VirtualNavigator: Can Autonomous Navigational Technologies be Used to Enhance Mobility by the Visually Impaired?

There are over 1.3M people in US and 39M globally* that are visually impaired. Beyond complete blindness, there are varying levels of visual impairedness. Table 1 provides an overview of common eye condition and level of visibility.

Common Eye Conditions

Age-related Macular Degeneration (AMD) is a degenerative condition affecting central vision. Reading and crossing roads safely may be difficult. Early detection can slow down progression of the disease and improve treatment outcomes.

Cataract is a clouding of the lens, resulting in blurry vision and faded colours. This leads to glare-sensitivity and increases the risk of trips and falls. Cataracts are usually safely treated by surgery.

Glaucoma is an eye disease that damages the fine nerves connecting the eye to the brain. Glaucoma can result in tunnel vision and even total blindness. Early detection is vital.

Diabetic Retinopathy is caused by diabetes and can result in increasingly blurred, patchy and fluctuating vision. Regular eye checks are crucial to reducing the risk of vision loss.

Retinitis Pigmentosa (RP) is a group of genetic eye diseases that can result in total blindness. Common signs are an inability to adjust to changes in lighting, night blindness, tunnel vision and reduced acuity.

Childhood Blindness is a group of diseases that if left untreated can lead to blindness.

Source: * https://en.m.wikipedia.org/wiki/Visual_impairment

Table 1: Common eye condition and what they see

Problem

Wayfinding is challenging for the Visually Impaired.

Question

Can technologies used in autonomous navigation be adopted by the visually impaired to significantly enhance wayfinding?

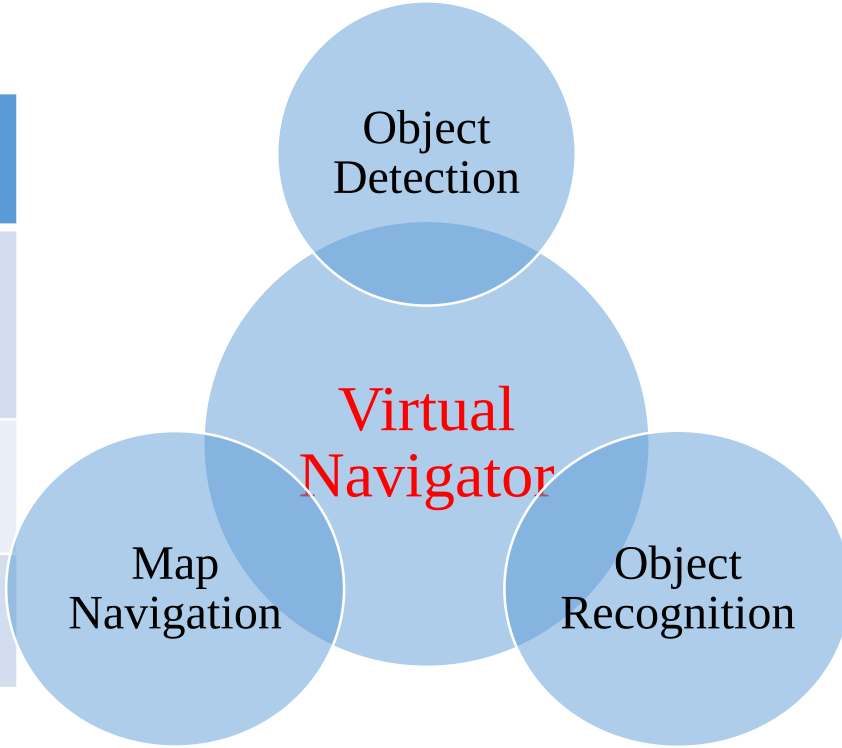
Hypothesis

Visually impaired can benefit from using autonomous navigation technologies for wayfinding and improving quality of life. Adoption of technology can be accelerated with additional training.

Background – Digital Assistive Wayfinding Technologies

Table 2: Select Digital Wayfinding Categories & Technologies useful to Visually Impaired

Category	Popular Apps / Technologies	Used in Study
Navigation	BlindSquare, Google Maps, Nearby Explorer	Google Maps
Obstacle Avoidance	UltraSound, Lidar, Infrared sensors	UltraSonic Sensor
Object Recognition	vOICe, SeeingAI, TapTapSee	TapTapSee



After exhaustive search, I was not able to find a convenient wearable device that included all three technologies. That led me to build VirtualNavigator.

Tools – Building VirtualNavigator (1)

VirtualNavigator was built using the following components

- **Vision-800 Smart Glasses:** Android Smart Glasses with Apps (TapTapSee, Nearby Explorer, 1Sheeld App) [Cost: $180]
- **Arduino Uno:** Microcontroller for controlling Ultrasound sensor [Cost: $20]
- **1Sheeld+**: Hardware connecting Arduino & iPhone [Cost: $20] (excludes iPhone / Android phone)
- **Ultrasound Sensor (HC-SR04):** Obstacle avoidance sensor [Cost $5]
- **Battery Pack**: Power for sensor & Arduino and – [Cost: $20]
- **Cane**: Cane used by visually impaired (Existing)
- **Connecting wires:** To connect Arduino and Ultrasound Sensor [Cost: $2]

Total Cost of VirtualNavigator: $247

Fig 1: Components of VirtualNavigator

Tools – Building VirtualNavigator (2)

Fig 2: Person wearing VirtualNavigator

- **Arduino Uno:** Microcontroller for controlling Ultrasound sensor
- **Battery Pack**: Powers Arduino, sensor, & 1Sheeld+
- **1Sheeld+**: Hardware that connects Arduino & iPhone
- **Ultrasound Sensor (HC-SR04):** Connect to GPIO Pins (e.g. pins 8 & 9 and Ground and 5V pins)
- **Vision 8000:** 1Sheeld+ App

Algorithm: Microcontroller algorithm for controlling Ultrasound sensor

- **Step 1**: If Object <91 cm – No beep
- **Step 2**: If Object >61cm & <90 cm – Single beep
- **Step 3:** If Object <61cm – continuous beep

Methods – Study Design

Participants: 12 blindfolded adult participants (Ages 23 – 72; Equal Male / Female) will walk an identical, but unknown, five-point navigation path twice – once with minimal instruction – and again after 2+ hours of usage & training

- Step 1: With cane only (traditional non-tech method)
- Step 2: Second, using cane plus each digital assistive wayfinding technology individualy
- Step 3: With cane plus all technologies together
- Step 4: Steps 1 – 3 repeated after training on device

Control: Starting point will be randomized to any of the five starting points in the path and particant will be disoriented before starting

Results: Participants will be clocked and will be surveyed for their experience

Source: https://i.dailymail.co.uk/i/pix/2014/06/20/ultra_cane.gif

Fig 3: Person walking with cane & Cane + Sensor

Methods - Data Collection

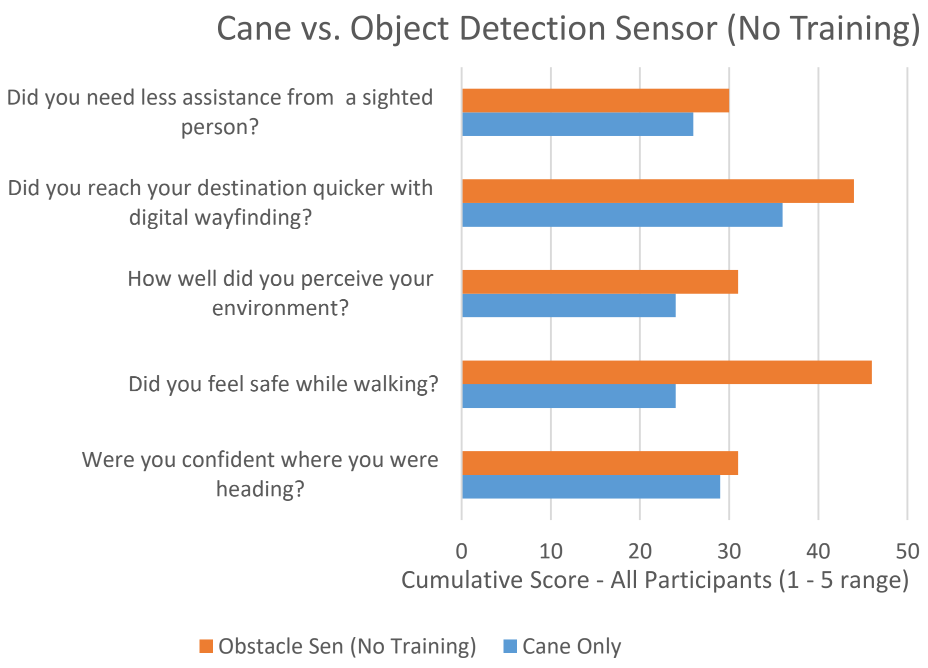
Survey Questionnaire

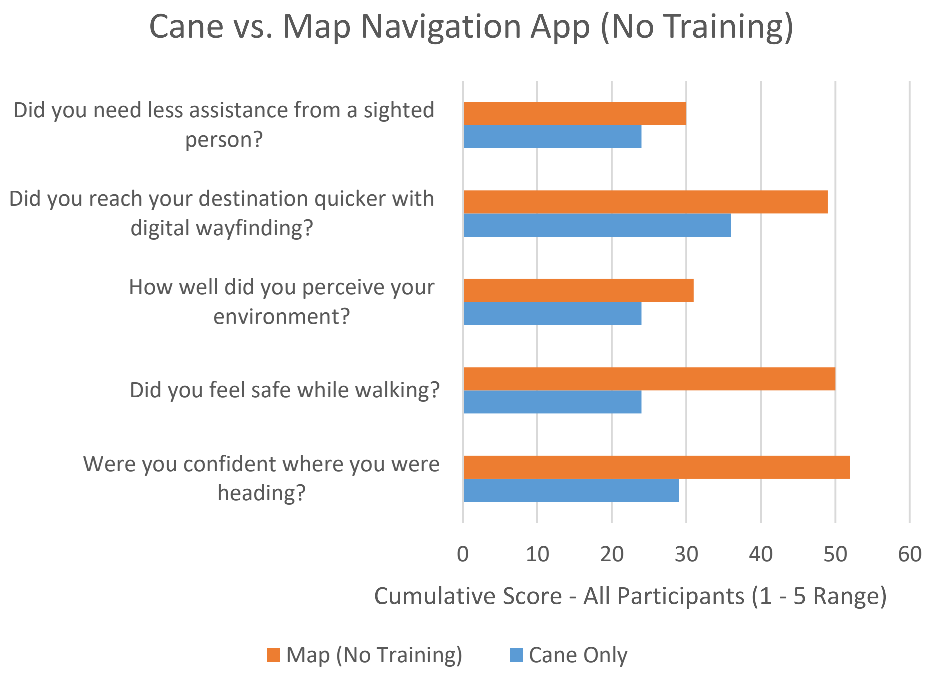
(1 - 5 Scale - higher is better)

- Were you confident where you were heading?
- Did you feel safe while walking?
- How well did you perceive your environment?
- Did you to get to your destination quicker with digital wayfinding (vs. cane only)?
- Did you need assistance of a sighted person?
- When would you consider adopting a digital wayfinding device? (Yes / No response)

- **Surveys**: Participants were surveyed after completing each trip (cane only, cane + obstacle avoidance, cane + map navgation, cane + object recognition, cane + all tech).
- **Results**: Results were computed to compare cane vs. digital wayfinding technologies individually – and also with all technbologies together.
- **Technology Adoption (No Training)**: Participants were asked about likeliness and timing of adoption.
- **Technology Adoption (Post Training)**: Participants were provided additional training and experiment repeated and surveyed again on likeliness and timing of technology adoption.

Results – Object Detection & Map Navigation

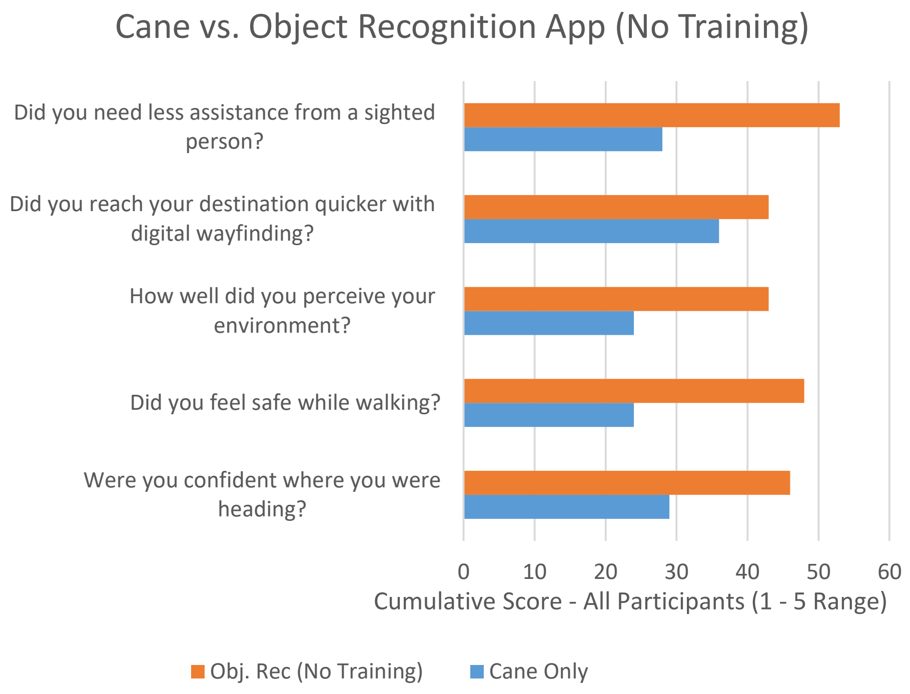


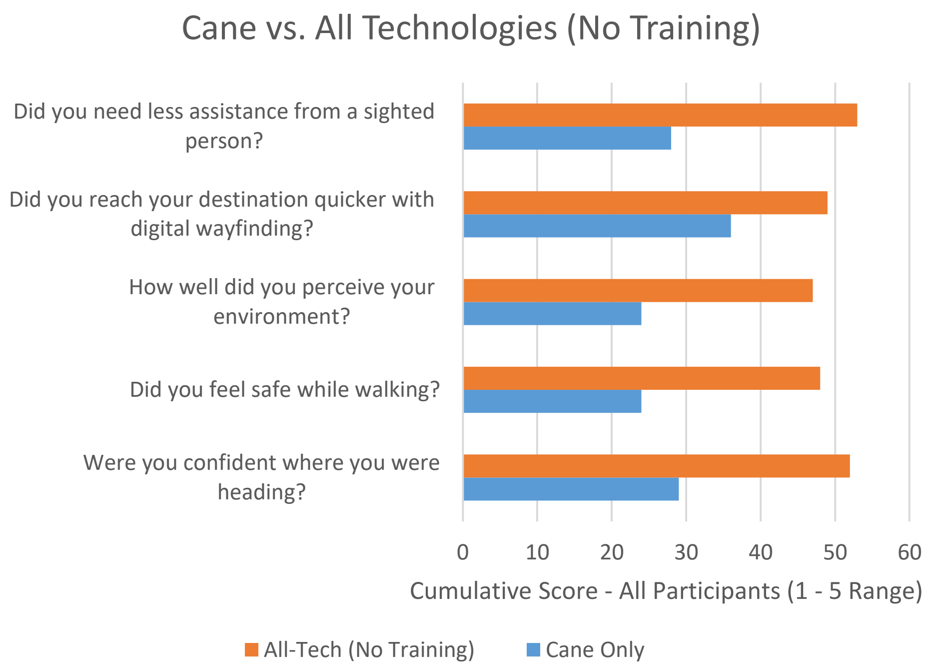


Object Detection Sensor makes participants feel safer while walking

Map navigation makes walking safer and getting to the destination quicker

Results – Object Recognition & All Sensors





Object recognition significantly benefits all aspects of navigation

A combination of sensors significantly benefits navigation and wayfinding

Results – Technology Adoption

https://www.mbaknol.com/strategic-management/technology-adoption-life-cycle/

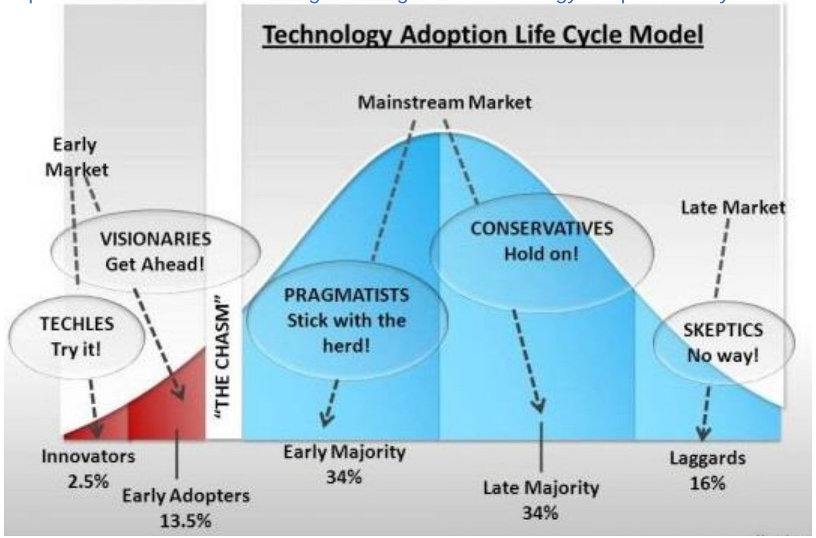
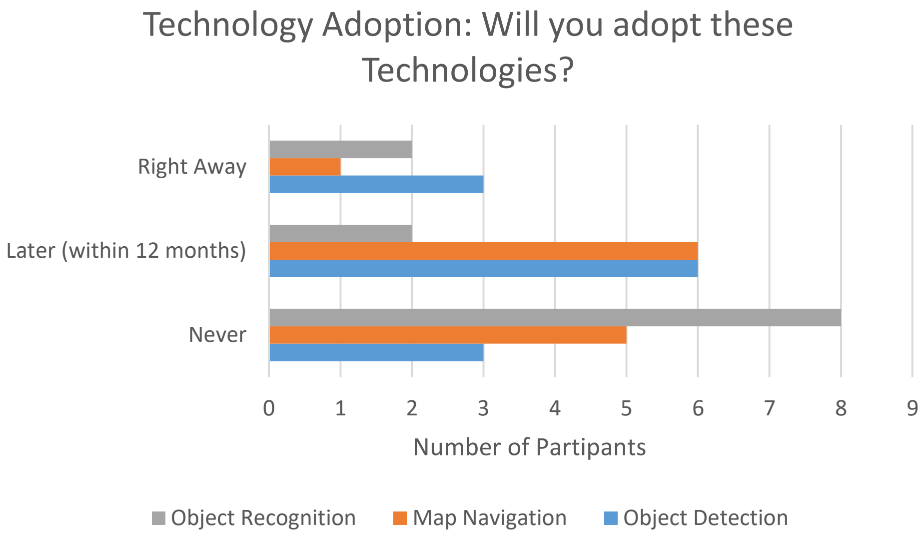


Fig 4: New Technology Adoption Curve – by user type

Maturity cycle of technology used in study based on market introduction

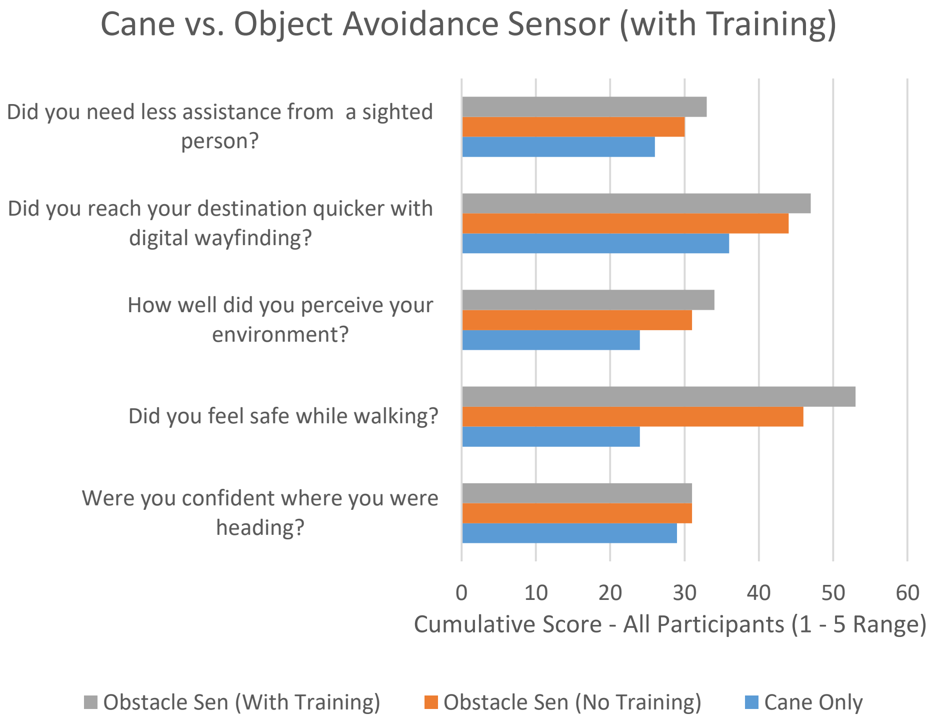
- Map Navigation: Early Majority Stage
- Object Detection: Early Adopter Stage
- Object Recognition: Innovator Stage

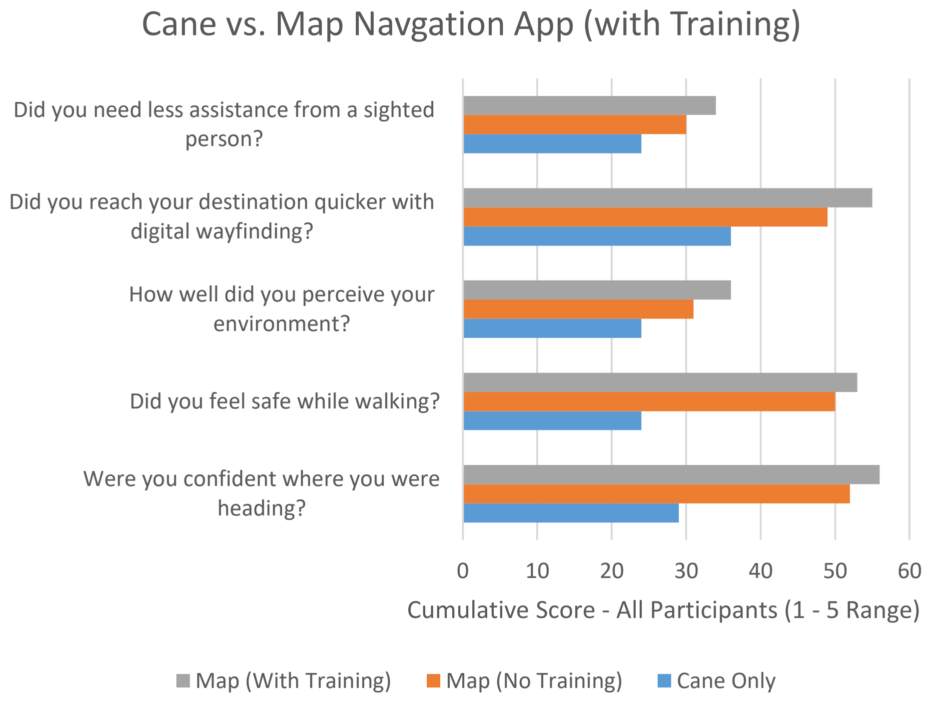


Adoption curve for VirtualNavigator was lower than expected. The primary feedback from users was difficulty in using the technologies

Can adoption be increased with additional training and use?

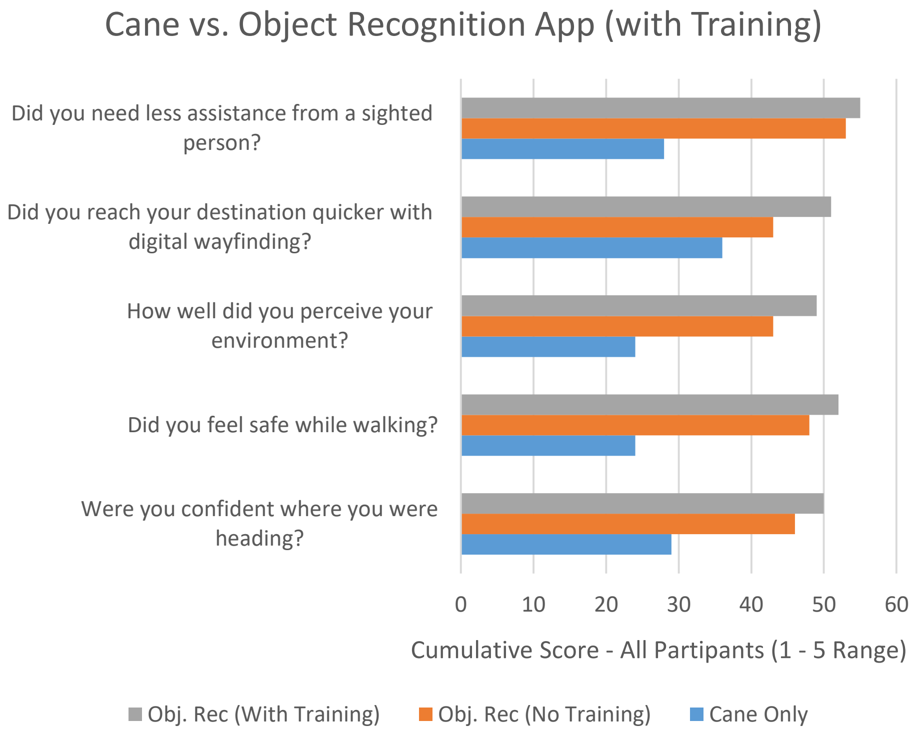
Post Training Results: Object Avoidance & Map Navigation

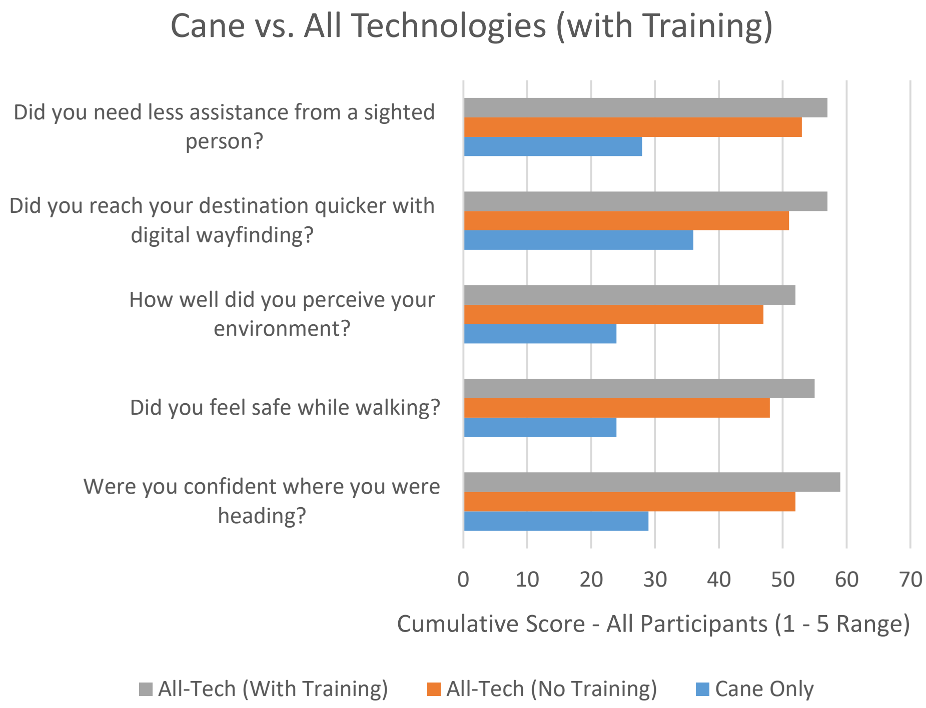




Training has measurable impact on Object Avoidance and Map Navigation results

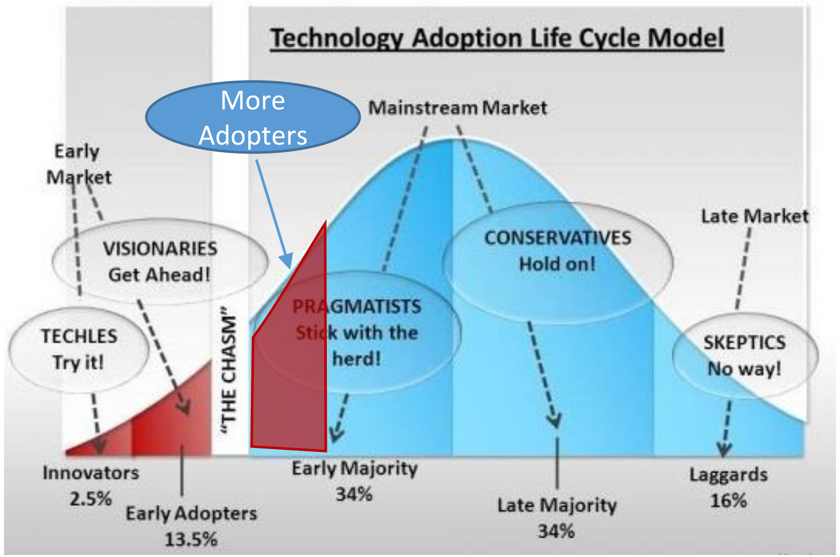
Post Training Results – Object Recognition & All Technologies





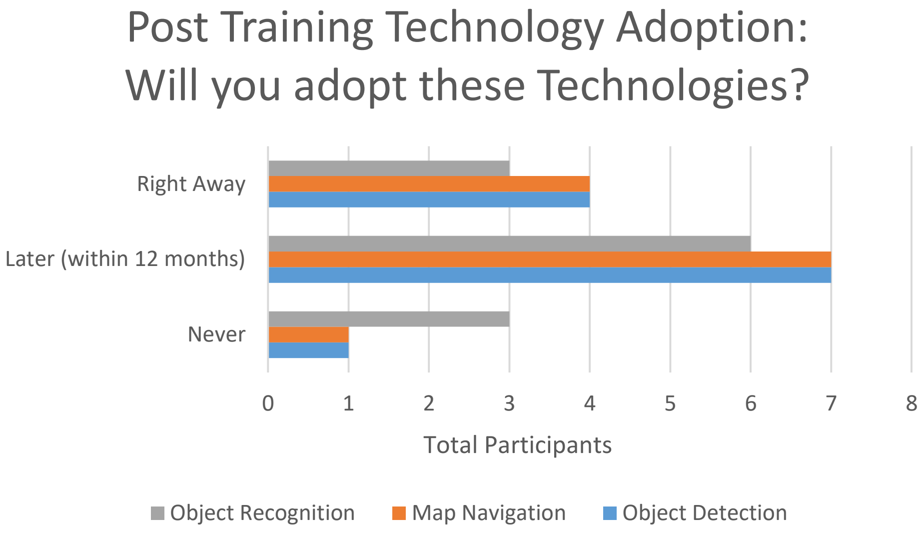
Training has measurable impact Object Recognition and All Technologies results

Post Training Results – Technology Adoption



https://www.mbaknol.com/strategic-management/technology-adoption-life-cycle/

Fig 5: New Technology Adoption Curve – by user type and new adoption curve. Adoption can be enhanced by training and usage (picture is indicative - not to scale).



Adoption curve for digital wayfinding technologies increased with training and usage

Conclusion

- Significant value seen in digital wayfinding technologies

- Combination of technologies can be used to significantly enhance wayfinding mobility vs. single technology.

- Overall, technology can be used to significantly improve wayfinding for visually impaired.

- Training is a key component of increasing adoption.

Next Steps

- **Enhance Study Design**: Expand sample size and include visually impaired participants instead of blindfolding participants – and validate usage in a real life trip scenario (to avoid trip 'familiarity' bias)
- **Enhance Technology**: Add additional sensors
  - **Additional sensors:** Add additional apps and sensors to VirtualNavigator such as Infrared, depth cameras etc.
  - **SMART Helmet**: Explore integrating Laser Imaging Detection and Ranging (Lidar) based helmet to detect distance more accurately
- **Adoption**: Study how to make behavior modification of using VirtualNavigator become habit.
- **Sales**: Explore how VirtualNavigator can be sold to customers.

Fig 6: Person wearing Helmet with Lidar

References

1. Statistics on blindness: https://en.m.wikipedia.org/wiki/Visual_impairment
2. How Visually Impaired can use Vision 8000: V800- https://www.seeingwithsound.com/android-glasses.htm
3. https://gowithfloat.com/2016/11/assistive-technologies-extend-abilities-whether-youre-disabled-not/
4. Tech adoption curve - https://www.mbaknol.com/strategic-management/technology-adoption-life-cycle/
5. How to Build with Aurdino: https://www.instructables.com/
6. Hodges, Brad, Huffman,Lee A Study of Factors Affecting Learning to Use a Computer by People Who Are Blind or Have Low Vision Access World Magazine March 2009, Volume 10, No2