Detachable Smartwatch: More Than A Wearable

RUSHIL KHURANA, Carnegie Mellon University
MAYANK GOEL, Carnegie Mellon University
KENT LYONS, Toyota Research Institute

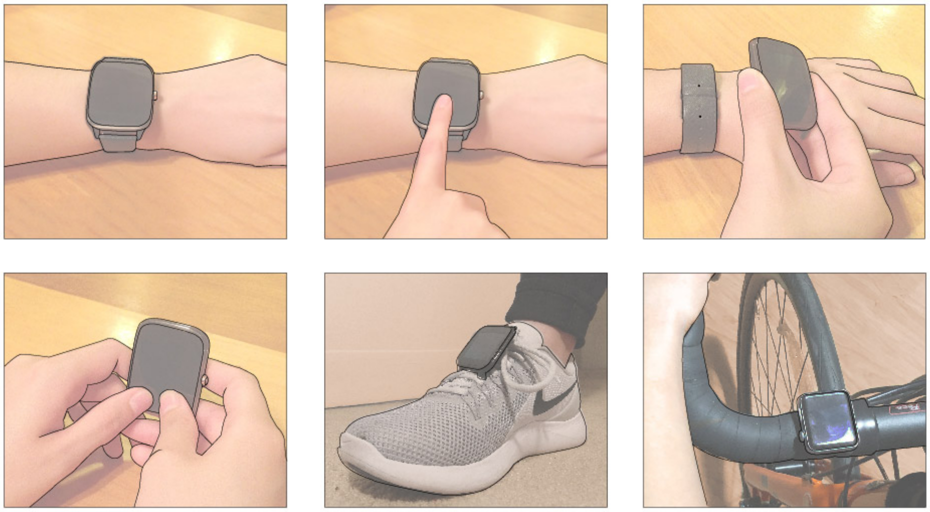

Fig. 1. (Top Row) In its default state, the watch on wrist can only be used by one hand. If the watchface is then detached: (Bottom Row) Three different uses of a detachable watch are shown; (1) mobility: ability to use the watch in both hands; (2) heterogeneity: the ability to morph into a better sensor like attaching it to the shoe for better gait analysis, and (3) docking on bike for navigation.

Glanceability and low access time are arguably the key assets of a smartwatch. However, smartwatches are currently limited to micro-interactions. They do not enable complex interactions and, in general, they do not afford continuous use for long. We believe that smartwatches can retain micro-interactions and glanceability, but also get better at long and complex interactions. We propose a smartwatch that a user can detach, and use as more than a wearable depending on their context, requirements, and preference. Detaching the watch enables it to morph into different forms, and thereby become a better interaction device, better display, and a better sensor suite. First, we interview participants to elicit usage themes for a detachable watch. Then, we build applications that showcase the range of use-cases where a detachable smartwatch offers additional functionality compared to an always-worn one, and highlights the affordances and benefits enabled due to detachability.

Authors' addresses: Rushil Khurana, Carnegie Mellon University, Pittsburgh, USA, rushil@cmu.edu; Mayank Goel, Carnegie Mellon University, Pittsburgh, USA, mayankgoel@cmu.edu; Kent Lyons, Toyota Research Institute, Los Altos, USA, kent.lyons@tri.global.

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1 INTRODUCTION

For decades, the smartwatch has been the torchbearer for wearables. However, the design space for a smartwatch is still in flux. Its limitations, rather than its strengths, often drive the interaction design on watches. One major limitation of the watch has been its restrictive position on the body, which inhibits it from being a more powerful device. Its position has been accepted as a natural property of the watch (instead of a limitation), and has not been adequately addressed. It leads to several issues. First, the watch-on-wrist position introduces several artificial situational impairments such as one-handed use and limited mobility. Novel interaction techniques [1, 14, 31] work around this limitation instead of addressing it. Secondly, holding the arm in a position to interact with the smartwatch leads to a form of gorilla-arm effect [3] in as little as 3 minutes of use [13]. So, the assumption that a smartwatch is supposed to be *only* a wrist-worn computer limits its potential. It begs the question "Could a smartwatch retain its key benefits but also encroach on what is now only possible on handheld devices?"

The idea of a non-limiting position for wearables has already been observed in some commercial products. 15 years ago, Apple iPod Shuffle was a handheld device, but it afforded the ability to be turned into a wearable using a wristband. A few years later, Sony introduced a smartwatch with a clip on the back of its watchface [23]. It allowed users to attach the watchface to their clothing. Despite a novel form-factor, no specific apps were developed to cater to the non-wrist position of the watch. More recently, in an effort to improve the phone call experience, some commercial smartwatches [27, 29] explored the idea of detaching the watchface to bring it near the user's ear. Garmin Forerunner took the concept of 'non wrist-worn watches' futher by allowing users to mount their watches on a bike instead of their wrist using customized bike mounts [28]. So, even though the idea of 'non wrist' located smartwatches has been teased for specific use-cases, we still have not fully explored the exciting possibilities. While the idea of detachability has been proposed before in literature too [18, 26], there has been little research to explore the design space it enables.

To this end, in this paper we systematically investigate the benefits and opportunities afforded by a detachable watch. The ability to detach a "wearable" from its default position, allows it to be more than a wearable. Simply removing the restriction of placement affords several benefits. (1) Mobility: In its detached state, the smartwatch is similar to a mini-phone. It can perform phone-like functions that do not require a big screen (*e.g.,* taking a photo, making a phone call); (2) size: Its smaller size makes it a more suitable choice over the phone for certain use cases (*e.g.,* limb tracker to monitor specific exercises); (3) distributed capabilities: both the watchface and the wristband have the ability to act as compute devices, and even interact with each other if necessary; (4) heterogeneity: the ability to morph into another sensor-based device (*e.g.,* blindspot detection, baby monitor). It means, the (detachable) smartwatch can now support new interactions, allows development of richer applications in its detached state while retaining its original assets: glanceability and low access time when used in its default state.

We demonstrate how making a watch detachable morphs it into more than just a wearable. We apply a disposition analysis [19] to smartwatches and formulate a detachable mode for the watch. Next, we prototype different mechanisms that allows the user to quickly detach the smartwatch from the wrist to use it in their hands (Figure 1). We conduct a study to evaluate the usefulness of the detachability concept by analyzing usage themes. We use these usage themes to illustrate different affordances and benefits of a detachable smartwatch. We also build applications and evaluate the usefulness and enjoyability of our detachability concept via those

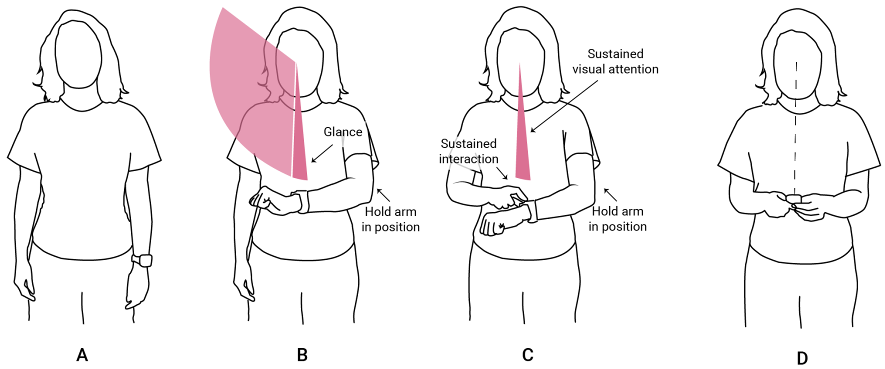

Fig. 2. A (Disuse), B (Glance), and C (Interaction), the three existing dispositions of a traditional smartwatch are shown. We introduce a new *Detached* disposition (D) which allows a user to use a detached watchface for extended interactions, akin to a handheld device.

applications. Finally, we briefly discuss the current dissonance between the handheld and wearable devices, and how a detachable smartwatch helps bridge the gap.

We would like to strongly emphasize that our example applications, while not technically innovative, demonstrate that a simple design change (detachability) can alleviate the on-body location issues such as restricted motion or one-handed. We demonstrate the benefits and new affordances of a detachable watch design, and how it can impact the potential applications of the watch; Our contribution lies, not in the idea of detachability or technical innovation of applications, rather in exploration of the opportunity space offered by a detachable form-factor. We outline the impact of a detachable design on the kind of applications it can be used for, and how it makes the watch more than a wearable.

2 BACKGROUND & RELATED WORK

As we consider how the smartwatch's form factor might improve its interaction paradigm, it is useful to examine the smartwatch's current design. Lyons and Profita provide a way to examine wearable design and outline the notion of a disposition as a representation of the user's pose and their relationship with the device [19]. Users and their wearable devices take several dispositions over time as the technology goes through different states of use and the user encounters different contexts. For example, examining a watch (smart or otherwise) reveals three dispositions (Figure 2):

(1) **Disuse:** Arm at rest; watch by side
(2) **Glance:** Arm raised to chest and wrist rotated toward eyes
(3) **Interaction:** Arm raised, wrist rotated toward eyes, and other hand used to interact with the watch

As the user goes about their day, they will transition between these watch dispositions based on various needs. When the smartwatch receives a notification, the user might *glance* at the watch, but not necessarily perform any *interaction*. In the *interaction* disposition, the user might dismiss the notification, examine their calendar, or use any of the other apps available on the watch. Prior work has focused on improving interactions, and thus the third disposition; specifically to overcome one of the biggest limitations of the smartwatch: its small display.

A small screen's biggest impediment is perhaps text entry. Numerous keyboards have explored different design opportunities that are tailored for the small touchscreen of smartwatches [9, 11, 24]. The lack of adequate screen space has also led to interactions being expanded to the arm. Skinbuttons projects button-like icons on the user's skin from the smartwatch to provide a larger interaction area [14]. Similarly, Skintrack uses a ring worn by the user to generate a high frequency signal and calculates the phase difference between the two electrodes on a custom smartwatch to track finger motion on the skin [31]. Other strategies include instrumenting the watch or watchband with new sensors, such as pressure sensors [1, 5, 6], to enable richer input beyond the watch face.

Due to the position of the watch on the wrist, one can traditionally only use one hand to interact with the watch. But, researchers have explored using the hand gestures of the same arm on which the watch sits to improve the interaction space. PinchWatch uses a chest-worn camera to monitor the user's hand and wrist to detect gestures such as pinching and dialing motions to invoke various functions within an application [16]. Zhang and Harrison added 8 electrodes to a smartwatch to measure the cross-sectional impedance between all pairs that allows them to distinguish between several hand postures. [30]. Similarly, EMPress used a combination of EMG and pressure sensing at the wrist to detect same-hand gestures [21]. Another common strategy is to use other input modalities than the user's arm. For example, Blowatch uses the microphone on a smartwatch to distinguish blowing gestures, which are then used to enable interactions such as navigation, swiping, zooming, and target selection [4]. Similarly, Orbits modified the smartwatch interface to move target objects (*e.g.,* buttons) in distinct circular trajectories. They then use gaze tracking to determine which circular trajectory (target) the user is looking at for hands-free target selection. [7].

These techniques potentially enable very powerful micro-interactions, but they are also examples of proposed techniques that have inherently assumed the restrictive position of the watch as a natural property. Despite their added utility, the user still misses out on high mobility applications which have been a cornerstone in the success of a smartphone (*e.g.,* taking a photo). A detachable watch does not increase the screen size, but it can potentially extract more from the device than its wrist-worn counterpart. By freeing the watch from the three dispositions, we can leverage affordances such as more degrees of rotation, extra mobility, distributed computing over the detached watchface and the wristband, and much more.

As discussed earlier, there are several commercial products that have used detachability in specific contexts such as improving the phone call experience [27, 29] or designed for use while biking [28]. Lyons also suggested the idea of detachability while positioning his work on ways to make smartwatch the primary device instead of the smartphone [18]. He only briefly mentions the idea in his article, but Doppio is a dual-face smartwatch where the second face can be moved relative to the first to provide a larger interaction space [26]. While not the focus of their work, the authors introduce a detached state where the second watchface moves independently to provide a notion of interactive detached watchfaces. While the notion of two watchfaces interacting with each other, especially when it may be possible to detach is quite interesting. Our focus, however is the affordances enabled by detaching the watchface, and not just on the interplay between a wrist-worn device and its detached part. One possible way to examine the characteristics of a detached smartwatch is to view it as a small handheld device. Prior research has investigated the use of small handheld interactive devices. Siftables [22] are compact devices with an onboard accelerometer, wireless radio and a graphical display. The authors investigate the interplay between multiple siftables, and lead with an example of photo sorting. Each siftable is linked to one photo, and the user can quickly sort the siftables physically, which in turns manipulates the photo ordering on their primary device. Similarly, Baudisch and Chu [2] examined a small handheld device (similar to the size of a smartwatch or smaller) and explored potential input mechanisms suited for such a small form-factor. They demonstrate that handheld devices provide access to their back, which is a suitable area to use for input via pointing. Both these works, do not directly address the detachability of a wearable, but provide insight into some of the affordances that a wearable may possess due to its form factor. It provides us with a good starting point to investigate the opportunity space of a detachable form factor in depth. Taking this vision forward, we add a new *Detached* disposition (Figure 2). In this mode, the device provides interaction affordances that are more flexible than those offered by a wristworn smartwatch.

Fig. 3. Prototypes of different detachability mechanisms. Press fit (top-left); Velcro (top-right); 2-sided tape (bottom-left); and magnets (bottom-right)

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3 DETACHABLE SMARTWATCH PROTOTYPE

By providing the user with the ability to quickly detach the smartwatch from the wrist, they are free to take on different poses while working with the watch. For example, the smartwatch can transition from its default *Interactive* state (Figure 2(C)) to one more analogous to a phone where the device is held in one or two hands.

To build our prototype, we used the watchface of the Samsung Gear Live smartwatch with Android Wear OS matched with different wristband supporting our low-fidelity mechanisms. We experimented with several low-fidelity design options to make the watch-face detachable: (1) interference fit clasp with a 3D printed custom watchface holder attached to a velcro wristband; (2) a piece of velcro attached to the watchface with a velcro wristband; (3) double sided tape on the back of the watchface paired with a wristband with double sided tape on the watchface holder; and (4) attaching magnets on the back of the watch paired with a wristband with a metallic watchface holder. (Figure 3). Due to longevity and ease of integration, we used two prototypes: (1) double-sided tape; and (2) magnet on the back of the watchface to conduct our evaluation.

The ability to detach the watchface offers several affordances that considerably increases the input space available on a smartwatch. To better understand how people may use it, we conducted an elicitation study to identify usage themes.

4 STUDY 1: ELICITATION STUDY

We conducted a study with six participants (4 male, 2 female, mean age = 27). Two participants (1 male, 1 female) had no experience with the smartwatch, whereas the other 4 participants were power users with an average of 1 year of smartwatch use. The goal of our study was to elicit usage themes, not investigate specific interactions, akin to other studies in the past [26].

We provided the participants with our prototype that uses magnets to connect the watch face to the wristband (Figure 3). The researcher first demonstrated that the participants could detach the watchface. Then the users wore the prototype on their arm, and were allowed to use the watch freely. The researcher encouraged them to think aloud and captured their first impressions and concerns about a detachable form factor. Next, the participants were asked to discuss use-cases where they may envision using the detached state of a watch over its wrist-worn location, and situations where they would not prefer the detached state. Next, leveraging insights from prior research on interactivity of small handheld devices [2, 22], and our observations from rapid prototyping of the form-factor, we asked the participants to think about the benefits of two affordances: (1) mobility, and (2) ability to dock the watchface on other surfaces. Each session consisted of the participants interacting with the prototype and providing feedback. On an average, the participants spent 5 minutes exploring the watch freely, and 15-18 minutes talking about use cases and limitations. All sessions were audio recorded. We transcribed all the comments for a thematic grouping.

4.1 Results

The participants explored the modified form-factor of the watch, and used the default applications (messages, navigation, and fitness app). They appreciated the idea of a detachable form-factor. 4 participants pointed out that the watch in its current form (tied to the wrist) leads to unnatural interactions due to the pose a user must maintain to interact with it. For example P2 [male, 25 years] commented, "*when it (smartwatch) is on my wrist, it's hard to keep your hand like this (Interactive disposition). But, it's easier and less awkward to hold it like this (Detachable disposition)*". 3 participants acknowledged that the current prototype was for research, but underscored the importance of a durable detachable mechanism. Based on our thematic grouping of the participants' comments, the following usage themes emerged:

- T1. **Contextual Mode Switch:** A total of 19 comments from 6 participants alluded to this theme. For example, P1 [female, 39 years] stated, "*Sometimes when I am at work, I don't (do not) want to get distracted. I think it would be really cool if this (smartwatch) would stop showing me notifications if it is not on my wrist.*" The transition between different dispositions can act as a trigger to change usage or context mode. For example, in the scenario described by P1, if a watch is detached and merely resting on the table, it would adopt a "Do Not Disturb" mode. Thus depending on the context, the watch can perform different functions and/or take different profiles without explicit user intervention.
- T2. **Heterogeneity:** When detached, the smartwatch is not a wearable device anymore, rather depending on the location, it is a suite of sensors to sense different activities on-body or in the environment. For example, P4 [male, 26 years] suggested, "*I could also stick it (detached watchface) to things like my coffee pot for a few minutes. When it (coffee brewing) is done, the watch can beep and notify me. It's a quick use for when I detach it.*" Fourteen comments from 4 participants contributed to this theme.
- T3. **Modularity:** It is not necessary that the *whole* watch gets detached; parts of it can remain on the wrist. Different activities may require only a part of the watch (*e.g.,* accelerometer to track exercises) and thus only specific "modules" of the watch can be detached which may interact with each other. This theme encompasses the affordance of the interaction between the band and the watch. They are just two pieces of a larger device. P6 [male, 21 years] noted, "*Can you separate the watch pieces? I am thinking that the watch parts (graphical display) remains on the band to tell me the time but I can pick up the speaker part for a phone call?*" 3 participants talked about the wristband and the watchface as separate interactive elements, and 2 of those participants furthered the idea by suggesting modularization of different watch sensors themselves. A total of 16 comments were grouped to develop this theme.

The overall feedback was positive, and the participants expressed that detachability could make the smartwatch a more powerful device. As stated earlier, we also encouraged the participants to discuss scenarios where they do not foresee them using a detachable watch. There were not enough negative comments raised by the participants to form a negative theme. But, one concern shared by 3 participants was that they might lose the watchface when it is detached. A potential solution here may be to use the signal strength to track proximity between the wristband and watchface; yet another example of interaction between different (distributed) watch components.

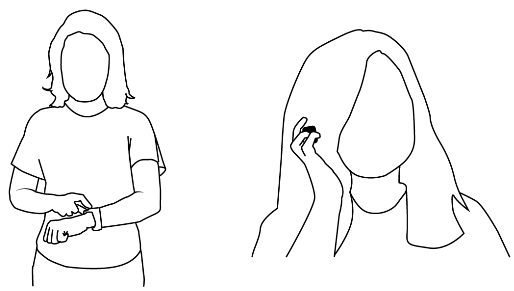

Fig. 4. A user detaches the watchface and receives the call by placing the watchface close to their ear.

The results of our elicitation study are similar to other studies in the past using custom smartwatches [26], or smartphones [17]. The similarity in the results shows that the participants could foresee using a detachable watch for everyday activities, which typically are relegated to smartphones, or required custom smartwatches. It strengthens our argument that our recommended relatively simple design change to the watch form-factor can enable several affordances that a traditional watch-on-the-wrist cannot.

5 EXAMPLE APPLICATIONS

Driven by the participants' feedback and the usage themes, we developed concept applications that highlight the value of a detachable smartwatch.

5.1 Phone Call Application

This application allows the user to use the watch to take a voice call discreetly. Instead of talking on speakerphone (as is prevalent in most smartwatches), the act of detaching the watch from the wrist and putting it near the ear alters the volume to enable a private interface. The user can then hold the watch next to their ear and talk (Figure 4). This is a prime example of T1 (contextual mode switch) theme that emerged from our elicitation study.

5.2 Camera

While some smartwatches have a built-in camera, it is yet to become a standard feature. However, it can be an indispensable feature for a detached watch. The traditional smartwatch camera is limited since there are constraints to the available degrees of freedom, which inhibits the range of the camera's positioning and its angle. Specifically for this prototype, we used the Pandadoo smartwatch DZ09 which comes with a built-in camera.

5.3 Messaging

A major limitation of the traditional smartwatch is one-handed input. Typing with one hand on a tiny touchscreen is inaccurate and tiring. Still, messaging is one of the most commonly used applications on a smartwatch. We implemented a T9 keyboard and a voice-based text entry where the users could seamlessly switch between the input modality. We chose a T9 keyboard instead of a QWERTY layout because of the limited screen space. However, it is not the contribution of this work, and any suitable keyboard layout can be used. Even though messaging using two hands might not be particularly faster on a small screen but potentially more usable. Messaging is just one example to demonstrate that detachability affords bimanual interaction that can be leveraged via other applications.

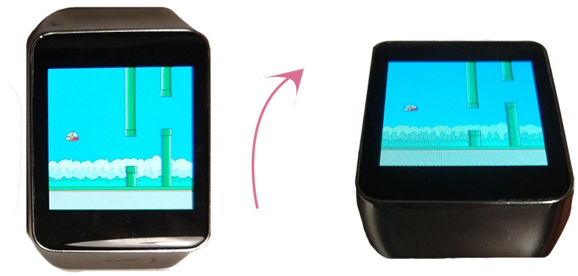

Fig. 5. The rotation of the watch (accelerometer) is used as an input to control the character in a game

5.4 Navigation

Many tasks, such as navigation, often require the user to switch visual attention between a screen and the primary task of driving. A smartphone is not useful when driving, and may even be distracting. However, the ability of a smartphone to be docked for quick and glanceable visual access to maps makes it one of the most popular GPS devices. In an effort to enable something similar on a smartwatch, a user can detach the watch from the wrist, and then dock it. Such an ability could be even more powerful on a bike where the watch can even act as a bike computer. Thus, a potentially distracting device morphs into something more than a wearable and becomes a useful aid. Now, the watch's small screen size can become an impediment. When the watch moves away from the user (docked on the bike), the small screen size makes it hard to effectively see the map. In our application, when the watch is docked on a bike, the map application automatically zooms in the interface (another example of T1).

5.5 Flappy Bird Game

We prototyped an adaptation of the popular Flappy Bird game. In our prototype, a user can play the game when the watch is strapped on their wrist by using touch to control the main character. If the user detaches the watchface and holds the watchface in their hand, they can use the accelerometer to control the main character. The accelerometer is used for input by having the user rotate the watch in space (Figure 5). The degree of rotation controls the jump (the same function a touch input provides while the watch is on the wrist) the main character makes in the game.

5.6 Blindspot Detector

Considering a watch already contains myriad of sensing and compute capabilities, it can act as a smart camera (similar to Google Clips[1]). We developed one such use-case, where the user detaches the watchface from their wrist when they get ready to drive a car, sticks the watchface to the car's window, and uses it as a blindspot-detection camera (see video figure).

5.7 Baby Monitor

Baby monitors are dedicated devices that typically use cameras and microphones. Both capabilities are already present on the watch. The watch's portability, small size and situation-appropriateness makes it an ideal baby monitor replacement when sudden need arises. It is unlikely that a smartwatch is ever going to completely replace a device like baby monitor. However, having this additional capability in a device you already have might be

[1]https://store.google.com/us/product/google_clips

Fig. 6. A user detaches the watchface puts it on their leg, and then does leg extension exercises.

useful in some situations. For example, in a car (if the watchface is attached to the back seat), or while traveling when you might not have access to your dedicated baby monitor.

5.8 Improved Fitness Tracker

Prior research supports the notion that quality of exercise tracking greatly varies by position of the sensor on the body [20]. The ability to detach a wearable from its default location, and attach it to another allows the user to place the device on the body part that is more involved in a particular exercise as shown in Figure 6. For purposes of our prototype and our evaluation later, we used the default Google Fit step counter and placed it on the leg, to be able to better count the number of steps a user may take.

6 STUDY 2: UTILITY AND ENJOYABILITY

We conducted a study to understand the potential usefulness of a detachable watch. We assess the concept usefulness using functional prototypes of 6 different applications. The baby monitor and blind spot detector apps are examples of new functionalities enabled via detachability (smartwatch as an environmental sensor), and as such do not address a current limitation on the smartwatch. Hence, they were not included in the evaluation.

6.1 Participants

16 participants (10 male, 6 female, mean age = 25) were recruited via word of mouth and snowball sampling. 7 participants had no experience, 3 had less than 6 months of experience, whereas 6 participants had more than a year of experience using the smartwatch.

6.2 Study Design

We chose representative scenarios for the 6 applications used in evaluation. We described each scenario to the participant [S1-S6] in Table 1. For each scenario, the participant responded to the question, "*I see this is an issue for current smartwatches.*" using a 7-point Likert scale (with 1 being strongly disagree and 7 being strongly agree). Next, we described our concept and demoed the pertinent application to that scenario. We let them use it on our detachable watch freely. They then responded to two questions: (1) "*This concept is useful*" and "*This concept looks enjoyable*" using 7-point Likert scales as well. Our questionnaire and study design is based on prior work that has evaluated futuristic devices [8]. The participants were also encouraged to provide lower ratings if it was a feature they could not foresee using for any reason. We also captured free-form feedback at the end to better understand their preferences. We encouraged the participants to not evaluate the finesse of the application prototype, rather the actual concept.

Table 1. Table of all scenarios and concepts used in the evaluation.

Scenario	**Concept**
S1: Responding to a text message using the smartwatch.	Detaching the watchface, and using two handed input to respond.
S2: Playing non-touch based input games on the smartwatch.	Detaching the watchface and using the IMU to control the game character.
S3: Receiving a phone call on the smart-watch.	Detaching a watchface, putting it close to the user's ear to listen to a call privately.
S4: Taking a photo using the smartwatch.	Detaching the watchface, positioning it appropriately and taking a photo.
S5: Using the smartwatch for navigation while biking	Detaching and docking the watchface on the bike.
S6: Using the smartwatch for non step-counted based fitness activities.	Detaching the watchface from the wrist and re-attaching to a different body part for improved tracking.

6.3 Results

We analyzed our data using Friedman signed-rank tests with post-hoc Wilcoxon tests with Bonferroni corrections. There was a significant difference in Scenarios ($\chi^2(5) = 45.37$, $p < 0.01$) and concept usefulness ($\chi^2(5) = 15.63$, $p < 0.01$). There was no observed difference in enjoyability. It demonstrates that there was variance in what the participants considered to be a limitation of the current smartwatch. Also, the subjects found some concepts more useful than the others. We summarize the results in Figure 7 and examine each of them in detail below. We analyze and report the mean and median scores to offset any outliers in the study.

The overall median ratings for all scenarios (issues) was greater than 4, and the mean rating was greater than 4.25 (with 1 being strongly disagree and 7 being strongly agree), thus indicating that majority of our participants considered the current smartwatch to be too limiting for the specified use-cases. Taking a photo using a camera on the smartwatch (S4) was considered the most problematic with a median score of 7, and a mean score of 6.81. Navigation (S5) was least problematic (median=4, mean=4.25). P8 [M, 29] stated, "*I am playing twisty with my arm trying to take a photo. Your way [detached watchface] is so convenient.*"

Similarly, both the mean and median ratings for usefulness of all concepts was above 5, which means that the participants believed that our proposed concepts were a useful solution to the pertinent issue. The camera application was perceived most useful (median=7, mean=6.68) along with the phone call application (median=7, mean=6.31), and was generally accepted as the most compelling use case of detachability by all participants. Interestingly, despite most participants not thinking of navigation while riding a bike as an issue with the current smartwatch model, it received a median score of 5 and a mean score of 4.62 on usefulness. It indicates that the detached model has some value that can help improve the existing interactions.

Navigation (ability to dock) and game (ability to rotate) concepts were rated less useful than Camera ($p < 0.05$ for both) and Phone call ($p < 0.05$ for both). This is an interesting result as the camera utilizes the same affordance of mobility and rotation, but clearly outshines the gaming application. P2[M, 23] rated the gaming app least useful and claimed, "*Who wants to play a game like that? I want a bigger screen.*" So, one possible reason could be that the users simply do not associate the smartwatch with a gaming device and it was hard form them to visualize doing so on a regular basis. Another possibility could be that the participants do not foresee using rotation as an input mechanism, but generally appreciate the natural affordance of mobility.

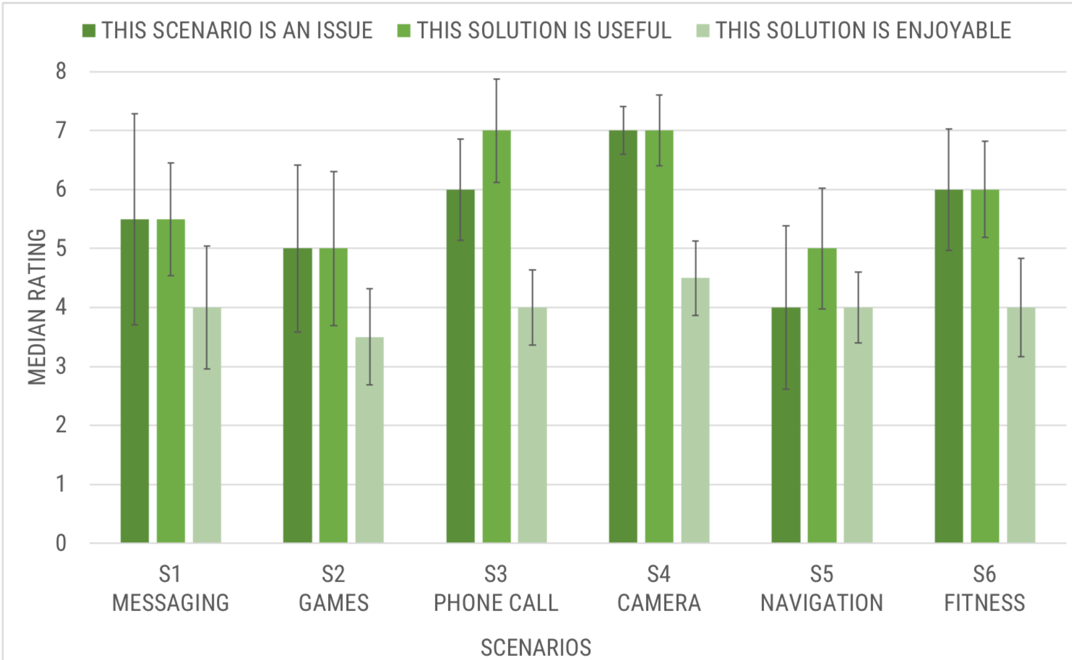

Fig. 7. Graph showing the median results with standard deviation error bars from our study questionnaire using a 7-point Likert scale (with 1 being strongly disagree and 7 being strongly agree).

Lastly, we received mixed responses for concept enjoyment. But, it is important to note that we used examples of commonly used applications. In such scenarios, there is an innate expectation of polished applications which may have affected their enjoyability score.

7 DISCUSSION

A detached disposition affects the application design in two ways: (1) it supports new interactions (*e.g.,* inertial input) and new use-cases (*e.g.,* dockability), and (2) it can support newer interactions and increase the breadth of the available applications and their richness. Detaching the watch allows it to act like a mini-phone suitable for applications that do not require a large screen. In this paper, we looked at some of the common phone/watch applications and how detachability improves the current watch-on-wrist model. By becoming handheld, we gain some of the affordances of smartphones by design. The watch when on wrist has limited mobility. It can only be rotated to a certain angle (based on arm rotation), along limited axes. The extra available degrees of freedom in a detachable form-factor enables rotation in the hands, docking in multiple locations and free motion in space, all of which can be used for a richer interaction and application space.

While it is hard to discount the novelty factor, participants found most applications useful and enjoyable. The tested applications highlight different aspects of a detachable smartwatch. For example, using the watch to make phone calls brings the watch close to a phone. A detachable watch sits comfortably between a traditional smartwatch and a smartphone. The exploration of the watch as more than a wearable prompts the co-evolution of the smartphone and a watch. A detachable watch now encroaches on a space, which previously was only occupied by handheld devices. A handheld device often enables the user to transition into a private space. When receiving a phone call, the user typically raises their arm and places the phone closer to their ear for a private conversation. A traditional smartwatch, on the other hand, uses a loud speaker that does not lend a private interface, or bluetooth headsets that require carrying an additional device to make/receive a call. In fact, Apple Watch Series 4[2] purposefully made their speakers louder, which makes it nearly impossible to use the smartwatch for a voice call in a social setting.

The enhanced mobility afforded by temporarily detaching the watch from the wrist can be very useful too. The camera application benefits due to the ability to physically position the device, orient the camera and capture the desired shot. Detachability enables affordances (mobility, rotation) that advocate for addition of sensors such as a camera that are commonplace in other smart devices (phones and tablets), making the smartwatch a more powerful device. Another application that was highly appreciated by the users was the game. Contrary to a smartphone, a smartwatch is still not a popular gaming platform. A detached watch can overcome small screen size by amplifying maneuverability. Most smartwatches have an accelerometer, but again this is of limited value for input on a conventional smartwatch since the user needs to move their whole arm. The mobility afforded by a detachable watch leads to improvements in smartwatch hardware. More degrees of freedom allows a broader range of sensors to better work when paired with a watch; something that was restricted on the wrist (*e.g.,* camera). It also enables new locations for interactions such as the back of device possibly being used for input [2]. By adding the *Detached* disposition, we achieve maturity in hardware and the underlying software, and enable support for richer applications. We observed that the enhanced maneuverability enables additional benefits such as high dexterity and bimanual interaction when using the keyboard.

We earlier established that heterogeneity is a characteristic that both smartphones and a detachable watch possess. But, there is not a complete overlap between their heterogeneous behavior. As stated earlier, in some use-cases the watch is more size-appropriate. The size appropriateness of the device makes it suitable to be used where it can be easily stuck to different objects (*e.g,* the inside or potentially outside the car). It also makes it suitable to attach to other parts of body without looking outlandish, and simply act as a "better" sensor due to its ability to be placed in a location other than the wrist. A detached watch not only has the capability to augment the environment, but also the ability to take on the role of many wearables worn on different parts of the body.

The position of the detached face in relation to the wristband presents a previously unexplored interaction space. A detachable watch could potentially act as one device when attached, but two different devices, when separated. An interesting byproduct of this capability is that it fundamentally alters the design of the wristband, and nudges towards the use of sensor-laden bands. For example, we can build an even better physiological and fitness tracker. The wristband can have the capability and positioning to capture the physiological responses of the user, whereas the detached watchface can be placed either on a different part of the body, or on the gym equipment itself. It allows the user to retain both benefits: (1) physiological sensing provided by a traditional smartwatch; and (2) the heterogeneous capabilities of improved fitness tracking facilitated by detachability.

Another example where a two-piece system is imperative, and the detached smartwatch + wristband system can be used instead is AR/VR controller. Smartwatches have previously been used as controllers when a user is immersed in virtual reality [10, 12, 25]. However, the ability to detach a watch gives us controllers for both hands – one on the wrist (wristband), and the other in the hand (handheld watchface). Bimanual manipulation offers both physical and cognitive benefits [15], higher dexterity and more granular control over user input.

Detachable applications can ameliorate screen size and occlusion issues to some extent, but they still persist.

8 CONCLUSION

In this paper, we propose a detachable smartwatch, which adds a new disposition (*Detached*) to the smartwatch. The user can detach the watch from their wrists, and use it according to their context, requirements, and preference.

[2]https://www.apple.com/apple-watch-series-4/design/

The watch morphs into more than a wrist-worn watch. We use prototypes of a detachable watch to elicit usage themes for such a device. We then build demo applications to unveil the benefits and affordances of detachability. We conduct a second study and use these applications as feature proxies to validate the utility of our detachable system. We use a principled approach to demonstrate the feasibility of our idea. Lastly, we discuss the current state of smartwatches and how detachability may help improve it.

We situate our work with an eye towards making smartwatches more useful, we acknowledge that our proposed idea is not a panacea for smartwatches. For a detachable smartwatch to become successful, there is a need for an effective mechanism to ensure that the watch can be attached to many surfaces. We deem this as an opportunity to propel industrial design and material science forward that it may be able to support a ubiquitous role that a detachable watch seeks to take.

Due to its recent resurgence in popularity, the watch is already a potent device with a wide array of sensors, high computation power, and it integrates well into a user's routine. While we explored some facets of how we can improve the watch via an innovative form-factor, we hope that we can spur other radical visions that can work in conjunction with ours to help open the evolution of the smartwatch and exploration of approaches towards building a first-class, highly portable, adaptable, and maneuverable computer.

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