile user? A user that is on the move and that has only one hand available for communication purposes?

The wearable one-handed generic Finger-Joint Gesture (FJG) Wearable Keypad glove

By taking into consideration the work done by Rosenberg on his Chording Glove (1998) when deciding the location of the mode switches (see Figure 3) it was possible to suggest a layout of the Finger-Joint Gesture (FJG) keypad (Figure 4). Rosenberg suggested that mode switches (Shift buttons) be placed on the *side* of the phalanges of the index finger on his one-handed Chording Glove. By changing the location of the mode switch keys in Rosenberg's prototype and taking advantage of well known metaphors, it is possible to suggest the one-handed generic FJG keypad glove.

By holding the inside of the hand in front of you, and bending the fingers toward you and aligning the fingertips of the four fingers, a 4 x 3 matrix appears inside the hand. The 4 x 3 matrix is similar in shape to the traditional telephone keypad. By using the Thumb as an Operator and the insides of each finger's phalanges as Objects, a wearable FJG keypad is suggested (Figure 4). Here the hard keypad and the terminal is omitted altogether. The telephone layout is as well known for entering digits as is the QWERTY layout for entering text. The design approach is akin to that used when suggesting the Non-Keyboard QWERTY touch-typing paradigm. Here the FJG keypad employs the same layout as that encountered on any traditional mobile telephone. Nothing else has to be learned. Except for a moment of idiomatic (Cooper 1995) learning that has to take place. As Cooper states, "all idioms have to be learned. Good idioms only need to be learned once" (Cooper 1995, p. 59). Since the FJG keypad is based on a well-known layout, which is used in a different context, it requires negligible training time. It is assumed that the outcome regarding *digit* performance is similar to that encountered for novice users using the QWERTY soft layout and a stylus as operator for *text* input in MacKenzie et al's experiments (1996). Here a novice (text input) user fared much better than predicted, due to prior familiarity with the QWERTY layout.

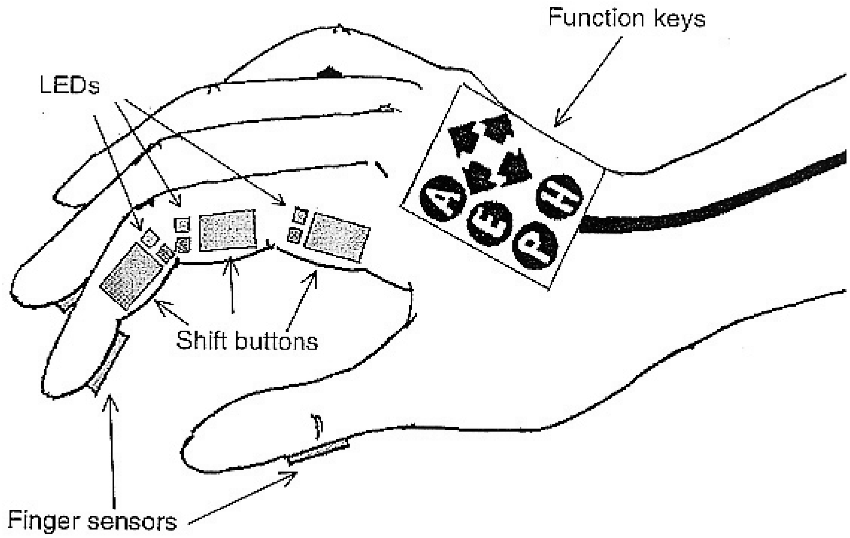

Figure 3. Rosenberg's placement of the Shift buttons on the *side* of the phalanges of the index finger (Rosenberg 1998, *Figure 3.1: Side view of the Chording Glove.* Reprinted with permission from the author).

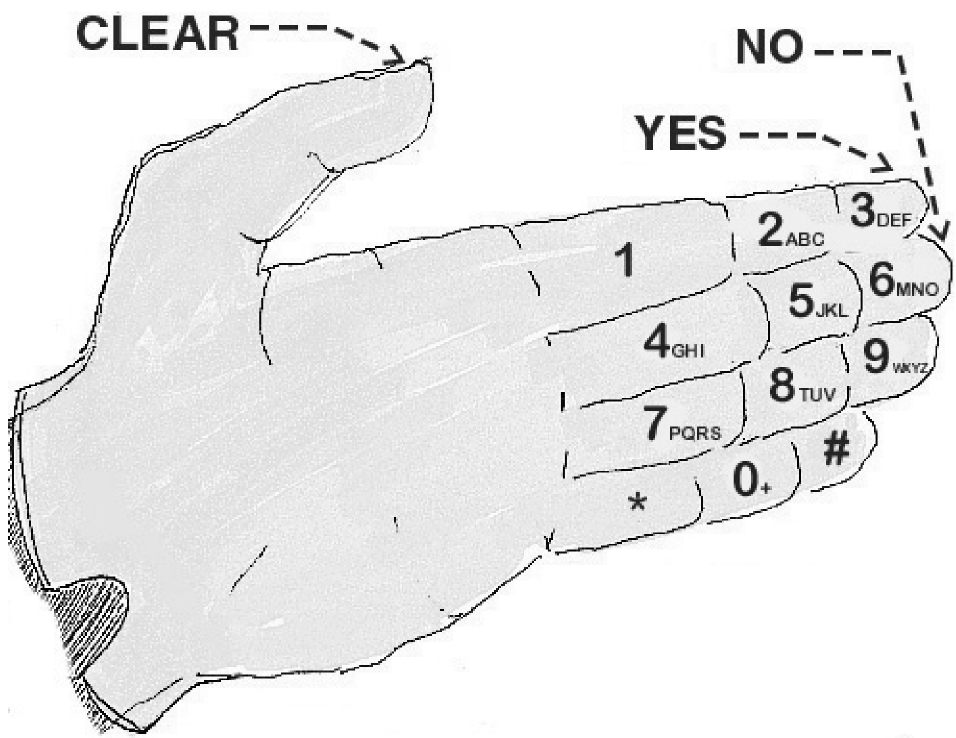

Figure 4. The Finger-Joint Gesture (FJG) keypad glove. The thumb is used as operator and the *insides of the finger phalanges are* used as (key) Objects. The YES, NO and CLEAR functions according to Ericsson's MMI are situated on the nails of the index, middle and thumb fingers *(Copyright © 1999 Didier Chincholle).*

The idea of using the thumb as an operator and the phalanges as objects is the same as the Thumbcode, a digital sign language, proposed by V. R. Pratt (1999). However, the keyboard layout is based on "assigning the most comfortable thumb positions to the most frequently typed characters" rather than employing well-known metaphors. This inadequacy is noted by the author who states that "we have put the numeric symbols in a slightly awkward position and for extended entry of numeric data it would be preferable to put the numeric symbols at more comfortable locations". The Thumbcode concept includes

eight closure states as well, which generates altogether 96 basic thumbcodes covering most of the ASCII characters in a one-to-one mapping. The subjects that will use the Thumbcode concept probably have to go through an elaborate training phase. The FJG keypad, on the other had, makes use of well-established metaphors when entering digits.
To generate the digit 5, the thumb depresses the medial phalang of the middle finger (see Figure 5).
The FJG concept is a generic way of combining the 12 keys of the keypad with 4+1 different functions. It can be used in a variety of different interfaces. The idioms of accomplishing the different telephone functions Call, Hang up, Clear and Phone book (retrieval) have to be learned once as well. On a typical Ericsson mobile phone (see Figure 1) the corresponding dedicated buttons are named: YES, NO, CLR and to select the Phone book in the Menu the left or right arrow key (down/up) has to be pushed. The different functions are accomplished by using the thumb as operator, depressing the nail area of the index, middle, ring and little finger, respectively. In Figure 6, the thumb is depressing the nail area of the index finger (YES), generating the function Call. Thus, a well-known layout of the Ericsson mobile telephone keyboard (see Figure 2) is employed and transferred to a new context. The thumb is used as operator, which is also in accordance with prior one-handed use when entering digits or characters on a mobile terminal. The new idiomatic design consists of using the thumb as an operator and the inside of the finger's phalanges as object keys whereas the nails are used as function keys. A wearable digit and text entry artefact is established. By building all these features into a glove it is possible to obtain an input paradigm that suits the mobile novice user.

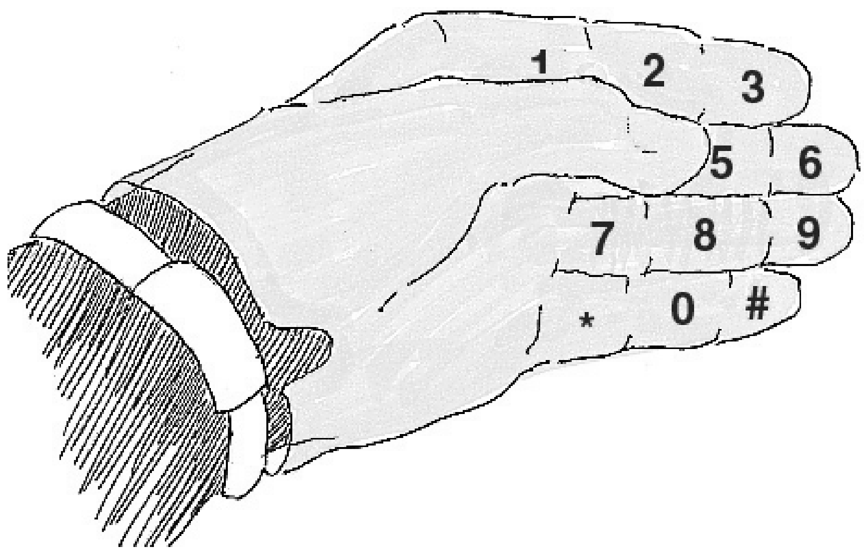

Figure 5. Idiomatic finger gesture to generate the digit #5. Using the thumb as operator and depressing the medial inside phalang of the middle finger *(Copyright © 1999 Didier Chincholle).*

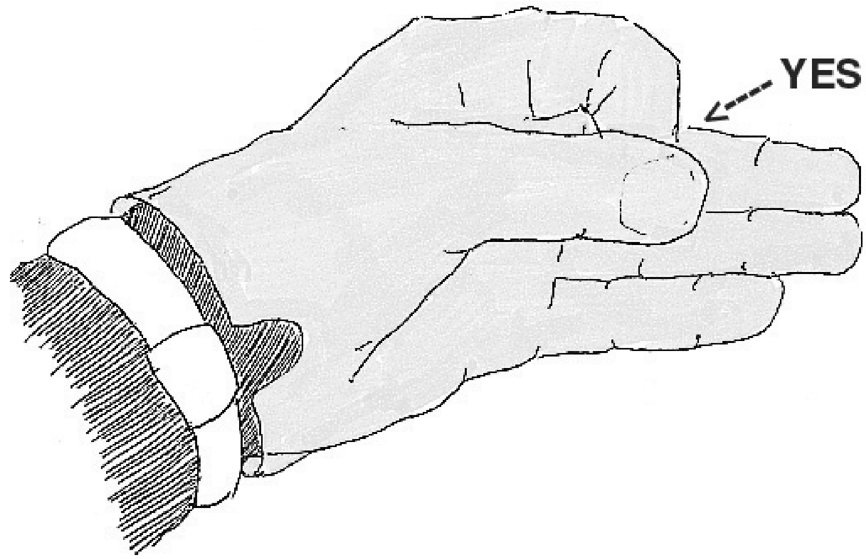

Figure 6. Idiomatic finger gesture to accomplish the function YES (Call) according to Ericsson's MMI for cellular phones. In a similar fashion the functions NO (Hang up), CLR (Clear) and alphabetic mode (name retrieval of previously stored information in Phone book) is accomplished *(Copyright © 1999 Didier Chincholle).*

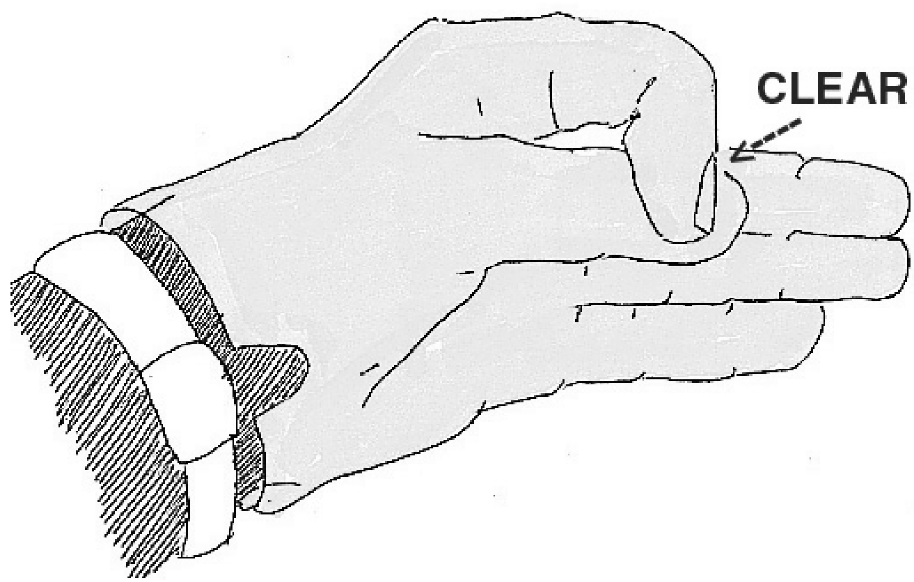

Figure 7. Idiomatic finger gesture to accomplish the function Clear according to Ericsson's MMI for cellular phones *(Copyright © 1999 Didier Chincholle).*

Towards a fragmentation of the mobile terminal concept

What will the future wearable mobile terminal concept look like? One scenario is suggested in Figure 8. Here the Finger-Joint Gesture Terminal Glove is used in conjunction with a separate earpiece and a wearable mobile central. The different units work in co-operation with the use of Ericsson's Bluetooth concept. The Bluetooth concept allows for short-range data exchange (< 10 metres) without any wires. Thus the ear piece , the FJG glove and the wearable terminal all possess Bluetooth as a tool for data exchange.
However, in a future scenario the glove itself may become superfluous. With the introduction of Personal Area Networks (PANs) (Zimmerman 1996) it is possible to show that the human body can exchange digital information by capacitively coupling picoamp currents through the body. The area of electric field sensing, sensing human gestures without any wires (Zimmerman et al. 1995) is also a viable technology. Thus, the glove may be omitted altogether in the future.

Previous experience and context affects thinking

The idea of the FJG keypad is simple and self-evident once the idiomatic pattern is displayed. However, what makes it difficult to think of the pattern? According to Birch and Rabinowitz (1951), the studies which have contributed most directly to an understanding of the manner in which the background of past experiences influences the nature of human thinking are those of Maier and Duncker (1954). Duncker is famous for coining the phrase *functional fixedness.* Functional fixedness refers to the fact that previous utilisation of an object for a dissimilar function affects its availability in subsequent problem solving. In a classical experiment, subjects who had received specific pre-utilisation experience with either a *switch* or a *relay* when instructed to build an electrical circuit differed in a striking manner from the behaviour of the subjects who had not received such experience.
Subjects initially instructed to build an electrical circuit using a *relay* never utilised this object as a pendulum weight for the solution of a subsequent problem: Maier's two-cord problem. The subjects consequently chose the switch, an object not previously manipulated, as the object which was to be converted into a pendulum.
Subjects who initially had been trained to use the *switch* for the completion of the electrical circuit chose the relay as the pendulum weight.
Duncker found that previous specific experience made the objects previously utilised in this manner less available as instruments when a new problem was presented. This line of reasoning might explain why the pre-utilisation of the phalanges of the fingers of the hand as objects, rather than a combination of operator + objects prevents thinking of the Finger-Joint-Gesture Wearable keypad. Although it is common practice to use fingers to create sound by snapping them (thumb and middle finger in combination) repeatedly, the thought of using them to create characters and digits apart from noise in the same way as using an external artefact is not self-evident.
The availability of a function may be highly dependent upon the situational context (Birch and Rabinowitz 1951). The specific constrained context in this case was one-handed use of a wearable input device.

Discussion

The FJG generic concept thus provides a way to enter the digits of the telephone keypad along with gesture function keys that can be combined in order to generate new modes and functions. The applications is thus no restricted to the telephone keypad and accompanying telephone functions: e.g., by switching mode, using one of the function keys, the cursor keys "Left-Right" and "Up-Down" can be implemented as well. It thus appears that context (or the restriction of it) plays a seemingly more important role for thinking than can be imagined. First a restriction of the environment by several degrees of freedom has to be made: mobile user, one hand constantly occupied by other tasks, no table to put the device on when inputting digits, etc. By first inducing the different restrictions regarding context it is possible to provide a solution to a problem. The same line of reasoning can be applied when looking at the Auditory AlphaWheel paradigm (Goldstein, Karlberg and Wilkne 1998, Goldstein and Bretan 1996). A pre-requisite for the solution lies in re-defining and constraining the context. Here the restricted context referred to the way of retrieving train timetable information using a voice-response information service when not having access to a manual where the digit code of a station name was displayed.

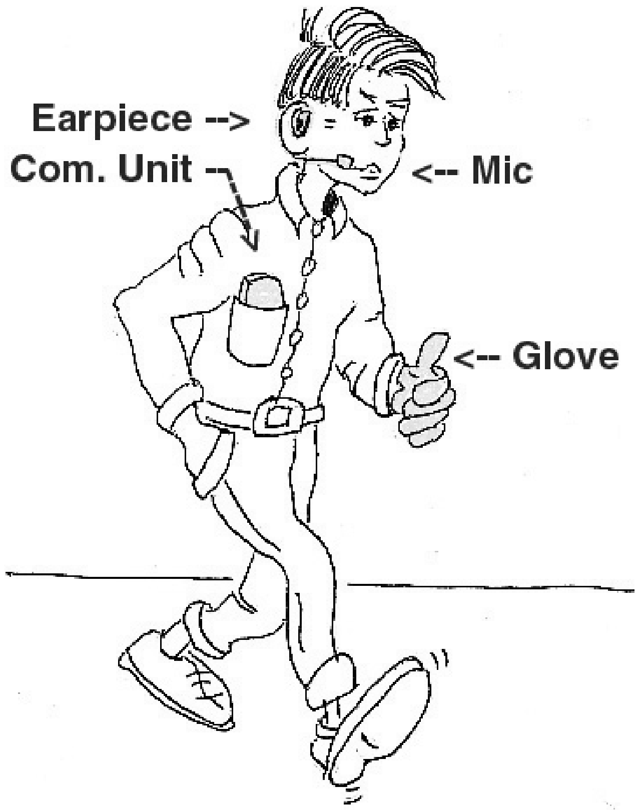

Figure 8. The fragmentised wearable mobile terminal concept employing Bluetooth for data exchange between the different units: Earpiece, Communication unit and FJG-keypad glove *(Copyright © 1999 Didier Chincholle).*

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