Designing and Prototyping a Glanceable wearable

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ABSTRACT

Wearable devices promise to be one of the next leading technologies, however they still struggle to emerge from the research laboratories. Perhaps it would be interesting to explore new ways to look at these kind of devices: aim of this paper is to discuss a new design space for wearable devices where they are not useful only to the wearer but also to an occasional glancer. The design space has been obtained through two field studies which gave an understanding of what kind of information should be conveyed in a wearable device and how it should be displayed. Finally it is also presented a possible implementation of those concepts through the developing of a prototype.

INTRODUCTION

The idea of wearable computers is certainly not new as demonstrated by the calculator watch produced by Casio [7] in the seventies. However, even if almost 30 years have passed, the technology cannot be considered mature nor pervasive, especially in the public market: if during the last years we have seen shy attempts to launch wearable devices, such as smart-watches or the much more promising Google Glass, it seems that the technology still struggles to emerge from the research laboratories.

The main aim of wearable devices has usually been improving human performance but during the last few years there has been a shift and the improvement of awareness of context is now considered crucial too. It has to be noted that in both cases all the benefits are developed around the wearer: for example a smart watch allows the wearer to read text messages, e-mails or to browse the internet without using his mobile phone, but clearly all these features are reasonably useful only to him. Therefore some researches focused their attention around benefits for someone who is not the wearer, and several examples come from the sport world. Chi et al. developed a wireless force sensing body protector for martial arts which supports the judges in scoring the sparring matches [3]. Again Bachlin et al. introduced a wearable assistant for swimmers, composed by acceleration sensors with microcontrollers and feedback interface modules, which allows to constantly monitor crucial parameters that can be used for a swimmer performance evaluation [1]. Finally very little attention has been paid to a third perspective, which considers both aspects mentioned so far: developing wearable devices which can be helpful for the wearer but also others in close proximity.

Therefore the purpose of this paper is to explore the possibility that information displayed by the wearer's device can be successful exploited by the owner himself but also by a casual observer. I will present two studies: the first study will help to understand what kind of information conveyed by a wearable device can be useful both to the wearer and to an occasional observer; the second study will help understand in which way we can convey that information in a wearable device such as a smart-watch. Then, using the information retrieved from both studies I will develop some concepts and guidelines which will be applied to the developing of a prototype. Finally, I will highlight strengths and limitations of the presented prototype by the comparison with other existing wearable devices.

RELATED WORK

A very promising study in this direction has been made by Pearson et al. [8]. The main aim of their research was to introduce a new way of looking at mobile devices, where displays become public spaces, beneficial not only to the wearer but also to a occasional observer: the *glancer*. The first part of their research focused on the possible impact of wearing devices on the social interaction: in particular they wanted to make sure that it was socially acceptable for a casual observer to glance at someone else wearing device. Using results from the performed studies Pearson et al. built a design space which allowed them to construct a prototype, which was then tested by the researchers themselves during different situations and in different environments. One of the tested feature of the smart watch was, for example, to display a meeting reminder when the meeting was getting closer: the glancer's reaction to the reminder was very interesting since he has proven to be proactive in the sense that it was not necessary for the wearer to ask to finish their meeting, as the observer was already aware that their time together was running out. Overall results showed that the development of a wearable device that is useful both to the wearer and to the occasional glancer not only is possible but is also highly beneficial. These results are very important because they introduce a new doable path in a era where the presence of wearable devices is sharply increasing.

STUDY 1

The goal of the study 1 is to understand *what* kind of information could be interesting for a casual observer to glance[1]. To achieve the goal I spent three days taking note of all the

[1] In my study I am mainly concerned about glances rather than long observations. This is justified by the fact the hardware of mobile devices is usually characterized by small size and small display, so that the available information must be catchable in a short time.

occasions where I looked at someone else's *resource* in order to get any kind of information which could be beneficial to me. With the term resource I do not necessarily mean a piece of technology like a tablet, a notebook or a phone: a resource can in fact be a newspaper, a shopping bag, an ID badge, or any artefact that allows a glancer to derive a useful clue. For example during one of my observation I was at the bus station waiting for the bus, and to figure out if I was waiting on the right lane I glanced at a passenger's ticket trying to see his destination: in that case the passenger's ticket can be considered as a resource. During the three days of observations I did not change any particular habit, except of course, I jotted down every time I performed an observation which took place in different environments such as university, bus station, restaurant and a library. Using a diary I kept track of the following information: date and time, location, context, observed resource, observed person identity, resource distance, glance duration time, acquired information and glancing reason, plus a section for additional notes[2]. Because at this phase I was interest in what kind of information a glancer can catch, rather than how, I did not take note about the resource visibility. Moreover, since the resource has be defined as something that does not have to be a wearable device, information about visibility would have been useless.

Results

Over a period of three days 10 different observations were captured. The limited amount of retrieved data is justified by the fact that I have been the only observer. Moreover in several occasions I observed the same situation more than once: for example it has happened more than once that I glanced at someone else laptop screen just to catch the time. However since during this phase I was interested in understanding what kind of information could be interesting to a glancer, taking note of the same information more than once would not have added any value to the experiment's results.

The observations highlighted some important key aspects. Firstly, regarding the acquired *information ownership* we can distinguish between two possibilities: when the information is public and when the information belongs to the person who is holding the resource, so it is private. Secondly, in terms of *who is benefiting* for the acquired information, we can again discern between two cases: benefits can be for the wearer, for the glancer or for both of them. Thirdly we can notice that observations took places in two different *environments*: public places or private places. Finally a last important distinction can be observed in terms of *relationship* between the glancer and the wearer: in fact they can be stranger or not, such as friends or relatives. Results are summarized in the table at the end of the paragraph.

According to the collected data it has happened more frequently that I looked at someone else resource to retrieve private rather then public information (only 20% of total cases) and in most of cases the information was useful only to me (80% of total cases). Finally all the observations took place only in a public place (but it has to be noted that I live alone) and it has happened more frequently that I looked at stranger's resources (80% of total cases).

[2] For a detailed explanation of each field look at Appendix A

Information ownership	
Public	The information does not belong to the wearer, e.g. time, date, weather.
Private	The information belongs to the wearer, e.g. incoming calls, name, nationality.

Final beneficiary	
Wearer	The acquired information is beneficial only to the wearer, e.g. the wearer got notified by a friend that his phone has got a notification.
Glancer	The acquired information is beneficial only to the glancer, e.g. The glancer looks at someone else phone to catch the language to figure out if he can speak to him in another language.

Environment of observation	
Public place	The glance can take place in public places, e.g. restaurant, bus station, pubs, university.
Private place	The glance can take place in private places, e.g. home, private office.

Glancer/Wearer relationship	
Stanger	Glancer and wearer can be complete strangers, e.g. bus passengers, other students, waitresses.
Well-known	Glancer and wearer can be in a close relationship, e.g. friends, parents, partners.

Conclusion

Results from the observation suggest some interesting correlations.

Firstly, while when we look at stranger's devices to get information which is beneficial for ourselves, when we look at our friends' devices it seems to be for their own interest. For example, during my observation I looked at friends' resources only twice. The first time I wanted to warn him that someone was calling him because he had not noticed that his mobile phone was flashing. The second time I wanted to ask a friend something but because he was working with his laptop and I did not want to interrupt him in a critical moment, I glanced at his monitor to understand if he was doing something important or not. However something similar happened also with strangers: I was at the library and besides me and a friend there were only two other people; at some point I needed to talk to my friend but because it was a silent area I looked at the other students' monitor to understand if they were actually studying or not, so that I knew that I could chat with my friend without disturbing too much. These observation seems to point out that an important key aspect which should be considered when designing a wearable devices, is the status of the wearer.

Secondly, the fact we are more interested in glancing at strangers' resources rather than friends' ones could be related to the level of closeness and familiarity. For example during my observations I looked at a stranger's phone while he was playing a game to look at his best score, but I would have probably just asked the information to a friend without look-

ing at his phone. Or, as mentioned before, while waiting at the bus station I looked at a stranger's ticket to figure out if I was in the right place but I would have definitely asked if he was a friend. This attitude does not seem to be related to the ownership of the information, if fact it is easy to see that we would usually prefer to just glance at a stranger's watch to catch the time while we would easily ask for that information if with a friend. Getting clues from the environment seems to be a good way to retrieve useful information avoiding social interactions and in these term it would be interesting asking ourself if these technology would make us more antisocial. If it would be definitely useful to implement some functionalities to help a glancer to retrieve beneficial information (such as the time) it would be even more interesting to think about other functionalities which could improve the environment level of socialization.
Finally it has to noted that during the experiment I only took note of occasion where I looked at someone else resource pushed by a reason: however it could be interesting to explore another path, that is trying to understand how those devices could get the glancer's attention and why.

A space design for information	
Status information	The glancer is mainly interested in the wearer activity, e.g. the wearer is busy and he cannot be interrupted, he is going to be busy soon.
Casual information	The glancer is not specifically interested in the wearer and he simply treats him as a source of clues, e.g. the time.
Information for socialization	The wearer's displayed information can be used to improve the environment level of socialization, e.g. showing the last score of a played game, showing a played song.
Information to get the glancer attention	The wearer does not look at someone else's device pushed for reason but his attention is captured instead, e.g. advertisement.

STUDY 2

The main aim of study 2 was understanding *how* the information displayed by a wearable device can be caught by a glancer. Because, as mentioned before, wearable devices are still not pervasively diffused it would have been difficult to perform a study without a real device to observe. For this reason I decided to focus the study on observation of watches: in fact information retrieved with these kind of observations can be easily applied to the design of a wearable device as a smart watch. Furthermore, especially from the point of view of the wearer, the wrist seems to be the best point in terms of visibility, as pointed out by the work of Harrison et al. who performed an experiment to calculate reaction time and performance of visual alerts from tip to toe [4]. My observation lasted two days, during which I jotted down all situations where it was possible to glance at someone else watch. As for the study 1 the observation took places in different environments such as restaurants, pubs, library, university and bus station and in order to keep track of the observation a capture method has been set up. During this phase, because we already have clarified what kind of information could be useful for a glancer, I wanted to look deeply only on the way the information can be retrieved. For this reason the capture method only needed to keep track of the following information: date and time, location, context, observed person identity, watch distance, watch surface visibility, glance duration time, watch time visibility, plus a section for additional notes[3].

The data capture method

As capture method the native Android's voice recorder application has been chosen.
The decision of using a phone rather than other methods, such as the paper diary of the study 1, is justified by the fact that observations needed to be fast and frequent and the diary has proven to be lacking in those characteristics. Moreover, while we almost always have our mobile phone with us, we cannot say the same for pen and paper. Finally, in several circumstances, finding the right place to write on a diary could be challenging. Among all the free applications available on the phone the voice recorder seemed to be the most straightforward: as soon as a fact was observed it was possible to record it just touching an icon. Moreover speaking is definitively faster than other input methods such as typing, especially with a mobile phone. Finally, using the voice note application, some of the required information such as data and time are immediately available, since the application store those information by default.
However the chosen capture method did not come without any disadvantages. First of all, it was not always possible to speak: this meant that sometime I had to move to another location to record the vocal note or alternatively I had to keep the observation in mind until I changed location; unfortunately, it occasionally happened that during that time I forgot some information so that the recording was less precise and reliable. Another problem was related to the quantity of information I wanted to take note: it has happened a couple of times that during the recording I forgot to mention some important information, with the result that I had to discard the observation. Also if at a certain point I realized that there was an error in the recorded note it was not possible to change it: in the best case I could only take a new vocal note to take record of the error. Finally, even if the method was very fast in terms of recording time (as mentioned the phone was always close to me, and voice recording is probably the fastest input method), once the experiment was over, the process of translating the data from the audio form to a written form has been very time consuming.

Results

The collected data allowed us to make two different important considerations. First I observed that the wearer, according to their *attitude* can be divided in two different groups: active, if they were moving their hands or passive if they were not. It

[3] For a detailed explanation of each voice look at Appendix A

has to be noted that the active or passive attitude was strictly related to their hands: for example a person can be seated, so that he is in a global passive attitude, but he can still move his hands to eat. The observation were fairly divided with a 50% of people characterized by an active attitude and the other 50% by a passive attitude.

Wearer Attitude	
Active	The wearer move his hands frequently, even if the rest of the body stays still.
Passive	The wearer hands are not moving at all, even if the rest of the body is.

The glance has been categorized according its *continuous visibility* as uninterrupted if I was able to look at the surface of the watch without any interruption, or as interrupted otherwise. Results shown that uninterrupted glances (60% of total cases) were possible only when the observation lasted for a short period of time or if the wearer was characterized by a passive attitude.

Glance duration	
Uninterrupted	The glancer can look at the wearer's resource without any interruption for a certain amount of time.
Interrupted	The glancer look at the wearer's resource for a certain amount of time but with some interruption caused by the wearer movements.

It would seem that there was no correlation between the *visibility* of the watch's surface and the wearer attitude or the glance uninterrupted categorization. During the experiment I did not consider cases where the watch was almost or completely hidden, however it could be useful to notice that it has been almost impossible to find a visible watch along the streets.

Wearer's devices visibility	
Total	The surface of the device is completely visible.
Partial	The surface of the device is partially covered, mainly by clothes of by environment causes, such as light glare.
Hidden	The surface of the device is completely covered, mainly by clothes of by environment causes, such as light glare.

Conclusions

Looking at results it appears that if we need to catch an information on the fly, it does not matter if the wearer is moving his hands or not, but if the information needs more than a glance to be understood then the wearer needs to be passive. Consequences are that during the design of a wearing device we should carefully choose which kind of information can be shown in a specific moment: in fact, knowing the limits in terms of human perception, if would be completely useless to show an information which cannot be physiologically caught. As mentioned before, watches were almost always hidden in open places: this can be easily justify by the fact that observations took place during winter, when people usually wear jackets with long sleeves. This fact has got multiple implications for the design of a wearable device. On one hand we could think of developing a device which can be interchangeably worn over or under sleeves. On the other hand we should provide mechanism to understand if the watch is hidden and in that case the watch should go in a sleeping mode, where no message is shown; the changing state between hidden and visible could be also used to infer useful information about the user. For example, if the watch goes from a hidden state to a visible state and then back to a hidden state again very quickly it could be that the wearer is just checking the time or that the sleeve movement makes the watch visible for a short period of time. However if the watch goes from a hidden state to a visible state without changing any more, it could be the sign that the user has moved from a open environment to a close environment taking out his jacket. This kind of information, conjugated with other kind of information such as the current location retrieved by the GPS, could be used to decide what kind of content should be displayed by the device.

A space design for Interaction	
Information persistence	The information should persist on the display for a reasonable amount of time according to the nature of the information itself and considering human physiological limits.
Information representation	Since the surface of the device is not always completely visible or it is but for a short period of time, the *shape* of the information should be modelled according to the situation. Fast glance, and partial covered surface need a more abstract representation such as colors or icons.
Information contextualization and timing	Inferring context information from the wearer using different sensors (GSP, accelerometers, proximity, etc) sould be used to decide what information is relevant in a certain time and when is the correct time to show it.

Imagine the following example: it is raining and the wearer device goes, as mentioned, from a hidden state to a visible state (supposing that the wearer moved from a open to a close location) while the GPS reveal he is actually close to his office. It would be the perfect moment for the watch to display the next appointment for the day, maybe followed by a sound to get his attention if the accelerometer notices that his arm is along his leg. On the other hand, exactly because his arm is along his leg it would also be the perfect moment to show the weather information so that a glancer, who is in a close environment and maybe he does not have visibility to windows, could benefit of the information.

PROPOSING A PROTOTYPE FOR A NEW WEARABLE DEVICES

Considerations from study 1 suggested *what* information is considered interested for a glancer, whereas consideration from study 2 helped to understand *how* and *when* that information should be conveyed in a wearable device and then displayed. In the following section I will use the knowledge acquired so far to derive some design concepts and considerations that should be applied to the space design for a prototype.

Information space design

The information space design answers to the following question: *what kind of information should we display in the wearable devices?*. In the following paragraphs it will be proposed a possible answer.

Status information

Status information belongs to the wearer, so they are characterized by a private ownership, and they answer to questions as *What is the wearer doing?* or *What is the wearer going to do?*. Can be considered as status informations those relative to the device status too, and in this case they answer to questions such as *Is the wearer's phone ringing?* or *Does the wearer's phone have any active notifications?*. Status information are beneficial to the wearer: they work as a reminder but they can also help him to manage social interaction with people around him. The typical situation would be: the wearer has got a meeting in 5 minutes, so that he needs to dismiss the person who is with him at the moment; if that person can glance at the notification on the wearer's devices, he will probably dismiss without being asked. In this prospective information are also beneficial to the glancer, who can better understand the wearer status avoiding, for example, to interrupt him if busy.

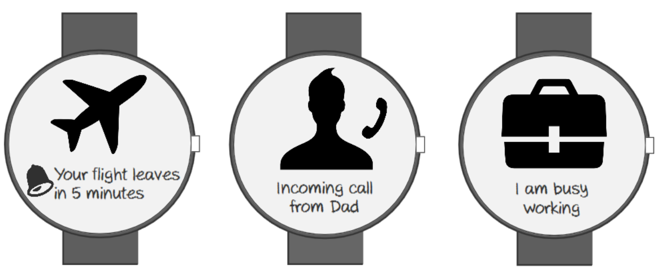


Figure 1. Example of status information.

Casual information

Casual information can belong to the wearer or they can be public, and they answer to generic questions such as *What is the wearer name?*, *What is the default language of the wearer's device?*, *What time is it?*, *How is the weather?*. Those information can be useful to the wearer, but they can be even more beneficial to the glancer: as mentioned before in this case the wearer is barely treated as a source of environmental clues that can be used by a glancer for achieve his purpose. A typical example would be the glancer looking at the wearer's device to catch the time.

Figure 2. Example of casual information.

Information for socialization

We have seen that the casual information can push people to a misanthropic behaviour, that is they tend to use glancing to retrieve information completely avoiding a direct interaction. To balance this negative effect it could be interesting to introduce information which can stimulate socialization. Those information could highlight common interested point between people offering a clue to start a social interaction. They could answer to questions toward the wearer character such as *What is the wearer favourite sport?*, *What game the wearer is playing?* but they could be of generic interest such as *What is going on in the world right now?*, *Is the bus late?*. Information for socialization can be clearly characterized by both a public and a private ownership.

Figure 3. Example of information for socialization.

Information to get the glancer's attention

As mention before usually the glancer has got a proactive attitude and he is the one who actively looks for devices to glance in order to catch beneficial informations. However, a mechanism can be used to get his attention even when he is not actually looking for anything: the more intuitive example would be for advertising. Clearly in this case the information ownership is public.

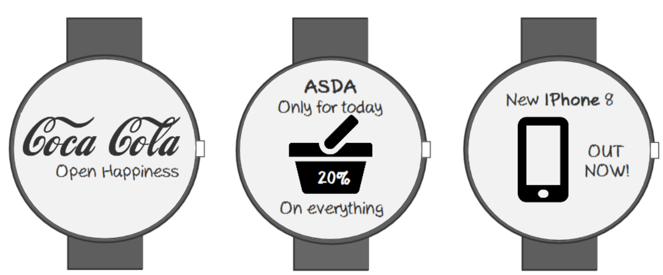


Figure 4. Example of attention information.

Interaction space design

The interaction space design answer to the following question: *How should we convey the information in a wearable design? When should the information be displayed?*. In the following paragraphs it will be propose a possible answer.

Information persistence

Information persistence can be defined as the period of time the information should be displayed on the device's surface. As mentioned before persistence should be strictly related to the user attitude: if active, that is the wearer moves his hands frequently, it should persist longer to give a glancer a real possibility to catch the information. Persistence could be defined as short, medium and long.

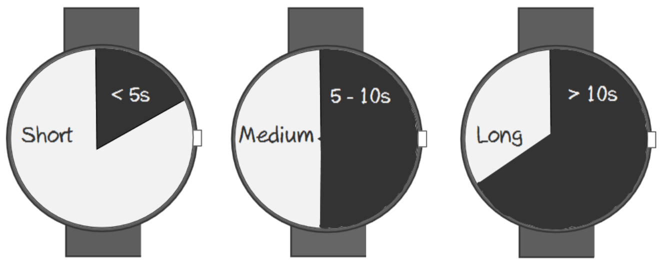


Figure 5. Three type of persistence.

Information representation

Another way to help the user to catch a information quickly is to use a more abstract representation: the representation is therefore the shape we choose to display the information. We also have to be aware that the limited size of a wearer's device actually dictate an impossibility to offer too many details. On the other hand we have to be careful because if the representation is too abstract the glancer could be unable to figure out the meaning of the displayed information. Representation can be defined as abstract, sketched and detailed.

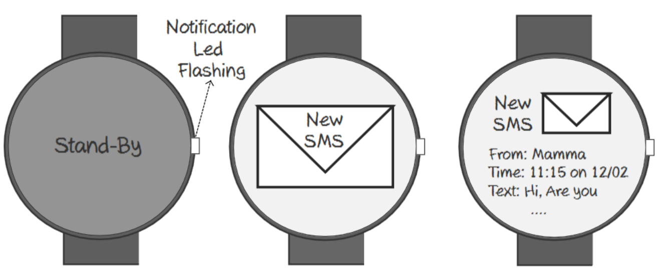


Figure 6. Three types of representation.

Information timing and context

Finally it is important to show information in the right context and the right time. As mentioned before sensors and other information should be used to infer context conditions: for example if the wearer is already attending a meeting it would be useless to show him a reminder, or even more obvious if the device surface is hidden there is not point in showing any message at all.

Figure 7. Example of information showed considering both time and context.

Physical Limitation

When using wearable mobile devices we have to face some serious limitations such as limited screen size (but more in general limited size), power consumption, battery life and limited processing power. From the interaction design point of view the limited screen size seems the one which can affect the interaction the most. This is why several studies focus their attention in new paradigms of interaction: if usually the interaction still happens using physical buttons and touch screens but this is definitely not the only possible way. For example Knibbed et. al developed a wrist watch prototype which support bimanual gestures on the side of the device, by using a combination of infrared proximity sensors and ultrasound sensors positioned underneath the watch [6]. The idea of using the skin as a possible extension surface for interaction was used also by Harrison et al. in their *Skyinput*, a technology that using the human body to transmit acoustic information allow the skin to be used as input surface [5]. As said the limited size of the screen is not the only limit. We have seen, for example, the importance of using sensors to get contextual data to show the user the right information at the right moment: however, the limited dimension of the device does not allow to include a high number of sensors and even if it would be possible, a massive use of sensors would affect negatively on power consumption.

Building a prototype.

In figure 8 are illustrated main characteristics of the device.

Input methods

Because as said dimensions of mobile wearable devices are very limited, input methods have to be developed taking account of those limits. The interaction happens mainly via touch screen which supports multiple gestures: swiping up, down, left, right and finger touching. All gestures can be performed with one or two fingers. There is also a led-button on the right side of the device which, besides flashing according to the active notification, can be pushed or rotated. The response to each input can change according to the application, however some gestures are considered standard. The device also has three light sensors all around the edge of the device ((figure 8g)): combination of information retrieved by those sensors are used to understand if the devices is hidden or not, but can also be used by the user to impart command to the device. Finally other sensors, such as accelerometers, are also considered as input methods: as explained below for example shaking the device allows to perform pre-set actions.

Basic interaction and default gestures
To help the user some of the gestures are considered standard. The learning curve is expected to be high since we are developing a new paradigm of interaction, that is needed by the new technology. However, once the user have learnt the basic gestures, tasks will be performed faster. Moreover quick suggestions could be suggested to the wearer especially during his first utilize to help him discovering all the hidden device functionalities.
Example of default behaviours when an application is open are: swiping up with two fingers to open the application's menu (figure 8a) and swiping down with two fingers to look at the application settings (figure 8g). When different options are entirely visible on the screen they can be touched separately (figure 8a); however when the options are too many they need to be scrolled (8b and 8c): options are designed as three dimensional, and active item are brighter so that their affordance suggest they can be scrolled.

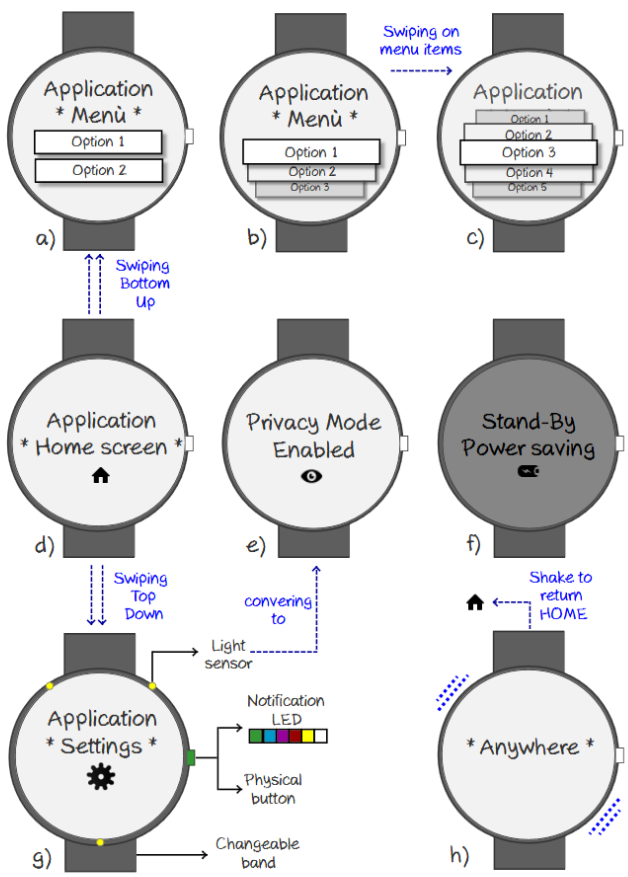


Figure 8. Main features of the device.

The led-button (figure 8g) can rotate, and as mentioned before the behaviour it is not fixed since it depends on the context: however in general it is used to increase or decrease values. For example while listening to music it can increase or decrease the music volume while reading a text message it can increase or decrease the font size.
Finally, from each point it is possible to go back to the home screen just shaking the device: obviously to avoid errors input values for each sensor need to be considered and filtered carefully.

Privacy considerations
An important consideration about privacy needs to be made. The developed device opens a new way to look at wearable devices: displayed information is not any more beneficial only to the wearer but also to an occasional glancer. However, since sensible information could be shown and it could be not convenient in certain contexts, we have to give the wearer a possibility to disable determined functionalities in a easy way. This feature is implemented by covering two crossed light sensors, in fact as soon as the wearer do it the devices goes to a privacy mode (figure 8e).

Hidden state and power consumption
All device's sensors are used to figure out when the device is not used and should therefore put in a sleeping mode (figure 8f). This happens for example when the wearer is wearing a jacket or more in general clothes which hide the devices. We have in fact to remember that the power consumption is a critical factor for a mobile device. However. sometimes the wearer could have the need to keep the device active: it is possible by wearing it over clothes and for this purpose the watch comes with a changeable band (figure 8g) that allow to wear it even over clothes.

Example of usage
In the following images are shown some examples of usage of the developed prototype. In figure 9 is detailed a possible work-flow for a memo application: swiping up it is possible to look at the application menu while swiping down to the application settings[4].

Figure 9. Possible work-flow for a memo application.

The developed prototype offers multimedia characteristics: for example to show that the application is emitting a sound, which is external to the device itself, some paper notes come out from the device (figure 10).

[4]Detailed explanation of the work-flow are reported in Appendix B.

Figure 10. Multimedia aspects in a reminder application.

In figure 11 and 12 are shown two examples of utilization of the device in real contexts. In the first case the wearer is playing a game with his phone and the actual score is shown in his watch: in the second case the wearer is busy working and his status is displayed in his watch.

Figure 11. Example of social information. A glancer could be pushed to engage a conversation with the wearer if he likes the game too.

Figure 12. An example of status information. The glancer knows just glancing at the watch that he should not interrupt the wearer because he is busy.

Finally in the last example (figure 13) a glancer notes that the wearer phone is flashing so that he can inform the wearer about it. To be noted that the content of the watch is shown upside down: this would be possible with a correct use of sensors which is indispensable to show information to the glancer in the correct way.

Figure 13. Another example of status information where the glancer can see something when the wearer cannot.

A COMPARISON

To better understand limits and strengths of the developed device's interface it could be useful to make a comparison with other wearing devices. In the following paragraphs I will summarize three different works to highlight how they could improve the developed prototype of how they could be improved.

Go Skiing: Using Wearable Computers to Support Social Interaction

The *Hummingbird* is a wearable computer specifically developed to support communication in co-located groups of people providing a constant awareness of physical presence of others [9]. In particular the devices emits a 'hum' sound when another person from the group is close, displaying his name on the device. To see the actual potential of the device it has been tested on six ski instructors during a five days trip. Results from the experiment showed that the device has been used in a different way than the one it was developed for. The main aim of the device was in fact to help people during the sport activity by increasing the awareness of presence, but it has been used instead for social purposes. Results depended also on the fact the device was actually difficult to use during the sport activity: the emitted sound was not loud enough and instructors usually looked at the device only when they were in the lifts or while taking a break. However the devices was a success if used for social purpose, and instructors used it often when for example they wanted to meet each other to have a break.

The interesting feature of the developed device is certainly its capacity to improve awareness of presence, an aspect which has not been considered when developing my prototype. However there has to be considered that the Hummingbird is a single purpose device where my prototype is a multiple purpose devices so that it is more difficult to keep adding new functionalities. In fact, even where possible, a increasing number of implemented functionalities come with a prices since it will be more difficult for the final wearer to manage all of them. Finally wearer who tried the Hummingbird expressed concerns about privacy issue, which is instead managed in my prototype by using the privacy mode.

Exploring Wearable Ambient Displays For Social Awareness
Another interesting study regarding wearable devices used to improve social awareness comes from Williams et al. who developed *Damage*, a wrist bracelets which works paired with a mobile phone to support communication between a group of friends [10]. The bracelet is composed by a small number of led (from 5 to 7) where each led corresponds to a specific person of the group. When a friend wants to send a notification to another friend (or to the entire group) he has to interact with the bracelet by opening and closing three metal snaps which triggered the led on the receiving devices: the led flashes on different colours chosen between red, green and white.
On of the interesting point of the device is that it supports interaction using public interface trying to fostering a sense of connection without constant distraction. In fact, when mobile are involved, because they cannot always be at the center of our attention, they need to be developed to support a interaction without distraction. A weakness of the devices is that the conveyed information (the colour of the led) does not have a unique meaning so that the user has to agree on the meaning of colours in advance. This task can be very demanding in terms of cognitive effort especially because of the nature of the signal (colours) which is very abstract. On the other hand the abstract form of the information helps privacy since only the involved users know the meaning. Finally, it has to be noted that also in this case the device is single purpose, so that it could be difficult to think of a way to implement those functionalities in the prototype I developed. Nevertheless a higher effort on developing a device which does not required the complete user attention should be taken.

DisplaySkin: Exploring Pose-Aware Displays on a Flexible Electrophoretic Wristband
DisplaySkin is a wearable device characterised by a large cylindrical display surface which surround the wrist for 320 degree. It is the first wearable device with a such big display surface, and it is also pose-ware that is the device is capable of present its content according to the user movement: in other terms the display content moves according to the wrist position [2]. As in the previous work, one of the main aim of the device is to provide user information without requiring a complete attention. However, where Damage gives information with a very abstract from, DisplaySkin provides a much more detailed information. During the developing of my prototype I have carefully considered how to present information in the most suitable way for the wearer. I considered persistence, representation, context and timing, meaning the right information for the right moment. However DisplaySkin does something more, providing a devices which changes not only the type of information displayed but also the way and the place where it is displayed, an approach which is definitely innovative. It is interesting to notice that the research focuses on the concept of glanceable: however while Burstyn et al. developed their device to be glanceable only by the wearer, main aim of my research was to develop a way to make information glanceable both by a wearer and by an occasional observer. Perhaps it would be interesting to study how such a big display can be used in this way: in fact since it covers 320 degree of the writs it means that when the wearer is looking at it, there is always another part which is not visible to him but which is potentially visible for an external glancer.

CONCLUSION
Wearable devices will increase their presence on the market during the next years so that it would be interesting to think about new way we could use them. We have seen for example that a promising research field focuses its attention on developing devices which are not useful only to the wearer but can be also beneficial to a occasional glancer. In this terms the wrist device becomes a public display. In this paper I presented a possible implementation for a wrist wearable device which implements this view. In the first part I presented two studies: during the first one I tried to understand why a person should look at someone else resource, to figure out what kind of information should be showed in a wearable device; during the second study I focused on the way watches are glanceable to learn the best way the information should be showed by a devices: we have seen for example that we have to take decisions in terms of persistence, representation, timing and context. In the second part, using knowledge derived from the first part of my research, I developed a possible prototype which implements some basic functionalities. Moreover during the developing I tried to find a solution for all those problems which could be faced when dealing with small devices. Example of real use of the device are also reported. Finally I compared my prototype with three other similar devices, highlighting strengths and weaknesses of the developed design. Results from my research show that, at least from a theoretical point of view, it is definitely possible and interesting to look at wearable device as a shareable source of information. However, in order to really understand if this path is actually walkable, it is needed to test the developed prototype in the real world.

REFERENCES

1. Bächlin, M., Förster, K., and Tröster, G. SwimMaster: a wearable assistant for swimmer. In *Proceedings of the 11th international conference on Ubiquitous computing*, ACM (2009), 215–224.
2. Burstyn, J., Strohmeier, P., and Vertegaal, R. DisplaySkin: Exploring Pose-Aware Displays on a Flexible Electrophoretic Wristband. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, ACM (2015), 165–172.
3. Chi, E. H., Song, J., and Corbin, G. Killer App of wearable computing: wireless force sensing body protectors for martial arts. In *Proceedings of the 17th annual ACM symposium on User interface software and technology*, ACM (2004), 277–285.
4. Harrison, C., Lim, B. Y., Shick, A., and Hudson, S. E. Where to locate wearable displays?: reaction time performance of visual alerts from tip to toe. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM (2009), 941–944.

5. Harrison, C., Tan, D., and Morris, D. Skinput: appropriating the body as an input surface. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM (2010), 453–462.
6. Knibbe, J., Martinez Plasencia, D., Bainbridge, C., Chan, C.-K., Wu, J., Cable, T., Munir, H., and Coyle, D. Extending interaction for smart watches: enabling bimanual around device control. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*, ACM (2014), 1891–1896.
7. Luce, N. A. Electronic calculator watch structures, May 11 1976. US Patent 3,955,355.
8. Pearson, J., Robinson, S., and Jones, M. It's About Time: Smartwatches as Public Displays.
9. Weilenmann, A., and Holmquist, L. E. Hummingbirds go skiing: Using wearable computers to support social interaction. In *Wearable Computers, 1999. Digest of Papers. The Third International Symposium on*, IEEE (1999), 191–192.
10. Williams, A., Farnham, S., and Counts, S. Exploring wearable ambient displays for social awareness. In *CHI'06 extended abstracts on Human factors in computing systems*, ACM (2006), 1529–1534.

APPENDIX A

Here are reported the diary of the study 1 and the transcription for the audio recording of the study 2.

Date (DD/MM)	**Time** (HH:MM)	**Location**	**Context**	**Observed Resource**	**Observed person identify**	**Observed person actions**	**Resource distance** (m)	**Glance duration time** (s)	**Acquired information**	**Glancing reason**	**Other**
10/02	19:02	PC Lab at University	/	PC monitor	Friend	Typing on a word processor of a PC	< 1m	3s	The user is busy working	Understanding if I can talk to him without interrupting anything	/
10/02	20:00	PC Lab at University	Silent area	PC monitor	Unknown student	Browsing websites	3m	5s	The user is not busy doing any important job	Understanding if I can talk out loud with a friend without disturbing anybody	/
11/02	12:00	Classroom at University	Silent area, High illumination	Laptop monitor	Unknown student	Browsing websites	< 1m	5s	Time	Knowing the time without taking my phone	Because of the glare it is not easy to read
11/02	15:00	Classroom at University	/	Laptop monitor	Unknown student	Browsing FaceBook	1m	60s	His name	Trying to understand who he is to know if we are in the same class	
12/02	13:30	Bus station	/	Paper ticket	Unknown person	Holding the ticket	1m	10s	Where the person is going	Knowing if I am waiting for the bus in the correct place	/
12/02	13:40	Bus station	/	Mobile phone	Unknown person	Using the phone	1m	5s	Language of the phone	Knowing his nationality understand if I could ask smth	/
12/02	13:45	Bus station	/	Tablet	Unknown person	Playing a game	< 1m	20s	Maximun score achieved	Knowing if his record is better than mine	/
12/02	15:00	Restaurant	/	Order notes	Waitress	Writing customer's order	< 2m	1min	Other customer's order	Having suggestion about what to order for myself	/
12/02	15:20	Restaurant	/	Mobile phone	Friend	Not looking at the phone, just talking to me	1m	5s	Incoming call from his friend	Understanding if I have to inform my friend of what's going on	/
12/02	16:00	City center streets	/	Shopping bag	Unknown person	Walking with a shopping bag	10m	5s	Name of the shop of the shopping bag	Trying to understand from which direction he is coming to infer where the shop is	/

Fields Explanation

In the diary are reported several fields defined as following:

Date The date of the annotation in the format DD/MM, all annotation are supposed to be taken in the 2015:

- Eg: 20/02;

Time The time of the annotation in the format HH:MM:

- Eg: 20:12; 01:20;

Location The place where the annotation took place;

Context information about the context if relevant:

- Eg: number of people, weather, illumination condition, silent area;

Observed resource the devices which has been glanced:

- Eg: monitor, watch, tablet, phone;

Observed person identity: who the observed person is related to the observer:

- Eg: student, friend, relatives;

Observed person actions: what the wearer is doing:

- Eg: typing a text using a word processors, chatting on facebook;

Device distance distance between the glancer and the observed devices expressed in meters;

Glance time duration duration of the glance expressed in seconds;

Acquired information kind of information acquired through the glance;

Glancing reason why the glancer is looking at someone else resource;

Other other notes that can be helpful for the observation.

Date (DD/MM)	**Time** (HH:MM)	**Location**	**Context**	**Observed person identify**	**Observed person actions**	**Watch distance** (m)	**Watch surface visibility**	**Glance duration time** (s)	**Watch time visibility**	**Other**
16/02	12:30	Classroom at University	/	Teacher	The teacher is moving his arm a lot so the watch is not always visible	4m	Complete	10s	Interrupted	/
16/02	14:00	Classroom at University	/	Unknown student	The student is following the lecture	< 1m	Complete	10s	Uninterrupted	/
16/02	14:30	At the bus stop	High illumination	Unknown student	The person is waiting for the bus	< 1m	Partial	5s	Uninterrupted	The surface is not visible because of the glare from the sunlight
17/02	12:30	University cafeteria	/	Unknown student	Eating lunch	3m	Complete	10s	Uninterrupted	He is eating with the right hand but the watch is on the left side, so it stays still
17/02	12:40	University cafeteria	/	Waitress	Eating lunch	1m	Complete	6s	Interrupted	The waitress is cleaning the table
17/02	12:45	University cafeteria	/	Unknown student	The student is sit talking and moving hands	2m	Partial	5s	Interrupted	/
17/02	12:55	University cafeteria	/	Unknown student	Eating a sandwiches	3m	Complete	10s	Uninterrupted	She is eating but with very small movement
17/02	12:55	University streets	/	Unknown student	Walking	2m	Complete	2s	Interrupted	One of the rare case where he was outside but wearing only t-shirt
18/02	16:00	University library	Silent area	Unknown student	Sitted and studying	2m	Complete	∞	Uninterrupted	/
18/02	16:00	Swimming pool	/	Unknown person	Swimming	1m	Complete	2s	Uninterrupted	/

Fields Explanation

In the diary are reported several fields defined as following:

Date The date of the annotation in the format DD/MM, all annotation are supposed to be taken in the 2015:

- Eg: 20/02;

Time The time of the annotation in the format HH:MM:

- Eg: 20:12; 01:20;

Location The place where the annotation took place;

Context information about the context if relevant:

- Eg: number of people, weather, illumination condition, silent area;

Observed person identity who the observed person is related to the observer:

- Eg: student, friend, relatives;

Observed person actions what the observed person is doing

Watch distance distance between the observer and the observed watch expressed in meters;

Watch Surface visibility the portion of the watch surface which is visible during the observation. The value must be choose between:

- *complete*: if the surface is completely visible
- *partial*: if the surface is only partially visible (it could be for example covered by clothes, or by glare because of high illumination).

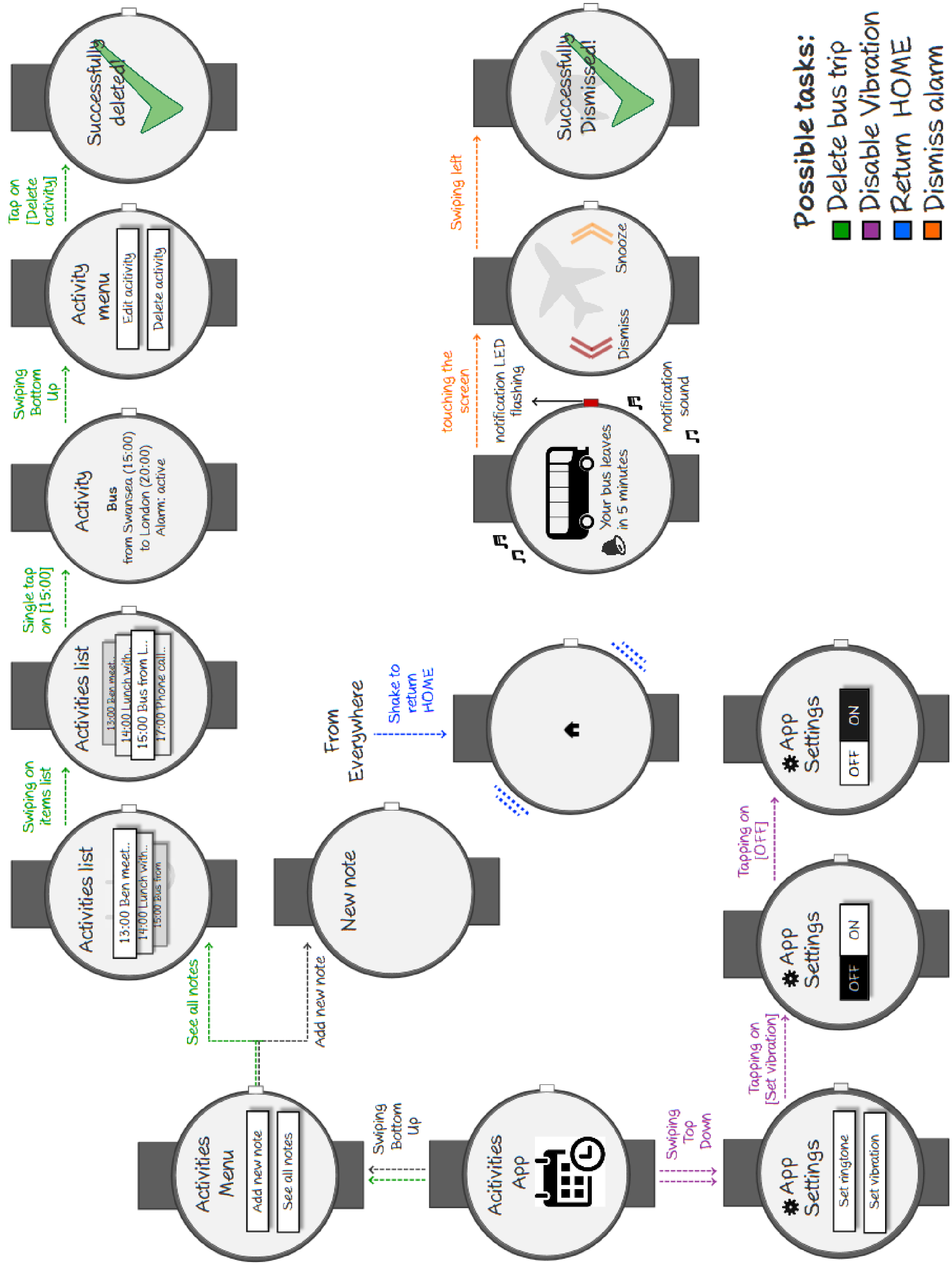
Glance time duration duration of the glance expressed in seconds;

Watch Time visibility the time during which the face of the watch is clearly observable in relationship with the duration of the glance. The value must be choose between:

- *uninterrupted*: the watch was visible for the entire period of time
- *interrupted*: the watch was visible but not continuously

APPENDIX B

Here is reported the taskflow fot the example show in the prototype section.


Activities Menu
Add new note
See all notes
Swiping Bottom Up
Acitivities App
Swiping Top Down
App Settings
Set ringtone
Set vibration
Tapping on [Set vibration]
App Settings
OFF
ON
Tapping on [OFF]
App Settings
OFF
ON
See all notes
Add new note
Activities list
13:00 Ben meet..
14:00 Lunch with..
15:00 Bus from
Swiping on items list
Activities list
13:00 Ben meet..
14:00 Lunch with..
15:00 Bus from L...
17:00 Phone call..
Single tap on [15:00]
Activity
Bus
from Swansea (15:00)
to London (20:00)
Alarm: active
Swiping Bottom Up
Activity menu
Edit acitivity
Delete activity
Tap on [Delete activity]
Successfully deleted!
New note
From Everywhere
Shake to return HOME
touching the screen
notification LED flashing
Your bus leaves in 5 minutes
notification sound
Dismiss
Snooze
Swiping left
Successfully Dismissed!
Possible tasks:
Delete bus trip
Disable Vibration
Return HOME
Dismiss alarm