SnapBand: a Flexible Multi-Location Touch Input Band

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ABSTRACT
The form factors of current wearable devices are designed and limited to be worn at specifically defined on-body locations (such as the wrist), which can limit the interaction capabilities based on physical constraints in body movement and positioning. We investigate the design of a multi-functional wearable input device that can be worn at various locations on the body and may as well get mounted onto objects in the environment. This allows users to adjust the device's location to different affordances of varying situations and use cases. We present a *SnapBand* as such a multi-location touch input device that can be quickly snapped to different locations.

Author Keywords
Wearable; multi-location; touch input device; on-body; off-body

ACM Classification Keywords
H.5.2. User Interfaces: Input devices and strategies

INTRODUCTION
For on-body wearable input devices, the form factor specifies the body location the device is worn, each having different properties in reachability. Wagner et al. introduced a body-centric design space [6] showing that different involved body parts lead to different physical contraints in body movement and positioning. E.g. a smartwatch on the wrist requires two hands for touch interaction and restricts movement and position of the watch hand [1]. This can make interaction more difficult to perform, potentially dangerous or even impossible depending on other mobile tasks that simultanouesly involve these body parts, such as biking.

Lyons et al. argued that wearable designer should examine multiple dispositions, i.e. the user's varying poses and physical relationship between them and the wearable device [4]. Users can adjust their pose or the on-body placement of a wearable device for active or passive use, however wearable input devices are mostly designed to be used on only a single on-body location (such as the wrist), which limits the interaction capabilities and constrains the users' poses. In this work, we investigate the possibilities of using an input device that can be used on multiple on- and off-body locations. We present a *SnapBand* as a flexible touch input band that can quickly be snapped to different locations.

MULTI-LOCATION TOUCH INPUT
Depending on varying affordances and use cases, different on - and off-body locations can be suitable for touch input. One solution for this is to integrate touch capabilities into more and more everyday objects and environments [5]. By this, a selection of touch capabilities can be available to users on multiple locations at once. This principle is also utilized for personal mobile devices, such as phones, watches and tablet computers that might be accessible at the same time but embody different affordances.

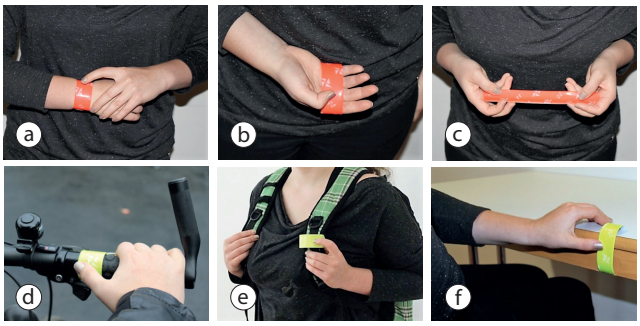

Figure 1. ***SnapBand*** **is a touch input device that can be snapped, worn and attached to multiple on- and off-body locations, such as onto the wrist similar to a smartwatch (a), as a one- or two-handed touch controller (b&c), attached to a handlebar on a bycicle (d), on a strap of a backback (e) or the edge of a table (f).**

We propose an approach that does not require a wide instrumentation of everyday objects and environments, but instead to use a form factor that can be worn or attached to multiple locations within the environment. Such a design could take various forms. An example could be a clipping-mechanism (cf. iPod Shuffle) to allow the input device to be attached to various locations on clothing. Clipping directly onto the user's skin (such as the wrist) however remains unsuitable due to stretching. Ideally, a form factor for a multi-location input device should be comfortable to wear on clothing as well as on the user's skin. We found the *snap band* form factor to be suitable for both.

SnapBand
A *snap band* is a flexible bistable spring band that can have two distinct configurations: In a first equilibrium position the spring band is flat. By slapping the end of the band against a body part such as the wrist or an object such as the edge of a table, a second equilibrium is reached, at which point the band curls into a circular form factor (see Fig. 1). We utilize the *snap band* form factor to enable touch capabilities at varying locations. The act of snapping the device is a transition between multiple interaction dispositions [4] and was shown by its origin as a toy to be a pleasant interaction. *Snap bands* were mostly snapped onto wrists, but could also be attached to other body parts such as arms or thighs or into the environment. When used in the curled configuration, the location is ideally roundish and embraceable by the band. In this position, the band remains in its position and tightens itself by its spring mechanism. It can however also be used in its flat configuration, e.g. as a bimanual handheld input device (see Fig. 1c). Suitable off-body locations are ideally close in range of the user's hands such as the handlebar of a bicycle (see Fig. 1d) or gym machine or the edge of the user's desk (see Fig. 1f). When snapped into location, the band is immediately available for touch input that can be used for a variety of mobile or stationary interaction, e.g. to control smart eyewear, external displays, smart earbuds, a music player or smart home appliances.

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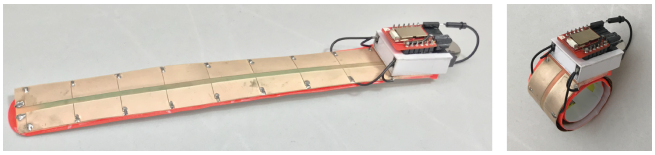


Figure 2. The *SnapBand*-prototype in a flat (left) and curled (right) configuration. A BLE Nano at the end of the band serves as a micro controller powered by a CR2032 coin cell battery.

PROTOTYPE

For the *SnapBand* prototype, a common commercially available snap band was extended with a custom touch input design (see Fig. 2). The base band had dimensions of 22 x 2.5cm which was long enough to wrap around an upper arm, but not too long to not fit a small wrist. For the touch sensor, we used a flexible printed circuit design with a copper coating and active capacitive sensing in shunt mode using the capacitive sensing library for Arduino. A touch resolution of 8x2 pixel showed to be sufficient for a simple 2d touch gesture set of left, right, up and down swiping and tapping for selection. For processing of the touch sensing, a BLE Nano Arduino was mounted to the end of the band. Power was supplied by a CR2032 coin cell battery beneath.

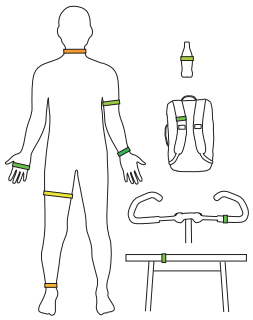
USER STUDY

We conducted a user study to investigate whether the concept of multi-location touch input is suitable and which locations are preferred for interaction. We recruited 16 participants between 19 and 29 years (m = 23.6; 8 female) of which all stated to be familiar with touch devices, but having only very little experience with wearables. Participants would use the device within three different use cases: First, participants would use the *SnapBand* as an input device for a head-worn display (a Google Glass). In this use case, the *SnapBand* was worn on the wrist and participants would navigate through a contact list and open and dismiss information. The second use case was using the *SnapBand* as a handheld controller for a (staged) presentation, where participants would show 16 slides of an illustrated story. For the third use case, participants would use the *SnapBand* to control music while simulating a workout on a gym machine (ergometer) where the *SnapBand* was attached to the handlebar. These use cases served to make participants familiar with the concept of multi-location touch input in varying situations. Following this, participants provided feedback using a structured questionnaire with open-ended questions and 5-point Likert scales.

Results

Participants found the concept of using a single device on multiple locations useful (m = 4.69, sd = 0.46; from 1 - strong disagreement to 5 - strong agreement) and agreed that depending on the use case a different location can be preferable (m = 4.56, sd = 0.50). The *SnapBand* was seen as a suitable form factor for multi-location input (m = 4.56, sd = 0.61) and interaction with the device was reported to be easy to learn (m = 4.86, sd = 0.33).

Participants were asked which advantages and disadvantages they see in the introduced *SnapBand* concept. Appreciated was foremost the versatility (P6) and flexibility (P4, P8, P15) of the input device and that its location can be changed quickly (P10, P16), which was seen as efficient for interaction (P11, P13). The form factor was also seen as lightweight (P3) and easy to transport in a curled configuration (P2, P5, P6). Mentioned downsides were that the device could slip off a location (P12, P15) and potentially get lost (P4, P6, P16) which was seen as a big problem when the device is the only available input device (P1, P7, P8). It was also commented that the band size would always be a compromise and could be too large or too small for some locations (P5, P6, P9).



Location	*User Ranking*		*User Rating*				
			Interaction	in public		in private	
	Median	IQR	Length	Mean	SD	Mean	SD
Wrist	1	1 - 1.5	2-4s	4,81	0,53	4,81	0,53
			4-10s	4,75	0,43	4,81	0,53
Hand Palm	3	2 - 4.5	2-4s	4,19	1,01	4,25	0,97
			4-10s	3,94	1,25	4,13	1,17
Handle Bar	3	2 - 5	2-4s	4,13	1,16	4,25	1,09
			4-10s	3,81	1,47	3,88	1,27
Upper Arm	4,5	3 - 6	2-4s	3,75	1,20	3,75	1,15
			4-10s	3,38	1,22	3,56	1,22
Table Edge	5,5	4 - 6.5	2-4s	4,06	1,14	3,75	1,30
			4-10s	3,94	1,14	3,69	1,40
Backpack Strap	6	3 - 7.5	2-4s	4,13	1,17	3,19	1,59
			4-10s	4,00	1,32	3,13	1,65
Bottle	7	6 - 8.5	2-4s	3,56	1,22	3,50	1,22
			4-10s	3,31	1,36	3,38	1,17
Thigh	8	5 - 8.5	2-4s	2,75	1,44	2,94	1,50
			4-10s	2,38	1,54	2,75	1,60
Ankle	8	6 - 9	2-4s	2,25	1,44	2,44	1,50
			4-10s	1,94	1,30	2,25	1,39
Neck	10	10 - 10	2-4s	2,25	1,44	2,25	1,44
			4-10s	1,81	1,38	1,94	1,39

Figure 3. User evaluation of *SnapBand* input locations. Participants rated whether they can picture themselves using a touch input band on the respective location on a 5 point-Likert scale (1 = totally disagree; 5 = totally agree) under the conditions of interaction length and whether the setting is in public or in private. Participants would also rank the locations for preference.

For the multi-location touch input, participants were asked to rate for a set of 10 locations (6 on-body, 4 off-body) whether they would use a touch input band on the respective location (see Fig. 3) under the conditions of interaction length (c.f., [2]) and whether the usage would take place in private (at home) or in a public setting. Subsequently, participants would rank the locations for their personal preference. Participants overall preferred the locations that they used within the three use cases (*wrist*, *handheld*, *handle bar*). For the on-body locations, acceptance was very similar as reported by Karrer et al. for interactive clothing [3] in that *wrist*, *hand* and *arm* are preferred over body parts more distant to the fingers. Interestingly, while on-body locations were rated lower for a setting in public, off-body locations like the *backpack strap* and the *table edge* were rated *higher*. This could hint at present concerns regarding the social acceptance of on-body locations in public. In this regard, a multi-location input device like the *SnapBand* can enable users to choose and adjust an input location based on *individual preference* of a respective usage situation, including expected efficiency, reachability, comfort and social acceptance.

CONCLUSION AND FUTURE WORK

We presented *SnapBand*, a multi-location touch input band that can be worn or attached to multiple on- and off-body locations. In the future we want to improve the prototype with a higher touch resolution and want to explore possibilities for the device to automatically detect its location based on orientation and alignment. We plan to use this information to infer its intended use case.

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