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Supplementary Materials for

Multimodal sensing and intuitive steering assistance improve navigation and mobility for people with impaired vision

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SUPPLEMENTARY MATERIALS

Fig. S1. Pseudocode for the obstacle avoidance algorithm. This algorithm was used by the Augmented Cane in the indoor experiments. The Augmented Cane reads the 2D LIDAR distance measurements to determine if an object in front of the participant is closer than the distance threshold. If an obstacle is detected then the Augmented Cane finds the angle closest to the forward direction that has a measurement greater than the distance threshold. If the button the handle of the cane is not pressed, the motorized omni-wheel steers toward this angle with a proportional controller. If the button is pressed, the participant overrides the steering from the Augmented Cane and the motor is turned off. If no obstacle is detected, the Augmented Cane assists the user in sweeping the cane back and forth in front of themselves in a sinusoidal manner. The full code is available in the code repository (*53*).

Algorithm: Obstacle avoidance

- distance_threshold = 1.8 # distances less than this threshold cause avoidance
- angle_of_lidar_measurements = [-170:10:170]
- front_lidar_index = (length(angle_of_lidar_measurements)-1)/2
- **While** ()
    - distance_measurements = ReadLIDAR()
    - distance_in_front_of_subject = distance_measurements[front_lidar_index]
    - **If** distance_in_front_of_subject < distance_threshold
        - angle_to_turn = 0
        - **For** i = 1:front_lidar_index
            - **If** distance_measurements[front_lidar_index + i] < distance_threshold
                - angle_to_turn = angle_of_lidar_measurements [front_lidar_index + i]
            - **End**
            - **If** distance_measurements[front_lidar_index - i] < distance_threshold
                - Angle_to_turn = angle_of_lidar_measurements [front_lidar_index - i]
            - **End**
        - **End**
        - motor_command = proportional_motor_controller(angle_to_turn)
    - **Else**
        - motor_command = SinusoidalSweepCane()
    - **End**
    - button_not_pressed = CheckIfButtonNotPressed()
    - **If** button_not_pressed
        - UpdateMotors(motor_command)
    - **End**
- **End**

Fig. S2. Pseudocode for the GPS waypoint tracking algorithm. This algorithm was used by the Augmented Cane in the outdoor experiments. The Augmented Cane reads the 2D LIDAR distance measurements to determine if an object in front of the participant is closer than the distance threshold. If an obstacle is detected, the Augmented Cane alerts the participant by playing an audio file "Obstacle ahead" through an earbud. The Augmented Cane reads the current GPS position and computes the distance to the current waypoint along the route. If the current position is less than 5 meters from the waypoint, it updates to the next desired waypoint. The Augmented Cane then computes the desired heading angle between the current GPS position and next waypoint as well as the heading angle of the inertial measurement unit (IMU) attached to the Augmented Cane. The motorized omni-wheel steers toward the desired heading angle with a proportional controller. The full code is available in the repository (*53*).

Algorithm: GPS waypoint tracking

- distance_threshold = 1.8
- front_lidar_index = (length(angle_of_lidar_measurements)-1)/2
- waypoints_GPS = list of GPS locations
- waypoint_index = 1
- waypoint = waypoint_GPS[waypoint_index]
- distance_GPS_threshold = 5
- position_GPS
- not_at_destination = True
- **While** (not_at_destination)
    - distance_measurements = ReadLIDAR()
    - distance_in_front_of_subject = distance_measurements[front_lidar_index]
    - **If** distance_in_front_of_subject < distance_threshold
        - PlayAudioToParticipant("Obstacle ahead")
    - **End**
    - heading = ComputeHeadingFromIMU()
    - prev_position_GPS = position_GPS
    - position_GPS = ReadGPS()
    - distance_to_waypoint = DistanceBetweenGPSLocations(position_GPS, waypoint)
    - **If** distance_to_waypoint < distance_GPS_threshold
        - waypoint_index = waypoint_index + 1
        - **If** waypoint_index == length(waypoints_GPS)
            - not_at_destination = False
        - **Else**
            - waypoint = waypoint_list[waypoint_index]
        - **End**
    - **End**
    - heading_to_waypoint = HeadingBetweenGPSLocations(position_GPS, waypoint)
    - motor_command = ProportionalController(heading, heading_to_waypoint)
    - button_not_pressed = CheckIfButtonNotPressed()
    - **If** button_not_pressed
        - UpdateMotors(motor_command)
    - **End**
- **End**

Fig. S3. Participant specific changes in speed for the indoor hallway experiment. (**A**) All but two of the novice participants had a faster walking speed with the Augmented Cane than a white cane during the hallway experiment. (**B**) All of the expert participants had a faster walking speed with the Augmented Cane than a white cane during the hallway experiment, although the amount of increase varied.

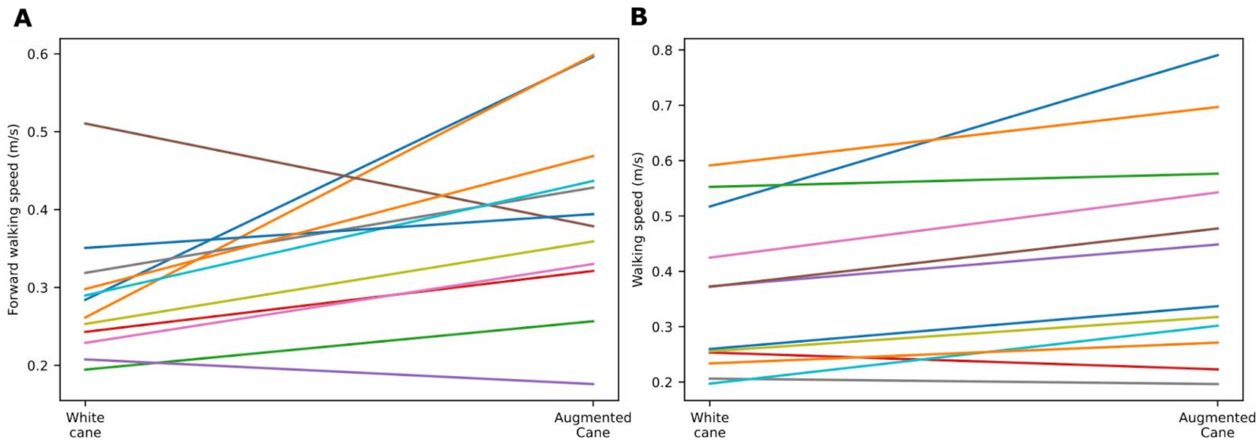

Fig. S4. Participant specific changes in speed for the indoor obstacle avoidance experiment. (**A**) All but two novice participants and one expert participant had a faster walking speed with the Augmented Cane than a white cane during the obstacle avoidance experiment, although the increase was smaller than the hallway experiment. (**B**) Two of the expert participants had a faster walking speed with the Augmented Cane than a white cane during the obstacle avoidance experiment.

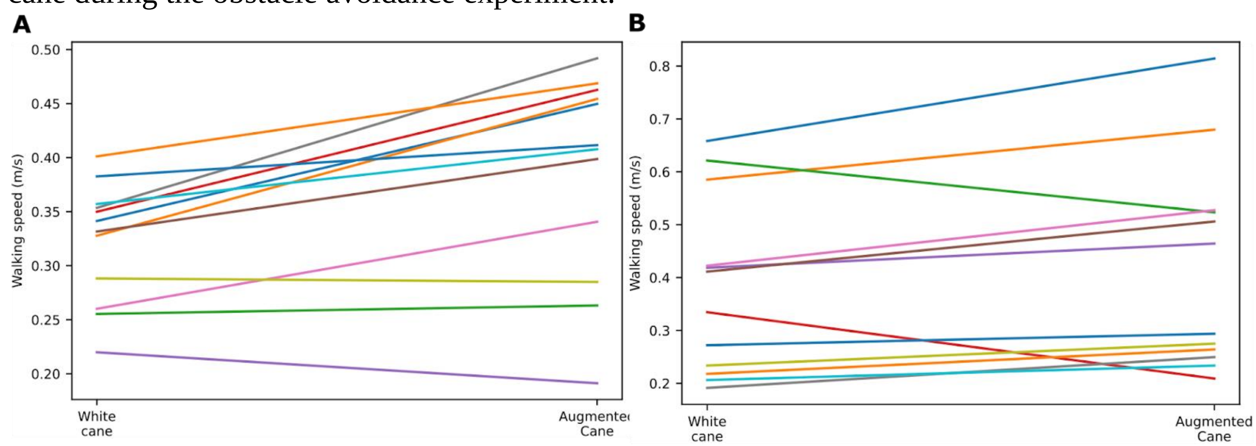

Fig. S5. Participant specific changes in speed for the outdoor experiment. (**A**) All but two of the novice participants had a faster walking speed with the Augmented Cane than a white cane. Those two participants walked at roughly the same speed with the augmented and white canes. (**B**) All of the expert participants had a faster walking speed with the Augmented Cane than a white cane, although the amount of increase varied.

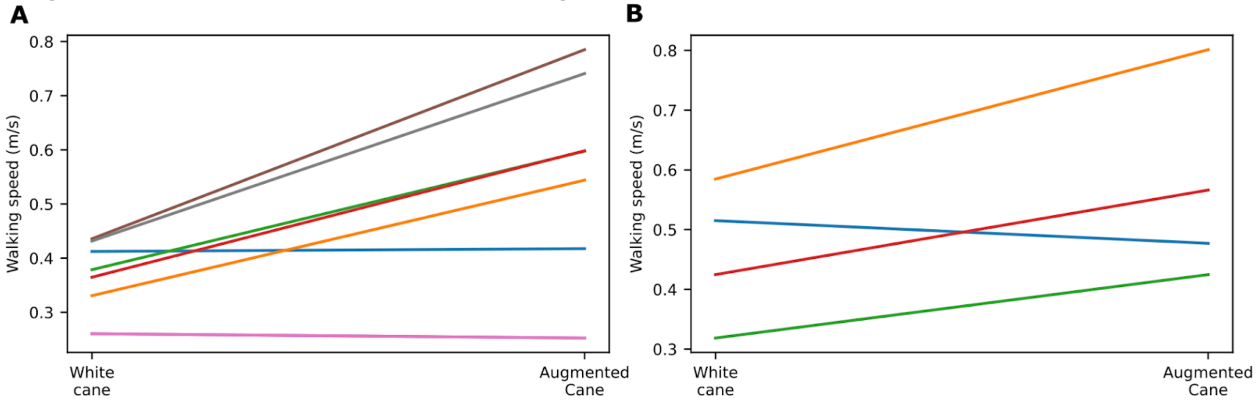

Fig. S6. Experimental setup for the turn in place experiment. A white cane was connected to a supporting rod with a potentiometer that measured the heading angle as novice blindfolded participants turned in place, receiving grounded kinesthetic, audio, or vibrotactile feedback to reach target angles. The experiment consisted of a blindfolded participant turning to the left or right to reach a randomized target angle while receiving feedback. Once the participant thought they reached the target angle, they pressed the push button on the cane handle, returned to their initial position, and pressed the button to receive the prompt for the next target angle. The two vibrating motors are located between the strap and the participant's hand at the positions marked with blue tape.

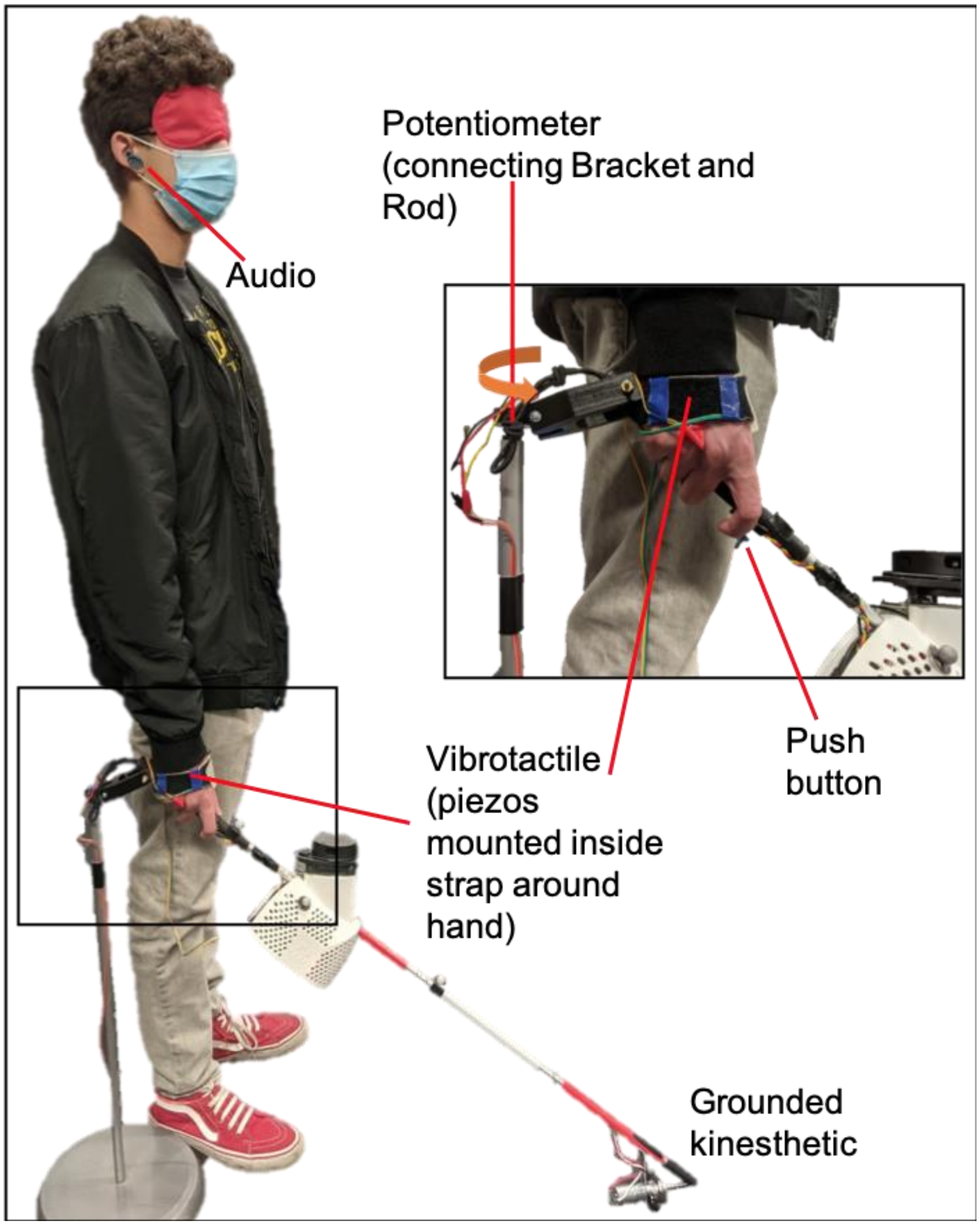

Fig. S7. Indoor navigation experimental setup. This experiment evaluated how well participants could navigate cardboard hallways with a series of (**A**) turns or (**B**) obstacles. The hallway with turns was 1.2 meters wide, with 1.8 meters between turns. The hallway with obstacles was 1.8 meters wide and 4.3 meters long. The obstacles had widths of 0.6 and 0.8 meters and the same length and width of 0.8 and 1 meter. The obstacles were evenly spaced in the width of the hallway and positioned randomly along it, at least 0.5 meters from the start and end.

A **B**

Fig. S8. Outdoor navigation experimental setup. This experiment evaluated how well participants could navigate along an outdoor asphalt path. The course was approximately 150 meters long. The asphalt path was approximately 15 feet wide. Two sets of bollards near the beginning and end of the course were the only obstacles directly along the path.

Table S1. Overview of select assistive devices for helping people with impaired vision navigate. We have selected a subset of devices which cover all combinations of sensor inputs and feedback modes of previous devices described in previous surveys (*47*, *58*, *59*, *60*) to provide a representative, but not exhaustive, list of related work for comparison. The weight and cost for the devices were approximated when a component list was provided, otherwise the information was listed as not able (NA) to be provided.

System name	Sensor inputs				Navigation challenges				Feedback modes		Specifications		
	Distance sensors	Vision sensors	Position sensors	Inertial measurement unit	Obstacle avoidance	Outdoor wayfinding	Indoor wayfinding	Object recognition	Audio	Tactile	Weight (kg)	Cost (USD)	Open-source (Y/N)
Augmented Cane	2D LIDAR	Camera	GPS	9-DOF	Y	Y	Y	Y	Y	Grounded Kinesthetic	1.2	400	Y
White cane	NA	NA	NA	NA	Y	N	N	N	NA	Y	0.2	50	NA
Katzschmann, et al. (*21*)	1D LIDAR	N	N	N	Y	N	N	N	NA	Vibrotactile	0.6	1,500	N
GuideCane (*43*)	Ultrasonic	N	Encoder	N	Y	N	N	N	N	Grounded kinesthetic	9	200	N
Electro-Neural Vision System (*58*)	None	Stereo camera	None	None	Y	Y	N	N	N	Electro-tactile	5.6	NA	N
CaBot (*28*)	2D LIDAR	Stereo camera	None	9-DOF	Y	N	Y	Y	Y	Vibrotactile	25.2	6,000	N
BBeep (*27*)	None	Stereo camera	None	None	Y	N	N	Y	Y	None	10	3,000	N
Co-robotic cane (*42*)	None	Depth & normal camera	None	9-DOF	N	N	Y	N	N	Grounded kinesthetic	0.8	500	N
NavCog3 (*26*)	None	None	Bluetooth beacons	9-DOF	N	N	Y	N	Y	Vibrotactile	0.2	700	N
Fusco, et al. (*14*)	None	Camera	GPS	9-DOF	N	N	Y	Y	Y	Vibrotactile	0.15	700	N
Mocnu, et al. (*30*)	Ultrasonic	Camera	GPS	9-DOF	Y	N	N	Y	Y	Vibrotactile	0.75	700	N
Gallo, et al (*59*)	Ultrasonic	None	None	None	Y	N	N	N	N	Vibrotactile	0.5	NA	N
Pyun, et al. (*60*)	Ultrasonic	None	None	None	Y	N	N	N	N	Vibrotactile	0.5	NA	N

Table S2. Participant specific information for the expert participants.

Participant number	Gender	Age (years)	Experience with white cane (years)	Cane length (cm)	Cane tip type	Level of visual impairment
1	M	26	3.2	137	Marshmallow roller	Visually impaired
2	F	31	9	136	Marshmallow roller	Visually impaired
3	M	29	7	140	Pencil	Visually impaired
4	F	73	35	125	Marshmallow roller	Blind
5	M	69	30	160	Roller	Visually impaired
6	M	57	15	150	Roller	Blind
7	F	61	25	130	Marshmallow roller	Blind
8	M	42	17	137	Roller	Visually impaired
9	M	33	6	140	Marshmallow roller	Visually impaired
10	M	51	32	143	Marshmallow roller	Visually impaired
11	F	35	13	130	Pencil	Visually impaired
12	M	42	20	145	Marshmallow roller	Visually impaired

Table S3. Participant specific results of the novice participants for all experiments. Results include the time taken, distance walked, and average walking speed for the indoor hallway, indoor obstacle avoidance, and outdoor navigation experiments.

		Indoor Hallway			Indoor Obstacle Avoidance			Outdoor Navigation		
User	Cane Type	Time (s) Mean ± Std	Distance walked (m) Mean ± Std	Walking speed (m/s) Mean ± Std	Time (s) Mean ± Std	Distance walked (m) Mean ± Std	Walking speed (m/s) Mean ± Std	Time (s)	Distance walked (m)	Walking speed (m/s)
1	Augmented	8.6±0.7	3.94±0.07	0.6±0.051	11.1±1.3	3.93±0.22	0.45±0.061	332	211	0.42
	White Cane	18.1±1.9	4.54±0.35	0.28±0.031	14.6±1.8	4.14±0.12	0.34±0.041	337	209	0.41
2	Augmented	8.5±0.4	3.91±0.16	0.6±0.025	10.9±1.0	3.75±0.29	0.45±0.04	255	165	0.54
	White Cane	19.9±2.6	4.93±0.74	0.26±0.038	15.2±1.8	4.27±0.11	0.33±0.042	420	190	0.33
3	Augmented	20.1±2.2	4.35±0.09	0.26±0.027	19.5±4.1	4.14±0.27	0.26±0.056	232	171	0.6
	White Cane	26.5±2.6	4.41±0.35	0.19±0.021	19.3±1.2	4.22±0.14	0.26±0.016	366	256	0.38
4	Augmented	17.6±6.5	4.12±0.57	0.32±0.089	10.9±1.7	4.01±0.15	0.46±0.073	232	147	0.6
	White Cane	25.5±13.7	5.87±2.87	0.24±0.081	14.4±2.6	4.18±0.21	0.35±0.052	380	229	0.36
5	Augmented	30.8±7.6	4.24±0.79	0.18±0.043	26.7±5.7	4.88±0.5	0.19±0.038	550	185	0.25
	White Cane	26.5±7.1	4.19±0.64	0.21±0.058	22.6±2.7	4.24±0.3	0.22±0.028	533	207	0.26
6	Augmented	15.6±6.7	4.27±1.38	0.38±0.121	14.2±5.8	4.41±0.86	0.4±0.141	177	141	0.79
	White Cane	10.3±1.7	3.5±0.22	0.51±0.082	15.0±1.7	4.02±0.44	0.33±0.038	318	146	0.44
7	Augmented	16.1±3.4	3.97±0.28	0.33±0.061	14.8±2.5	3.92±0.33	0.34±0.053	550	185	0.25
	White Cane	22.7±3.0	4.65±0.4	0.23±0.03	18.9±1.3	4.38±0.15	0.26±0.018	533	207	0.26
8	Augmented	11.9±0.4	3.89±0.06	0.43±0.016	10.0±0.4	3.86±0.13	0.49±0.022	187	171	0.74
	White Cane	16.6±3.1	4.36±0.52	0.32±0.064	14.1±1.8	4.2±0.32	0.35±0.047	321	256	0.43
9	Augmented	14.2±0.7	3.9±0.11	0.36±0.018	17.5±2.2	4.7±0.66	0.28±0.036	NA		
	White Cane	20.5±2.6	4.85±0.47	0.25±0.032	17.2±1.6	4.59±0.21	0.29±0.027			
10	Augmented	11.7±0.7	3.92±0.24	0.44±0.026	12.1±0.8	3.99±0.19	0.41±0.024			
	White Cane	17.8±2.2	4.6±0.27	0.29±0.031	13.8±1.0	4.4±0.31	0.36±0.028			
11	Augmented	13.3±2.1	4.03±0.26	0.39±0.066	12.0±1.0	3.99±0.27	0.41±0.035			
	White Cane	14.6±1.2	4.38±0.39	0.35±0.03	13.2±2.2	4.43±0.28	0.38±0.061			
12	Augmented	11.0±1.2	3.69±0.06	0.47±0.049	10.5±0.8	3.78±0.06	0.47±0.037			
	White Cane	17.2±0.8	4.66±0.23	0.3±0.014	12.4±1.6	4.18±0.33	0.4±0.048			

Table S4. Participant specific results of the expert participants for all experiments. Results include the time taken, distance walked, and average walking speed for the indoor hallway, indoor obstacle avoidance, and outdoor navigation experiments.

		Indoor Hallway			Indoor Obstacle Avoidance			Outdoor Navigation		
User	Cane Type	Time (s) Mean ± Std	Distance walked (m) Mean ± Std	Walking speed (m/s) Mean ± Std	Time (s) Mean ± Std	Distance walked (m) Mean ± Std	Walking speed (m/s) Mean ± Std	Time (s)	Distance walked (m)	Walking speed (m/s)
1	Augmented	6.5±0.5	3.56±0.19	0.79±0.059	6.1±0.7	3.72±0.28	0.81±0.086	291	205	0.48
	White Cane	10.1±1.5	3.81±0.28	0.52±0.075	7.5±0.5	3.4±0.15	0.66±0.046	269	151	0.52
2	Augmented	7.4±0.5	3.7±0.17	0.7±0.055	7.3±0.9	3.73±0.27	0.68±0.081	173	149	0.8
	White Cane	8.7±0.5	3.74±0.13	0.59±0.037	8.4±0.5	3.68±0.08	0.59±0.039	237	161	0.58
3	Augmented	11.3±4.6	3.08±0.8	0.58±0.329	9.5±1.0	3.41±0.22	0.52±0.052	327	210	0.42
	White Cane	10.0±2.7	3.38±0.72	0.55±0.17	8.0±0.8	2.99±0.07	0.62±0.065	436	250	0.32
4	Augmented	25.4±8.4	5.37±0.88	0.22±0.071	24.1±3.8	4.51±0.4	0.21±0.035	245	210	0.57
	White Cane	25.5±10.5	6.64±2.5	0.25±0.138	15.2±2.8	4.53±0.7	0.33±0.064	327	250	0.42
5	Augmented	11.4±0.9	3.95±0.26	0.45±0.033	10.6±1.0	3.57±0.17	0.46±0.043	NA		
	White Cane	14.1±2.3	4.41±0.42	0.37±0.063	12.0±1.7	4.05±0.12	0.42±0.068			
6	Augmented	10.9±1.6	3.69±0.14	0.48±0.075	10.0±1.6	3.46±0.2	0.51±0.088			
	White Cane	14.1±2.2	4.41±0.43	0.37±0.067	12.0±1.3	3.85±0.23	0.41±0.04			
7	Augmented	9.5±1.0	3.78±0.18	0.54±0.063	9.4±1.1	3.52±0.12	0.53±0.065			
	White Cane	12.5±2.6	4.28±0.27	0.42±0.081	11.8±1.4	3.94±0.08	0.42±0.059			
8	Augmented	26.1±1.8	3.91±0.13	0.2±0.014	21.5±5.5	3.84±0.05	0.25±0.084			
	White Cane	25.3±3.7	4.56±0.23	0.21±0.031	26.0±3.3	4.16±0.05	0.19±0.024			
9	Augmented	16.1±1.0	3.9±0.06	0.32±0.021	18.0±1.6	3.93±0.05	0.28±0.024			
	White Cane	20.2±2.2	4.54±0.21	0.26±0.028	21.2±2.2	4.25±0.28	0.23±0.024			
10	Augmented	17.9±3.8	3.94±0.08	0.3±0.081	21.1±1.6	3.98±0.09	0.23±0.018			
	White Cane	26.0±2.2	4.4±0.28	0.2±0.016	23.8±1.5	4.52±0.27	0.21±0.013			
11	Augmented	15.2±1.0	3.88±0.07	0.34±0.023	16.7±0.9	3.83±0.05	0.29±0.016			
	White Cane	20.1±3.2	4.85±0.11	0.26±0.037	18.1±1.2	4.29±0.21	0.27±0.02			
12	Augmented	18.8±0.9	3.96±0.11	0.27±0.013	18.8±2.2	3.89±0.06	0.26±0.03			
	White Cane	22.0±1.6	4.66±0.26	0.23±0.018	22.6±1.4	4.28±0.11	0.22±0.013			

Table S5. Usability survey results of novice users. This is the System Usability Scale (*39*) which uses a Likert scale to evaluate the augmented and white canes. Participants completed this survey after completing the indoor experiments. Compared to a distribution of 5000 devices (*41*), the augmented and white canes were in the 44th and 71st percentiles, respectively.

Question text (1 = Strongly Agree, 2 = Somewhat Agree, 3 = Neither Agree Nor Disagree, 4 = Somewhat Disagree, 5 = Strongly Disagree)	**Augmented Cane Mean ± Std**	**White cane Mean ± Std**
I think that I would like to use this system frequently.	1.69 ±0.95	2.31 ±1.11
I found the system unnecessarily complex.	3.69 ±1.11	4.62 ±0.65
I thought the system was easy to use.	2.15 ±1.07	1.77 ±1.09
I think that I would need the support of a technical person to be able to use this system.	2.85 ±1.21	4.77 ±0.44
I found the various functions in this system were well integrated.	1.69 ±0.85	2.46 ±1.2
I thought there was too much inconsistency in this system.	3.46 ±0.97	4.54 ±0.78
I would imagine that most people would learn to use this system very quickly.	2.08 ±0.76	1.62 ±0.65
I found the system very cumbersome to use.	3.08 ±1.32	3.46 ±1.45
I felt very confident using the system.	1.77 ±0.73	3.0 ±1.35
I needed to learn a lot of things before I could get going with this system.	2.31 ±1.03	3.38 ±1.39
Total usability score (out of 100)	**65.0 ± 12.5**	**74.0 ± 12.8**

Table S6. Usability survey results of expert users. This is the System Usability Scale (*39*) which uses a Likert scale to evaluate the augmented and white canes. Participants completed this survey after completing the indoor experiments. Compared to a distribution of 5000 devices (*41*), the augmented and white canes were in the 22nd and 37th percentiles, respectively.

Question text (1 = Strongly Agree, 2 = Somewhat Agree, 3 = Neither Agree Nor Disagree, 4 = Somewhat Disagree, 5 = Strongly Disagree)	**Augmented Cane Mean ± Std**	**White cane Mean ± Std**
I think that I would like to use this system frequently.	2.8 ±1.03	1.6 ±0.7
I found the system unnecessarily complex.	3.1 ±1.2	3.8 ±1.23
I thought the system was easy to use.	2.2 ±1.32	2.1 ±1.37
I think that I would need the support of a technical person to be able to use this system.	3.3 ±1.16	4.0 ±1.25
I found the various functions in this system were well integrated.	2.3 ±1.16	2.0 ±0.67
I thought there was too much inconsistency in this system.	2.6 ±1.26	3.6 ±1.26
I would imagine that most people would learn to use this system very quickly.	1.9 ±0.88	3.7 ±1.34
I found the system very cumbersome to use.	2.1 ±0.74	3.3 ±1.25
I felt very confident using the system.	2.2 ±1.23	1.9 ±0.99
I needed to learn a lot of things before I could get going with this system.	3.1 ±0.99	2.4 ±1.35
Total usability score (out of 100)	**57.0 ± 14.9**	**64.5 ± 16.0**

Table S7. Perceived workload survey results of novice users. This is a subset of the NASA Task Load Index (*40*) survey, designed to evaluate perceived workload. Participants completed this survey after completing the indoor experiments. Compared to a distribution of 1000 devices (*42*) the augmented and white canes were in the 91st and 51st percentiles, respectively.

Question text (1 = Very Low, 2 = Somewhat Low, 3 = Neither High Nor Low, 4 = Somewhat High, 5 = Very High)	**Augmented cane Mean ± Std**	**White cane Mean ± Std**
Mental Demand. How mentally demanding was using the system?	2.33 ± 0.89	3.83 ± 1.19
Physical Demand. How physically demanding was using the system?	3.67 ± 0.65	2.83 ± 1.53
Effort. How hard did you have to work to accomplish your desired level of performance?	2.58 ± 1.0	3.75 ± 1.22
Frustration. How insecure, discouraged, irritated, stressed, and annoyed were you?	2.58 ± 0.9	3.17 ± 1.11
Question text (1 = Excellent, 2 =Good, 3 = Average, 4 = Poor, 5 = Terrible)		
Performance. How successful were you in accomplishing what you were asked to do?	1.75 ± 0.45	2.83 ± 0.58
Total score (out of 100)	**68.4 ± 15.6**	**54.4 ± 22.1**

Table S8. Perceived workload survey results of expert users. This is a subset of the NASA Task Load Index (*40*) survey, designed to evaluate perceived workload. Participants completed this survey after completing the indoor experiments. Compared to a distribution of 1000 devices (*42*) the augmented and white canes were in the 84th and 51st percentiles, respectively.

Question text (1 = Very Low, 2 = Somewhat Low, 3 = Neither High Nor Low, 4 = Somewhat High, 5 = Very High)	**Augmented cane Mean ± Std**	**White cane Mean ± Std**
Mental Demand. How mentally demanding was using the system?	2.7 ±1.42	2.7 ±0.95
Physical Demand. How physically demanding was using the system?	3.8 ±0.92	2.4 ±0.7
Effort. How hard did you have to work to accomplish your desired level of performance?	2.7 ±1.25	2.7 ±1.16
Frustration. How insecure, discouraged, irritated, stressed, and annoyed were you?	2.5 ±0.97	2.5 ±0.97
Question text (1 = Excellent, 2 =Good, 3 = Average, 4 = Poor, 5 = Terrible)		
Performance. How successful were you in accomplishing what you were asked to do?	2.2 ±0.92	2.5 ±0.71
Total score (out of 100)	**64.4 ± 21.9**	**54.4 ± 18.0**

Table S9. Expert participant responses to the open ended survey questions about the Augmented Cane system. Participants completed this survey after completing the indoor experiments.

Question: What are some of the system's best attributes?
The system gives helpful steering directions. It was easy to understand what it was trying to get me to do.
The way the system steers you is very intuitive and easy to follow. I also really like the motorized sweeping which helped decrease the effort I needed to apply to understand my path ahead.
Did a nice job of keeping me away from obstacles in the hallway without needing to contact then
I think it is intuitive but it needs to be more refined for everyday use
It was easy to understand what it was trying to do once I got used to it
I like the steering guidance
It attempts to turn you in the direction you need to go to miss the object (curving left, right, etc.).
the high tech Slamtech RP lidar a1 sensor
Question: What are some of the system's worst attributes?
The weight of the system is very heavy, although the motor helped move the cane back and forth which made it somewhat easier. Holding the cane upright while turning was challenging
The weight of the system is quite heavy making it very challenging to pick up off the ground which is important for exploring more complicated terrain. In the test cases in this study the device worked very well and did not need to be picked up.
Heavy, couldn't put my hands how I wanted on the cane, feedback took time to become familiar with, in a truly unstructured environment where I'd have to worry about uneven pavement the roller was too rough to feel ground in front of me, I wouldn't trust the haptic feedback around stairs
Quite heavy
It took a while to get used to the system. I would like to try it out in different settings and change settings for my needs
It is pretty heavy and the wheel could be smoother
The cane doesn't tell you soon enough when you should begin to turn, as if the sensors (lidar, camera, etc.) are not perceiving the objects in time to give the user enough warning for proper course correction. It allows itself to run into the object first, then it gets stuck, and the user must back up a bit before the cane starts moving again, and then it might tell you which way you should turn. (It's really cool when it does tell you, though.) The cane is excedingly heavy, which makes it exceedingly cumbersome to use, and your arm gets pretty tired after a while. It is very sensitive about how it is oriented; so to alleviate that situation, there needs to be either a flat area on the handle where your thumb would rest, or an area with a slit where your thumb would rest, so it would be easier for the user to provide the proper orientation. The user has to help and encourage the cane to do wider sweeps, because the sweeps it does automatically don't cover enough of the area in front of a person as they walk. Having said all this, I think the idea for a cane to give direction around objects has potential, if some of these defects could be corrected and the system improver.
sometimes I wasn't sure which way to go
Question: Beyond the study, would you be interested in using this system for navigation?
I think a device like this could be very useful if it was lighter and smaller. It would be great if it were more similar to my normal cane in length and weight.
I would definitely want to use a commercialized version of this system. The amount of extra information

it provides would be very useful if it was a lighter and more polished device. I think additional time to practice with the feedback would allow for me to better understand the device.
If it added negligible inertia (more important than mass) I would take it as a feature but not if it took extra maintenance or any additional daily work from me. If i could learn to trust the haptic feedback and it only activated around obstacles or to set an initial navigation direction, I’d be most likely to use it.
As the system exists now, I would not be interested in using it. That's not to say that I wouldn't give it a second chance when some improvements have been made. But as it stands at present, my white cane is safer and more helpful to me than this system is.
yes