Explorer le potentiel des interactions tangibles rotatives pour les Smart Watches

Investigating the Design Space of Smartwatches Combining Physical Rotary Inputs

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ABSTRACT

Watches benefit from a long design history. Designers and engineers have successfully built devices using rotary physical inputs such as crowns, bezels, and wheels, separately or combined. Smart watch designers have explored the use of some of these inputs for interactions. However, a systematic exploration of their combinations has yet to be done. We investigate the design space of interactions with multiple rotary inputs through a three stages exploration. (1) We build upon observations of a collection of 113 traditional or electronic watches to propose a typology of physical rotary inputs for watches. (2) We conduct two focus groups to explore combination of physical rotary inputs. (3) We then build upon the output of these focus groups to design a low fidelity prototype, and further discuss the potential and challenges of rotary inputs combinations during a third focus group.

CCS CONCEPTS

• **Human-centered computing** → *Interaction devices*;

KEYWORDS

Smartwatch, wearable, eyes-free interaction, rotary input, focus groups

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RÉSUMÉ

L'histoire des montres est pleine d'exemples utilisant une ou plusieurs modalités tangibles d'interaction comme les couronnes, les lunettes et les molettes. Pourtant les concepteurs de "smartwatches" ont seulement exploré un sous ensemble de ces mécanisme et surtout n'ont pas considéré la possibilité de les combiner. Dans cet article, nous étudions les possibilités offertes par la combinaison de plusieurs de ces mécanismes rotatifs en trois étapes pour les smartwatches. (1) Nous rassemblons une collection de 113 montres traditionnelles ou électroniques pour faire une typologie de leurs mécanismes rotatifs, (2) dont les combinaisons sont explorées et discutées durant deux focus groups. (3) Ces discussions nous mènent à développer un prototype pour discuter des potentiels et des défis des combinaisons d'entrées rotatives au cours d'un troisième focus group.

MOTS-CLEFS

Montre intelligente, objet connecté porté, interaction non-visuelle, mécanismes rotatifs, focus groups

1 INTRODUCTION

The history of watches includes numerous types of designs using a large variety of physical rotary inputs : bezels, crowns, wheels, and even pointing sticks. They may be used alone or combined. As watches are "cultural icons" [6], these aspects of their design are part of our cultural and visual knowledge. In addition to being culturally significant, physical rotary inputs have several advantages. For instance, they allow for continuous and spatially unbounded motions [14]. They also provide spatial landmarks easily reachable and memorizable (e.g. a quarter turn) which can be used eyes-free [20].

There are a few studies using a bezel for interaction (e.g., [23, 25]). Kerber *et al.* [9] have investigated usability and preference regarding the use of crowns and bezels, while others have explored twist gestures [22, 24]. Simple rotary interactions are being integrated in commercial devices such as the Samsung Gear and the Apple Watch, which respectively use a bezel and a crown, for scrolling or swiping. Despite this, we argue that the previous research has not explored in detail the design space of physical rotary inputs for smartwatches, as it has largely ignored the combinations of inputs so frequent on traditional watches to parameter them or to make calculations. We argue that combining rotary inputs can provide more opportunities for eyes-free or remote manipulation : not only does it enable to design new gestures but it could also provide more expressiveness by mapping information to multiple inputs. To inform future designs and take full profit of the interaction advantages of this type of input, we need to investigate this design space.

We propose an exploration of the design space of physical rotary inputs in three folds. We first study a collection of 113 traditional watches [1] and identify three types of rotary inputs to take into account when designing the hardware. Building upon these findings, we describe a design space for the combination of physical rotary inputs and conduct two focus groups to explore the potentialities of this design space. Multiple design combinations enriching the input vocabulary emerge from the focus groups but participants converged towards a double stacked bezel design illustrated Fig. 5 because (1) they can easily switch from one bezel to the other or (2) use both at the same time. They also foresaw (3) that it allows a rich gestures set and (4) envisioned multiple scenarios benefiting from its use. We then build a low fidelity prototype of this double stacked bezel design and further refine our understanding of rotary inputs combinations through a third focus group.

Our main contributions are : (1) a survey and a design space for physical rotary inputs on watches ; and (2) insights and design challenges regarding the possible hardware combinations of two physical rotary inputs.

2 MOTIVATIONS AND RELATED WORK

Previous studies suggest that smartwatches [12, 17] or bracelets [10, 13, 15, 16] are useful for frequent actions (e.g. notifications, remote control of a media player, activity logging) because they can support subtle micro-interactions [2, 3]. Micro-interactions enable users to quickly access digital information in situations of mobility, while interacting eyes-free or with peripheral attention. However, implementing robust and useful micro-interactions is challenging : voice commands can be error-prone in noisy environments, and raise privacy issues ; Simple physical gestures [7] are only appropriate as shortcuts for a limited number of commands ; On-body gestures [4, 18] raise social acceptability issues and their implementation remains difficult. For such scenarios, several studies suggest that physical inputs, rotary or not, are more usable or preferred by users [8, 20], but only few of these studies focus on smartwatches [9, 23, 24].

Several projects augment smartwatches with mechanical inputs including panning and tilting [22], buttons (e.g., Pebble watch), and rotary physical inputs [9, 23, 24]. In particular, physical rotary inputs have several advantages. (1) They support spatially unbounded motions, which allows for the continuous manipulation of any kind of variables [14]. For instance, interactive crowns are preferred to touch for scrolling a list [9]. (2) Users can easily reach and memorize spatial landmarks such as half or quarter turns because they allow positional control through direct manipulation, while enabling to change velocity in an intuitive and efficient way [20]. (3) Moreover, their circular design favors eyes-free interaction [20]. For instance, Xu and Lyons [23] propose to use a rotary bezel for setting a smartphone mode while eyes-free.

Figure 1: Examples of watch combining different types of rotary inputs

Despite these advantages, only few commercial smartwatches (the Samsung Gear and the Apple Watch) use a physical rotary input for scrolling a list or for swiping from screen to screen. However, none of these works have explored combinations of physical rotary inputs while the following study reveals that many traditional watches exploit this input.

3 PHYSICAL ROTARY INPUTS ON TRADITIONAL WATCHES.

In this section, we study traditional watches to inform the design of smartwaches. While similar approaches have been proposed to study the aesthetism of smartwatches [1] or their potential uses [12], we focus on interaction and more precisely on the use of physical rotary bezels. We identify design dimensions related to rotary inputs, and present the insights gathered through the survey on their combinations.

We collected and classified 113 examples of watches using physical rotary inputs (see Fig. 1 for an example) by interviewing 2 watch designers with more than 5 years experience (one working on luxury watches, the other on smart watches) and 4 watch collectors.

Then we looked for detailed information on the history of these design features. We decided to focus on circular watch cases (i.e. excluding rectangular ones), to include rotating bezels in the design space. However, wheels and crowns can be found on rectangular watches. We also included a conceptual haptic watch illustrated Fig. 1-d, which makes use of two physical rings to display the hour. From this collection, we identified four dimensions related to rotary inputs that we now describe.

3.0.1 Type of rotary inputs. One of the authors annotated the physical rotary inputs of the 86 remaining examples (after removing the rectangular ones) with keywords to identify common features (e.g. "one crown, top" ; "two crowns, right, bezel"). We then identified three main types of physical rotary inputs : *crowns*, *rotating bezels*

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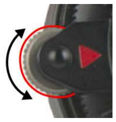
[1] This collection will be available online - blank for review

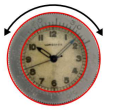
and *wheels*. Among the 86 watches, 84 had at least one crown, 10 had a rotary bezel and one had a wheel[2].

The three types of rotary inputs are illustrated in Fig. 1 and described below :

Crowns have been used since the XVIIth century for winding mechanical watches or to set the time. Today, they still remain the main rotary input for both traditional and smart watches. Over time, crowns have moved from the *top* of the watch (Fig. 1-a) to the *right and/or left* side (Fig. 1-b).



Wheels are present on multi-purposes watches, such as map meters or radio watches. They are embedded in the watch case.



Rotating bezels have the size of the watch. They were initially used for measuring time or to make calculations, as a slide rule[3]. Rotating bezels are quite common on professional watches.

3.0.2 Size of rotary inputs. In our watch collection, bezels have an average size of 42mm and crowns of 6 mm. But in the conceptual haptic watch (Fig. 1-d) or in radio watches, bezels and wheels can have intermediary sizes.

3.0.3 Style of rotary inputs. We also observed that bezels (rotary or fixed) may be used to convey tactile information (with either 4, 6, 8 or 12 landmarks), and may be toothed or slanted to ensure a good grip.

3.0.4 Combination of rotary inputs. 67/86 of the watches surveyed had at least two types of physical rotary inputs. Rotary inputs can be combined the watch case : For instance the watch presented in Fig. 1-b has two crowns in addition to the bezel. They may also be combined to each other : For instance, the wheel is clamped in the bezel in Fig. 1-c. The majority of these watches (48) combines two or three crowns, while the others combine crowns and bezels (18) or bezels and wheels (1). Thus, there are combinations of rotary inputs that have not been explored yet.

3.1 Discussion

From the interviews, watch designers and collectors reported that watches using wheels and/or bezels inputs are quite rare ("*Your typical watch have a single crown*"). They underlined that this rarity was not due to usability, but rather to user needs. Most users of regular watches were only interested in getting and setting the time and did not need additional controls. In contrast, the watches dedicated to specific contexts and complex tasks (e.g., making calculations, listening to the radio, counting steps - many functions performed by smartwatches) often combine physical rotary inputs to provide additional controls and expressiveness. They are highly represented in our sample because we asked specifically for examples of watches with tangible rotary inputs.

With the increasing amount of functionalities on smartwatches, we argue that it is worth exploring the potential benefits of combining physical rotary inputs. Beyond the advantages of physical rotary inputs listed above, combining them might increase the expressiveness without consuming more screen real-estate or impairing precision [9], as well as foster eyes-free interaction. In line with traditional watches design, we now explore the design of smartwatches combining two physical rotary inputs.

4 EXPLORING THE DESIGN SPACE : FOCUS GROUPS

There is many ways to explore design spaces of devices. We choose to use a focus group method [21] because it is particularly suitable to gather experts opinions on multiples diverse solutions. Each expert can very quickly generate and explore solutions to difficult design problems [5] while other approaches (e.g. comparative evaluation) can only focus on a small part of the enormous design space and thus miss out on promising design.

We conducted two focus groups with design experts. The focus groups were videotaped and annotated afterwards by one of the researcher. The transcript was then open coded and analyzed thematically. The goal was to (1) validate with designers the benefits this class of inputs, (2) identify the most promising configurations inside the design space, and (3) generate interaction principles and scenarios taking advantage these configurations.

Participants : Our two focus groups were each composed of eight participants (age 23 to 38, M=28 years, 16 participants in total). 12 of them were designers (User Experience, User Interface or product designers, including two working on wearables), and 4 were HCI researchers. Two of them used a smartwatch regularly, two from time to time, eight used traditional watches. The others did not use any watch.

Design cases : To support the discussion, we designed 9 cases that cover the combinations of three rotary input *type* (bezel, wheel and crown). The watches cases are illustrated in Fig. 2. Their sizes are closed to what could be expected from a commercial smartwatch, and they may be used as a support of interface paper prototyping. We designed 24 elements that could be used either as a wheel, bezel or crown : they come in 4 sizes (6, 18, 30 and 42 mm−standard deviation 12) and 6 styles (toothed, slanted and with various tactile landmarks). However, not all combinations are possible without impairing usability : in our case, we let the two focus groups rule them out.

Procedure : We first explained that our goal was to collect feedback on the design of new smartwatches, for which we were considering different form factors. We explained that all our watch cases were low resolution prototypes, and that they should imagine the final commercial version. We also indicated that we wanted to

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[2] The rest of our corpus revealed two watches with a pointing stick. It is a joystick that can be found on electronic or radio watches to navigate through screens or menus. While it can be first be perceived as a rotary input, it does not provide positional control and was therefore ignored from our typology. Moreover, this control is very rarely used. However, we decided to include the wheel because it was present on 6/27 watches of other shapes in our sample

[3] breitling.com/user-manuals/breitling-user-manuals/en/19370/navitimer_1461

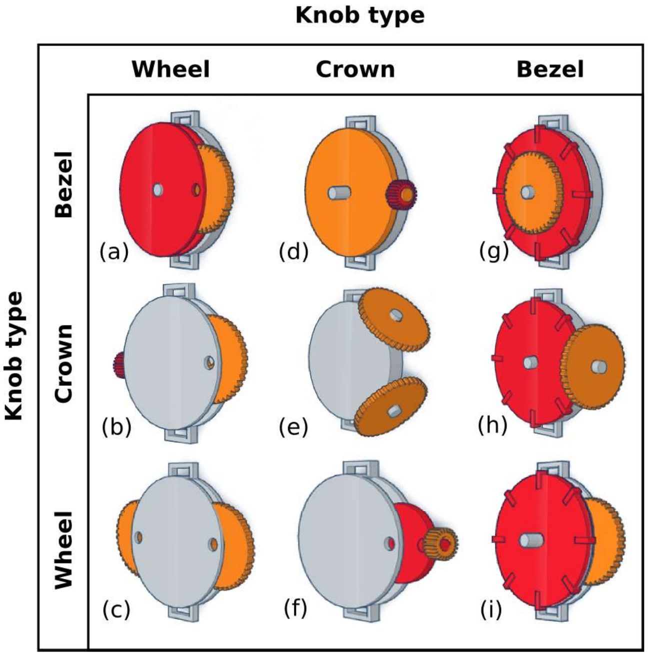

Figure 2: The 9 combinations of physical rotary inputs explored by our focus groups.

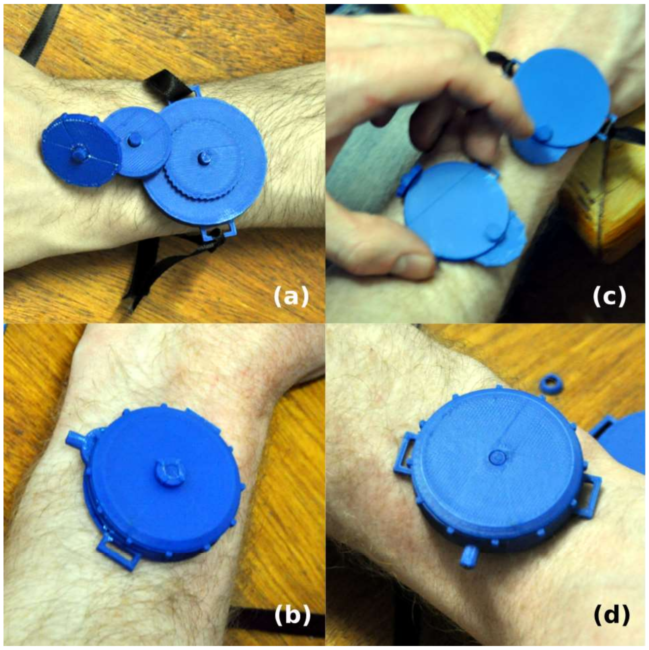

Figure 3: Combinations proposed by our participants : (a) Non-functional design, (b) combination of three inputs : stacked, around and clamped, (c) various combinations, (d) preferred design.

explore eyes-free use. The instructor invited participants to think aloud, discuss and freely test combinations. After 15 minutes of free interactions, the instructor asked them to express their preferences, which were discussed for 15 more minutes. Then she invited the focus group to engage a discussion for 20 minutes on potential gestures for their preferred design. She did not intervene, except to seek clarification.

4.1 Results

4.1.1 Device. Participants cooperated and created both potentially usable designs. They also voluntary created non-realistic designs to trigger new ideas and discussions as shown in Fig. 3.

Participants proposed combinations involving three physical rotary inputs, or including a button on top (as simulated in Fig. 3-d). They discarded the use of three physical rotary inputs as too complex. All participants proposed various combinations of wheels and bezels of different sizes (Fig. 3-b&c), to expand the number of controls. However, these could not be used simultaneously, which limited their use to applications benefiting from the eyes-free use of two functions (such as a music player, for volume and songs). Nine participants were also interested in the possibilities of a large wheel augmented with a crown (Fig. 2-f), in particular for remote interaction with a two levels menu. However, the other seven found this model too limited for interaction, and outlined that it would be more difficult to operate with a single finger, at the contrary of bezels.

Both focus groups gradually converged towards a double stacked bezels prototype (Fig. 5) through two different pathways. The first focus group's participants focused on general interaction principles and argued that the size of the bezel allowed for more control and sensitivity than the wheels and crowns ("*I've been playing with [the bezel], I think I can easily distinguish twelve landmarks–I'm not so confident for the crown. And it requires to use two fingers*"). Two people in the first group argued that rotary inputs of different sizes (e.g. crown and wheel) would probably be interpreted as having a different span, while same size inputs could be configured on a case-basis ("*if you take this one [i.e. Fig. 2-f] you're going to suppose that the wheel has a larger span than the crown, that the crown can only be used for details*"). The rest of the participants agreed, which led the group to exclude all the designs other than the double stacked bezels. Two other participants also pointed out that combining two bezels enables the same gesture to be performed on one or the other bezel, or with both very easily (see also Section 4.1.2), opening opportunities for supporting novice to expert transition in using menus. Finally, they foresaw the advantages of a double bezel for all kind of selection : two participants argued the first bezel can be used to select a set of item, the second bezel to select an item within this set ("*if you think about it, almost every app we use daily is a two, maximum three, levels menu*"). With experience, they foresaw users could select a large number of items while eyes-free.

As for the second focus group, the participants rather focused on the scenarios enabled by the different types of combinations. They emphasized the playfulness and expressiveness of tangible controls and that it was well adapted to everyday, situated interaction. Four of them were particularly interested by its use as a remote (eyes-free) controller ("*We've got so many remote and controllers now ! It's*

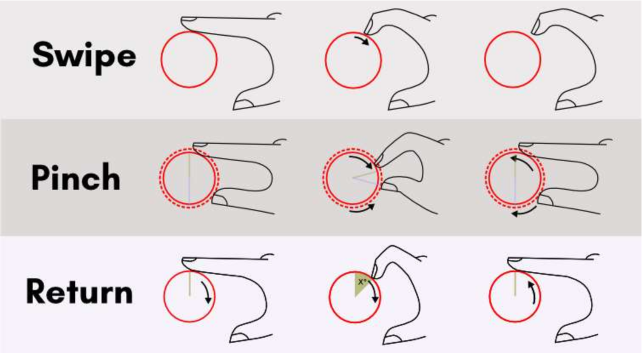

Figure 4: The swipe, pinch and return gestures proposed by our participants, as described in the findings of our focus groups

gotten worse than it was a few years ago, with the TV and satellite and DVD player remotes. And I really like tangible controls, but we need something more complex than buttons, and this kind of sliders, I'd be curious to use them"). The whole group discussed the potential for controlling the environment, rather than just the watch. One example was scratching the music currently playing, or controlling a slides player. They hesitated longer between a model using a wheel and a bezel (Fig. 2-i), and a double-stacked bezel, because *two participants argued* that on both these models the two inputs can be used in the same movement, rather than one after the other ("*It might be more practical, to have them separated. Maybe the mapping would be more intuitive. But that's definitely less practical for a power user*"). They however settled for a two bezels design, emphasizing that the amplitude of the movement would enable for more precise control than the other rotary inputs ("*I definitely prefer the two stacked bezels. You're less likely to manipulate them by mistake*"). Although all participants tried to create designs using middle size crowns, they all agreed that only small crowns (6mm) were usable. As for wheels, they all preferred the two smallest sizes (6 and 18mm).

4.1.2 Interaction on the preferred model. During the last 20 minutes of the focus group, the participants discussed potential interactions on their preferred model (two stacked bezels), which justified their choice.

Circular menus : The first idea in both focus groups was to use the bezels to explore a circular menu : each bezel would be assigned to a menu level. While both groups thought of circular menus, the subsequent proposals differed : the first focus group discussed on interactions (e.g. *"you could have something different if both bezels turn at the same time*" or "*one of the bezel could be used for choosing the apps, the other for navigating within the app*), while the second focused on use cases (e.g. a music app, smart home remote control, game controller) and challenges regarding different navigation needs.

Gesture shortcuts : Participants proposed four classes of gestures. All participants agreed on *continuous rotation*, whereas the gesture acts as a slider and can be used for setting the hour. All participants agreed on the use of *swipe* (Fig. 4-Top), as a very short gesture to the left or to the right, that can be used for navigation. Fifteen participants agreed on the design of a *pinch* gesture (Fig. 4-Middle) involves two fingers, one per bezel, pushing in opposite or similar ways. Finally, eleven participants agreed on the use of *returns* (Fig. 4-Bottom), as a gesture starting from the top and quickly going to a given position and then back.

Touch input : Five participants proposed to combine touch inputs on the screen with tangible inputs. For example, in a calendar app, the day or the hour could be selected by a touch input on the screen, and then be set using a bezel swipe (or a wheel on a rectangular watch). Three participants also proposed that the bezel itself could be touch sensitive, so that an input could be confirmed at the end of the bezel rotation.

To sum up, participants identified several combinations of physical rotary inputs, but the only one they agreed on was the double stacked bezels. Regarding the interactions with this watch case, they proposed a menu system, a set of gesture shortcuts as well an interaction technique combining touch and gestures.

5 PROTOTYPE

The outcome of the focus groups informed the design of a prototype called RotaryWatch illustrated in Fig. 5. This prototype is mainly intended to collect reactions and gather new insights on potential scenarios (including eyes-free interaction).

Device. RotaryWatch is a circular watch with two stacked bezels. The top bezel is slanted, while the bottom bezel is toothed, to ensure a firm grip as the contact area between the finger and the bezel is smaller.

The watch case width and height are 42mm, which is similar to traditional watches and current commercial smartwatches. The RotaryWatch's depth is more important than traditional watches due to embedded electronics (which can be reduced on a high-fidelity prototype). However, the bezels' height is realistic.

The angular positions of the bezels are acquired by two rotary encoders, wired to an Arduino board, powered by the computer through a USB cable. The graphical interface is shown on the computer screen, or on an OLED display of 1.5", which can be fixed to the forearm.

The graphical interface is controlled by a NodeJs server and by two controllers.The first tracks bezels' rotation. The second recognizes the gestures (return, pinch and swipe) illustrated Fig. 4. These gestures are defined by three features : the angular amplitude, the rotation direction and time length.

Interaction and applications We distinguished gestures dedicated to the whole system (e.g. sound) and gestures for in-app interactions (e.g. list navigation). Whole system gestures are performed by interacting simultaneously with the two bezels. For instance, the system sound level could be set by moving both bezels continuously. In-app gestures use only one of the two bezels. We designed three use cases (music player, menu, map) to exemplify potential uses.

6 EXPLORATORY EVALUATION

Through a focus group supported by the use of this prototype, we aim at gathering professional designers' point of view on rotary inputs combinations for smartwatches. We chose to gather this qualitative feedback from experts rather than quantitative data, as we focus on usage (rather than performance comparison). Focus

Figure 5: (a) The three implemented applications and the envisioned device. (b) Our proof-of-concept, a watch using two stacked *bezels.* The bottom bezel is toothed, the top bezel is slanted. (c) For demos, we used a deported screen when visual feedback was necessary

groups enable to gather an articulated account by representatives the design community [21]. Would they propose to use them, and if so, for which scenarios ? What are the benefits and challenges they foresee ? Is this a promising approach for smartwatches ? These insights should nurture the design space, as well as confirm that it opens promising perspectives for designers. The focus group discussion was recorded, transcribed and annotated following the same procedure than the first focus groups.

Participants : The participants were six designers. Two are working on wearables, while the four others work in related fields (e.g. User Experience, User Interface or product design). They were different from the participants in the first focus groups.

Procedure : We explained that we wanted to infirm or confirm the interest of combining two rotary inputs. To achieve this, we needed to elicit their benefits and challenges as perceived by designers working or likely to work in this field. The instructor asked the participants to describe use cases for which rotary inputs combinations would be more adapted than a single input and current devices. The participants were also invited to discuss the difficulties and benefits foreseen from their professional point of view for 45 minutes. We demonstrated the prototype and the three applications implemented. We were particularly interested by remote interactions We stated that it was a low resolution device, and that they should imagine a refined version. They could use the prototype as well, and they manipulated it during discussion.

6.1 Results

One aspect emerging from this focus group is the versatility of the device. The participants described 21 scenarios for which they perceived that our proof-of-concept would be preferable to a single rotary input and to current touch-based interaction. 8 of them were related to the smart home (e.g., controlling smart lightning or television), 5 to activity tracking (e.g., setting the chronometer, itinerary planning), 3 to smart cars (e.g., control of glasses), 2 to their professional activities (e.g., controlling 3D objects) and 2 to gaming (e.g., as a controller or as a basis for new games). One participant also envisioned a text-input technique. The main benefit identified was the use of complex commands eyes-free.

Accessibility : Two participants foresaw this device could be helpful to people with visual impairments. They argued that it could help users to better visualize certain interactions, such as navigating within an audio content, or as an audio edition tool. They outline users would get immediate haptic feedback of their position and be able to perform shortcuts (while touch based interactions are most often consecutive gestures and taps). They also proposed that the bezels could be actuated to display information, such as activity stats, time or orientation and distance. These remarks points towards more generic use for tangible data manipulation. The other participants underlined they were not as versed in accessibility, and that they could not provide other insights on this.

Sensitivity : One advantage foreseen by three designers was the possibility to customize the device sensitivity (the control / display ratio) easily. For instance, the same function could be achieved by expert users using a small movement while other users could use ample movements. Overall, it allows to adapt to the user dexterity or accuracy. The device sensitivity can also depend on the chosen bezel. E.g. the first bezel allows precise control (e.g. scrolling one item per one item) while the second bezel allows fast control (e.g. jumping ten items at a time) which is useful for long lists such as contact lists. Two other participants supported these insights.

Energy saving and generating : One participant suggested that the rotary inputs could be used to generate the energy necessary to its functioning. This had been proposed for single rotary inputs in the literature as well [19].

Playfulness : Two scenarios were proposed for gaming, by two different participants. One was an original music game, while the other envisioned the use of RotaryWatch as a controller for existing video games. Additionally one participant outlined that using RotaryWatch could make other applications playful : he suggested that it could be used for lock and unlock a house or a bike using a combination of gestures ("*like in spy movies. It would be so much more fun that way*"). The four other participants agreed on this.

Eyes-free : In many scenarios proposed (e.g. gaming, professional, and smart cars applications, remote control for home appliances), participants envisioned the watch could become a controller for deported screens, suggesting these rotary inputs are well suited for eyes-free interaction. Participants also debated whether 8 or 12 landmarks could be reached eyes-free on each bezel. Although a majority (5/6) argued that 8 landmarks would be better manageable and can be described as would a direction be (e.g. "North", "Southwest"), this should be further tested. In any case, this opens multiple possibilities for eyes-free interaction : there should be at least 64 combinations of landmarks reachable.

Style : One participant working on luxury watches underlined that this form factor could generate new aesthetic propositions (by the superposition of two different material for instance) and be well received by designers of high-end watches. He also pointed out that people valuing watches are interested in complex and unique mechanisms, and that this could the opportunity to design a specific UI–just as watch faces used to be work of art. The other participants agreed but also underline it would require the development of new skills in this industry.

Limitations : The main drawback was the perceived complexity of the device. A UX designer participant was concerned with how to convey the use of each bezel and their combinations. Two others argued that it would mainly appeal to expert users, although they also underlined that it could support novice to expert transition (by first interacting with only one bezel, and gradually learn to use the second one).

7 DISCUSSION

A survey of traditional watches enabled us to identify dimensions of the design space of physical rotary inputs. It provided a useful structure to help focus group participants to explore and generate new devices and scenarios. The number, diversity and richness of the details of scenarios they proposed tend to confirm that combining rotary physical inputs is a promising design space to investigate for interaction with smart watches. The scenarios they envisioned were highly contextualized and often involved multi-tasking. The focus groups confirmed our motivations : designers identified eyes-free use and a higher number of shortcuts as a primary benefit, and spatially unbounded motions as a way to customize sensitivity. Our participants also suggested that (1) these aspects would be beneficial for accessibility and that (2) physical rotary inputs not only consume less energy than touchscreen, but they can also generate the energy necessary to the functioning of the device. This might be especially useful for bracelets such as Fitbit, which do not have a tactile screen. (3) These inputs can also be used with, or in parallel of, more traditional inputs techniques, such as voice or touch. Interacting with physical rotary inputs does not occlude the screen. (4) Finally, it can reinforce expressiveness in several applications (e.g., in manipulating various kinds of data, from the time to audio content). Albeit use of rotary inputs would not be indicated on all types of interactive bracelets, it seems to be an interesting lead for people working on accessibility, but also, surprisingly, on high-end watches. Combining rotary inputs may also be beneficial for other devices using this type of physical inputs during complex tasks (e.g., Mental Canvas). Indeed, it adds a dimension for interaction.

A critical point raised during the focus group was the learning curve in using a device combining rotary inputs. However, the designers also discussed several strategies to address this : Learning to use one input at a time, customizing gestures, sensitivity and applications. Gesture-based teaching methods such as Marking menus [11] can also guide users step to step for selecting commands. This would need to be evaluated with end-users, rather than with designers.

8 CONCLUSION AND FUTURE WORK

To sum up, the survey of traditional watches enabled us to identify three main types of physical rotary inputs, and their combinations, describing a design space for physical rotary inputs for smartwatches. Our first step was to explore this design space through focus group, and proposed to specifically explore a two-stacked bezels watch, RotaryWatch, which is, to our knowledge, a new design proposition. Our second step consisted in organizing a second focus group with experts designers with elicited the design challenges and opportunities for smartwatches combining physical rotary inputs based on the proof-of-concept. It focused on one device, but many of their insights (e.g. sensitivity) may apply to other combinations identified earlier in the exploration process, or to the use of a single rotary input.

Future work should focus on : (1) Evaluating the usability of rotary inputs with users, and in particular of eyes-free use. We note that it would be too demanding for users to try every combinations of the two bezels. The evaluation could consist in a specific subset of shortcuts using both bezels. It should also be performed while walking or while doing another activity ; (2) Exploring users' preferences, by implementing a few scenarios on both our prototype and a touch-based smartwatch, and enabling their use outside of the lab ; (3) Investigating combinations with other interaction modalities, and touch in particular, both for this prototype and on commercial watches using rotary inputs.

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