Tampere University

Tomi Häsä

DoubleType

A WEARABLE DOUBLE BRACELET CONCEPT FOR TEXT ENTRY

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ABSTRACT

Tomi Häsä: DoubleType: A wearable double bracelet concept for text entry
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Wearable devices are used for text entry on a daily basis. Nowadays, people use their fingers to type text on touchscreens. Unfortunately, the screen size is too small to be able to type text for a longer period of time comfortably compared to quick tasks, such as checking social media posts or email.

I present DoubleType, a wearable solution where two bracelets are used together to type text. When used together, the combined display area offers the user more screen estate for a larger software keyboard with larger keys to type and more area for the text being edited to look at. Three concepts were created and a paper prototype for each concept was produced. A video prototype was created to illustrate how the user interacts with the bracelets when entering text to the system. An online questionnaire was published and it contained images of the paper prototypes and a link to a video of the prototypes in use. 34 volunteers participated. Five background questions were asked and then five questions about the prototypes.

In general, participants did not see DoubleType as a comfortable system to use for typing text. Also, majority of participants did not think DoubleType will help avoid getting neck and shoulder pains from typing text. And, most participants would not use DoubleType to type in a standing position for some parts of one's days to avoid sitting long periods of time. Of the three concepts, participants favored the most concept C, where the concept is put on a table. From the open-ended questions it was revealed participants disliked the size of the bracelets.

There could be use of the prototype in a factory for technicians who need to make notes of the procedures they have done. Future research with working prototypes is needed to find out how ergonomic and efficient DoubleType is for text entry.

Keywords: text entry, text input, smart bracelet, smartwatch, wearable

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

Contents

1 Introduction

Wearable technology has evolved from devices, such as the 1970s cassette tape player Walkman, to large phones with high performance processors and also to small smart rings collecting data of your health. Wearable technology means devices that can be worn on your body or on your garment. Even smartphones can be seen as such when worn in the pocket of one's trousers or jacket. Tablet computers are more difficult to wear because of their size, so tablets can be categorized as mobile devices. Examples of wearable devices are high-end smartphones (Apple iPhone 13, Samsung Galaxy S22 Plus, Google Pixel 6), foldable phones (Samsung Galaxy Z Fold 3, Huawei Mate Xs, Motorola Razr), smartwatches (Apple Watch, Samsung Galaxy Watch, Oppo Watch), fitness trackers (Fitbit Charge, Garming Forerunner), GPS trackers (Suunto Ambit3), and smart rings (Oura Ring, Movano Ring, Circular Ring, Opn NFC Ring, Go2Sleep). In the health sector there are heart rate monitors (Polar H9, Wahoo TICKR, Garmin HRM-Dual) and even blood glucose monitors (FreeStyle Libre, Dexcom G6, Eversense CGM).

Wearable devices are used for text entry on a daily basis. People read and send chat and email messages, make notes with text editors, search for information with web browsers, use their calendars to read and edit information about meetings, check notifications from applications, and so on. In 2021 it was estimated the world population was over 7.8 billion [Worldometer 2022] and there were over 6.2 billion smartphone subscriptions [Statista 2021]. Some of the most popular mobile note taking applications, including Evernote, ColorNote and Microsoft OneNote, have over 100 million installations, each, on Google Play [Google Play 2022c, Google Play 2022a, Google Play 2022d]. Among the mobile Android office applications, Microsoft Word and Google Docs, have over a billion installations, each [Google Play 2022e, Google Play 2022b].

Wearables connect to the Internet using 3G, 4G and/or 5G networks, depending on which ones are available in the area and which technology is supported by the wearable. Mobile Internet connections allow people to continue editing their documents, which have been edited with a desktop computer and uploaded to a cloud service that shares the document with other devices the same user owns. Wearables, such as smart watches, may also connect to other wearables using the Bluetooth technology. This way smart watches are able to receive notifications sent to a user's smart phone so that the user does not need to pick up one's phone from the pocket or bag.

How do people input text on their mobile and wearable devices and what kind of problems do they encounter and what kind of solutions are they using? Nowadays, people use their fingers to type text on touchscreens. Wearable devices that have displays, usually show on the display a software keyboard, which the user taps with a finger. Another way of entering text is to use speech recognition technology of the phone. With that technology user may give commands to a phone or may also dictate longer texts for later editing with a desktop computer. Before smart phones existed, one wrote using a physical keypad on one's mobile phone or used a stylus to write with a PDA (personal digital assistant). Mobile phones did not usually have as many physical keys as desktop keyboards. To be able to type text, for example multi-tap was used. With PDAs, the tip of the stylus was small enough so that a software keyboard could be used on the display. Because mobile phones usually did not have a QWERTY keyboard, for example smaller non-QWERTY keyboards were used. With multi-tap one physical key is pressed multiple times until the correct character appears on a phone's display. Assistive technologies were invented to make it easier to type text using a small physical keypad on a mobile phone or using a small touchscreen on a smart phone. If autocorrection is enabled, phone will replace incorrectly typed words by predicting what the user was thinking of writing. This technology is not perfect and the user may need to delete the suggested word and type the correct word instead. Word suggestion technology suggests the rest of the characters of an unfinished word. Unfortunately, this will burden the user's cognitive abilities as the user needs to look at the display and the keyboard switching gaze from the text to the keyboard multiple times during a text entry session. With smart watches very small software keyboards are used, but they are slow and cumbersome to use. One could carry a wireless desktop keyboard with them, but people do not always like to carry devices larger than a phone with them. There are also silicone or "rubber" keyboards that can be folded, but they do take space and do not fit into pockets easily. Some people use wrist-worn keyboards, but they are clumsy and they are meant to be used with desktop computers instead of phones. Another solution could be a glove for one-handed text entry, such as Hifinger [Jiang *et al*. 2019], but is designed for computer use. HandyKey Twiddler [Lyons *et al.* 2006] is an eyes-free keyboard, but you need to learn the key combinations to be able to use it. One could just buy a smart phone with as big display as possible, but it would not be easy to wear anymore.

To solve the problems mentioned above, I present DoubleType: a solution where two bracelets are used together to type text. There are three concepts which are different, but also similar: DoubleType A, DoubleType B, and DoubleType C. DoubleType A consists of two smart bracelets that are worn on the left and right wrist. When the user needs to type text, he will remove the bracelets and use the left bracelet to display text being edited and the right bracelet for typing text on a software keyboard. The bracelets attach to each other forming a cross-like figure so that the user only needs to hold one of the bracelets and use the other hand for typing. Not all people use their index or middle fingers to type, so the second concept is for thumb typists.

DoubleType B also consists of two bracelets that can be attached to each other creating a cross-like figure. The only difference is that keys of the software keyboard are closer to the thumbs for thumb typists to edit text with. DoubleType C also consists of two bracelets, but is designed to be used on a table. The left bracelet is bent approximately to an L-shape figure and put on the table to display text being edited. The right bracelet is put in front of the left bracelet and used as a keyboard.

The gap in the research regarding mobile and wearable text entry is that there is no research on making text entry easier using two bracelets together to increase the area of display, so that both the area of text being edited and the area containing the software keyboard is larger than with current average-sized smartphones and smartwatches. This study fills this gap by presenting three concepts that use two bracelets to increase the display area for text being edited and to increase the area for the software keyboard.

In this study, the concepts are presented and paper prototypes of the concepts are produced. A video [Häsä 2021] is made of the paper prototypes where a person is using them and screenshots are generated from the video. The screenshots are embedded to a questionnaire that is shown to the participants of this study. The video may also be viewed, but it is not necessary because of the screenshots.

In the questionnaire, the participants are asked their opinions about the prototypes and they are also asked how they use their phones: do they type with one hand or with two hands and what kind of actions they perform with their phones i.e. what kind of applications they use. In addition to finding out how people use their phones, the aim of this study is to find out the reception of people regarding the concepts.

This thesis consist of seven chapters. Chapter 2 provides a background for the reported study. It discusses the problems and solutions involved with mobile and wearable text entry. In Chapter 3 the concepts are explained, assessment of the concepts is made via a questionnaire and results of the questionnaire are presented and discussed. Chapter 4 contains the conclusions, which are a summary of the research results and future work.

2 Mobile and wearable text entry

Heller *et al.* [2021] categorize wearable displays from the perspective of how they are used: accessories (e.g. eyewear, headwear, watches, bracelets, rings, earrings, handbags, shoes), clothing (e.g. shirts, pants, skirts, suits, dresses), and skin & body (display is applied directly on to body). This chapter omits for example garment, rings, earrings, handbags, and shoes as they are not very suitable for text entry.

In this chapter, six categories, which have been researched from the viewpoint of text entry, are used: mobile phones [Silfverberg *et al.* 2000], handheld computers [Silfverberg 2007], wrist wearables [Dunlop *et al.* 2014], HMDs [Adhikary and Vertanen 2021], smart glasses [Ghosh *et al.* 2020], and wearable computers [Thomas *et al.* 1998]. Some of the first or notable devices in each category are mentioned and what kind of problems each category has. Lastly, text entry speed research is discussed.

2.1 Mobile phones

In the 1980s, the first mobile phones had a physical keypad for text entry. Full-size QWERTY keyboards were generally not practical. A 12-key keypad was commonly used with mobile phones [Silfverberg 2007]. For the 12-key keypad multi-tap is one of the text entry methods used. With multi-tap, a key is pressed one or more times to generate one character for the text being edited as most languages have more characters than in the 12-key keypad. A predictive method, such as T9, can be used to decrease the number of key presses needed to type text. With T9, as the user presses the keys, the system can suggest words from a dictionary before the whole word has been typed. Silfverberg [2007] mentions alternative text entry methods to the 12-key keypad, such as the 26-key Fastap and the 20-key reduced QWERTY keyboard (and three buttons above it) on BlackBerry 7100v. Currently, people most probably buy a smart phone instead of a mobile phone, but there are people who buy dumbphones for example for nostalgic reasons or to avoid wasting time with social media [Bearne 2022]. The display is too small on current phones and tablets, which makes typing more error-prone [Kim *et al.* 2014].

2.2 Handheld computers

Early handheld computers did not have wireless communication technology [Narayanaswami 2006]. The first personal digital assistant (PDA), Hewlett-Packard

HP95LX, was released in 1991 [MacKenzie and Soukoreff 2002]. It had a QWERTY keyboard, numeric keypad, function keys and other buttons. One of the first notable pen-based handheld computers, Apple MessagePad, was announced in 1993. Unfortunately, the handwriting recognition was poor, like other pen-based handheld computers in the early 1990s. Palm Pilot, which was released in 1996, introduced a simplified handwriting technique known as Graffiti. It also had for example a feature called HotSync for transferring data between a desktop computer and the Palm Pilot using a cable. In the same year, Windows CE (Casio Cassiopeia) and Symbian (Nokia Communicator) handheld devices emerged. Nokia Communicator can also be seen as a foldable phone, as you can open it to reveal a QWERTY keyboard and a larger display. Nowadays, you could see phones, tablets and laptops having replaced handheld computers, which are too large compared to phones to keep with you and too small for text entry compared to laptops.

2.3 Wrist wearables

The earliest wristwatches were probably created in the 1790s. Mostly women wore wristwatches at that time. Men's wristwatches appeared in the late nineteenth century, but as military devices, at first. Before the early 1900s, men usually wore pocket watches. In 1957 Sony released pocket radios that were advertised as "pocketable", but they could only fit oversized pockets. Hewlett-Packard released a wristwatch calculator in 1977 and Seiko manufactured watches with small televisions in 1982. [Ryan 2014] More recent wrist wearables are for example FitBit, Nike FuelBand, Jawbone UP, Sony SmartWatch [Park *et al*. 2014] and Apple Watch. A wrist wearable may have a software keyboard or other ways of entering text, such as the bezel or physical buttons, but a small display and slow text entry is even a greater problem for wrist wearables compared to phones.

2.4 HMDs

In 1968 Ivan Sutherland developed a computer-based head-mounted display (HMD). It was too heavy to be usable, but worked as proof-of-concept. [Ryan 2014] In the late 1980s and early 1990s, VPL Research, Virtual Research, Phillips, and Nintendo started creating virtual headsets. [Starner 2014] These headsets or HMDs might be considered as wearables, but they are not very mobile, so that one could take them with them as one needs a desktop computer or a gaming system to use them.

2.5 Smart glasses

Google Glass was released in 2013 for beta-testing [Bruno 2015]. Google Glass is a brand of smart glasses that uses a multitouch trackpad, head motion and speech for its input. Networking is available using Wi-Fi or Bluetooth tethering to a phone. [Starner 2014] Smart glasses differ from HMDs in the sense that they are designed to be used without a direct connection to a desktop computer. They collect information from the surroundings and analyze them. The user may also for example connect to the Internet to search for information or send messages. [Hofmann *et al*. 2016] With smart glasses text entry is slow if you only use the trackpad of the smart glasses instead of a wireless keyboard.

2.6 Wearable computers

One of the earliest wearable computers was developed in 1961 and its purpose was to predict roulette wheels [Thorpe 1998, Narayanaswami 2006]. The computer was about the size of a cigarette pack. In the 1990s, a wearable computer called VuMan 3 [Bass *et al*. 1997, Narayanaswami 2006], was designed for marines to help inspect amphibious tractors. VuMan 3 consisted of a display worn on the head and buttons worn on the waist. Research papers about NetMan [Kortuem *et al*. 1999, Narayanaswami 2006] were published in 1999. NetMan was a collaborative wearable system to enhance the co-operation of network technicians. Technicians could have real-time audioconferences, transmit video images and access a shared notebook. The problem with wearable computers, such as VuMan 3 and NetMan, is that they are intended for certain kind of tasks whereas smart phones and laptops are designed for general use at work and in free time.

2.7 Text entry speed

One way of measuring the usefulness and efficiency of mobile and wearable devices regarding text input is the text entry speed. Words per minute (WPM), characters per second (CPS) and keystrokes per character (KSPC) are common measurements [MacKenzie and Soukoreff 2002]. Related to text entry speed, errors made during typing are often measured also, and measurements in that case can be for example total error rate (TER), corrected error rate (CER), and not corrected error rate (NCER) [Soukoreff and MacKenzie 2004]. Here we concentrate on WPM for easy comparison of text entry speeds.

Buschek *et al*. [2018] compare different hand postures when using a phone. Average speed for all participants for all hand postures was 32.1 WPM. Average speed for different hand postures were 36.8 WPM for two-thumb typing was, 25.3 WPM for right hand thumb typists, 27.3 WPM for left hand thumb typists, 36.7 WPM for two index finger typists, 24.4 WPM for right index finger typists and 30.8 WPM for left index finger typists. Individual participants did not always use one hand posture, instead they changed postures. In [Oulasvirta *et al*. 2013] participants were using a two thumb hand posture with a split software keyboard and reached a rate of 37 WPM. Does a grip ring, such as PopSocket, speed up text entry? Shen *et al*. [2018] tested a Bunker Ring and noticed grip rings do not affect text entry performance in terms of speed, accuracy, or keystrokes per character. Entry speeds without and with a grip ring were 25.56 WPM and 25.59 WPM, respectively.

Arif and Mazalek [2016] survey text entry techniques for smartwatches. They compare software keyboards and handwriting techniques from the literature. Keyboards are categorized as QWERTY keyboards and novel keyboards. The fastest non-predictive QWERTY keyboards are DualKey (19.61 WPM), ZoomBoard (17.08 WPM), and SplitBoard (15.07 WPM). Swype (29.3 WPM) is the fastest in predictive QWERTY keyboards and DualKey in novel non-predictive keyboards when using a SWEQTY keyboard (21.59 WPM).

Kristensson and Denby [2009] and Fleetwood *et al*. [2002] measured the speed for handwriting using a stylus. Kristensson and Denby [2009] report a mean text entry rate of 24.1 WPM after 250 minutes of practice. In Fleetwood *et al*.'s [2002] study, experts reached an average rate of 21 WPM. For comparison, they also measured the pen and paper speed, which was 26.8 WPM.

Lyons *et al*. [2006] and Clarkson *et al*. [2005] researched the speeds of mobile physical keyboards. Lyons *et al*. [2006] tested HandyKey Twiddler, a one-handed chording mobile keyboard. Five of the twelve participants achieved an average rate of 47 WPM after practicing approximately 25 hours. In Clarkson *et al*.'s [2005] study each of the participants were randomly assigned one of two different mini-QWERTY keyboards. After the twentieth session, average speed was 60 WPM. Single fastest session speed was 74.69 WPM.

How do the above speeds compare to a physical normal-sized keyboard? In Li *et al*.'s [2011] study participants achieved an average typing speed of 82.6 WPM with a physical keyboard. In Shi *et al*.'s [2018] study participants typed with an average speed of 68.4 WPM. In Findlater *et al*.'s [2011] study mean typing speed for twenty skilled typists was 85.0 WPM.

What speed is sufficient for mobile and wearable text entry? Kristensson and Vertanen [2014] introduce the concept of the inviscid entry rate where there is a point when the user’s creativity is the bottleneck rather than the text entry method. According to them, the sufficiently inviscid text entry rate for mobile text entry is around 67 WPM. With this concept we could rule out typing with a software keyboard on a phone or a smartwatch or using a stylus. On the other hand, it seems like typing with a virtual keyboard on a phone is good enough for people, but that probably means in the case of writing for example short chat and email messages instead of writing long articles. For longer texts, a physical mini-QWERTY keyboard, a device with a larger touchscreen or a wireless physical keyboard would help making it easier and faster to type. Problem with a larger touchscreen or a wireless physical keyboard is the space they take. They usually don't fit a pocket unless you can fold them and in that case they could be too thick to fit the pocket.

3 DoubleType

In this chapter, I present three concepts, DoubleType A, DoubleType B, and DoubleType C. The design rationale is explained for each concept.

3.1 Motivation

Five problems exist regarding wearable and mobile note taking. (1) The virtual keyboard is too small on current phones and tablets, so you make a lot of mistypings, which makes typing inefficient [Kim *et al.* 2014, Pereira *et al.* 2014]. For older people and people with big hands this is an even greater problem [Smith and Chaparro 2015]. Not everyone likes autocorrect [Madison 2011], so that is not a solution for small screens for everyone. (2) We sit too much and it is not healthy for us [Dunstan *et al.* 2011]. (3) Current laptops are too heavy if one wants to write text standing up without using a table. (4) If you want to walk outside and take notes [Ahtinen *et al.* 2017], there are no tables you can put your laptop on to be able to write ergonomically. (5) You do not always have a bag or even clothes with pockets, as in the situation you are jogging on a hot day or you take sun on the beach. You never know when you get an idea and you need to write down your ideas immediately before you forget them. If you have no pockets and you do not want to carry a phone in your palm, you could use a smartwatch or a smart bracelet, but the display is too small for writing text efficiently with them.

The DoubleType concept solves all five problems mentioned above. (1) The virtual keyboard is of the size of 26.5 cm x 5.9 cm (10.4" x 2.3"), which should be large enough for comfortably typing text without making mistypings as often as with phones and tablets. (2) With DoubleType you are able to type anywhere, sitting or standing up. (3) DoubleType is not as heavy as laptops and not as cumbersome to use while standing up. (4) You do not need a table with DoubleType (concepts A and B) as you do with laptops. (5) DoubleType does not need pockets, because you can carry it on your wrists.

3.2 Method

Protypes help designers share new ideas, get feedback from users and articulate reasons for final choices. They also encourage communication, help designers and users to discuss options and interact with each other. [Beaudouin-Lafon and Mackay 2012] In this study, three paper prototypes were created and then one video prototype to illustrate how the user interacts with the bracelets when entering text to the system.

In human-computer interaction (HCI), surveys are used to collect information about users' satisfaction, opinions, ideas, and evaluations about a system [Ozok 2012]. This study used an online questionnaire to ask participants closed and open-ended questions about the prototypes to get feedback about the pros and cons of the prototypes.

This study was done during the COVID-19 pandemic, so an online questionnaire was an obvious choice to avoid unnecessary contact with people [Amuedo-Dorantes *et al.* 2021, Reif *et al.* 2021]. There is a problem receiving enough feedback using feedback forms in Finnish schools [Henttinen 2000, Savolainen 2000], so my aim was to make the questions easy to respond to by avoiding too many open-ended questions.

3.3 DoubleType A

The first concept, DoubleType A, consists of two bracelets. Figure 1a shows the bracelets separated from each other. Each bracelet has a magnet. The magnets are shown as gray circles in Figure 1a and they are used to connect the braceletes together. The "Nonactive area" is the part of the bracelet that does not react to touch, so it is safe to touch while holding the bracelet. In Figure 1b the two bracelets have been connected to each other. Left-hand bracelet ("Keyboard Bracelet") shows a virtual keyboard for typing text. Right-hand bracelet ("Display Bracelet") shows the text that has been typed. The "Display Bracelet" is held from the "Nonactive area".

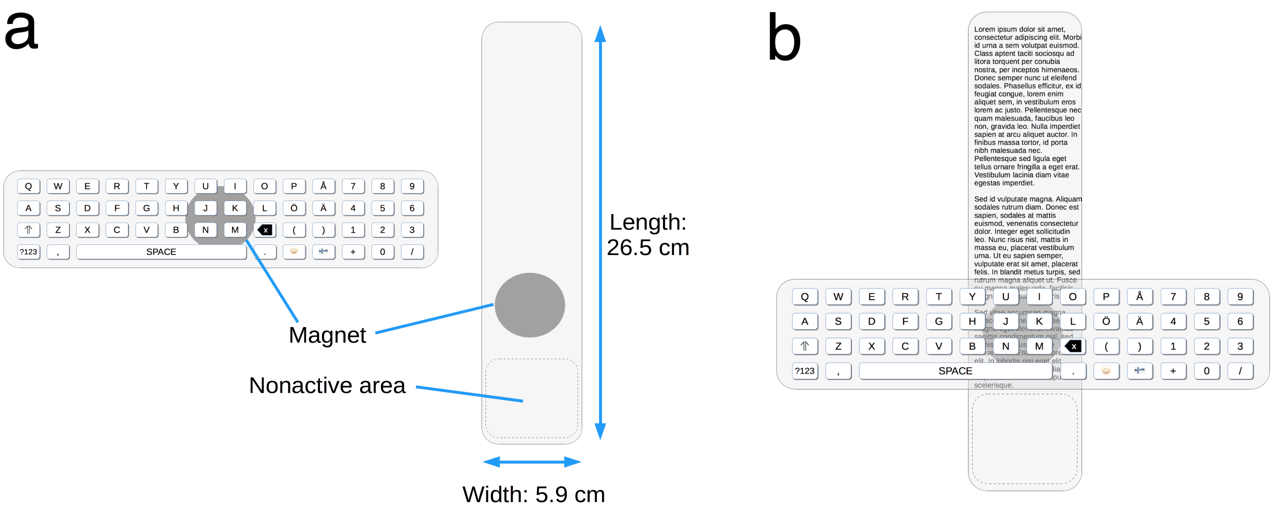

Figure 1. (a) Two bracelets separated. (b) Two bracelets connected to each other.

You can also see the measurements of the bracelets in Figure 1a. The width and length of each bracelet is 5.9 cm × 26.5 cm. The display size (i.e. diagonal of rectangle) of each bracelet is 10.69".

In Figure 2 you can see the paper prototype of DoubleType A. In Figure 2a the bracelets are connected to each other and held with one hand. In Figure 2b the bracelets are compared to every day items: a 2 € coin, a 20 cm ruler, a ballpoint pen, and a smartphone (iPhone 6 with a 4.7" display).

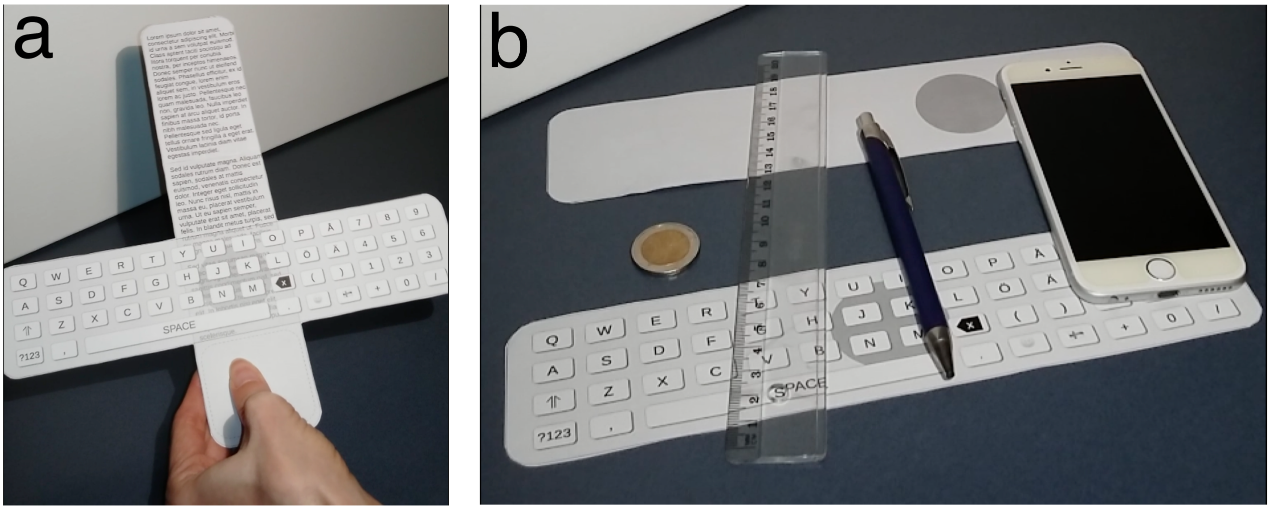

Figure 2. (a) Paper prototype held with one hand. (b) Bracelets compared to every day items.

3.4 DoubleType B

DoubleType B consists of two bracelets just like DoubleType A. The measurements i.e. width and length of the bracelets are the same also. The difference is that the software keyboard has been designed for two-thumb typing: the keyboard is split from the middle and the keys are closer to the thumbs. You can see DoubleType B in Figure 3a.

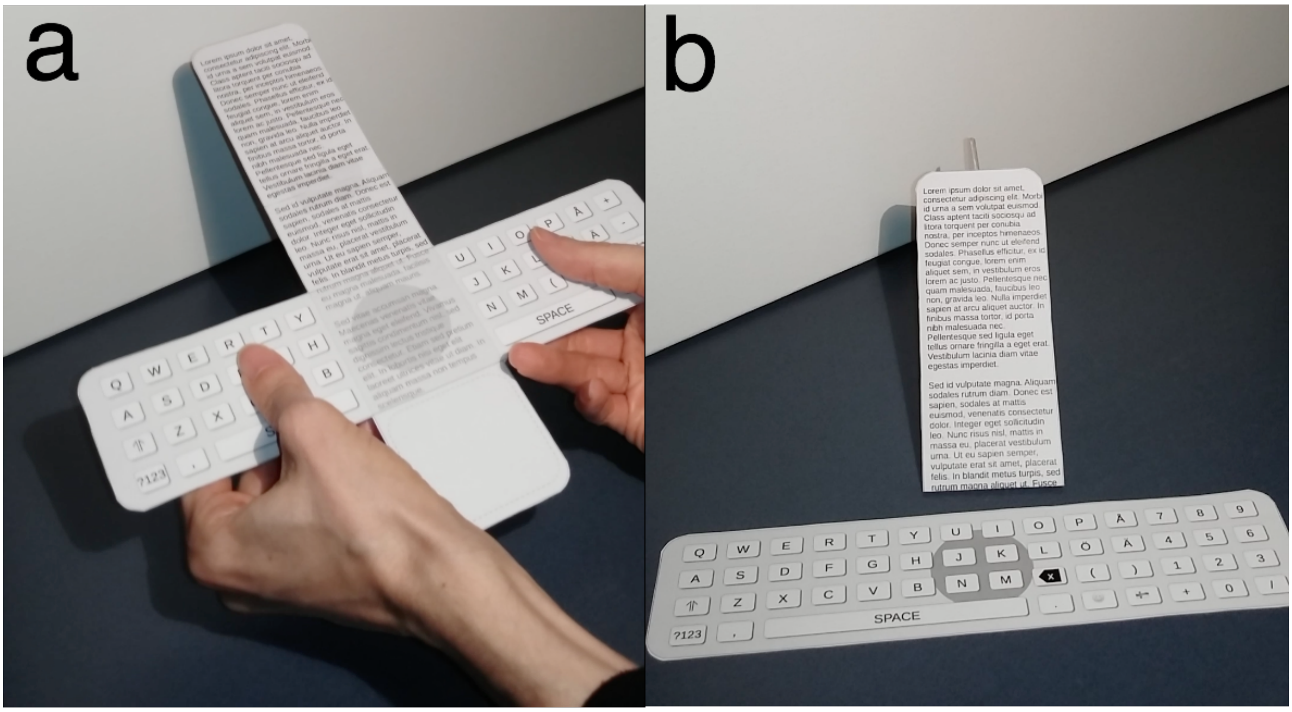

Figure 3. (a) DoubleType B. (b) DoubleType C.

3.5 DoubleType C

DoubleType C is designed to be put on a table unlike DoubleType A and DoubleType B. When the user has both hands available, text entry speed will increase. DoubleType C consists of two bracelets just like DoubleType A and DoubleType B. The measurements of the bracelets are the same also. You can see DoubleType C in Figure 3b. With DoubleType C the left-hand bracelet ("Keyboard Bracelet") is put on a table. The right-hand bracelet ("Display Bracelet") bends and forms an angle so that the user can easily see the text on the display.

3.6 Similar concepts and designs

DoubleType can be seen as a dual-display system or as two devices connected to each other both having their own display. Robertson *et al.* [1996] discuss about a multiple-device application consisting of a PDA that operates in conjunction with an interactive television (ITV). Using a stylus, the user interacts with the PDA, which sends data to a settop box. The settop box is connected to a server using a cable and downloads data from the server and that data is displayed on the television. Merrill *et al.* [2007] introduce Siftables, which are a collection of compact tiles, each with a LCD screen, an accelerometer, infrared transceivers, battery and an RF radio. User can manipulate the tiles as a group and the interaction is sensed and used as input to the system.

AugmentedForearm [Olberding *et al.* 2013] and Facet [Lyons *et al.* 2012] are wearables that have multiple displays. AugmentedForearm is a prototype consisting of four WIMM [Informationweek 2011] computers and sensors attached to the skin of the forearm. Each of the WIMM computers feature a 1.5 inch display, an accelerometer and Wi-Fi connectivity. AugmentedForearm detects the orientation of the arm and how much of a shirt's sleeve covers the forearm to interact with the user. Facet consists of a bracelet and WIMM One computers each forming one segment. The segments can be removed from and inserted to the bracelet. Facet uses pose detection and multi-segment touch for interaction.

Not only does DoubleType have multiple displays, the displays are also flexible. DisplaySkin [Burstyn *et al.* 2015] and Snaplet [Tarun *et al.* 2011] are wearables with a flexible display. DisplaySkin is a pose-aware wrist-worn device, which has a flexible electrophoretic display that is 6.5 inches long and 3 inches wide. DisplaySkin detects user's wrist relative to their shoulder using two inertial measurement units (IMU) where one is worn around the user's upper arm and one is integrated in the DisplaySkin. Snaplet is a wearable display augmented with sensors and it can be used in three forms. In a convex shape on the wrist (or on the forearm based on the images) it functions as a watch and media player. In a concave shape it functions as a phone. In a flat form it can be held in the hand like a PDA.

You can fold or wrap DoubleType on your wrist, which can remind of foldable phones [Lee *et al.* 2019]. Foldable phones are already in the market. Samsung Galaxy Z Fold 3 [Spoonauer 2022] is an example of a foldable phone. It has an external display of 6.2 inches and an internal display of 7.6 inches. One can fold it so that it takes less space.

3.7 Questionnaire

An online questionnaire was published on the intranet of University of Tampere. 34 volunteers participated. You can find the contents of the questionnaire in Appendix 1. At the beginning of the questionnaire, participants were informed answers were anonymous and there was no monetary compensation for participating. After that, five background questions were asked and then five questions about the prototypes. The questions are listed below, so that they can be easily referred to later in this thesis (closed and open-ended options have been removed from the questions for brevity):

Q1. How old are you?
Q2. What is your gender?

Q3. When using a phone, which of these actions do you perform when typing text?
Q4. Does your current phone have a big enough screen for typing text?
Q5. How do you type text with your phone?
Q6. How comfortable do you think DoubleType is for typing text?
Q7. Do you think DoubleType will help avoid getting neck and shoulder pains from typing text?
Q8. Sitting long periods of time is considered unhealthy. Would you use DoubleType to type in a standing position for some parts of your days?
Q9. Which of these prototypes would you prefer using?
Q10. Do you have any comments or opinions about DoubleType you would like to share?

Questions 1–5 are background questions and questions 6–10 deal with the DoubleType concepts. Questions 6–8 are about ergonomics. More precisely, question 7 is related to neck pain [Yoon *et al.* 2021] and question 8 is related to sedentary work [Antle *et al.* 2018, Dunstan *et al.* 2011]. Question 9 compares the concepts to each other. At the beginning of my design process I only had one concept, wich is DoubleType A. I had two other ideas that I wanted to evaluate, so I included them in this thesis to see what kind of opinions participants would have about them. Question 10 is an open-ended question for miscellaneous feedback, but it can also deliver new ideas the other questions did not discuss about. For example, there was no question about the aesthetics of the bracelets, but from the answers I can deduce there could have been a question about that also.

3.8 Results

The answers to the ten questions by the participants are presented below. Tables 1–9 show numerical data of the answers. There is no numerical data for question 10 as it was an open-ended question.

18–25	8
26–30	14
31–40	8
41–50	4
51–60	0
over 60	0

Table 1. Age distribution of the participants.

Q1. Of all the participants, who filled in the questionnaire, eight were 18–25 years old, 14 were 26–30 years old, eight were 31–40 years old, and four were 41–50 years old (see Table 1). No-one was older than 50 years old.

female	19
male	15

Table 2. Gender of the participants.

Q2. 19 participants were female and 15 were male (see Table 2).

use chat	34
make notes	32
search for information	32
use social media	29
use email	25
write a diary/journal	2
write office documents	1
write text messages	1

Table 3. Actions performed on phone when typing text by the participants.

Q3. Participants were asked what kind of actions they perform on their phone when typing text and ready-made categories were offered as choices (see Table 3). This was a multiple-choice question. There was also a free form section to give a more detailed answer. 34 people use chat, 32 people make notes, 32 people search for information, 29 people use social media, 25 people use email, two write a diary/journal, one writes text messages, and one writes office documents. In the free form section participant 17 answered "write short, unpolished fiction", which could be categorized as making notes or writing a journal, but of course, fiction is neither of them. Participant 20 replied "write google docs", which could be categorized as writing office documents, but you can use Google Docs for many different types of texts. Participant 22 replied "Writing english and russian to Duolingo", which could be categorized as "use translation service" if there was such a category.

Yes	33
No	1

Table 4. Is participant's phone big enough for typing text.

Q4. 33 participants think their current phone has a big enough screen for typing text and one thinks it is not big enough (see Table 4).

hold the phone with both hands and type with your thumbs	19
use one finger to input text and hold the phone with the other hand	9
hold the phone with one hand and type with the same hand using one finger	2

Table 5. Hand posture while typing text.

Q5. 19 people hold the phone with both hands and type with one's thumbs, 9 people use one finger to input text and hold the phone with the one's hand, and 2 people hold the phone with one hand and type with the same hand using one finger (see Table 5).

In the free form section of question 5 three participants replied their hand posture varies. Participant 8 wrote "Interchanging between three styles: holding the phone in one hand and writing with the thumb of the same hand using the gboard with swipes; holding the phone in one hand and writing with swipes using the other hand's index finger; holding the phone with both hands and using thumbs". Participant 25 wrote "It varies. I use both thumbs most often, but sometimes I hold the phone and type with the same hand using one finger, and sometimes I keep the phone on a table/lap and type with 1-3 fingers (either with one or both hands), and sometimes I hold the phone and type with one finger using the other hand". Participant 34 wrote "all options, depending on the situation".

Swiping [Chen *et al.* 2014] was not given as an option, but participant 19 wrote "With both thumbs or by swiping".

Very comfortable	0
Fairly comfortable	12
Quite uncomfortable	18
Very uncomfortable	4

Table 6. Perceived comfortability of DoubleType.

Q6. When asked how comfortable the participants think DoubleType is for typing text, 18 people responded "Quite uncomfortable", 12 "Fairly comfortable", 4 "Very uncomfortable", and no-one answered "Very comfortable" (see Table 6).

No	28
Yes	6

Table 7. Will DoubleType help avoid getting neck and shoulder pains from typing text.

Q7. When asked do participants think DoubleType will help avoid getting neck and shoulder pains from typing text, 28 answered no, and 6 replied yes (see Table 7).

No	22
Yes	11

Table 8. Would participants use DoubleType to type in a standing position for some parts of their days.

Q8. When asked would participants use DoubleType to type in a standing position for some parts of their days, because sitting long periods of time is considered unhealthy, 22 answered no and 11 answered yes (see Table 8). One person did not give an answer.

A	2
B	12
C	20

Table 9. Which prototype participants would prefer using.

Q9. When asked which prototype participants would prefer using, 2 answered A, 12 chose B, and 20 responded C (see Table 9).

Q10. At the end of the questionnaire participants were asked if they had any other comments or opinions about DoubleType.

Some participants criticized the large size of the bracelets. Participant 1 wrote "The bands are quite big to be worn on wrists". Participant 11 wrote "For me, as a person with tiny wrists (circumfrance 13,4/14 cm), I fear a device like this would not fit". Participant 12 wrote "the current prototype looks uncomfortably wide for smaller hands/arms". Participant 17 wrote "I do not believe DoubleType would offer me any benefit personally, since it seems less convenient than typing on a laptop (the screen is very small too, and that option does not help with ergonomy) and I would still have to carry my phone with me for my other mobile activities like games, photography and calling". Participant 27 wrote "DoubleType would be pretty inconvenient; it looks too big for me to be able to take it with me everywhere like a phone".

Some people told they would rather use a desktop or laptop computer if there is a need to type longer texts. Participant 7 wrote "Right now I can't think of a situation where a phone wouldn't be more convenient and a laptop faster to type on". Participant 8 wrote "If I need to write a text longer than a few sentences, I tend to avoid doing so with my phone and use a computer with a proper keyboard instead".

Some people do not like touchscreens as a medium to type text. Participant 20 wrote "For me, any kind of touch-screen keyboards are uncomfortable to use compared to regular keyboards where you actually push the keys". Participant 8 wrote "Even the cheapest and worst kind of physical keyboards are by far faster, more accurate, more comfortable and in all ways preferrable to typing on any kind of a touchscreen".

Some people noted that typing with one hand is slower. Participant 19 wrote "I can't find typing with only one hand to be any faster than typing with both my thumbs on my phone". Participant 25 wrote "Imo the A type would make typing slower because you could only use one hand".

People in general do not seem to write long texts with their phones. Participant 22 wrote "usually I do not write long texts with phone". Participant 27 wrote "I usually make quick notes on my phone when I'm on the move and need to write something down before I forget it".

One was worried about the bracelets limiting the wrist movements. Participant 7 wrote "there would have to be a lot of care put in for the bracelets to not limit arm movement and feel cumbersome or uncomfortable".

One person didn't like the idea of removing bracelets from the wrists before typing text. Participant 18 wrote "I'd like to use DoubleType in a way where one doesn't need to take the bracelets off".

Someone misses the physical keypads that were used on mobile phones. Participant 6 wrote "just bring back buttons on phones".

Someone criticized the idea of DoubleType being more comfortable to type text because of a larger display area. Participant 20 wrote "The level of comfort in typing on a mobile device ultimately has little to do with the size of the keyboard and screen, I find".

Someone (participant 12) suggested the bracelets should come in a variety of widths for different sized people.

Participants also gave new ideas I had not thought of. Participant 18's suggestion reminds me of the foldable smartwatch prototype I have seen on the Web [Kapale 2019]: "I'd like to use DoubleType in a way where one doesn't need to take the bracelets off. E.g. so that the keyboard bracelet would be wide open on my arm and the screen bracelet would be around the same arm". Participant 25 suggested that instead of carrying two bracelets, one bracelet could function like a Bluetooth keyboard and connect to a phone, which shows the text being edited. Participant 5 suggested carrying a keyboard at the back of the phone: "How about making qwerty (or close enough) sized version which could be attached into the back of the phone with magnet/popsocket etc. so that it could easily be taken into action when required".

The relation of participants' hand posture and concept preference was investigated (see tables 10–13).

A	1
B	7
C	11

Table 10. Hold the phone with both hands and type with one's thumbs: concept preference.

People who hold the phone with both hands and type with their thumbs voted 1 for A, 7 for B and 11 for C (see table 10).

A	0
B	1
C	1

Table 11. Hold the phone with one hand and type with the same hand using one finger: concept preference.

People who hold the phone with one hand and type with the same hand using one finger voted 0 for A, 1 for B and 1 for C (see table 11).

A	1
B	4
C	4

Table 12. Use one finger to input text and hold the phone with the other hand: concept preference.

People who use one finger to input text and hold the phone with the other hand voted 1 for A, 4 for B and 4 for C (see table 12).

A	0
B	0
C	4

Table 13. Open answer regarding hand posture: concept preference.

People who gave an open answer regarding hand posture voted 0 for A, 0 for B and 4 for C (see table 13).

3.9 Discussion

I was suprised how well the participants answered the questions. None of the questions were obligatory, so more people could have ignored questions that felt too difficult or laborious. Questions with ready-given options (questions 1–9) were all answered, except one question by one person. Participant 2 did not answer question 8, which might have been by mistake. 14 people gave answers to question 10, so not everyone wanted to give additional insights of their thoughts about the concepts.

I did not record how many people clicked the link and watched the video, so I do not have data on how many people watched the video. Microsoft Forms does not give information about link clicks. At the time of writing this (April 30th, 2022), the video has received 43 views according to YouTube (video was uploaded to YouTube on September 16th, 2021 and the questionnaire was published on September 30th, 2021). Approximately three of the views are from me as I tested the video on a phone, a tablet and a desktop computer to see how it looks like on different devices. I have not advertised the video to anyone outside this research and the video has not been defined as public on YouTube.

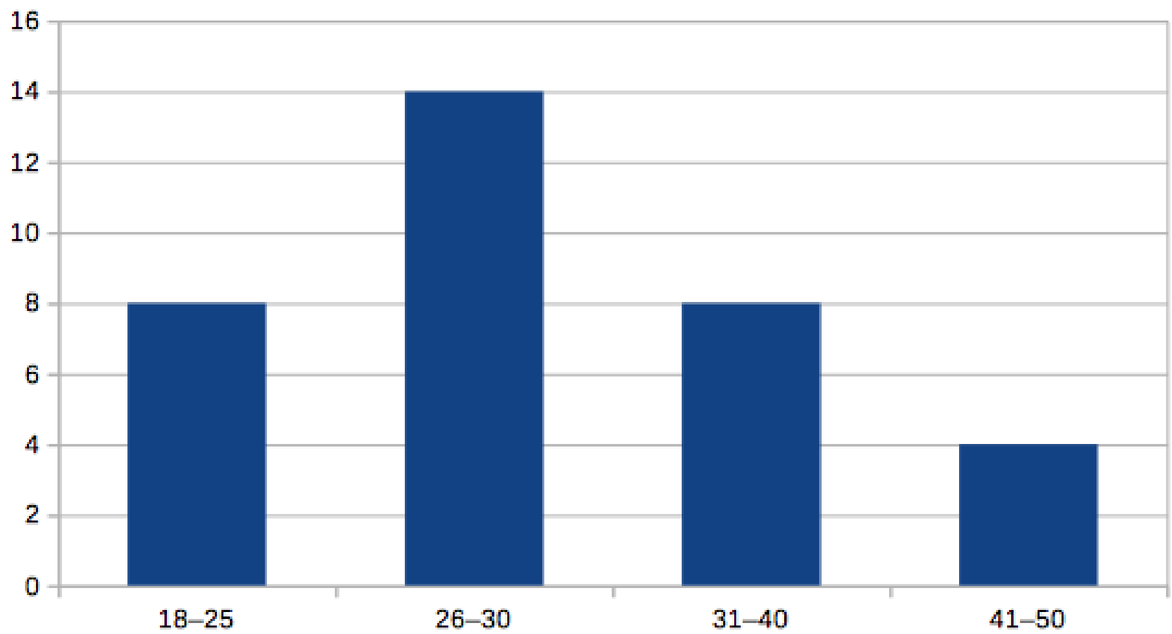

Figure 4. Age distribution of the participants.

Question 1 of the questionnaire inquiried the age range of the participants (see Figure 4). Most of the people (22) were in the age range 18–30 years old and the rest (12) were in the age range 31–50 years old. No-one was older than 50 years old.

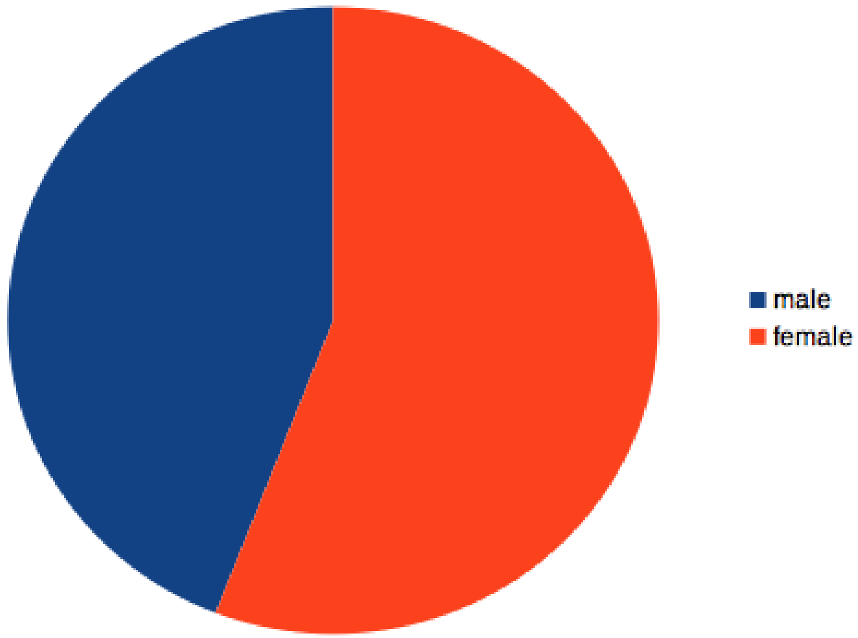

Figure 5. Gender of the participants.

Question 2 asked about sex of the participants (see Figure 5). More than half (19) were female and less than half (15) were male.

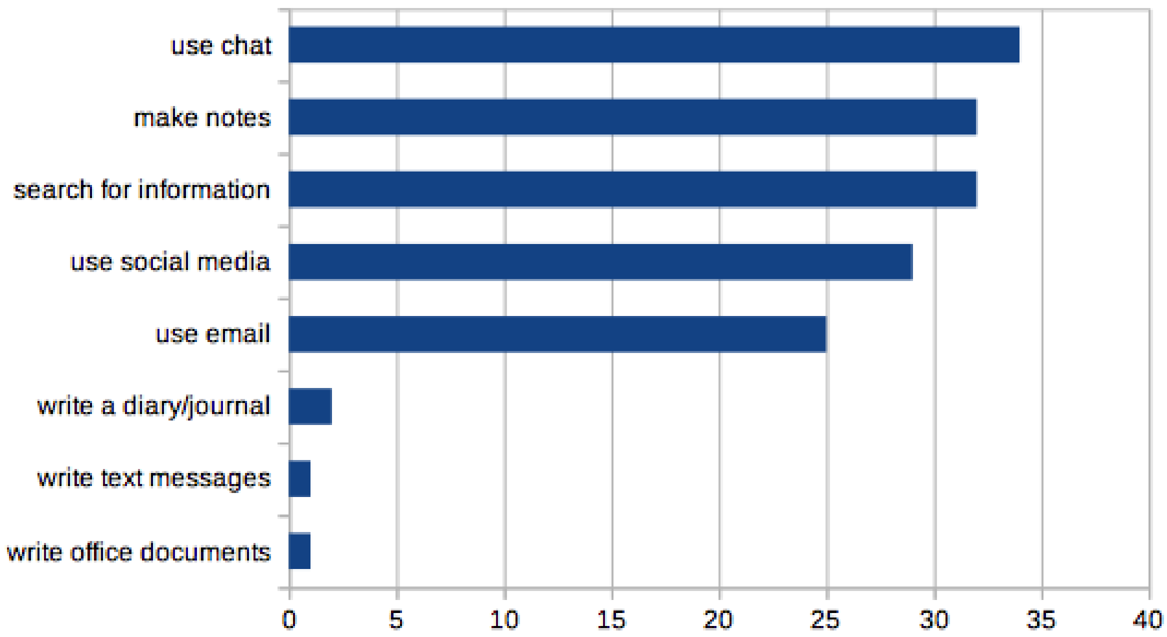

Figure 6. Actions performed on phone when typing text.

Question 3 asked about application categories regarding text entry (see Figure 6). All (34) people use chat and most people use notes (32) and search for information (32). Many people use social media (29) and email (25). These results conform with [Ceci 2021] and [Buschek *et al.* 2018].

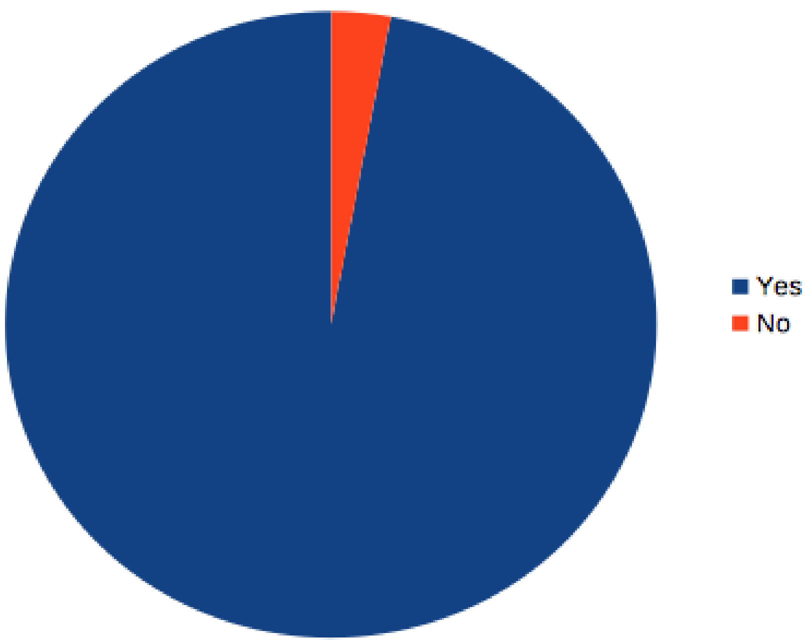

Figure 7. Is participant's phone big enough for typing text.

Question 4 asked does the participant's current phone have a big enough screen for typing text (see Figure 7). Almost everyone (33) answered yes and one answered no.

This question could have been more exact and query does the participant's current phone have a big enough screen for typing text for a longer period of time and/or does the user make too many mistakes while typing text with one's fingers on the touchscreen, because the keys of the software keyboard are too small for the fingers. It is possible that people have so much experience with smartphones already they know how to buy big enough phones. Or it is possible people are used to making more mistakes when typing with a phone instead of using a desktop computer.

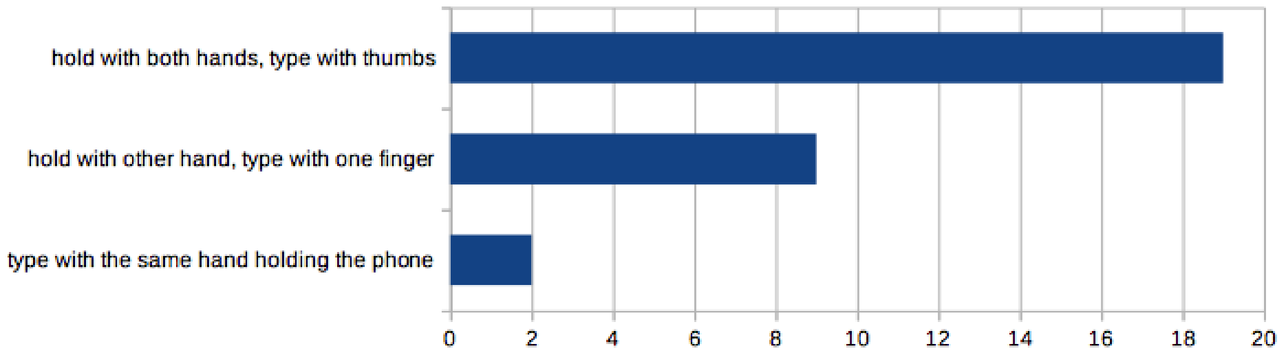

Figure 8. Hand posture while typing text.

Question 5 asked about the hand posture when using one's phone (see Figure 8). Most people (19) hold the phone with both hands and type with one's thumbs. Some people (9) use one finger to input text and hold the phone with the one's hand. It was also mentioned by some of the participants that the hand posture varies. This does not contradict with [Buschek *et al.* 2018] or [Gold *et al.* 2012].

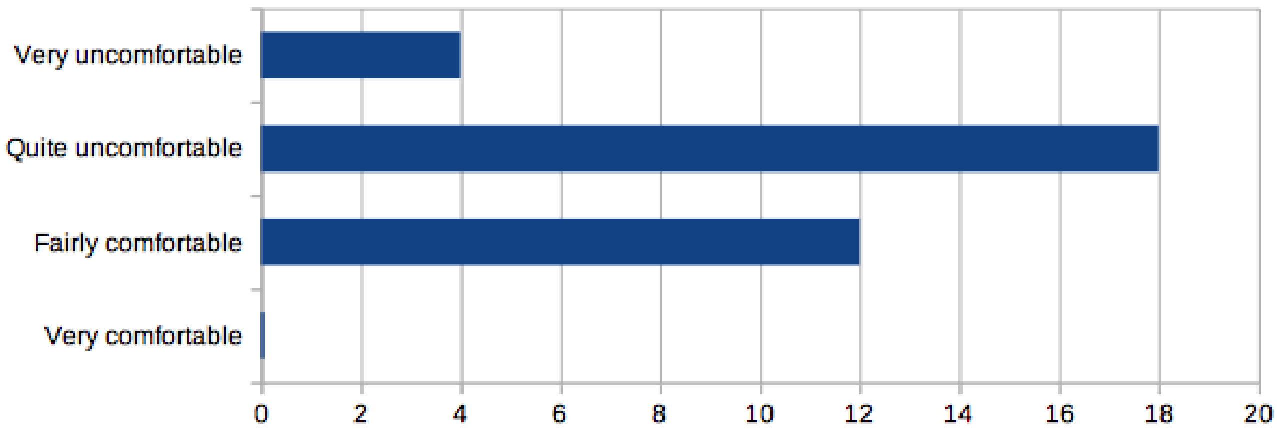

Figure 9. Perceived comfortability of DoubleType.

Question 6 asked how comfortable the participants think DoubleType is for typing text (see Figure 9). More than half (18) answered "Quite uncomfortable" and about 35 % (18) answered "Fairly comfortable". Without text entry tests with a paper prototype or a working prototype, it is difficult to say how correct the participants might be, but they could be right intuitively.

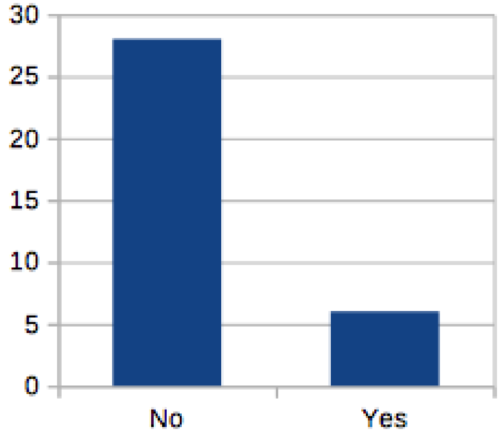

Figure 10. Will DoubleType help avoid getting neck and shoulder pains from typing text.

Question 7 asked do participants think DoubleType will help avoid getting neck and shoulder pains from typing text (see Figure 10). Most people (28) responded no. Neck and shoulder pains are difficult to predict without using a prototype for testing whether the participants could be correct. The reason for this question is that the correct ergonomical posture while typing is important. Yoon *et al.* [2021] have researched the neck's muscular load when using a smartphone. Jin *et al.* [2019] have compared biomechanical workload between smartphones and smartwatches. The consequences of incorrect ergonomical postures were not explained to the participants, which may or may not affect the answers. On the other hand, the ergonomical posture while typing with DoubleType might be incorrect as it has not been researched. There are people who use their phone for a short period of time when they need to use it and in that case ergonomics is not so important, but there could be people who use their phone even for hours each day.

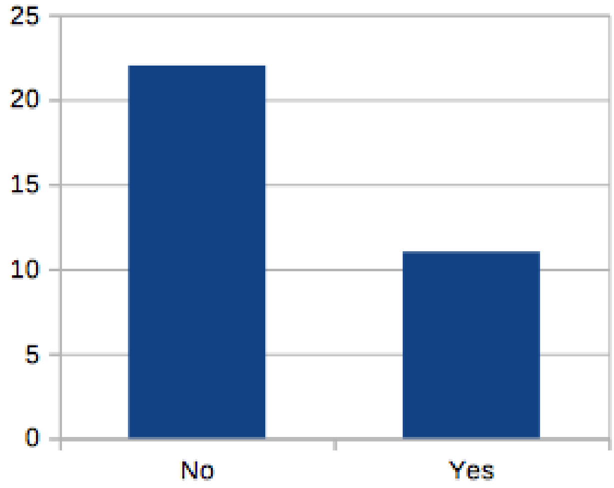

Figure 11. Would participants use DoubleType to type in a standing position for some parts of their days.

Question 8 asked would participants use DoubleType to type in a standing position for some parts of one's days, because sitting long periods of time is considered unhealthy (see Figure 11). Most people (22) answered no. Maybe standing for some parts of the day is not considered important or maybe participants would rather use a desktop computer instead while standing next to a table that is high enough for being able to stand next to it.

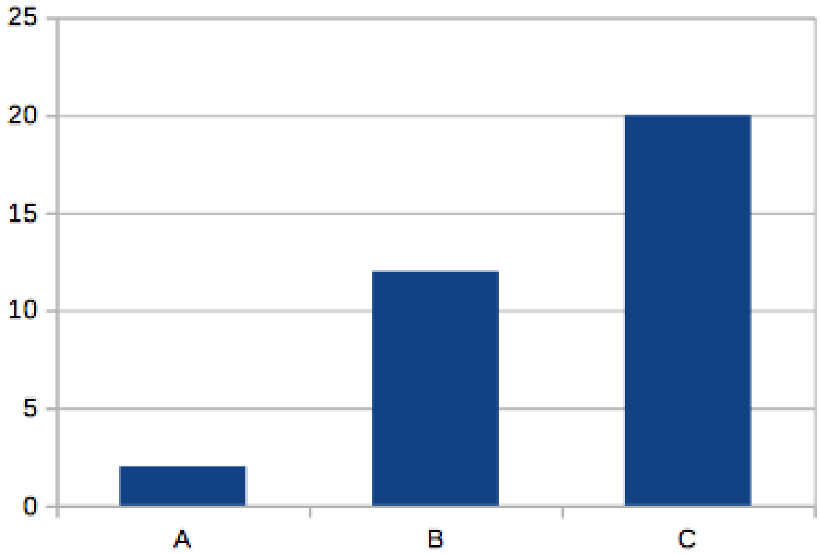

Figure 12. Which prototype participants would prefer using.

Question 9 asked which prototype participants would prefer using (see Figure 12). Most (20) answered C. The prototypes A and B might look too clumsy and therefore received the least amount of votes. Prototype C might feel more familiar as it could remind people of laptop computers.

Question 10 asked if participants had any other comments or opinions about DoubleType. DoubleType A did not receive favorable feedback in general. DoubleType C raised some interest. This open-ended question revealed new ideas I had not encountered before, such as (1) using one bracelet as a keyboard for their phone, (2) carrying a keyboard at the back of the phone, and (3) "keyboard bracelet would be wide open on my arm and the screen bracelet would be around the same arm". The size of the bracelets was not in favor of the participants

DoubleType seems to be a niche product, but it could be used in a factory by a technician making notes of procedures that have been finished. DoubleType could be used in situations where a person does not want to wear clothes that have pockets and does not carry a bag either. A beach would be one place for that kind of situation, but the wrists would not get sun unless the bracelets were removed from the wrists while taking sun.

4 Conclusions

This research introduced a novel concept DoubleType for wearable text entry to make it more comfortable to write text with a wearable device and aimed to find out people's views of the concept. Paper prototypes, a video prototype and an online questionnaire were used to assess people's opinions.

The concept was not seen as a comfortable system for text entry. Of the three concepts, participants favored the most concept C, where the concept is put on a table. From the open-ended questions it was revealed participants disliked the size of the bracelets. Also, people like to write longer texts using a desktop computer.

DoubleType does not seem to be of interest to people in general, but maybe it could be used in factories where the large size of the bracelets does not matter esthetically as long as text entry is easier than with normal-sized phones or small smartwatches. Another possible use for DoubleType could be situations where a person does not want to wear clothes with pockets and does not carry a bag either, such as taking sun on a beach. Avoiding sitting for a long period of time is a third situation that comes to mind where a user can stand up and type text while standing. Future research with working prototypes is needed to find out how ergonomic and efficient DoubleType is for text entry.

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6 Appendices

6.1 Appendix 1 - Questionnaire

Introduction to the questionnaire

Thank you for participating in this questionnaire and helping me with my Master's thesis. In my study I am researching how to make it possible to type longer and more comfortably with mobile devices, such as phones, tablets and bracelets. I will ask five background questions and then present my novel concept, DoubleType, which is a system of two bracelets. After that, I will ask your opinions about the DoubleType.

Duration

Filling this questionnaire will take approximately 5–10 minutes.

Participant rights

Your answers will be recorded anonymously. Participation is voluntary and there is no monetary compensation for participating.

Background

How old are you?
() under 18
() 18–25
() 26–30
() 31–40
() 41–50
() 51–60
() over 60

What is your gender?
[] male [] female [] other

When using a phone, which of these actions do you perform when typing text:
[] use email

[] use social media
[] use chat
[] make notes
[] write office documents
[] search for information
[] write a diary/journal
[] other, specify: ____

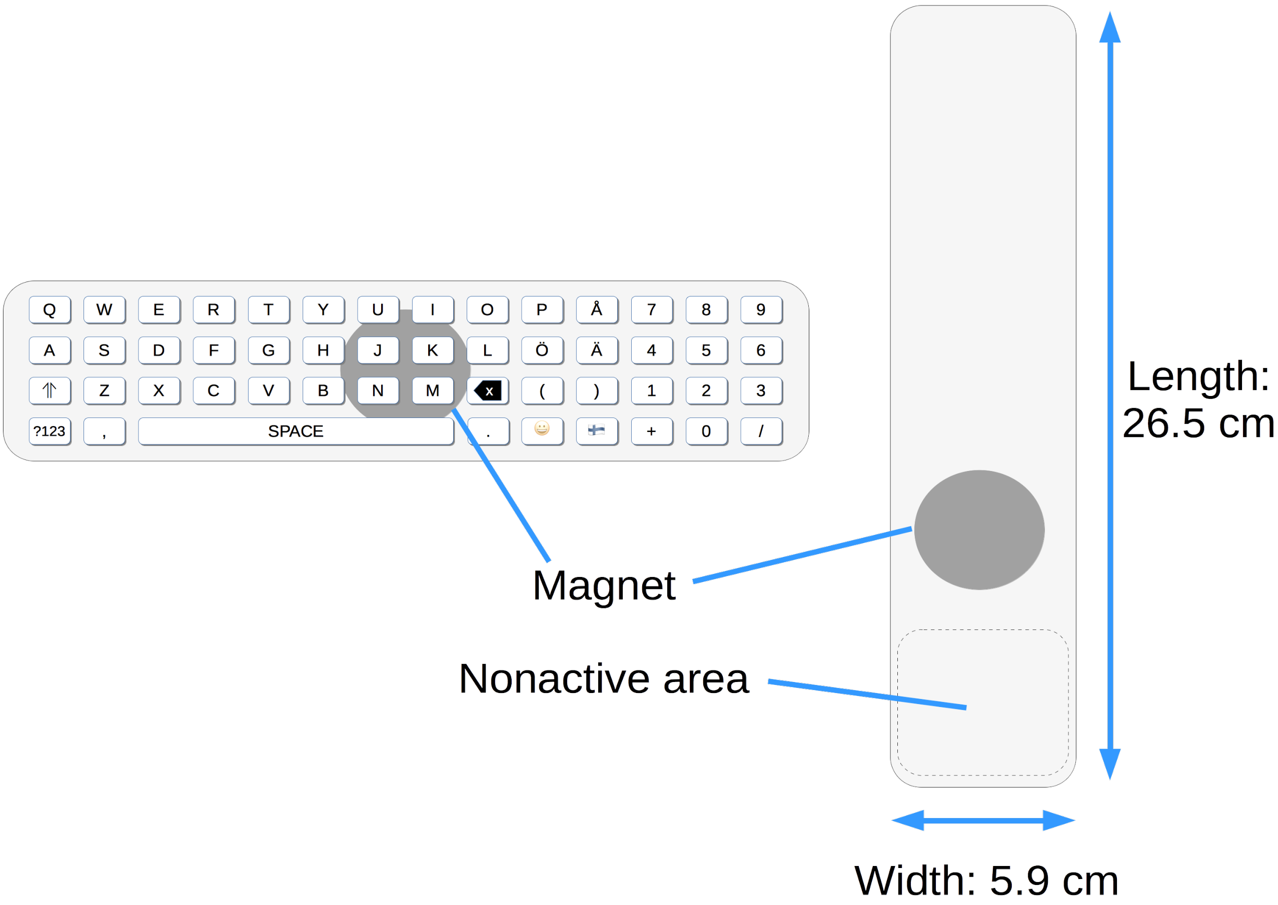
Does your current phone have a big enough screen for typing text?
() Yes () No

How do you type text with your phone?
() use one finger to input text and hold the phone with the other hand
() hold the phone with one hand and type with the same hand using one finger
() hold the phone with both hands and type with your thumbs
() other, specify:
____
____

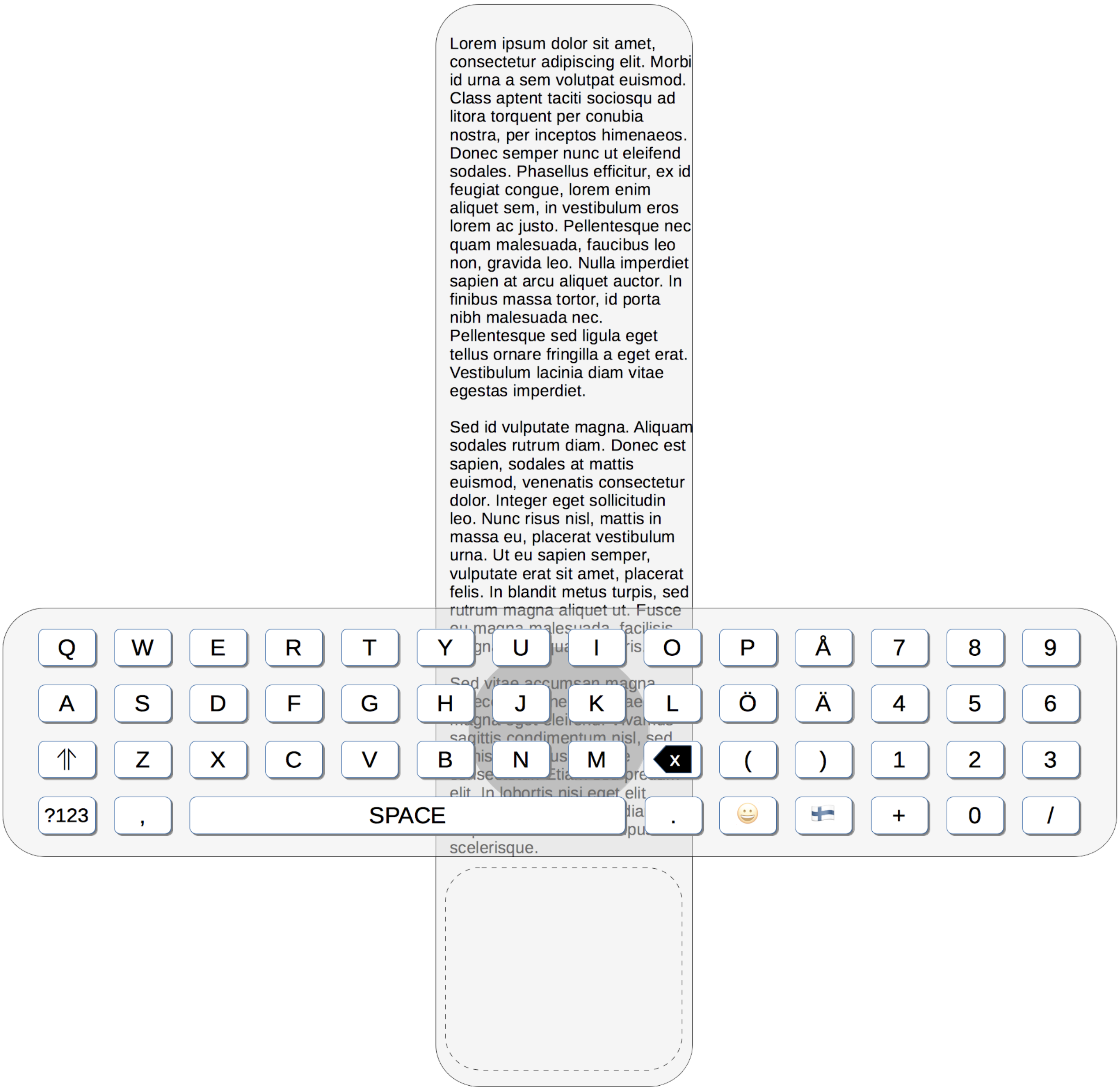
DoubleType

The following two pictures depict DoubleType – a double bracelet system for helping with longer typing sessions when using a mobile device.

The two bracelets can be connected to each other with magnets, shown on the below picture as gray circles. Left bracelet ("Keyboard Bracelet") shows a virtual keyboard for typing text. Right bracelet ("Display Bracelet") shows the text that has been typed. On the "Display Bracelet" there is a nonactive area that can be held with one hand without interacting with the touch screen. You can also see the measurements of the bracelets on the picture.



On the second picture, the two bracelets have been connected to each other using their magnets. The bracelets are partially transparent, so that the user can see the text he/she is writing through the virtual keyboard.



Paper prototype

Paper prototypes are used in human–technology interaction to design and test user interfaces. The following two photographs present the paper prototypes for DoubleType.

On the first photograph, you can see the bracelets on wrists.

On the second photograph, the bracelets have been combined to form a display and a keyboard. You can hold the combined bracelets with one hand and use the other hand to type text using the virtual keyboard.

Video

You can also watch a two minute video (https://www.youtube.com/watch?v=rzkI4rz_FNU) demonstrating the paper prototype of the DoubleType, but it is not necessary to be able to answer the questions. The video shows the prototype on wrists and then on a table. You will also see the prototype's size compared to every day items and a laptop computer. At the end of the video, you will see two other configurations of the prototype.

Questions

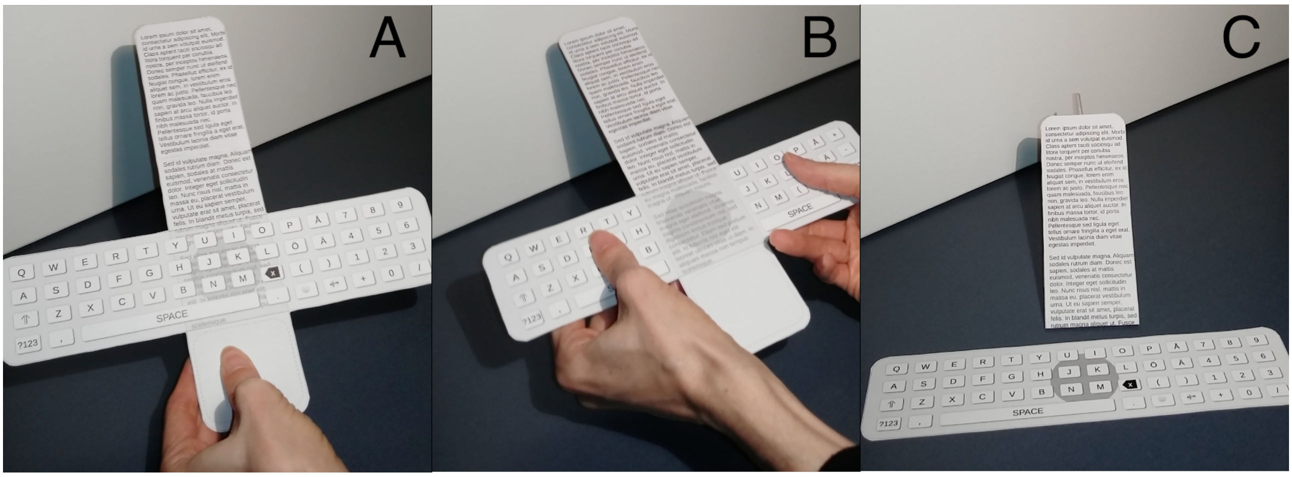
How comfortable do you think DoubleType is for typing text?
() Very uncomfortable

() Quite uncomfortable
() Fairly comfortable
() Very comfortable

Do you think DoubleType will help avoid getting neck and shoulder pains from typing text?
() Yes
() No

Sitting long periods of time is considered unhealthy. Would you use DoubleType to type in a standing position for some parts of your days?
() Yes
() No

I have designed three different prototypes shown below. You have seen the first prototype, which is for one-finger typing (A). The second prototype is for two-thumb typing (B) and the third setup is for typing on top of a table (C).



Which of these prototypes would you prefer using?
() A
() B
() C

Do you have any comments or opinions about DoubleType you would like to share?

Thank you!

Thank you for your answers. They help me to understand the user's point of view better. If you have any questions regarding this questionnaire, you can email me at tomi.hasa@tuni.fi.