Haptic Assistive Bracelets for Blind Skier Guidance

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ABSTRACT

Blindness dramatically limits quality of life of individuals and has profound implications for the person affected and the society as a whole. Physical mobility and exercises are strongly spurred within people, as ways to maintain health and well-being. Such activities can be really important for people with disability as well, and their increase is paramount in the well-being and assistive care system. In this work, we aim at improving the communication between the instructor and a visual impaired subject during skiing. Up to now, only the auditory channel is used to communicate basic commands to the skier. We introduce a novel use of haptic feedback in this context. In particular, the skier can receive directional information through two vibrating bracelets worn on the forearms. Haptic interaction has been proven to be processed faster by the brain demanding a less cognitive effort with respect to the auditory modality. The connection between the instructor and the skier is done by Bluetooth protocol. We tested different guiding modalities including only audio commands, audio and haptic commands and only haptic commands. Preliminary results on the use of the system reveled the haptic channel to be a promising way for guidance of blind people in winter sports.

Keywords

Haptic feedback; Winter sport; Blind Navigation; Assistive Device; Wearable Robotics.

1. INTRODUCTION

Persons with disabilities participate to a lesser extent in society than do the general population. They often find their social interactions and social network limited, as isolation may affect the range of life experience and influence effectiveness in social situations. Barriers within society seem to prevent people with physical disabilities from participating in social communities, and most types of disabilities have a reducing effect on all types of participation in society, which concerns social life in relation to family and friends as well as participation in societal areas such as education, employment and leisure time activities [1]. One important issue would be to make participation possible for people with disabilities in all fields to the degree that the individual may want to participate [2].

People with disabilities are able to participate in physical activities when made accessible and adapted to their preconditions [3]. In this work, we focus in skiing for visually impaired people [4]. Instructed blind skiers can face slopes of medium/high difficulty with the help of an instructor that skies in front of them [5]. Instructor typically communicates with the skier through voice giving commands about the turns, the velocity and the condition of the path. There are occasion when additional communication becomes necessary. In crowded areas and lift lines instructor and skier use horizontal ski pole as a guide. In congested areas requiring crispy movement, the grasp on the pole is even closer to get a more direct guidance [5]. This safety behavior is the inspiration for this work. We want to extend what happen only in particular

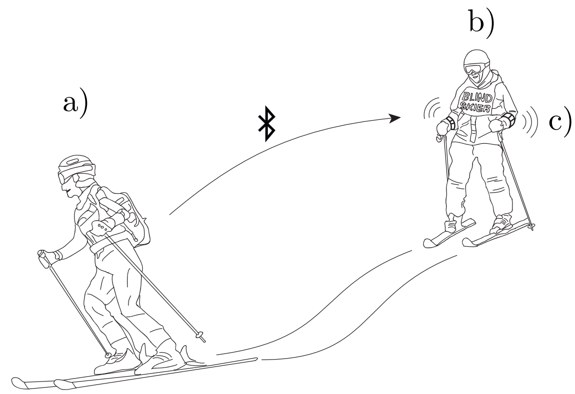

Figure 1: Concept. The main features: a) instructor equipped with the button-augmented ski poles; b) blind skier equipped with c) vibrotactile wristbands. The communication between the master and the slave sides is done by Bluetooth protocol.

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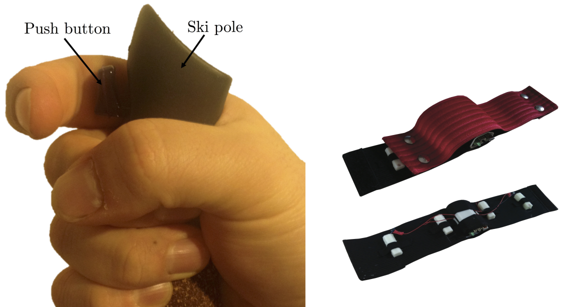
AH 2016, February 25-27, 2016, Geneva, Switzerland

DOI: http://dx.doi.org/10.1145/2875194.2875249



(a) (b)

Figure 2: System for suggesting turning direction to blind skier: (a) proposed button-augmented ski pole; (b) proposed vibrotactile haptic bracelets. The ski pole we introduce is provided with a button, connected with a Bluetooth antenna, an Arduino, and a battery (not shown) to a mobile computing device worn by the blind skier. The proposed haptic devices, i.e., vibrotactile bracelets, are composed of four vibrating motors, controlled by a on-board Arduino, connected with the augmented ski pole via Bluetooth, and powered by an on-board battery.

critical situations to the entire time of skiing. The idea is that the skier can always be in contact with the instructor not only through the auditory channel, but also with the touch one. Haptics can play a key role in the communication between the instructor and the blind skier.

We introduce a novel use of haptic feedback in this context. In particular, the skier can receive directional information through two vibrating bracelets worn on both the forearms. At the same time, the instructor can take advantage of his instrumented ski pole to pass information to the skier. The communication through haptic cues has been proven to be processed faster by the brain, demanding a less cognitive effort with respect to the auditory level. Haptics for blind navigation has been proposed in [6] for indoor localization. In [7], a comparison of different vibrotactile devices for guiding visually impaired people was proposed. The haptic stimuli can be provided in different parts of the human body. In [6] the system provided surrounding environment information by means of vibrotactile stimuli displayed to the chest and to the shoulders of the user. In [8], a waist belt was proposed. In [9, 10], the authors developed electronic bracelets which provided vibrations when an obstacle was close to the user in a real and virtual reality scenario, respectively. Vibrating phones were used for non visual way-finding in [11] and for tourists guidance in [12]. Results demonstrated that vibration patterns can be an efficient way to display spatial locations. In the framework proposed in this paper, the connection between the instructor and the skier is done by Bluetooth protocol. We have tested different guiding modalities in a simplified scenario where blind-folded users are asked to follow a predefined path in a dry environment. Three different guiding modalities are considered: only audio, audio and haptics and only haptics. Preliminary results on the use of the system show that the haptic channel can be used a guidance mode for blind people in winter sports.

2. SYSTEM IMPLEMENTATION

The proposed scenario is depicted in Figure 1. It includes a ski instructor and a visually impaired skier. In the proposed implementation, we consider the case in which the instructor is in front of the visually impaired and is leading the pace. Without losing functionality, the proposed system can be extended to include other types of ski teaching for visually impaired, e.g., when the instructor is placed backward w.r.t. to the blind skier.

The visually impaired is provided with a pair of vibrotactile bracelets, and a mobile computing device, e.g., a smartphone. The instructor is provided with a pair of augmented ski poles (see Figure 2a), embedding two additional electronic devices. Each augmenting device is composed of a microcontroller, a wireless communication antenna, a battery for powering the electronics, and a switch. Each pole is connected wireless with the mobile computing devices worn by the blind skier. Pressing the switch mounted on the left/right poles triggers a signal, with the aim to activate the left/right vibrating bracelet worn by the blind skier. This triggering signal is directly sent through the wireless communication to the mobile computing device on the blind skier, whose maximum distance from the ski instructor must be lower than 10 m, being this a confident functioning distance for the wireless communication. Once the mobile computing device has received a triggering signal, it activated the corresponding vibrotactile bracelet. The resulting vibration on the arm of the blind skier is the main novelty of this work. The bracelet keep vibrating until the instructor press again the button. This solution allows the instructor to regulate the length of the haptic stimulus.

For what concern the wearable haptic devices worn by the blind skier (namely c) in Figure 1, and b) in Figure 2), each bracelet is composed by four cylindrical vibro-motors which can be independently controlled (see Figure 2b). Moreover, every single wearable haptic device contains a microcontroller, a wireless communication antenna, and a battery for powering the electronics and the vibro-motors. When a bracelet is activated, by the triggering signal from the augmented instructor's poles, its vibro-motors vibrate alternatively, at 250 Hz, in pair so that the *aftereffect* problem, i.e., a vibration effect that persist after the end of the stimulation, is minimized.

The subject wears one haptic bracelet on each arm in order to maximize the stimuli separation while keeping the discrimination process as intuitive as possible.

We chose this configuration for the following reasons: (i) vibration is best on hairy skin due to skin thickness and nerve depth [13], in particular wrists and spine are generally preferred for detecting vibrations, with arms next in line [14]; (ii) movement can decrease detection rate and increases response time of particular body parts, e.g., lower body sites [14]. We fitted the haptic bracelet to the arm instead of to the wrist since: (i) users may wear accessories on the wrist, (ii) the bracelets can be visible as in outerwear or accessories or invisible as with underwear, as a consequence it is easier to hide them if they are placed on the arm rather then on the wrist. On each bracelet the distance between the motors is about 80 mm—when not worn; the minimal distance between two stimuli to be differentiated is about 35 mm on the forearms. In two-point discrimination perception, there is no evidence for differences among the left and right sides of the body [15], [13].

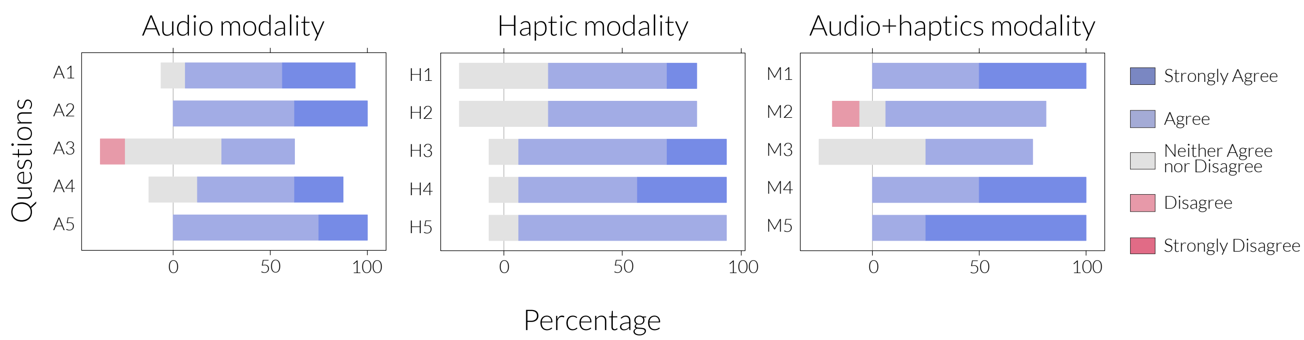


Figure 3: Likert scale data for the audio (left), haptic (center), and audio+haptics (right) modalities.

2.1 Technical implementation

From a technical point of view, each of the proposed augmented poles is composed of an Arduino Pro Mini 3.3 V board, a RN42 Bluetooth 2.1 antenna, and a 3.3 V LiPo battery, mounted inside the pole.

Each of the wearable haptic devices is composed of an Arduino Pro Mini 3.3 V board, a RN42 Bluetooth 2.1 antenna, a 3.3 V LiPo battery, and four Precision Microdrives 303-100 Pico Vibe 3.2 mm vibro-motors. All the aforementioned devices, i.e., the augmented poles and the wearable haptic devices, are connected to the mobile computing device worn by the blind skier. The mobile computing device acts, in fact, as a bridge between the augmented poles and the vibrating bracelets.

3. PILOT EXPERIMENT

The previous section was devoted to the description of the proposed system. We here present pilot experiments aiming to evaluate the feasibility of the proposed approach. In our tests, we considered the case in which one instructor is leading one skier, in a one-to-one relation. We evaluated our system in an outdoor dry environment. Both skier and instructor were walking instead of skiing. The instructor, using two switches placed at the top of two short poles, respectively, could command vibrotactile cues to a blind follower. One instructor (age 43, 12 years of experience) participated at the evaluation of the system. Seven blind subjects (age $18-54$, 3 of them with previous experience in blind skiing) were asked to follow the instructor while receiving suggestions regarding the turn to be done. The instructor followed predefined trajectories drawn on the floor. He activated the turn signal in the different modalities according to his experience in curve execution time related to the pace. Each suggestion recommended a turning of approximately 60^o according to the displayed direction, i.e., a vibration of the left haptic bracelets required a turning on the left, and viceversa. Three modalities have been evaluated: *i*) the instructor was signaling to the skier the turning direction by means of acoustic signals, namely voice directions (audio modality); *ii*) the instructor was signaling to the skier the turning direction by pressing the switches on the ski poles, thus by sending haptic cues to the blind skier (haptic modality); *iii*) the two aforementioned modalities were merged, so the instructor was both signaling to the skier the turning direction and by means of acoustic signals and sending haptic signal through the augmented poles (audio+haptics modality). The order of modality execution was pseudo-randomly selected. At the end of the trials, a questionnaire in the form of a bipolar Likert-type five-point scale was proposed to the subjects, for all three conditions. The questionnaire—consisting in five questions—dealt with the usability of the system, its hampering, its easiness of usage, and about the clarity of

Table 1: Questionnaire proposed at the end of the experiments for the audio (A1, ..., A5), haptic (H1, ..., H5), and multi-modal (M1, ..., M5) modality.

A1	The audio cues paradigm, i.e., the instructor voices commands, is easy to use.
A2	The audio cues system is not hampering.
A3	The sound produced by the instructor is not annoying.
A4	The audio cues produced by the instructor are easy to listen.
A5	The audio cues system is helpful in following the instructor directions.
H1	The vibrotactile bracelets are easy to use.
H2	The haptic suggestions are not hampering.
H3	The sound produced by the actuators of the vibrating bracelets is not hampering.
H4	The vibrations produced by the vibrating bracelets are easy to distinguish.
H5	The haptic suggestions system is helpful in following the instructor directions.
M1	The multi-modal cues paradigm, i.e., audio plus haptic commands, is easy to use.
M2	The multi-modal system is not hampering.
M3	The sounds produced by the instructor and the sounds produced by the actuators of the vibrating bracelets are not annoying.
M4	The cues produced by the multi-modal systems are easy to listen (for audio) and to distinguish (for haptic feedback).
M5	The multi-modal system is helpful in following the instructor directions.

the suggestions, see Table 1. An answer of 5 meant *strongly agree* while an answer of 1 meant *strongly disagree*. A visual result of the questionnaire is shown in Figure 3.

4. DISCUSSION

From Figure 3, we can say that for the usability of the system (first question on the three questionnaires) the users preferred to have both audio and haptic suggestions while skiing. Regarding the system hampering (second questions), the audio modality was preferred by the users. This could be expected, since no additional device has to be used for skiing. Regarding the third question, which deals with the annoyance brought by the suggestions, the haptic modality was considered as best, due to its discrete appliance, which do not imply sounds, and it can see as "private" for the user. On the comprehension easiness of the cues—which is the focus of the fourth question—, the haptic cues have been found more easy to understand than the audio suggestions. This is probably due to the spatial differentiation which derives from the position we chose for the bracelets, that maximize the discrimination of cues. It is also clear that merging the audio and the haptic cues together, as in the case of the audio plus haptics, i.e., multi-modal, brought to the user the best impression. Eventually, for what concerns the fifth question, which is about how helpful are the suggested cues, again merging the two types of recommendation in the audio+haptics modality brought the best appreciation of the user.

5. CONCLUSION

In this paper, we propose a novel haptic interface to enhance the guidance of blind skier. The system consists in a pair of vibrating bracelets worn on the skier forearm and providing the haptic feedback and a pair of augmented ski poles used by the instructor to assign commands. We tested the system with seven blind subjects in an outdoor scenario. We are currently testing the system in real conditions on a ski route. We are also testing if modulated vibration can be used to pass information about the pace to set, the condition of the snow or any other alert the skier must be informed by the instructor. The enthusiasm showed by early users of the system are pushing us toward a further development of devices which will include waterproof. Eventually, due to the simplicity of application of our .system, studies are on-going about the possibility of exploiting the proposed framework described in this paper as support in the teaching of healthy beginner skiers. There are plenty of other valuable data points that could be translated into haptic feedback automatically to help positioning and body angle.

Acknowledgment

The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n. 601165 of the project "WEARHAP - WEARable HAPtics for humans and robots".

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