Comparing the Haptic Perception of Directional Information Using a Uni-manual or Bi-manual Strategy on a Walker

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Inès Lacôte[1], Claudio Pacchierotti[2], Frédéric Marie[3], François Pasteau[1], Fabien Grzeskowiak[1], Marie Babel[1], David Gueorguiev[4] and Maud Marchal[1,5]

***Abstract*— This paper evaluates the haptic perception of directional cues conveyed through one or two handles mounted on a walker, with the objective of devising haptic rendering techniques for aiding people with diverse mobility, sensory, and cognitive impairments. We designed a haptic handle composed of a cylindrical soft plastic casing, which houses five custom voice-coil actuators distributed around the handle. We carried out a human subject study enrolling 14 participants to investigate the impact of using uni-manual or bi-manual conditions and to identify the most effective tactile patterns in a navigation assistance scenario. We tested the use of either vibration bursts or pressure "taps" to convey different directions of motion, relying on the concept of the apparent haptic motion illusion. Results show that the proposed technique is an effective approach for providing navigational cues. We identified specific patterns that were highly effective both in uni or bi-manual conditions in conveying directional instructions towards the front (93.7%), the back (90.5%), the left (97.2%), and the right (84.5%) directions, highlighting the viability of both strategies and their adaptability to various single or dual-handle mobility devices. No significant difference was found between providing vibratory or tapping signals.**

Keywords: Tactile devices - Navigation Assistance - Apparent Haptic Motion - Smart Walker.

I. INTRODUCTION

When focusing on mobility issues for people with visual impairments, a major point of interest is navigation assistance. Because autonomy is an important element to assure mental health for people with sensory impairments [1], [2], researchers have tried to develop new tools to assist people in their displacements. As the sense of vision is altered, users have to rely on the other ones to understand the world and navigate safely [3], [4]. To compensate the sensory losses, researchers have developed audio apparatus, such as the SonicGuide [5] or the Laser Cane [6], and haptic devices, like the Smart Cane [7], the Buru-Navi3 [8] the Animotus device [9], and the S-Ban [10]. Users with moderate to severe visual impairments (MSVI) who also need mobility aids, such as a walker or a power wheelchair [11] have needs that sometimes do not fit the solutions adapted for MSVI users with no mobility deficiencies. In this respect, audio indications have the advantage of being easy to broadcast and understand. However, there are also drawbacks associated with using audio technologies for guidance, especially for people with visual impairments. Indeed, it has been shown that people use their hearing to safely move in outdoor environments [12] and they may want their assistive devices to be quiet and private. Consequently, there is a growing interest for providing navigation information trough other means, including haptics [13]. Haptic navigation cues can be provided via vibrations [7], [11], shape changing objects [10], [14], or skin stretch [15]–[17]. In the spectrum of vibratory haptics for navigation assistance, Wachaja et al. [18] investigated obstacle avoidance and navigation strategies when using a walker adapted for the elderly. They used multiple vibrotactile actuators distributed on the handles of a walker and in a belt, and concluded that participants rather prefer the information on the walker handles than around the waist. However, providing information through multiple vibrotactile signals can also lead to cognitive fatigue and difficulty in discerning them [19]. Another exploratory subject for navigation assistance is the use of haptic illusion as a mean to convey rich information with limited hardware. The apparent haptic motion (AHM) is one of the main tools that can be used to provide continuous directional indications [18], [20], [21], as it conveys the impression of continuous movement by activating discrete stimulation points [22]. It consists of the discrete mechanical or electro-tactile stimuli presented sequentially on the skin conveying a sensation of movement [22], [23]. For this reason, in our previous works [24], [25], we investigated the ability of "tap" stimulations, which are short pressure stimuli, to convey the apparent haptic motion illusion and, in turn, directional cues. Results showed that the proposed "tap" stimulation was as efficient as a 120 Hz vibrotactile stimulation in generating haptic motion illusion. They showed encouraging results for eliciting directional cues when the user's hand rests on a curved surface, suggesting a potential use on hand-held devices [25]. Actuators could however be improved for a clearer omni-directional use of tap stimulations.

This paper presents the results of an experimental evaluation aiming at comparing different haptic rendering techniques on a walker as a navigation assistance device. Specifically, we compared the effectiveness of providing either vibrations or "taps" to convey navigation information through the AHM paradigm, either through a single handle or two handles mounted on a walker.

This work was supported by Inria Défi Project "DORNELL". This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by Inria's ethics committee (COERLE) under Application No. 2021-39.

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II. Experimental Device

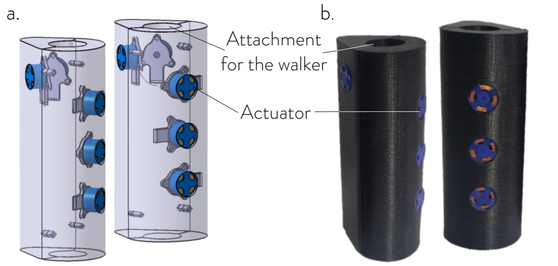

Fig. 1. Right and left haptic handles for giving directional tactile sensations. a) CAD of the soft 3D printed handle made out of TPU, 5 alcoves are included to house the actuators along and around the handle in a *"T"-shape*, so as to stimulate the thumb, the second metacarpal bone of the palm, and the index finger. b) Picture of the two handles, symmetrically designed to fit the two hands. For technical details, also see [25].

We designed a haptic handle composed of five electromagnetic actuators, shown in Fig. 1. Its design is inspired from one of our earlier works [25], but features an improved actuator design (see Fig. 2) and positioning, as well as the miniaturisation of the conditioning system for easier integration onto the walker. The handle is 3D printed out of TPU soft material (Filaflex 82A, 0.8 mm thickness). Its shape resembles that of a cylinder, and it has been designed to be comfortably held in one hand. The actuators are distributed across the handle in a "T"-configuration, so as to stimulate the metacarpal bones of the palm (three motors), thumb (one motor), and index (one motor) fingers. The handle is designed to be attached on a standard walker (ErgoClick 4 wheels walker), replacing the default handles of this assistive device. Fig. 3.b shows how a user holds the handle and how it is attached to the walker.

The actuators are custom electromagnetic motors inspired by the Hapticomm device [26] and used in previous studies on the AHM illusion [24], [25], [27]. They can convey both vibratory and tap signals, detailed in [25]. They are composed of coils as stators and magnets fixed in their repulsive position as movers, see Fig. 2.a. The contact between the actuators and the user's skin is made through a custom membrane, 3D printed out of TPU soft material, and designed to be threaded onto the coil with a cross shape on the top, keeping its top sufficiently soft and elastic, with a central space to glue the magnets (see Fig 2.b). This membrane acts as a lid and it is inserted onto the actuator. The actuators are then inserted in the handle dedicated alcoves from the inside with their attached membrane. With this design, the mover's rest position is up in the coil, glued on the membrane, no matter the orientation of the motor. When not electrically powered, the magnets stay maintained by the membrane in a neutral position. Its activation results in the extension of the membrane inside or outside the coil depending on the voltage sent to the actuator.

With respect to our previous handle [24], [25], [27], the setup was miniaturised, going from a 25L suitcase needing sector plugging to a 2L box. The original amplifiers and the National Instrument controller were replaced by M5 stacks and powered with a 12V, 3A power supply, that could be replaced by a power bank for portability (capacity: 10Ah/37Wh, Output: 6-9V DC, max 2A). This portability effort is crucial for future implementations in actual displacement on walkers and other mobility aids.

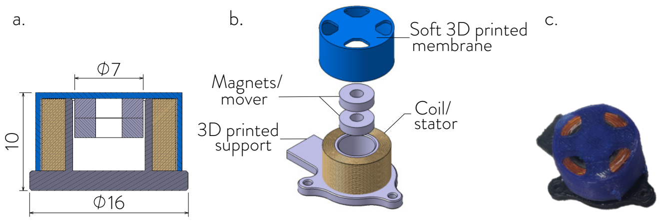

Fig. 2. Our custom-design electromagnetic actuator with the soft 3D-printed membrane. Five of these actuators are housed inside each handle (see Fig. 1). a) Cut view. b) Isometric View. c) Picture of the actuator.

III. User Study

We carried out a study to understand whether (i) different stimulation modes (vibrations, "taps"), (ii) rendering patterns (twelve patterns, distributed around or along the handles), and (iii) number of active handles (one, two) affect the performance of navigation assistance on a walker delivered through the AHM paradigm. This study has been approved by Inria's ethics committee (COERLE, n 2021-39).

A. Experimental setup and methods

1) Setup

The setup is composed of a standard walker, equipped with two haptic handles (Fig. 3b.), which are placed at 48 cm from each other, while their height can be adjusted for the comfort of the user. The walker has its brakes on and the participants stand behind it, hands placed on the haptic handles, as an everyday user would do. Participants wear noise-cancelling headphones and are facing a table, illustrating the possible directional interpretation they can give. The walker and the user do not move throughout the experiment.

2) Characterisation of tactile patterns

We employ the principle of the apparent haptic motion to deliver navigation cues, activating single actuators in sequences to give a sensation of continuous motion that can be interpreted as directional instructions. We consider twelve different tactile patterns (or signals), provided through vibrations or "taps". Six of them use one handle, six use two handles. The considered signals are illustrated in Fig. 4. Signals involving only one handle (top row) are referred to with "1H", while patterns involving two handles (second row) with "2H". The coloured arrows show the pattern of activation for each considered signal; their color gradient, from green to red, shows the temporal activation of the motors. For example, signal 1H-1 activates the three motors across the handle hold by the user's left hand, stimulating, in sequence, the thumb, the second metacarpal bone (across the purlicue), and finally the index; conversely, signal 1H-2 activates the three motors across the handle hold by the user's right hand, stimulating, in sequence, the index, the second metacarpal bone, and finally the thumb. In both

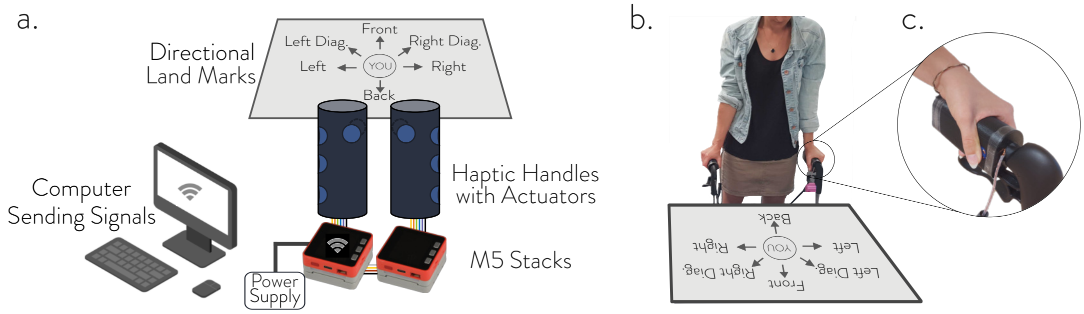

Fig. 3. a) Scheme of the experimental setup. The handles are powered and controlled through an M5 Stacks connected in WiFi with the PC sending the signals. The handles are used by the participants during the experiment as shown in b) and mounted on the walker as shown in c). b) shows a participant during an experiment. The participant is facing the illustration of the possible interpretations and orally gives her answers after receiving the directional cues. c) Focus on the handle mounted on the walker and a participant's hand position.

cases, only one handle is active. As an additional example, signal 2H-1 activates the three motors around *both* handles simultaneously, stimulating, first, the left thumb and the right index, then the second metacarpal bone of both hands, and finally the left index and right thumb; conversely, signal 2H-2 activates, in sequence, the three motors around the right handle and then those on the left handle hold by the user's left hand (i.e., the difference between 2H-1 and 2H-2 lies solely in the motors' temporal activation, shown by the different gradient across the arrows in Fig. 4).

There are two groups of stimulations: First, there are the AHM stimulations around the handle(s), with actuators positioned under the tip of the thumb, the second metacarpal bone and the tip of the index finger. Secondly, there are the AHM signals using the actuators positioned along the handle, across the metacarpal bones.

3) Type/mode of haptic actuation: vibrations vs. "taps"

We consider two different ways of providing haptic cues, vibrations and "taps", delivered by changing the activation mode of the electromagnetic actuators. The tap stimulation consists of a 220 ms square signal, while the vibration stimulation consists of 120 Hz sine within a 220 ms square signal envelope. For both modes, the signals are preceded by a negative impulse pulling the magnets down in the coil before pushing it out, so as to give them momentum. When two actuators need to be activated in sequence (see Fig. 4), they are activated with a delay of 110 ms between their beginnings, also called the Stimuli Onset Asynchrony (SOA).

4) Navigation direction

We asked participants to identify the different signals of Fig. 4 as directional cues. We considered six possible directional interpretations of these signals, presented as directional landmarks in Fig 3.a: left, left diagonal, front, right diagonal, right, and back. As walking backward is less common, we decided to reduce the instructions indicating such movements, not considering back diagonal instructions. These directions are illustrated on the table in front of the participant, as shown in Figure 3.b.

B. Experimental task and design

Participants are asked to stand behind the walker and hold both handles as if they were to navigate with it (see Fig 3). While standing in this position, they receive the stimulations. For each stimulation, participants are asked to interpret the perceived motion as one of the possible six directional instructions (Sec. III-A.4). After selecting a direction, they rate their confidence on a 9-point Likert scale. Answers are given orally and transcribed by the experimenter.

The experiment is divided into six series of stimulations. Each series is composed of thirty-six stimulations, being three repetitions of the twelve different signals, presented to the participant in a randomised order. Each series is delivered with the same type of haptic actuation, meaning all thirty-six stimulations in a series are either vibrating or tapping signals. To prevent participants from becoming accustomed to the stimuli and mitigate learning bias, the type of actuation is alternated. Half of the participants starts the first series with tapping and the other half with vibrations. This experimental protocol leads to 12 (signals) $\times$ 3 (repetitions) $\times$ 3 (series) $\times$ 2 (actuation type) = 216 direction identification trials per participant.

C. Participants and experimental procedure

Participants start the experimental session by reading and signing the consent form, as well as answering demographic questions about their gender, age, and handedness (the identification of their dominant hand). Finally, they start the direction identification task detailed in Sec. III-B.
We enrolled fourteen participants between 20 and 50 years old, four being women, and all being right-handed. Their dominant hand was determined by the ten-item version of the EHI (Edinburgh Handedness Inventory) about their daily habits. The participants were naive about the objectives and hypotheses of the study. The experiment lasted one hour.

The data collected from the participants were the direction they perceived ("left", "left diagonal", "front", "right diagonal", "right", "back", see Fig. 3) and their confidence rate from 1 (no confidence at all) to 9 (total certainty). At the end of the experiment, participants also gave open comments and feedback about the experiment and setup.

IV. Results

For a global overview of the data, we generated radar graphs to show the overall tendency in the identification of directions, shown in Fig. 5. The radar graphs present the percentage of answers distribution given by all participants

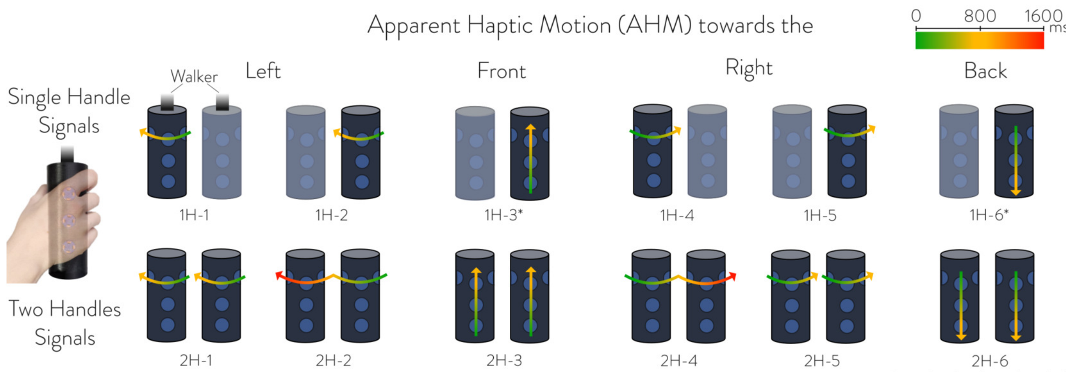

Fig. 4. Directional patterns using the AHM illusion. Each of the six handle pairs represent a stimulation. The top row shows patterns using only one handle, 1H-* (we greyed out the handle that is not activated), whereas the bottom row shows patterns using both handles, 2H-*. The colored arrows show the pattern of activation; their colour gradient shows the temporal activation of the motors, green first, then yellow, and finally red. Each motor is activated for a period of 220 ms, either for providing a tapping sensation or a vibratory sensation, according to the condition at hand.

when receiving a signal, pooling together vibrating and taps feedback types. Figs. 5a, b, c, d show these results for patterns employing AHM towards the left, front, right, and back of the handle(s). For example, from Figs. 5b and d, we can notice that signals 2H-3 and 2H-6 show a clear tendency to be interpreted as directional cues towards the "front" and "back", respectively, with very few alternative interpretations. Conversely, signals 1H-3 and 1H-6 have been mostly recognised as indicating directional cues either towards "front" or "right" and "back" or "right", respectively. In Figs. 5a and c, we can see that interpretations are more varied. While signals are still mostly recognised as indicating directional cues following the movement of the AHM pattern (i.e., 1H-1, 2H-1, 1H-2, 2H-2 towards the "left"; 1H-4, 2H-4, 1H-5, 2H-5 towards the "right"), we registered other interpretations, especially involving the diagonal directions when only one handle was activated (i.e., 1H-1, 1H-4 towards the "left-diagonal"; 1H-2, 1H-5 towards the "right-diagonal".)

Generalised Linear Mixed Model (GLMM): The data were processed using RStudio software (version 4.3.1). To assess the impact of the pattern, the fact that the strategy was uni- or bi-manual and actuation type/mode (vibration vs. tap) on the comprehension of directional information, we employed a Generalised Linear Mixed Model (GLMM). The GLMMs were fitted using maximum likelihood estimation (Laplace Approximation) with a logit link function and binomial error distribution. The Wald Chi-square test (signal, uni/bi-manual, actuation mode) performed on the GLMM showed a significant effect of the signal sent ($\chi 2(1) = 11.767$, $p = 0.001$) but no significant effect of uni-manual vs bi-manual ($\chi 2(1) = 0.110$, $p = 0.741$) or the actuation mode ($\chi 2(1) = 0.102$, $p = 0.750$). For this statistical analysis, we assume the presence of *correct* and *wrong* answers to have binary data. In order to do that, we considered correct: (i) *Left* or *Left Diagonal* answers when conveying AHM patterns moving towards the left of the handle, (ii) *Right* or *Right Diagonal* answers when conveying AHM moving towards the right, (iii) *Front* answers for AHM moving towards the front, and finally (iv) *Back* answers for AHM moving towards the back (the user).

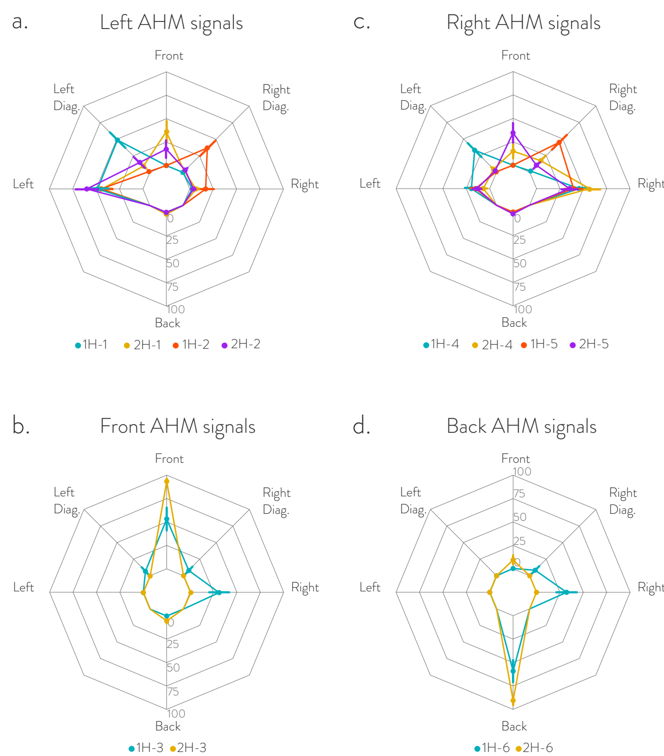

Fig. 5. Radar graphs showing the user's identification answers based on the sent signal. a) Signals 1H-1, 2H-1, 1H-2 and 2H-2, using the apparent haptic motion (AHM) towards the left side of the handle. b) Signals 1H-3 and 2H-3, using the AHM towards the front of the handle. c) Signals 1H-4, 2H-4, 1H-5, and 2H-5 using the AHM towards the right of the handle. d) Signals 1H-6 and 2H-6, using the AHM towards the back of the handle.

The GLMM analysis showed significant difference between the signals success to evoke what we determined as the good answers. For the following data, you can refer to Table II for p-values and significance. From this analysis it was found that to elicit an instruction of left direction, the signal 1H-1, which uses one handle, is considered better and significantly different from signal 2H-1 and from signal 1H-2. Signal 2H-2, using both handles, is also considered significantly different from signal 2H-1 and from signal 1H-2. Even though the difference between signal 1H-1 and 2H-2 is not significant, we can see on Table I that 1H-1 is better

	Left	Left Diag.	Front	Right Diag.	Right	Back
1H-1	48.4	48.8	0.0	0.0	2.8	0.0
2H-1	43.7	9.5	36.1	2.0	6.7	2.0
1H-2	44.8	1.2	0.0	36.9	17.1	0.0
2H-2	59.9	15.1	17.5	3.6	4.0	0.0
1H-3	0.0	7.1	53.6	8.3	31.0	0.0
2H-3	0.0	0.0	93.7	0.4	0.8	5.2
1H-4	19.4	32.9	0.0	1.6	45.6	0.4
2H-4	6.7	4.4	15.1	17.1	56.7	0.0
1H-5	15.1	0.4	0.0	44.8	39.7	0.0
2H-5	13.5	2.0	34.5	10.3	35.3	2.0
1H-6	0.0	0.0	0.4	8.3	32.1	59.1
2H-6	0.0	0.0	9.5	0.0	0.0	90.5

TABLE I

DISTRIBUTION OF ANSWERS (IN %) DEPENDING ON THE SIGNAL SENT. IN GREEN ARE THE ANSWERS TOWARD THE SAME DIRECTION AS THE AHM AND IN ORANGE TOWARD A DIFFERENT DIRECTION.

at evoking answers toward the *Left* or *Left Diagonal* (1^{st} and 2^{nd} columns in Table I) and almost no contradictory interpretations compared to 2H-2 which has 17.5% in *Front* answers (3^{th} column of Table I). Signal 1H-1 with the AHM towards the left on the left handle thus appears to be the best pattern to convey a guiding instruction towards the left. Similarly, observations and conclusions can be made for the signals using the AHM towards the right. Signal 1H-5 uses one handle and is considered better and significantly different from signals 1H-4 and 2H-5. Signal 2H-4 which uses both handles is considered better and also significantly different from signals 1H-4 and 2H-5. Even though the difference between signal 1H-5 and 2H-4 is not significant, Table I shows that most of 1H-5 results gather in *Right* and *Diagonal Right* (4^{th} and 5^{th}), whereas signal 2H-4 presents higher contradictory interpretations. Signal 1H-5 with the AHM towards the right on the right handle thus appears to be the best pattern to convey a guiding instruction towards the left.

For the AHM towards the front, we compare the signal 1H-3, using one handle on the side of the dominant hand with signal 2H-3 made of two AHM elicited on both handles simultaneously. Just as Fig. 5 shows, the GLMM indicates significant difference and better performance of signal 2H-3 over 1H-3 see Table II. Signal 2H-3 gathers 93.7% of answers in the *Front* answer (Table I). Finally, For the AHM towards the back, we compare the signal 1H-6, using one handle on the side of the dominant hand with signal 2H-6 made of two AHM elicited on both handles simultaneously. The GLMM validates the first observations on Fig. 5 and indicates significant difference and better performance of signal 2H-6 (90.5% success Table I) over signal 1H-6 (59.1%).

Wilcoxon repeated-measures analysis: In the GLMM model, we saw the effect of the signal on the interpretation of the direction, highlighting the optimal patterns to use to indicate left, right, front and back directions. We performed a Wilcoxon repeated-measures post-hoc analysis between all the six possible answers of all twelve signals (180 tests) showing a significant effect of the signals on the interpretations. The post-hoc analysis also confirm the absence of significant effect of the mode on the interpretation, with equivalent performances and interpretations for both vibrations and tap signals.

TABLE II

Experimental evaluation

Conditions	Active handles: 1H (one handle), 2H (two handles)			
	AHM stimuli: six ways of providing AHM stimuli towards the left (←), bottom (↓), right (→), or top (↑) side of the handle (see Fig. 4)			
Statistical analysis: direction identification	Comparisons for signals with AHM cues in the same direction			
←	**1H-1** vs 2H-1	$p = 0.002^*$	**1H-1** vs 1H-2	$p < 0.001^*$
←	1H-1 vs 2H-2	$p = 0.471$	**2H-2** vs 2H-1	$p = 0.001^*$
←	**2H-2** vs 1H-2	$p < 0.001^*$		
↓	**1H-3** vs 2H-3	$p = 0.002^*$		
→	1H-5 vs 2H-4	$p = 0.569$	1H-5 vs 1H-4	$p < 0.001^*$
→	**1H-5** vs 2H-5	$p < 0.001^*$	2H-4 vs 1H-4	$p < 0.001^*$
→	**2H-4** vs 2H-5	$p < 0.001^*$		
↑	1H-6 vs **2H-6**	$p = 0.019^*$		

V. DISCUSSION

We conducted experiments with fourteen participants, who received signals on one or two handles with either vibrations or taps. They provided responses based on the direction cue they perceived. Our analysis focused on determining which stimulation mode, rendering pattern, and number of active handles is best for providing navigation assistance on a walker.

Left/Right Direction: Signal 1H-1, which employed a single handle, was more effective at conveying a “left” direction cue compared to other signals using the AHM towards the left. This is shown by the combination of Left and Diagonal Left, with less than 3% of alternate response. It is true that 2H-2 has more answers on the Left axis, but it also engenders contradictory interpretations with more than 15% of answers on the Front axis. Similarly for the right side, Signal 1H-5, using a single handle, outperformed signals 1H-4, 2H-4, and 2H-5. This result suggests that a single-handle pattern with the AHM towards the left on the left handle or an AHM towards the right on the right handle emerged as the most effective pattern for side instructions. Signals 2H-2 and 2H-4, however lightly less efficient, are a good two-handle alternatives to elicit such navigational instructions. Without a learning phase, we see here that the duality of information for left/right instructions can be misleading.

Front/Back Direction: Signals 2H-3 and 2H-3, conveying the AHM cues along both handles simultaneously towards, respectively, the front and the back, demonstrated superior performance in conveying the desired directional cues compared to signals 1H-3 and 1H-6. This result suggests that a pattern involving simultaneous activation of both handles was more effective in that case, as the presence of two identical information seems to reinforce the information of front/back.

On Fig. 5.b and d, we can also notice an ambiguity leading to some alternate interpretation on the single handle answers (in blue). Those mislead interpretations mainly gathered on the Right axis. We interpret this artefact as a consequence of the use of the dominant hand for the Signals 1H-3 and 1H-6 all on the right handle as all the participants were right handed.

It also appears that for the signals 1H-2 and 1H-4 respectively on Fig. 5.a and b and Table I, we can clearly see that the interpretation is split in two main groups, which are the side of the AHM direction and the opposite direction. The confusion here seems to come from the fact that the motion indicates one direction different from the side of the activated handle. For example, signal 1H-2 is an AHM towards the left side but conveyed onto the right hand.

We found no significant difference between using one or two handles and between vibrations vs. taps actuation modalities to deliver the target navigation information. These results mean that, first, the guiding strategy can be employed with limited hardware, on a single handle, which is easier to adapt to other mobility assistance devices that only have one holdable end-effector, such as white canes or power wheelchair. Two-handles can be used in some cases to reinforce the information, depending on the user's preference. Similarly, as no actuation mode was found better than the other, it can be chosen according to the user preference as well as the capabilities of the considered haptic actuation system. Overall, our findings revealed that the AHM paradigm can be used to provide rich directional cues.

VI. Conclusion

This work aimed to assess the effectiveness of different patterns in conveying directional information through the Apparent Haptic Motion Illusion (AHM), with the objective of developing rich navigation techniques for mobility aid systems, such as a walker. We enrolled fourteen participants in a human-subjects experiment to evaluate the haptic perception of directional cues conveyed through two handles attached on a walker. We investigated three key elements: the difference between uni-manual and bi-manual guiding strategies, and the identification of the most effective tactile patterns and actuation modality for navigation assistance. For this study, we designed a haptic handle with five custom electromagnetic actuators, able to give sensations of movement in four directions through the AHM illusion on the hand.

The results of the study are promising, highlighting several key findings: The study identified specific patterns that were highly effective in conveying directional instructions towards the front (93.7%), the back (90.5%), the left ((Left = 48.4%) + (Left Diagonal = 48.8%) = 97.2%), and the right ((Right = 39.7%) + (Righ Diagonal = 44.8%) = 84.5%). The study also identified cases where participants' interpretations were divided, often influenced by the side of the stimulated handle vs. the direction of the AHM moving pattern. The result and statistical analysis showed no significant difference between using vibratory vs. tapping modes for conveying directional cues. Because there was also no significant difference induced by providing vibrotactile cues on one or two handles, the guiding strategy can be adapted to both uni-manual and bi-manual setups and assistive devices. This adaptability makes the technology suitable for various mobility aids, such as white canes, power wheelchairs, walkers and precanes. This research wishes to contribute to the development of assistive devices enhancing the autonomy and safety of people with sensory impairments.

In future works, the aim will be to help users on a walker follow complex trajectories by using tactile instructions.

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