Improving Perception of Sound Source Direction using Visual and Vibrotactile Indicators via Wearable Accessories

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Overview

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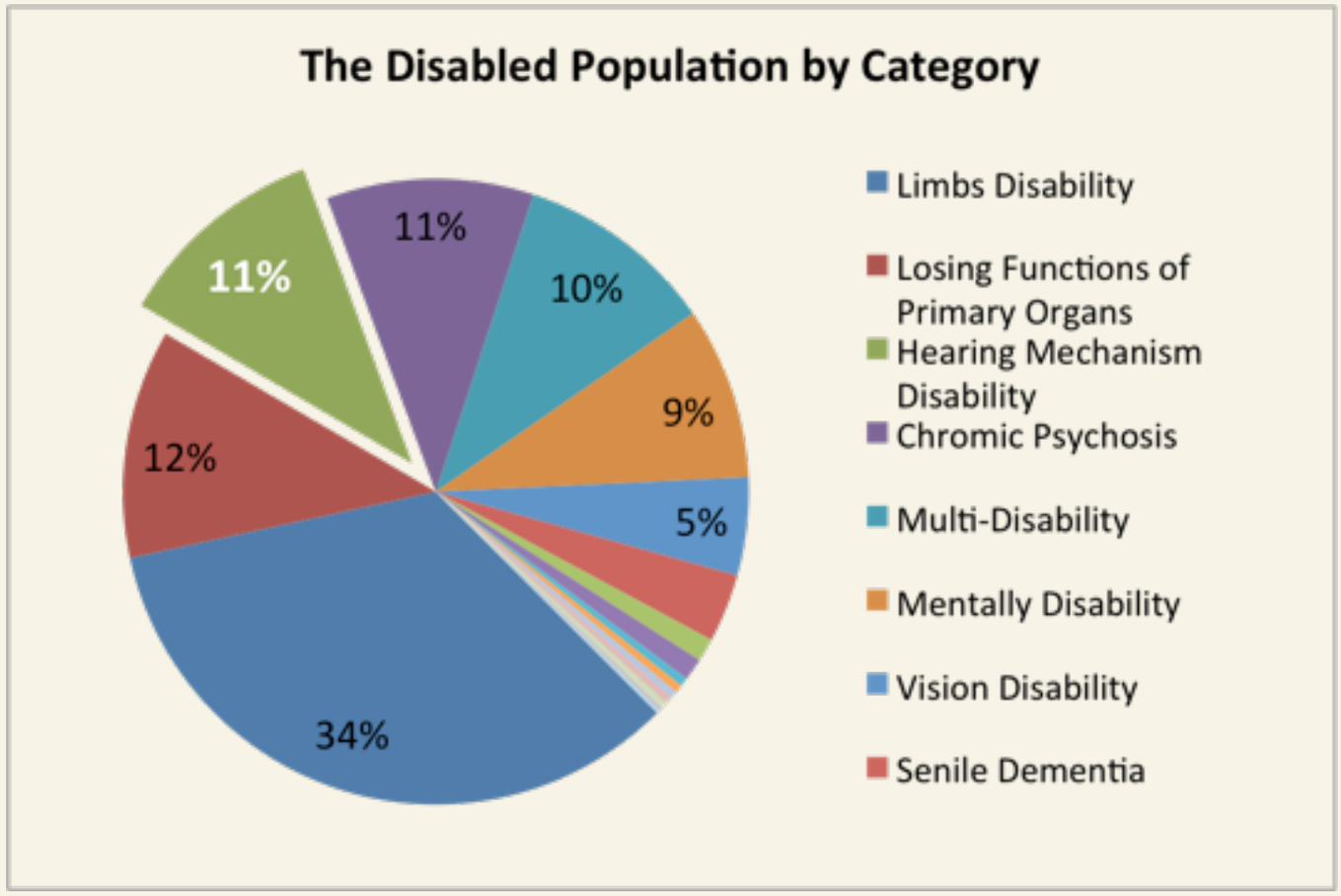
Research Background

- Hearing impaired in Taiwan
- Estimated 12 million citizens* and still growing annually



*Data retrieved from Ministry of Interior and Department of Statistics

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Hearing Instruments and Property

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Interview

- Interview 6 people with hearing loss
- Hearing aids and cochlear implants do not fully meet the needs of helping hearing-impaired people to identify the direction of the sound source

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Overview

- Background of Research
- Introduction
- Related Work
- Type of Accessories
- Prototype and Pattern Design
- Experimentation
- Conclusion and Discussion
- Future Research
- References
- Acknowledgements

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Introduction

- We propose several wearable visual and tactile interfaces with respective patterns to assist people with hearing loss improve acoustic awareness of sound directions
- All the designed patterns and accessories will be evaluated

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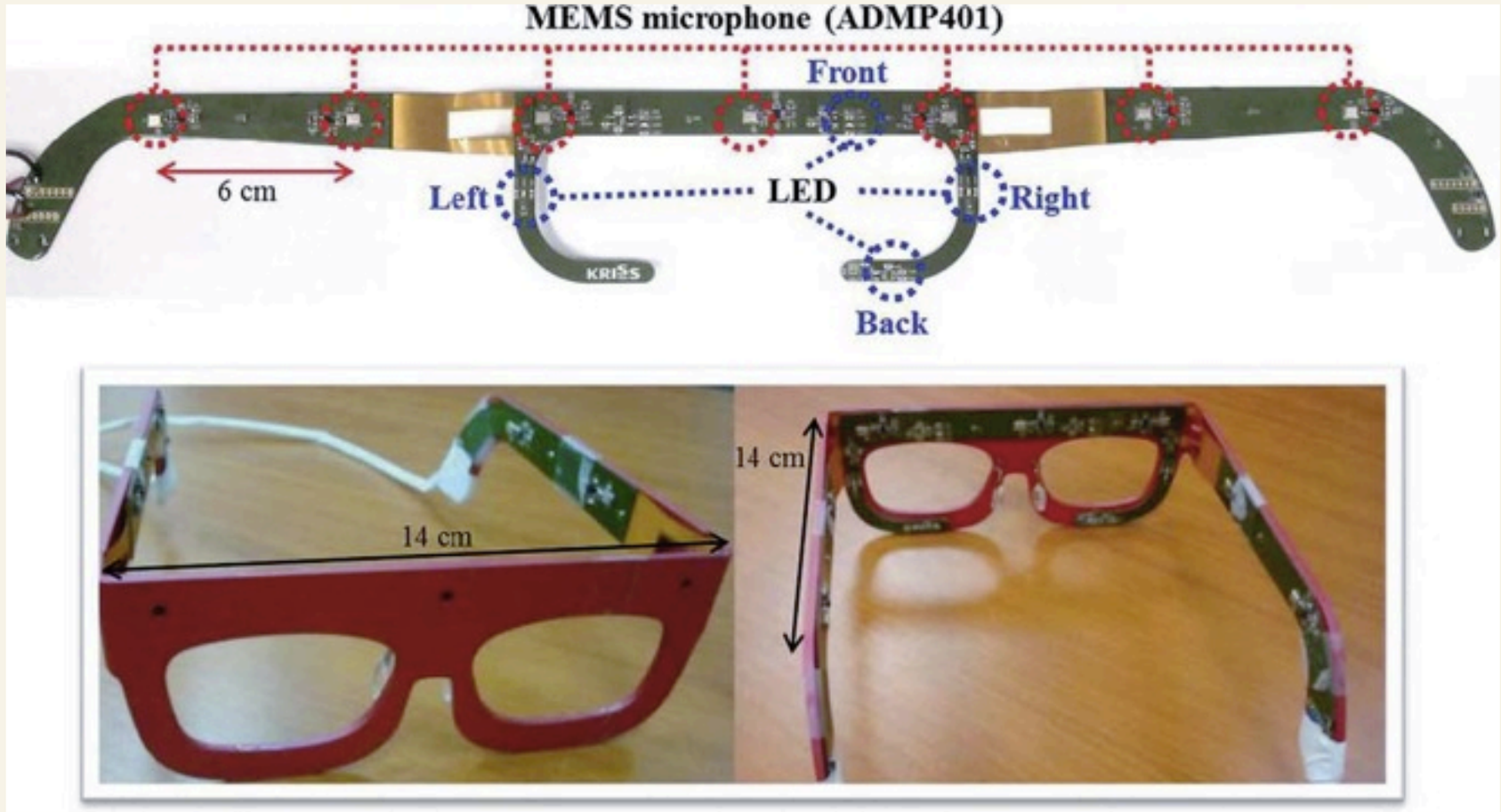
Related Work

- A glasses-type assistive device was designed to detect ambient sound from four directions by using various Microelectromechanical-systems (MEMS) microphones attached to the surface.



Kim, K., Choi, J., and Kim, Y. An assistive device for direction estimation of a sound source. *Assistive Technology* (2013).

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Related Work

- An artist/designer from UK elaborated a project to design a pair of shoes that is capable to navigate its owner to any destination using build-in GPS and light indicator on the shoes.

Wilcox, D. No Place Like Home, GPS shoes. http://dominicwilcox.com/portfolio/gpsshoe/.

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Related Work

- A system using augmented reality system to assist hearing impaired visualize sound source location in indoor settings.

Shen, R., Terada, T., and Tsukamoto, M. A System for Visualizing Sound Source using Augmented Reality. *Proceedings of the 10th International Conference on Advances in Mobile Computing Multimedia MoMM 12* (2012), 97.

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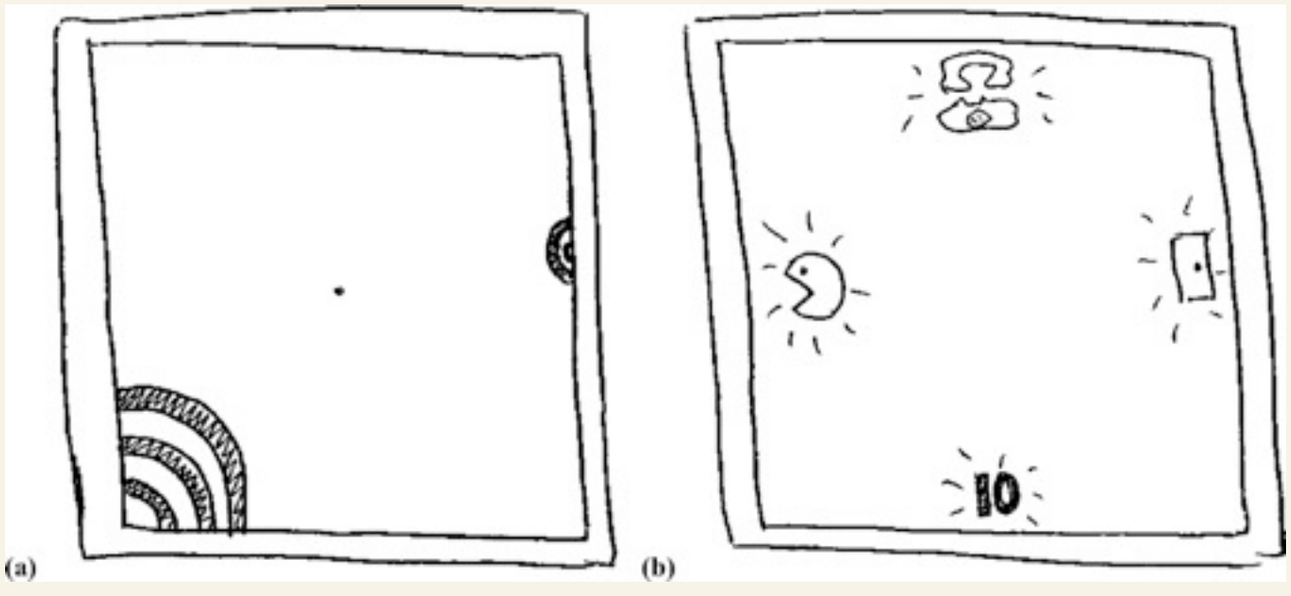
Related Work

- Several other researches investigate types of forms of visual display and display devices for providing awareness of environmental sound to deaf individuals.
- Various figure representation such as iconic imagery, spectrograph, and ripples are exhibited on large displays, for instance, personal computers, televisions, and even ceiling.



Matthews, T., Fong, J., Ho-Ching, F. W.-L., and Mankoff, J. Evaluating non-speech sound visualizations for the deaf. *Behaviour Information Technology 25,* 4 (2006), 333–351.

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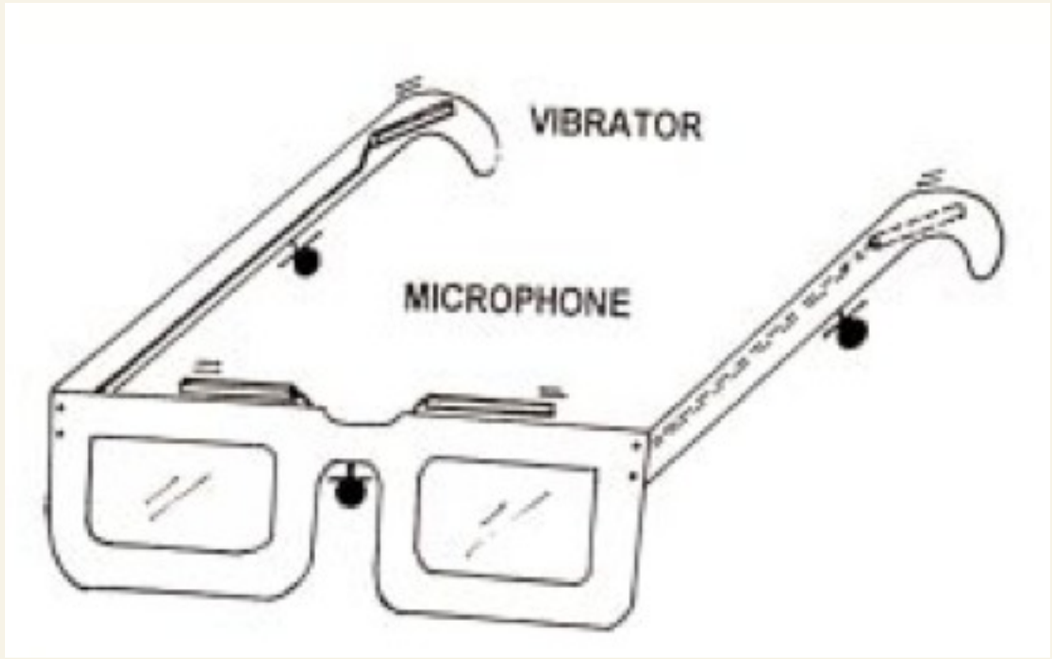
Related Work

- A pair of glasses enhanced with 4 vibrators and 3 microphones with the purpose to locate sound sources for visually and hearing impaired people was presented.



Borg, E., Ronnberg, J., and Neovius, L. Vibratory-coded directional analysis: evaluation of a three-microphone/four-vibrator DSP system.

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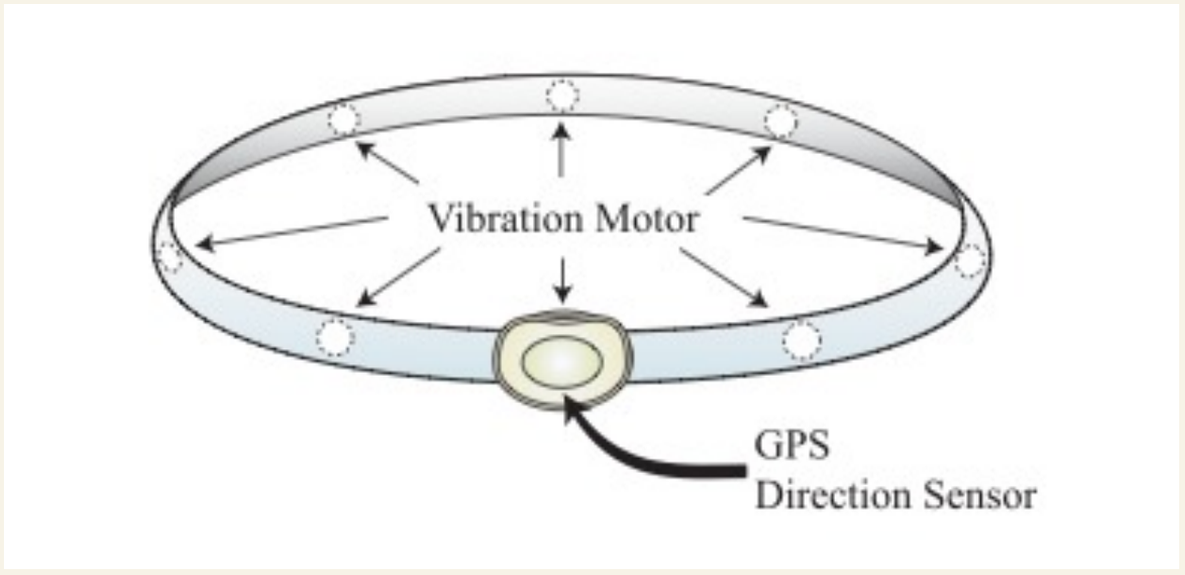
Related Work

- ActiveBelt is a waist belt with GPS sensor and eight vibration motors installed that enables users to obtain multiple directional information for navigational purposes.



Tsukada, K., and Yasumura, M. Activebelt: Belt-type wearable tactile display for directional navigation. *UbiComp 2004: Ubiquitous Computing* (2004).

Related Work

- GentleGuide proposed a tactile navigation system via two bracelets. It outputs three commands, left, right, and stop.

Bosman, S., and Groenendaal, B. Gentleguide: An exploration of haptic output for indoors pedestrian guidance. . . . *interaction with mobile* . . . (2003).

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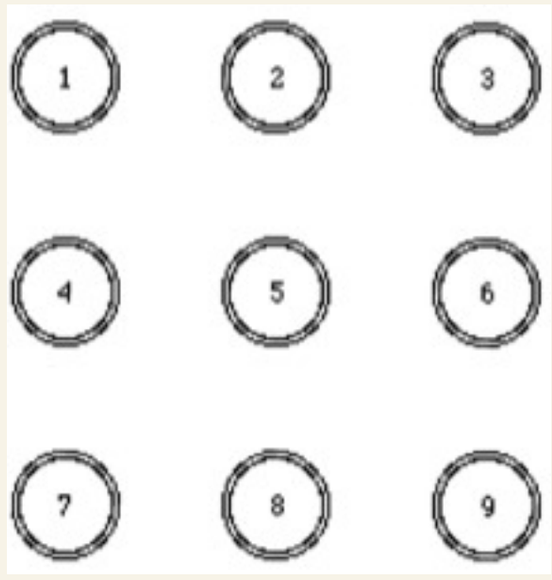
Related Work

- This work focuses on the transmission of directional and simple geometric information on a user's back.



Tan, H., and Pentland, A. Tactual displays for wearable computing. *Personal Technologies* (1997).

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Type of Accessories

- Visual
  - Glasses, cap, and smartwatch
- Tactile
  - Hat, belt, wristband, and armband

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Why do we chose these accessories?

- More frequently seen/used unisex accessories
- Feedbacks can be actively detected by vision or tactile sensation
- Surface area are sufficient and suitable to deliver multiple directional information

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Prototype and Pattern Design

Device	Pattern (P1)	Pattern (P2)	Pattern (P3)
Glasses	Single-double	Light array	Tail tracing
Lighting Cap	Loading dots	Progress bar	Combo loader
Smartwatch	Single arrow	Basic compass	Big pointer
Vibration Hat	Single pointer	Radar search	Alternate-cornering
Belt			
Wristband			
Armband			

Table of devices and corresponding patterns

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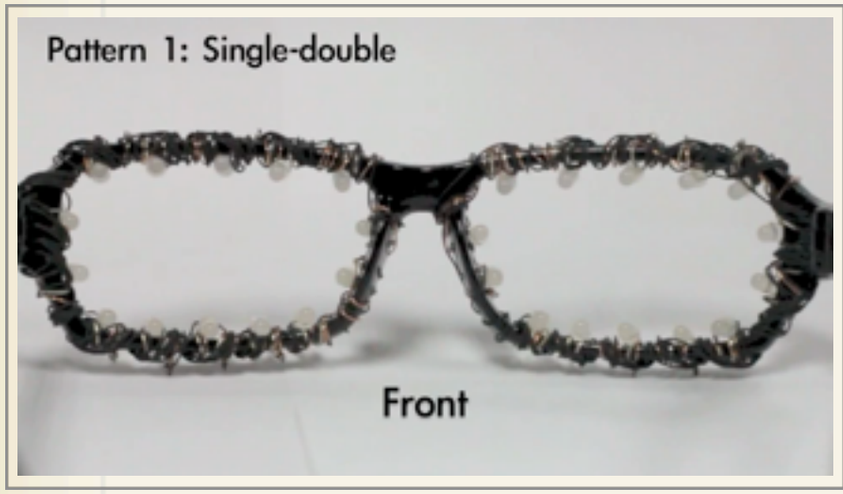
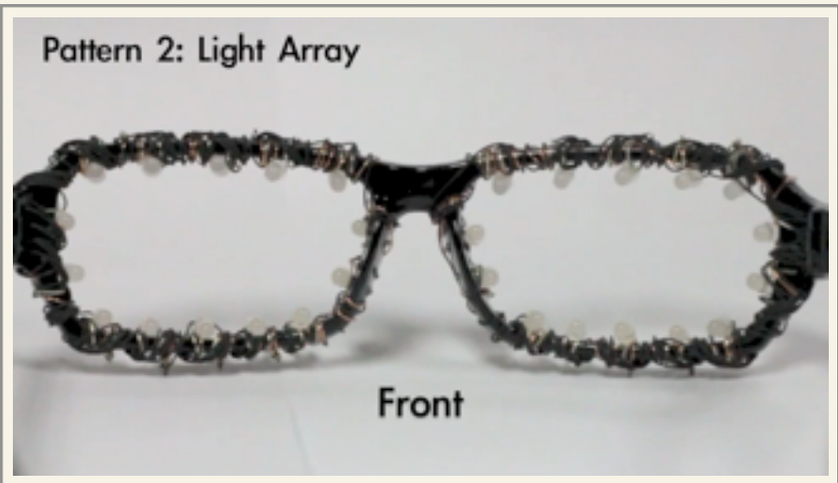
Glasses


Pattern 1: Single-double
Front


Pattern 2: Light Array
Front


Pattern 3: Tail Tracing
Front

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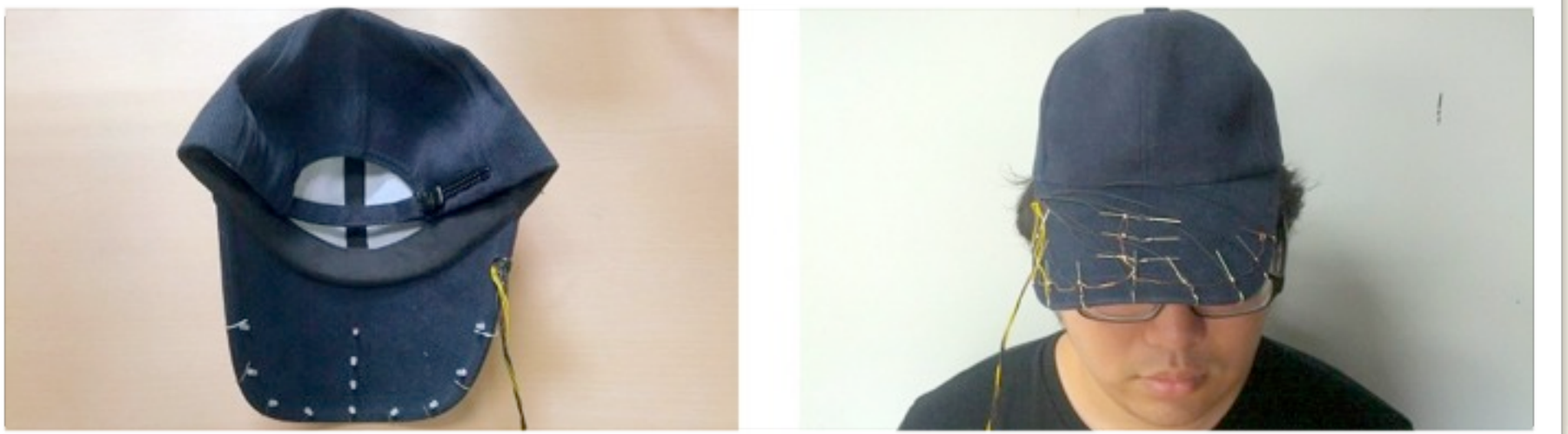
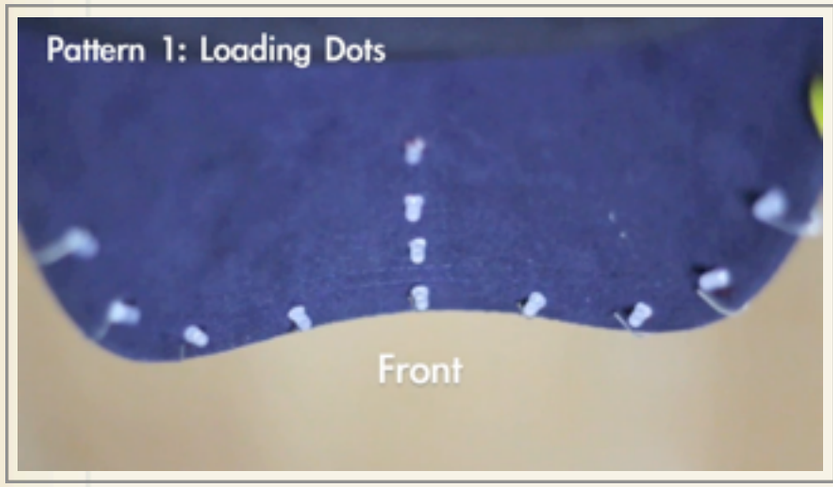
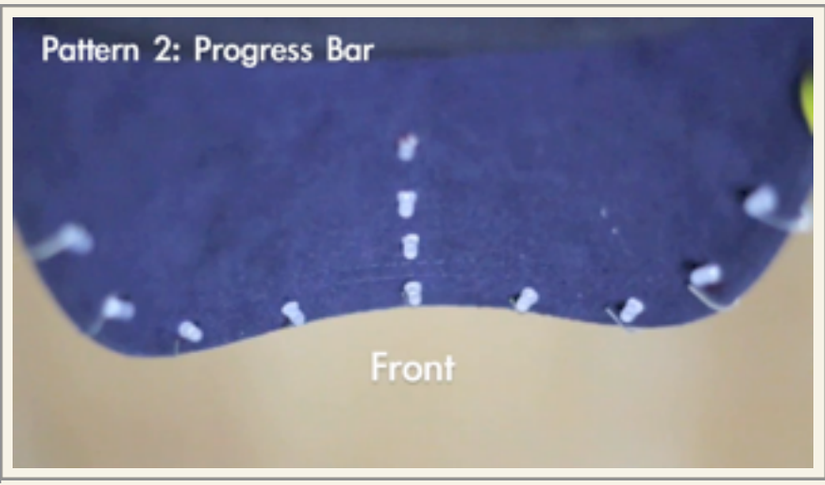
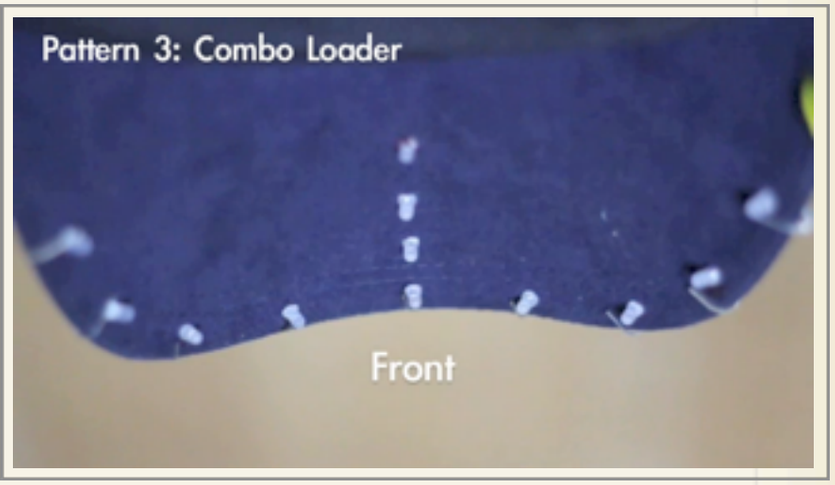
Lighting Cap









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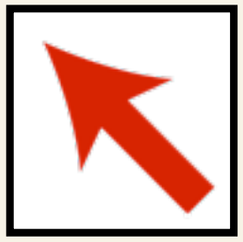
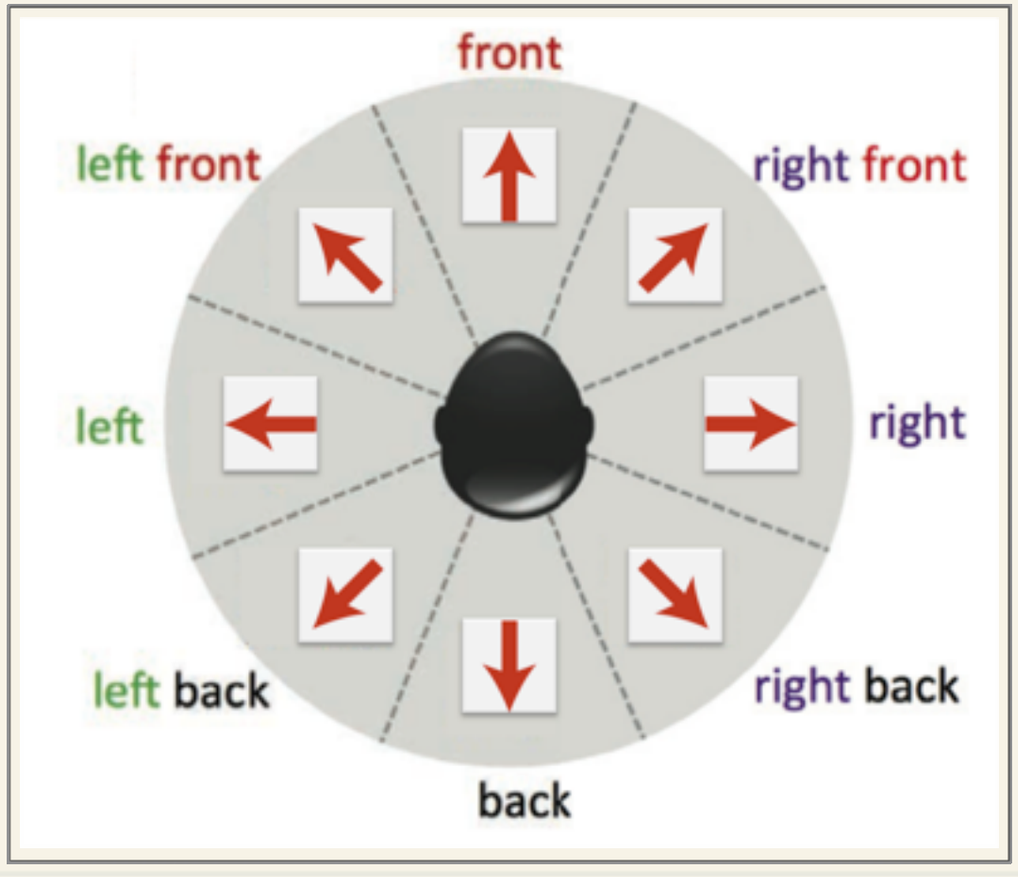
Smartwatch

Pattern 1:
Single Arrow



Pattern 2:
Basic Compass

Pattern 3:
Big Pointer



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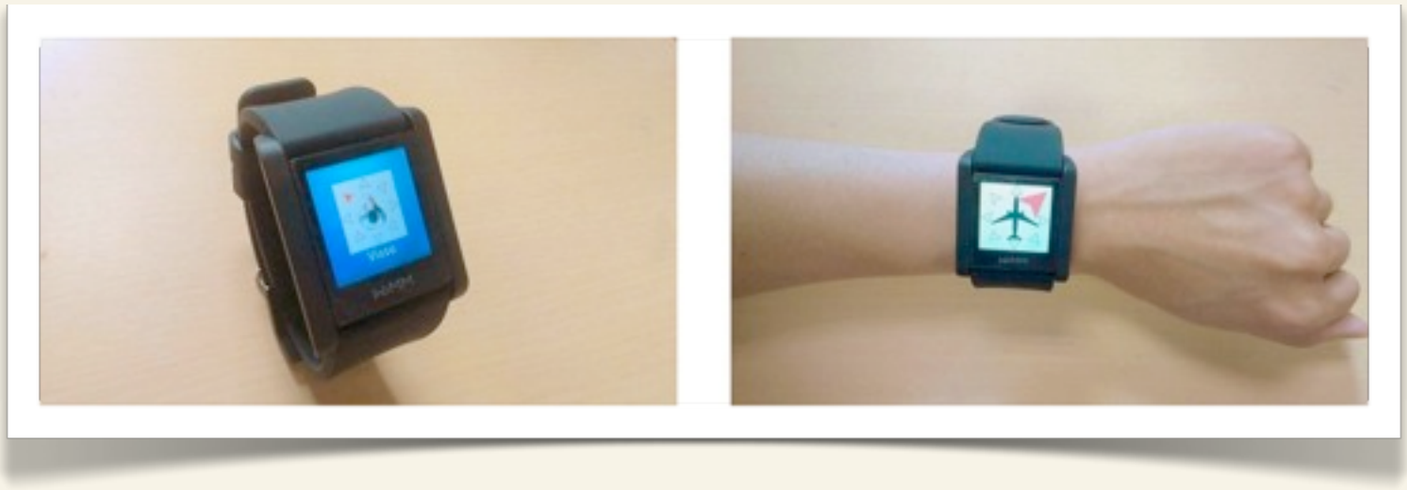
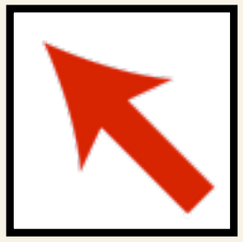
Smartwatch

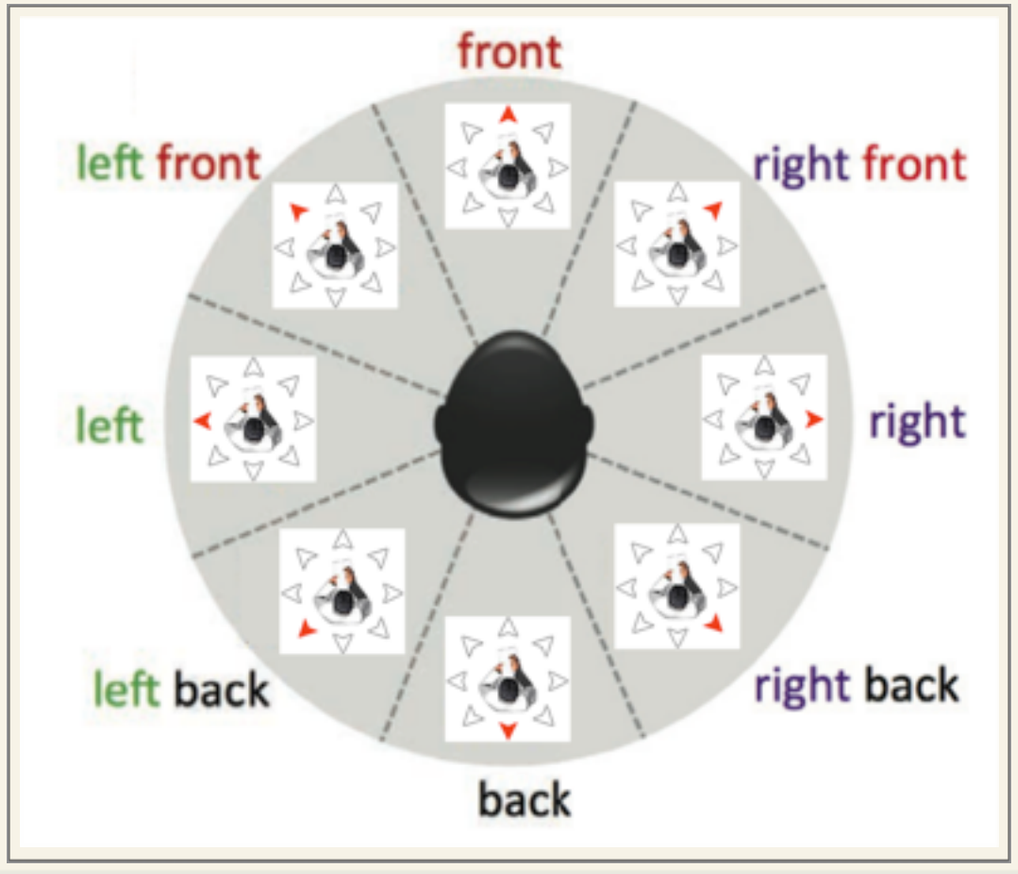


Pattern 1:
Single Arrow



Pattern 2:
Basic Compass

Pattern 3:
Big Pointer



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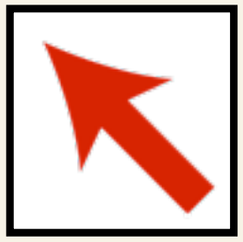
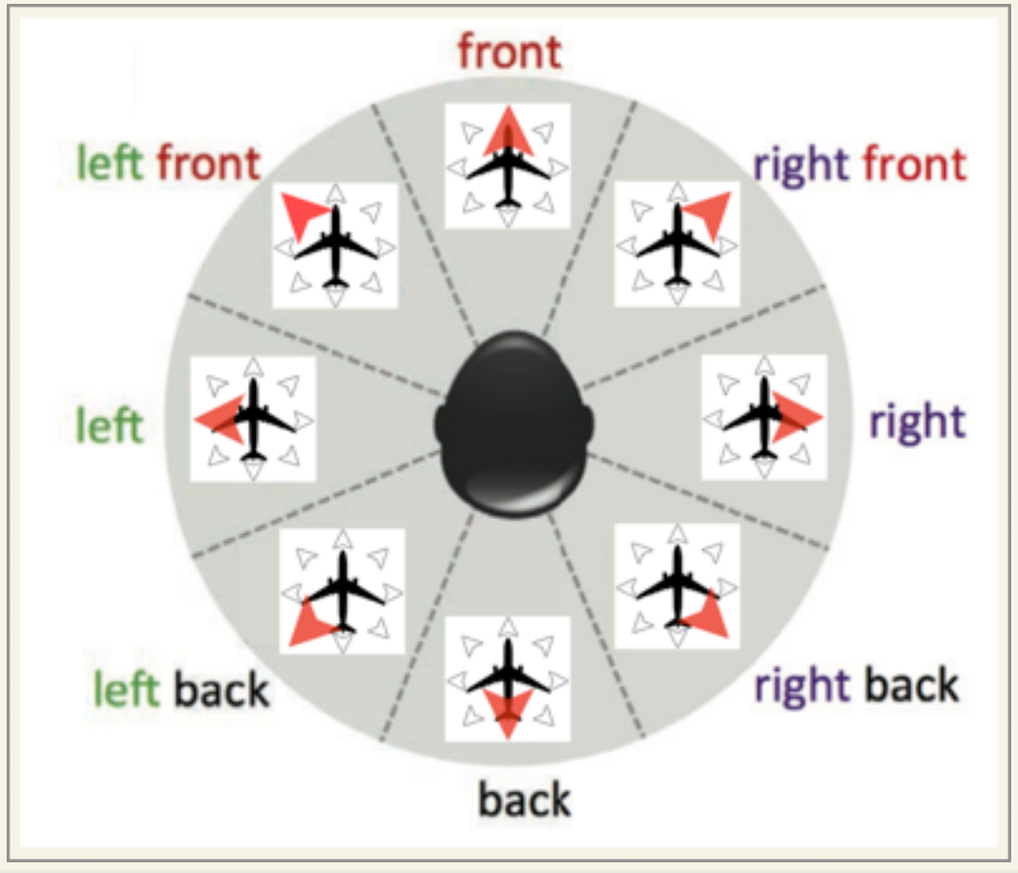
Smartwatch

Pattern 1:
Single Arrow



Pattern 2:
Basic Compass

Pattern 3:
Big Pointer



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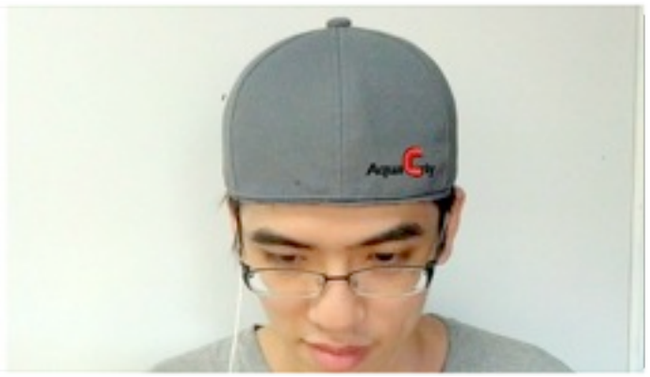
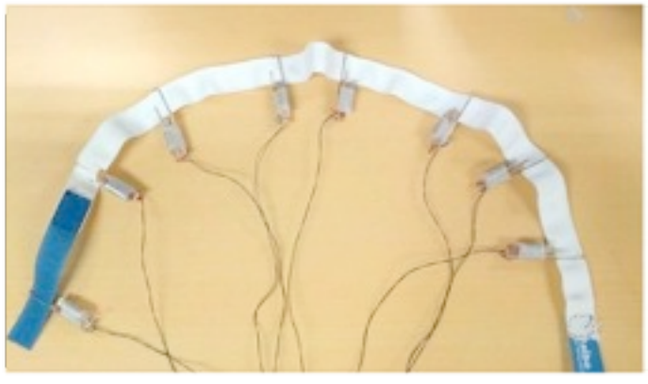
Head and Waist

Vibration Hat



Belt



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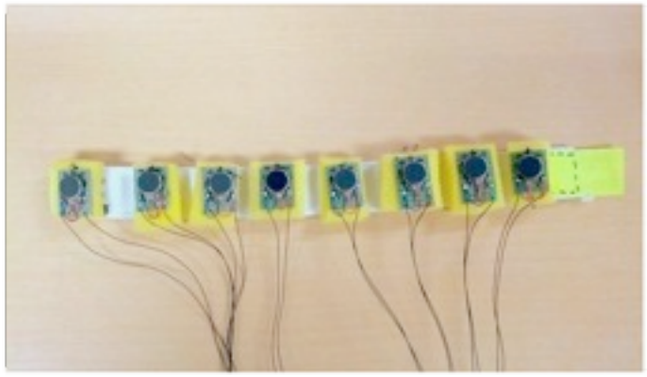
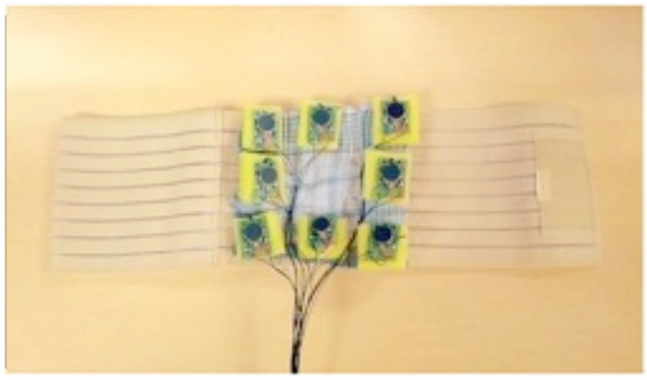
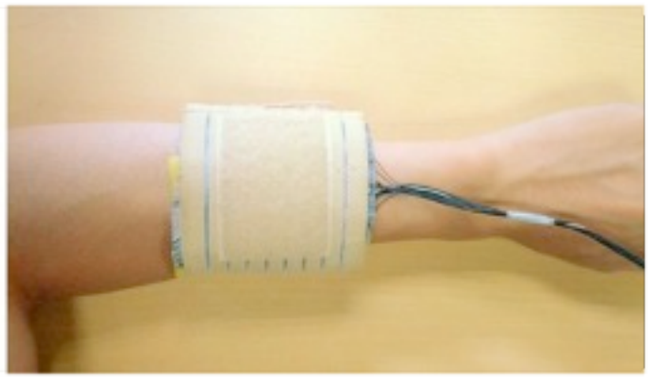
Wrist and Forearm

Wristband



Armband





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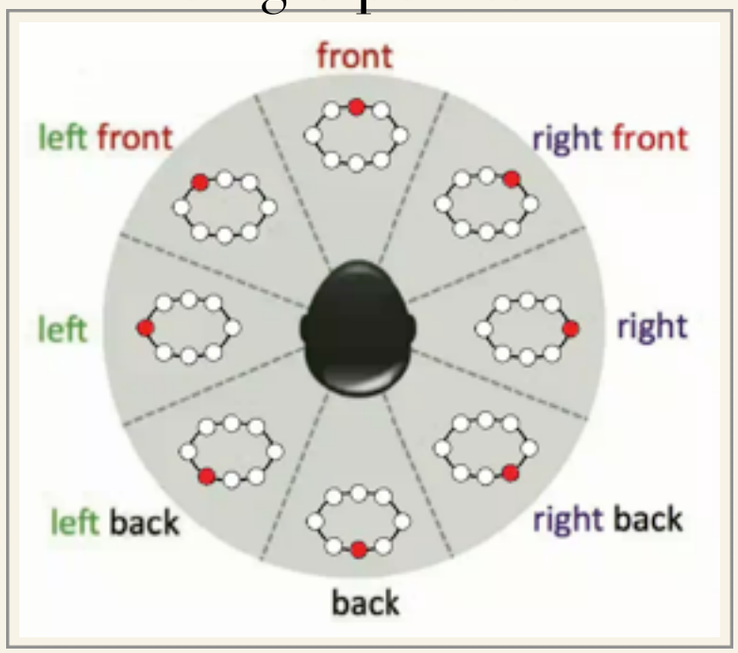
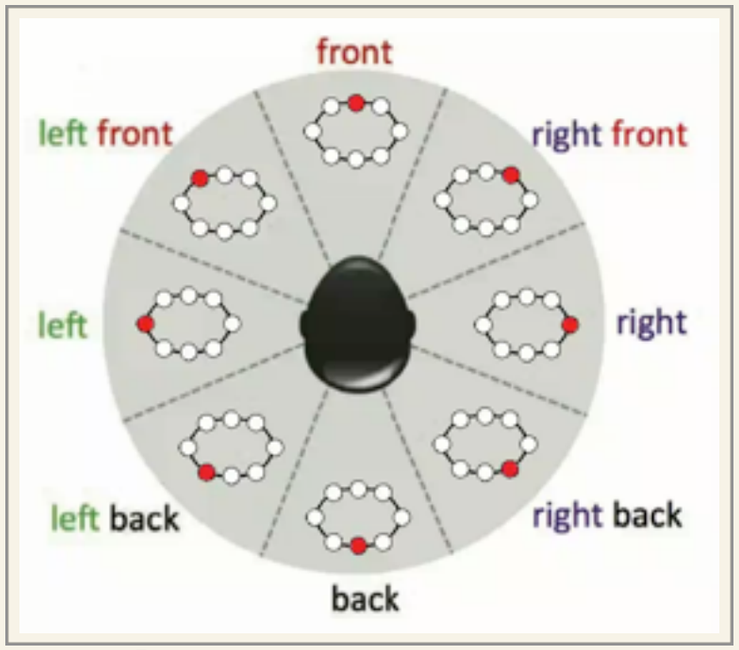
Vibration Pattern

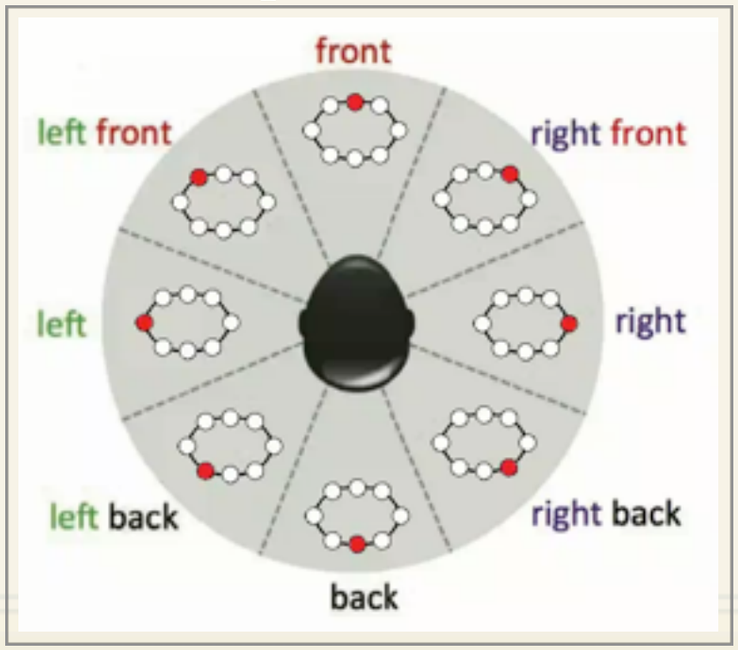
single pointer



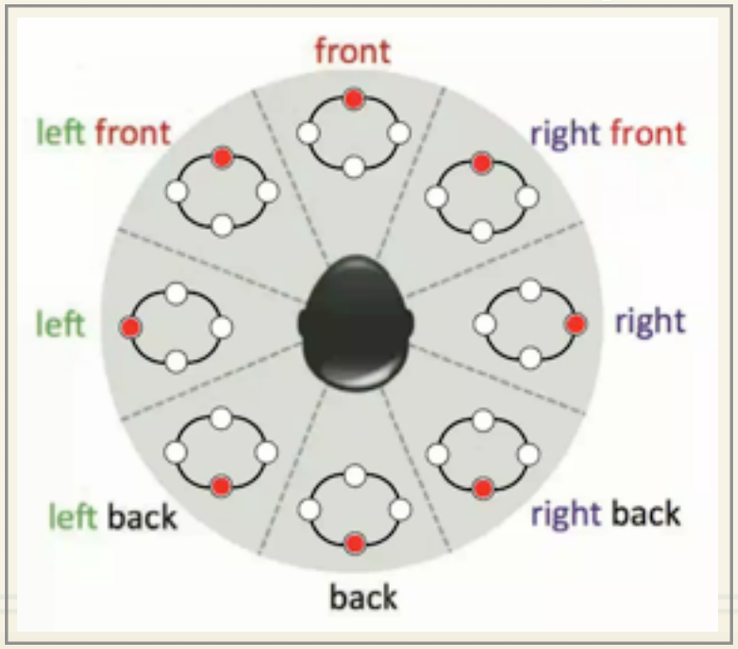
radar search



compound radar



alternate-cornering



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Experimentation

- Experiment 1 (Hearing individual)
  - Understanding of which devices and which patterns are intuitively chosen by the users
    - Experiment 1A and 1B: study the usability and performances of **visual** and **tactile** interfaces individually
- Experiment 2 (Hearing impaired)
  - Evaluating the usability of our devices and feedbacks selected from the previous experiment

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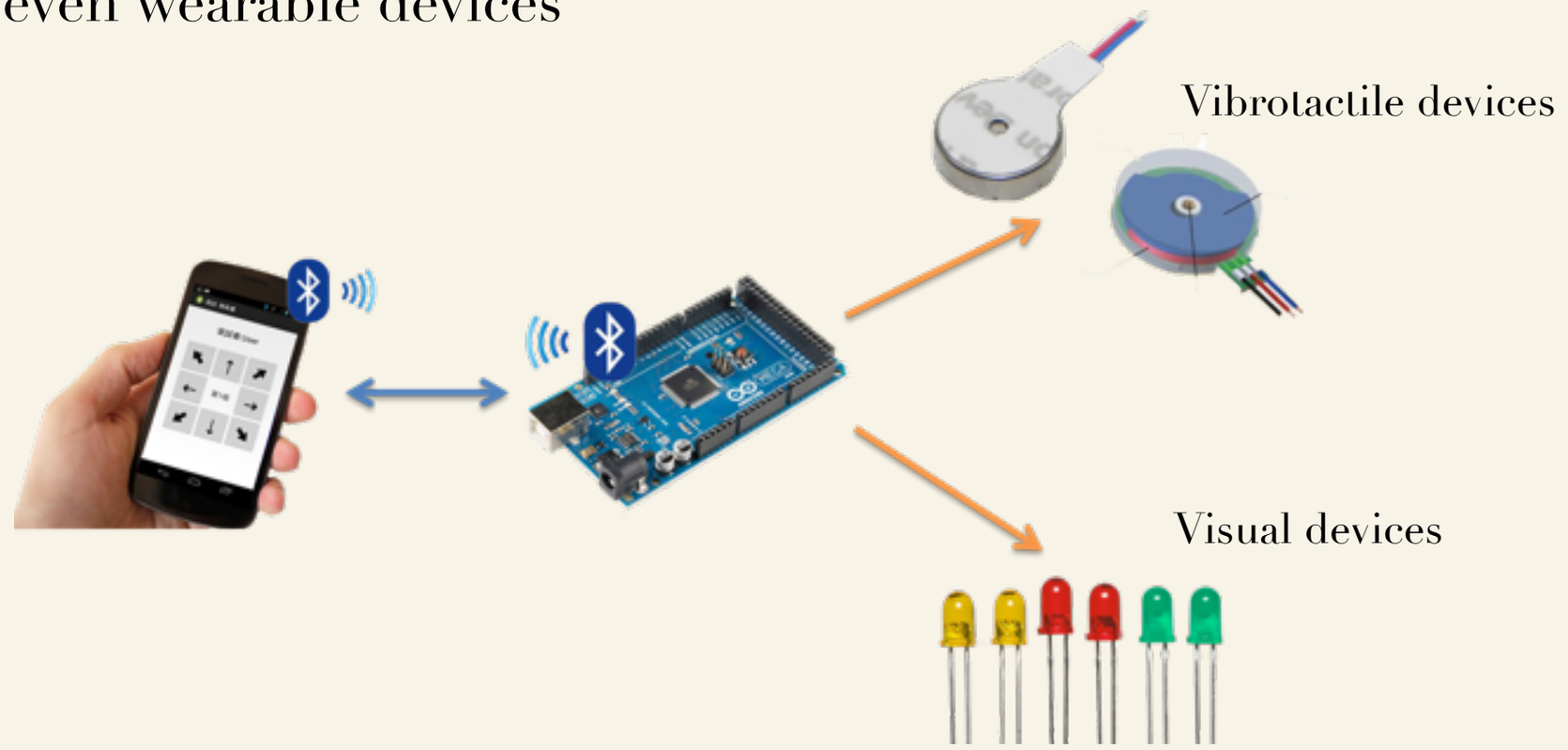
Experiment 1: Equipment

- The experiment was conducted using
  - A mobile device (Galaxy Nexus)
  - An Arduino Mega 2560 R3
  - Seven wearable devices



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Experiment 1: Participants

- There are 20 participants
  - 8 males and 12 females age between 19 and 29 (an average of 22.6)
- The participants are in a variety of academic backgrounds, such as advertising, management, ocean engineering, computer engineering and etc.

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Experiment 1: Procedure

- 9 tests (3 patterns x 3 devices) for visual devices were conducted
- 12 tests (3 feedback patterns x 4 devices) for tactile devices
- Order of the tests are counter balanced
- 90 seconds to learn each pattern
- 16 trials of tasks
- 10 seconds to select an answer
- Answers and response time were recorded
- A questionnaire and short interview are done between each device

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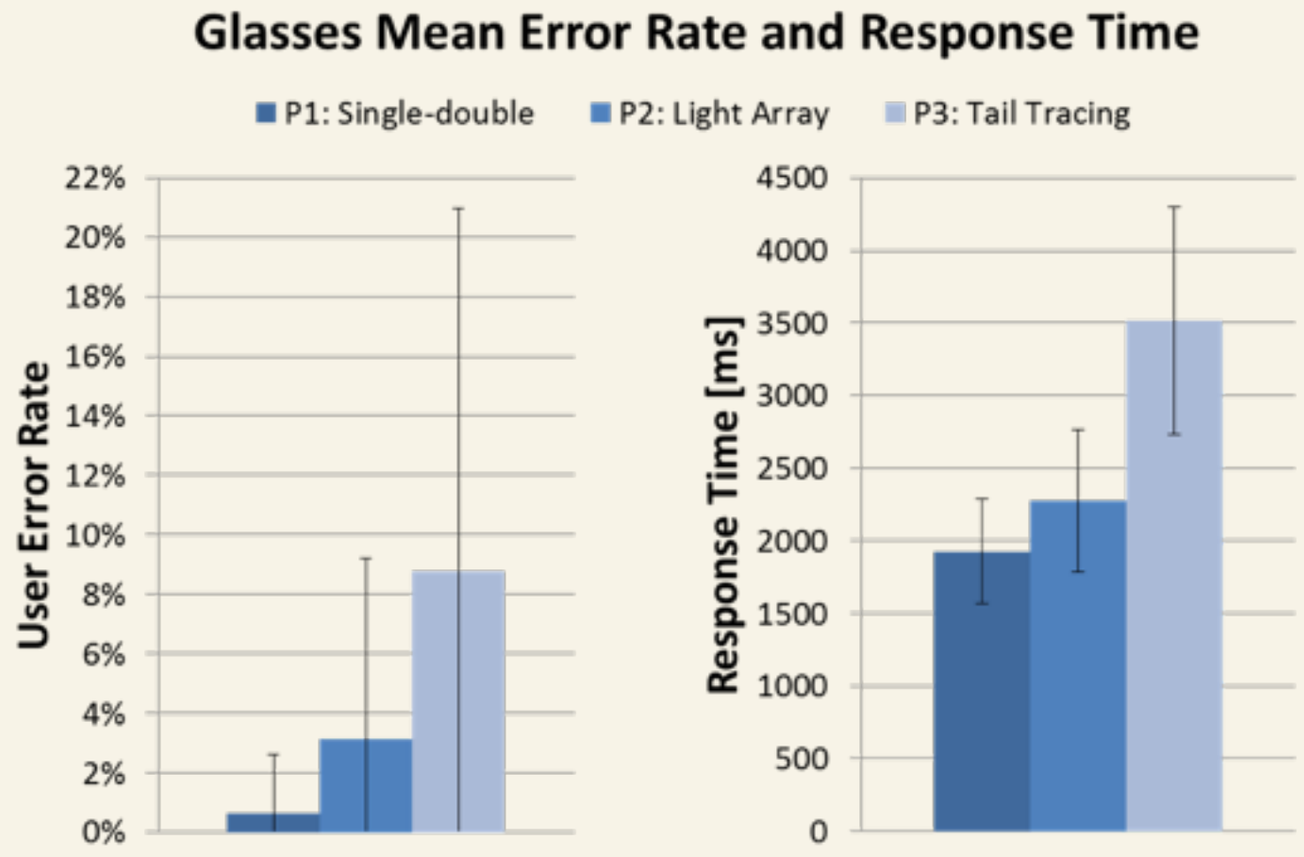
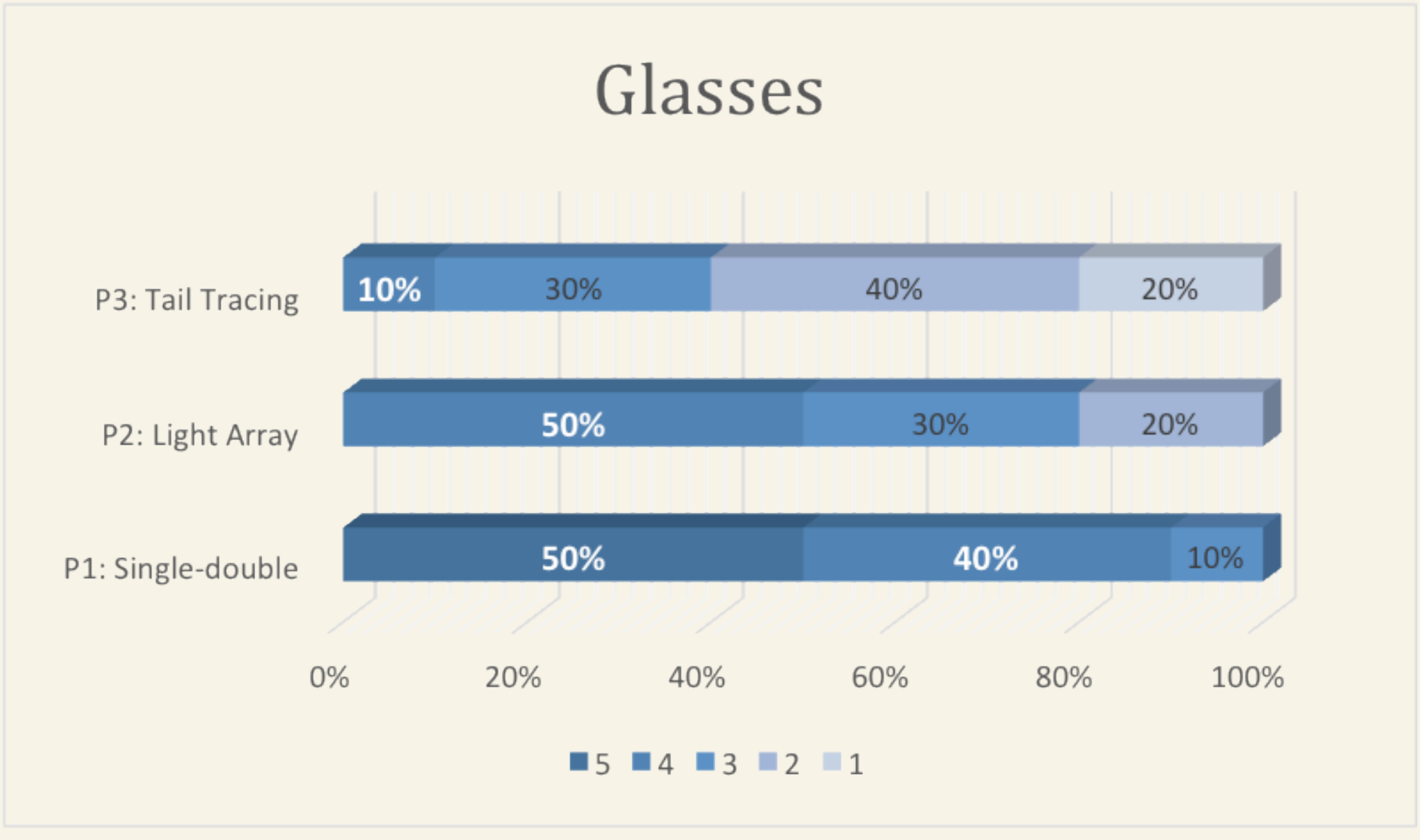
Experiment 1A: Glasses Result

- First and third patterns are significantly different in error rate. ($p<0.05$)
- Response time in third pattern is significantly higher than other two. ($p<.0001$)

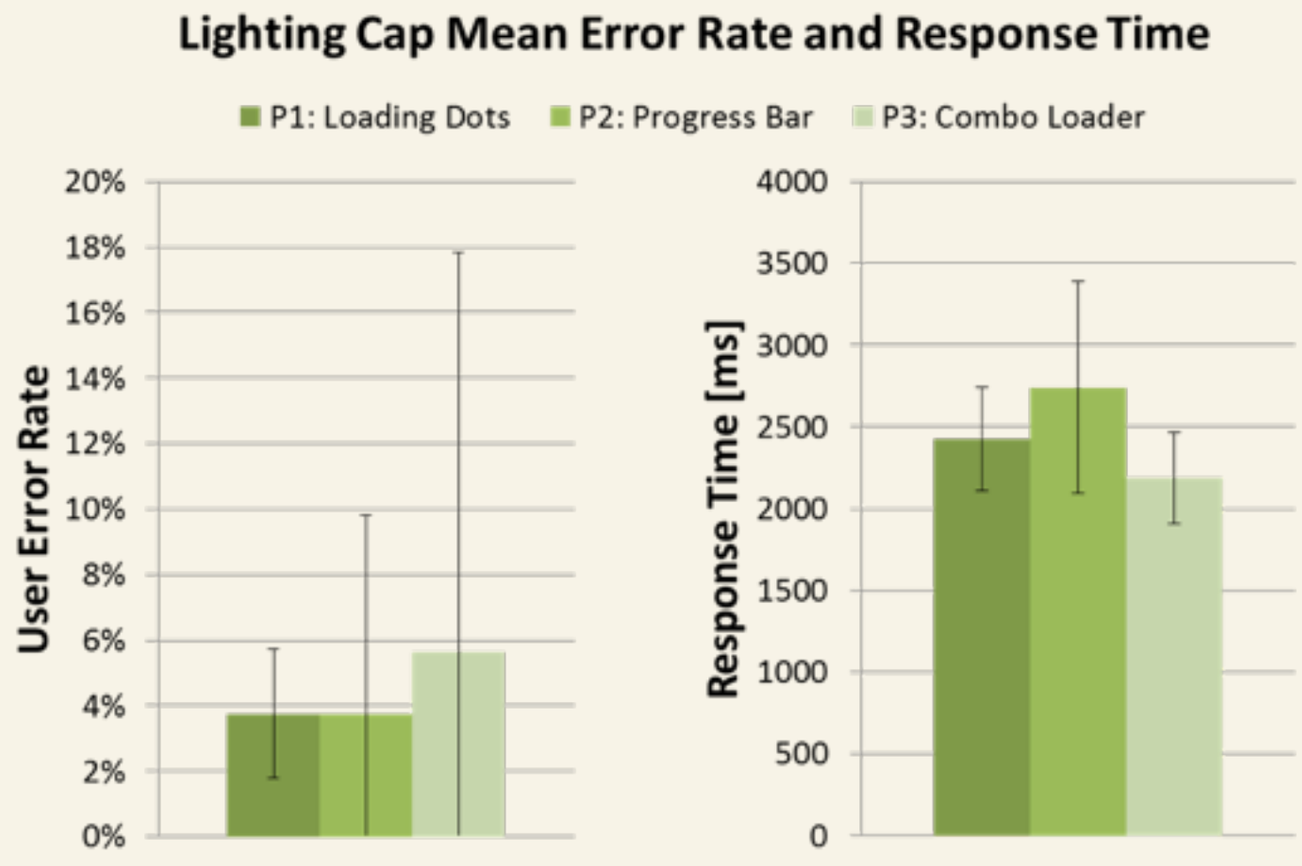


Experiment 1A: Glasses Likert Scale

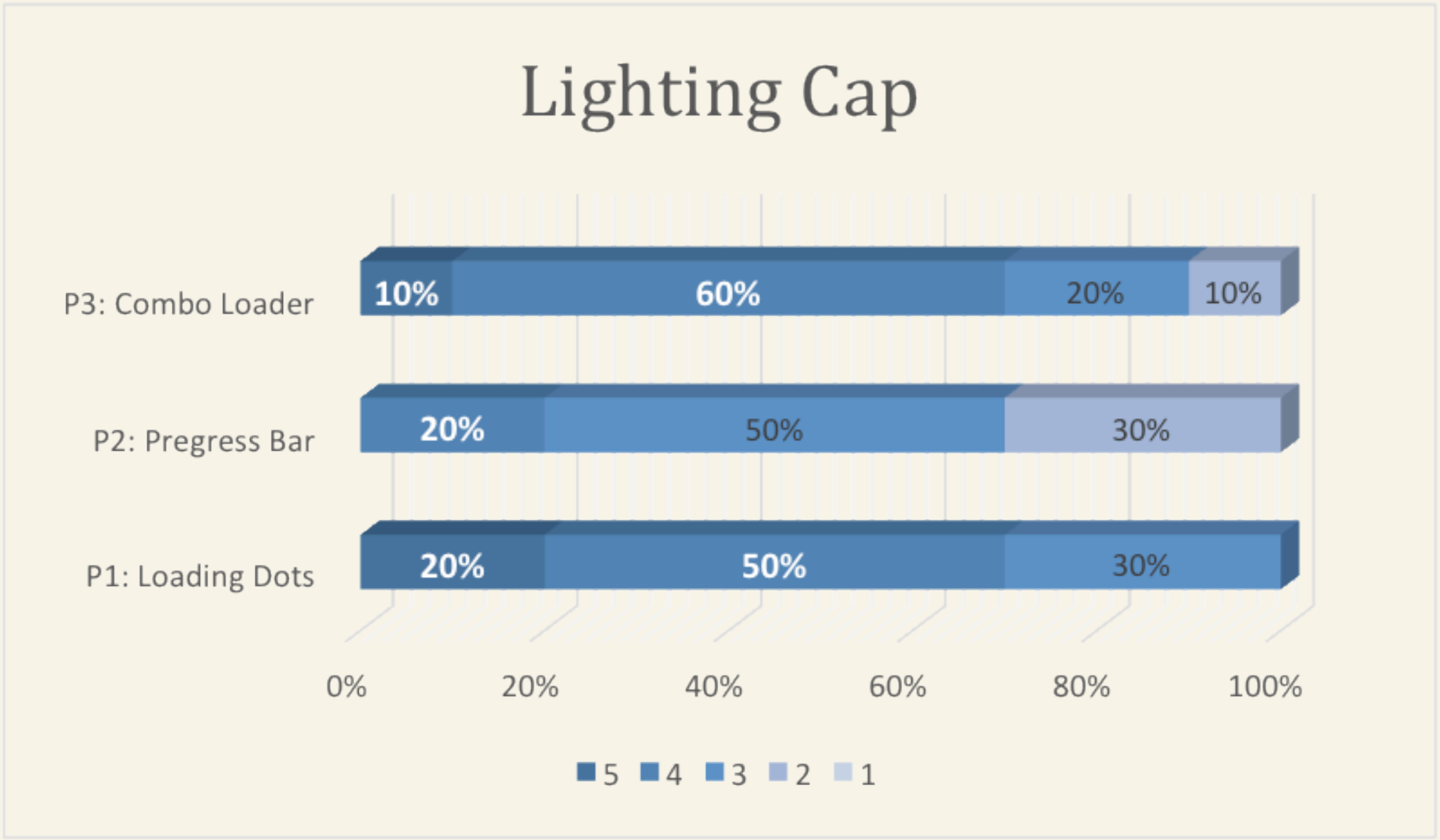


Experiment 1A: Lighting Cap Result

- Based on error rate and response time, there are no significant difference in between each pattern except P1 “loading dots” and P3 “combo loader” in response time. ($p<0.05$)

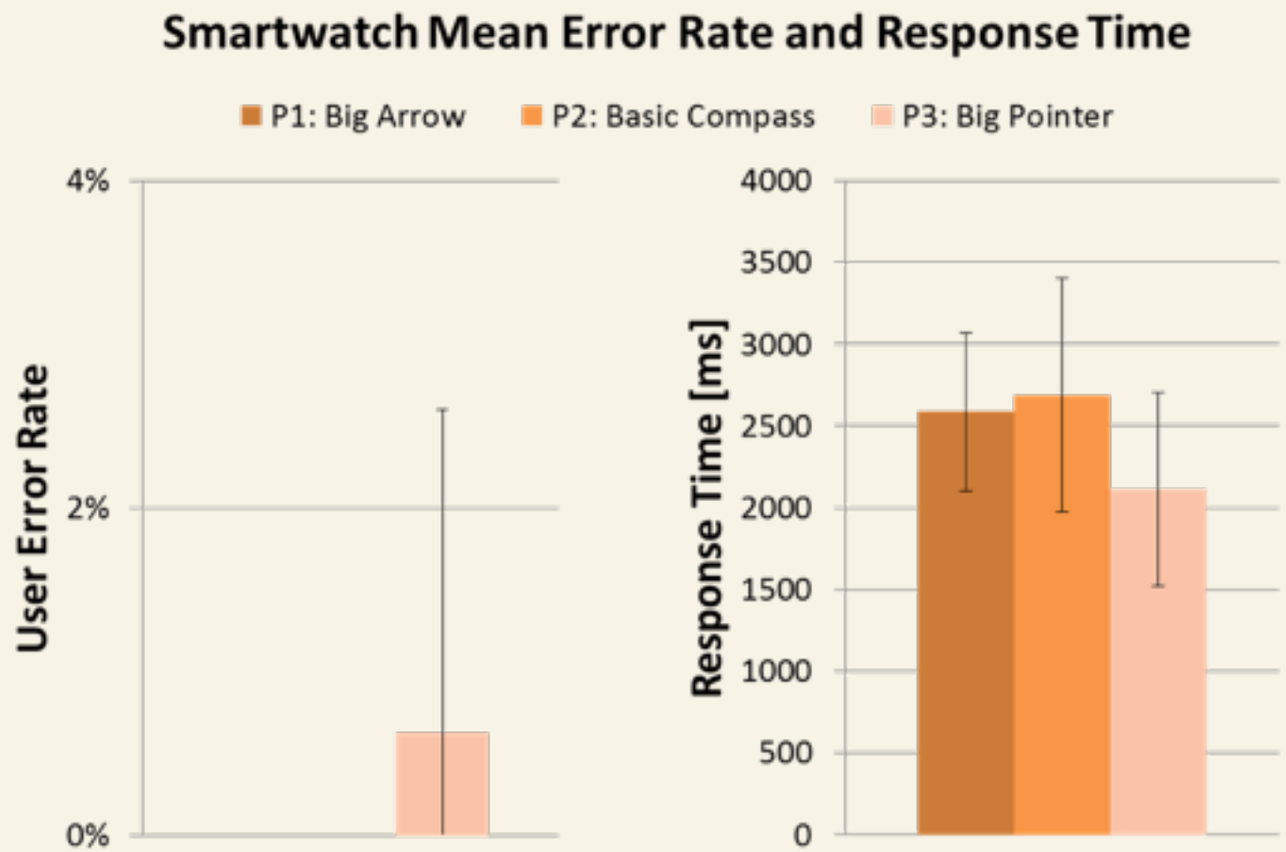


Experiment 1A: Lighting Cap Likert Scale

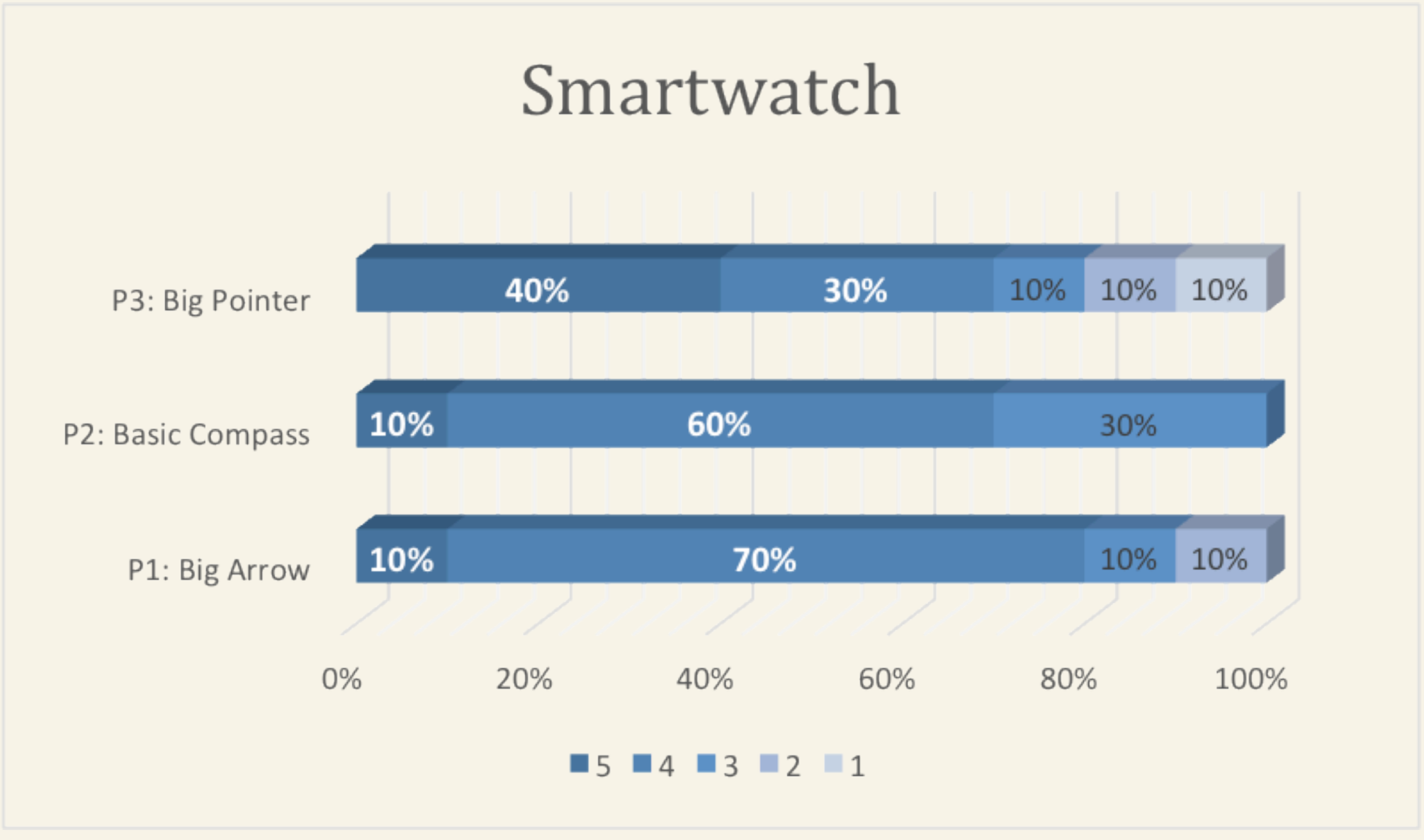


Experiment 1A: Smartwatch Result

- Though error rate is a bit higher in third pattern “big pointer” (0.63% vs 0%), the response time is slightly shorter then the rest (About 1000 ms less).
- No significant differences overall.



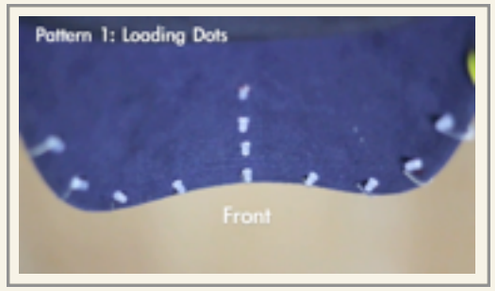
Experiment 1A: Smartwatch Likert Scale



Experiment 1A: Conclusion

- Glasses:
  - "Single-double"
  - "*The simpler the better; and animations are confusing and unnecessary.*"

- Lighting Cap:
  - "Loading Dots"
  - *"Too much lights and overlapping makes it hard to distinguish."*



- Smartwatch:
  - "Big Pointers"
  - "*Easier to understand and more intuitive*"

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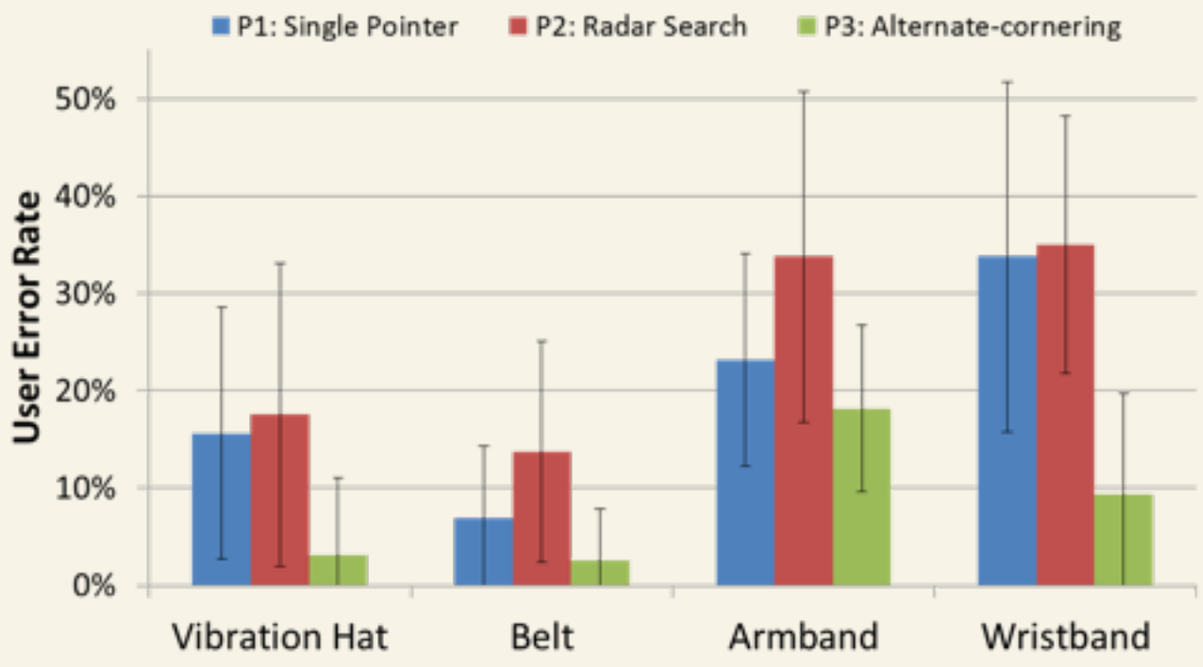
Experiment 1B: Result

- Vibration hat & wristband
  - The error rate of “alternate-cornering” is lower than other two patterns.($p<0.05$)
- Belt & armband
  - The error rate of “alternate-cornering” is lower than “radar search”.($p<0.05$)



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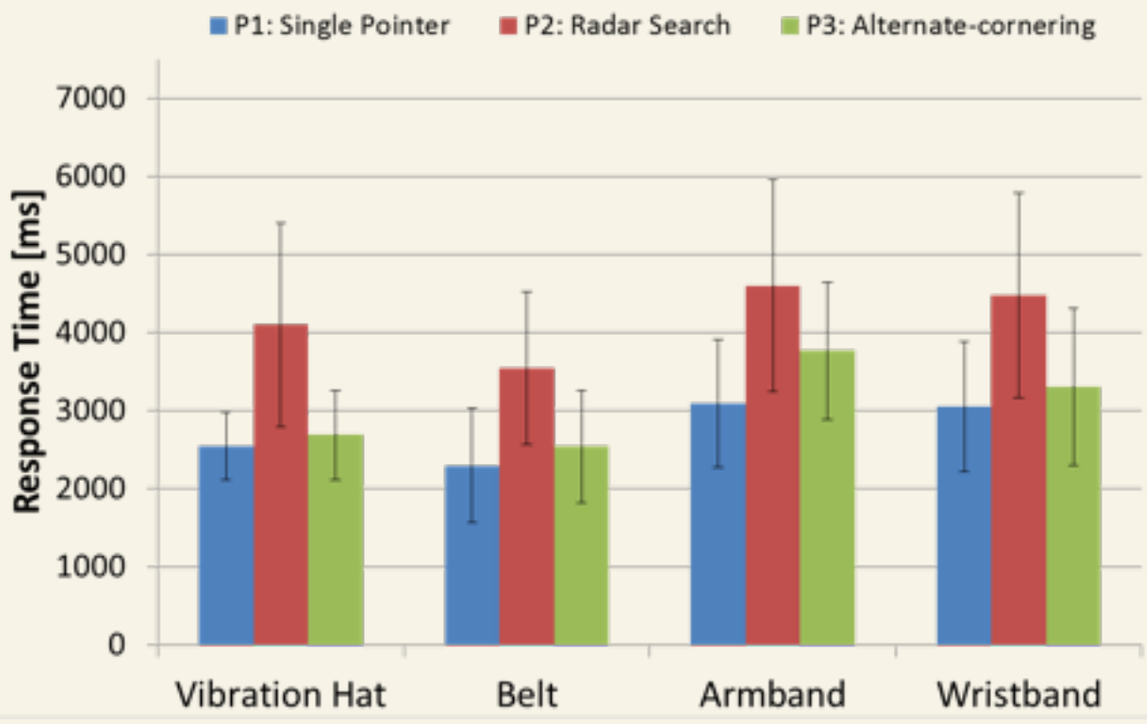
Experiment 1B: Result

- Vibration hat & belt & wristband
  - The response time of “radar search” is longer than other two patterns.($p<0.05$)
- Armband
  - The response time of “single pointer” is shorter than “radar search” ($p<0.05$)



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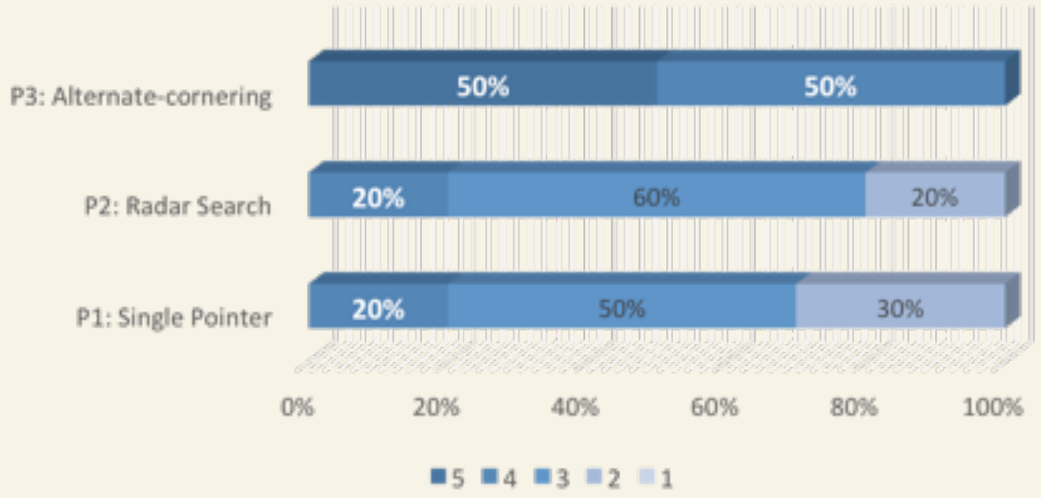
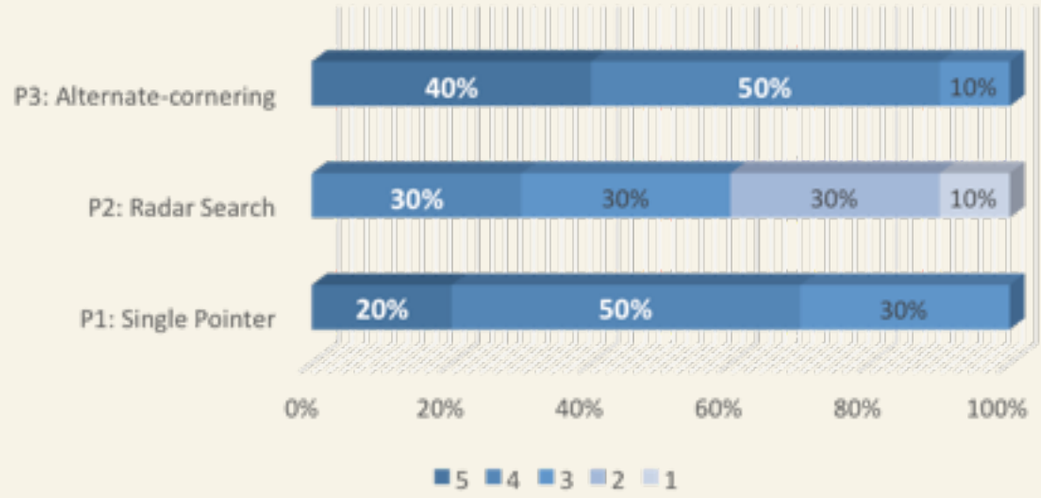
Experiment 1B: Likert Scale

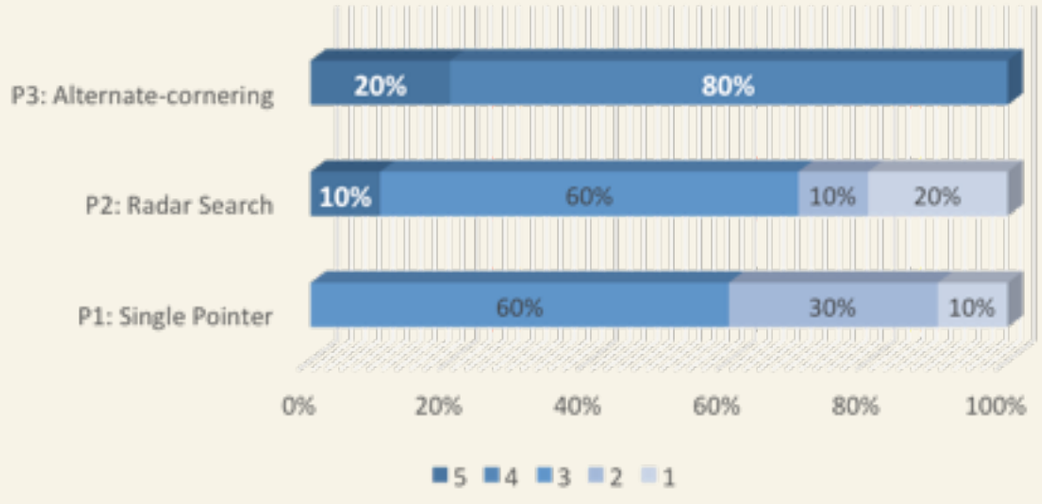
Hat



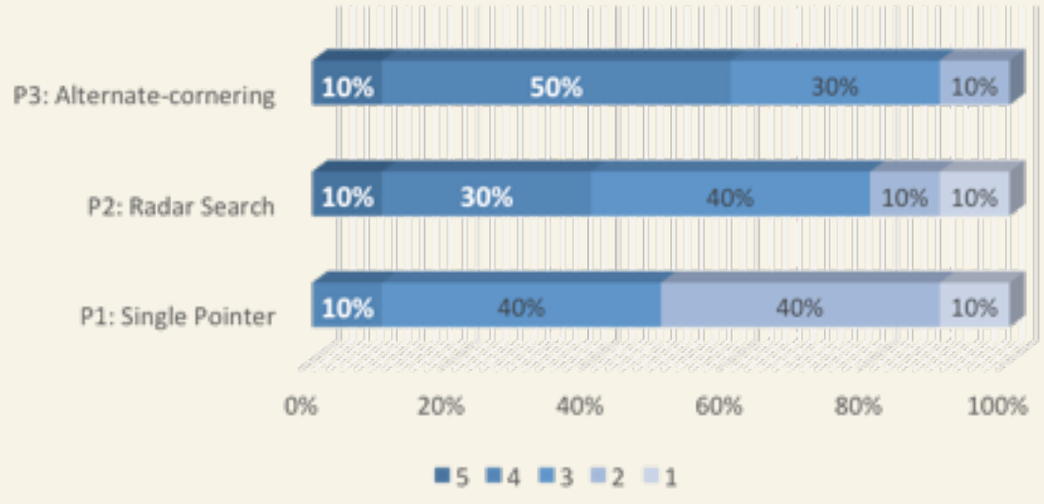
Belt



Wristband

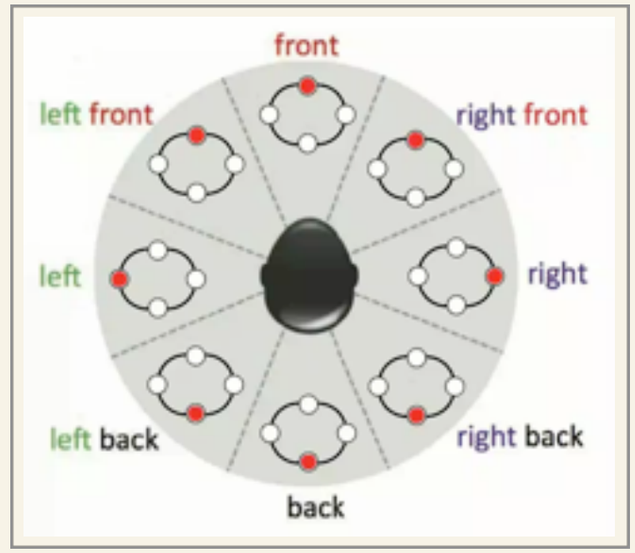


Armband



Experiment 1B: Conclusion

- "Alternate-cornering" is easier to distinguish
  - "Alternate-cornering" has lowest error rate on every device
  - "*When sensing two vibrators activated, it is clear and easy to distinguish its representation as corner.*"
- The simpler pattern has lower response time
  - "Single pointer" has shortest response time on every device
  - The result of "alternate-cornering" is close to "single pointer"(from 142ms~670ms)



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Experimentation

- Experiment 1 (Hearing individual)
  - Understanding of which devices and which patterns are intuitively chosen by the users
    - Experiment 1A and 1B: study the usability and performances of **visual** and **tactile** interfaces individually
- **Experiment 2 (Hearing impaired)**
  - Evaluating the usability of our devices and feedbacks selected from the previous experiment

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Devices and Patterns for Experiment 2

We've selected the following patterns for the second experiment:

Device	Pattern (P1)	Pattern (P2)	Pattern (P3)
Glasses	Single-double	Light array	Tail tracing
Lighting Cap	Loading dots	Progress bar	Combo loader
Smartwatch	Single arrow	Basic compass	Big pointer
Vibration Hat	Single pointer	Radar search	Alternate-cornering
Belt			
Wristband			
~~Armband~~			

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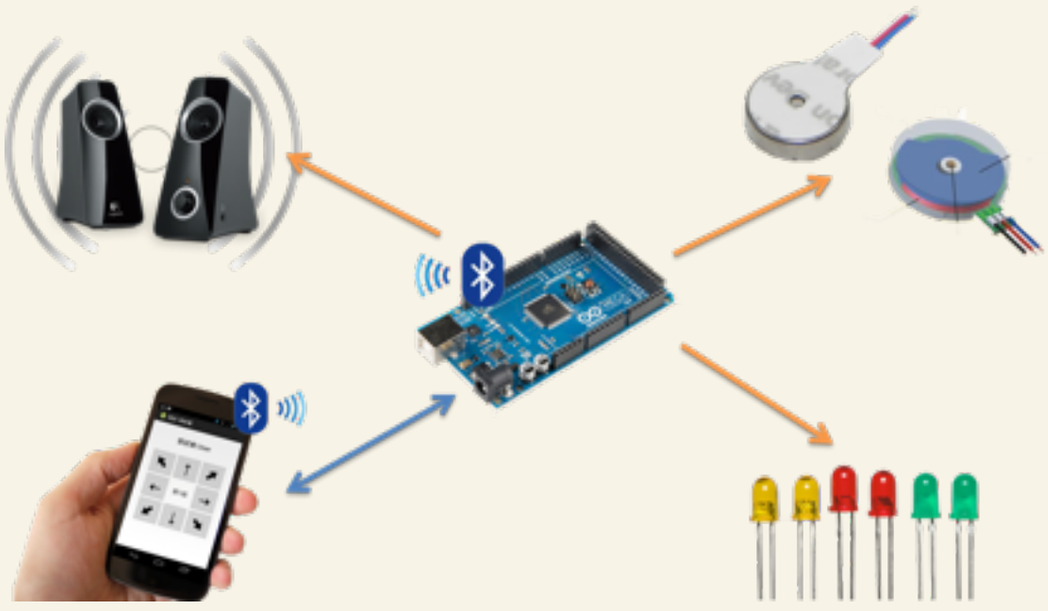
Experiment 2: Equipment

- Six devices are compared in the experiment:
  glasses, **lighting cap**, **smartwatch**, **vibration hat**, **belt**, and **wristband**
- Eight loudspeakers for environmental sound simulation



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Experiment 2: Participants

- **10** hearing impaired participants
  - 6 males and 4 females aged between 19 and 48 (average 28.8)
- **2** moderately deaf, **5** severely deaf, and **3** extremely deaf
- **9** participants wear hearing aids and **2** of them have cochlear implants

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Experiment 2: Procedure

- 7 tests:

  1 with only hearing instruments, 3 visual devices, 3 tactile devices

- Order of the tests are counter balanced

- 90 seconds to learn each pattern

- 16 trials of tasks

- 15 seconds to select direction

- Answers and response time were recorded

- A questionnaire and short interview are done between each device

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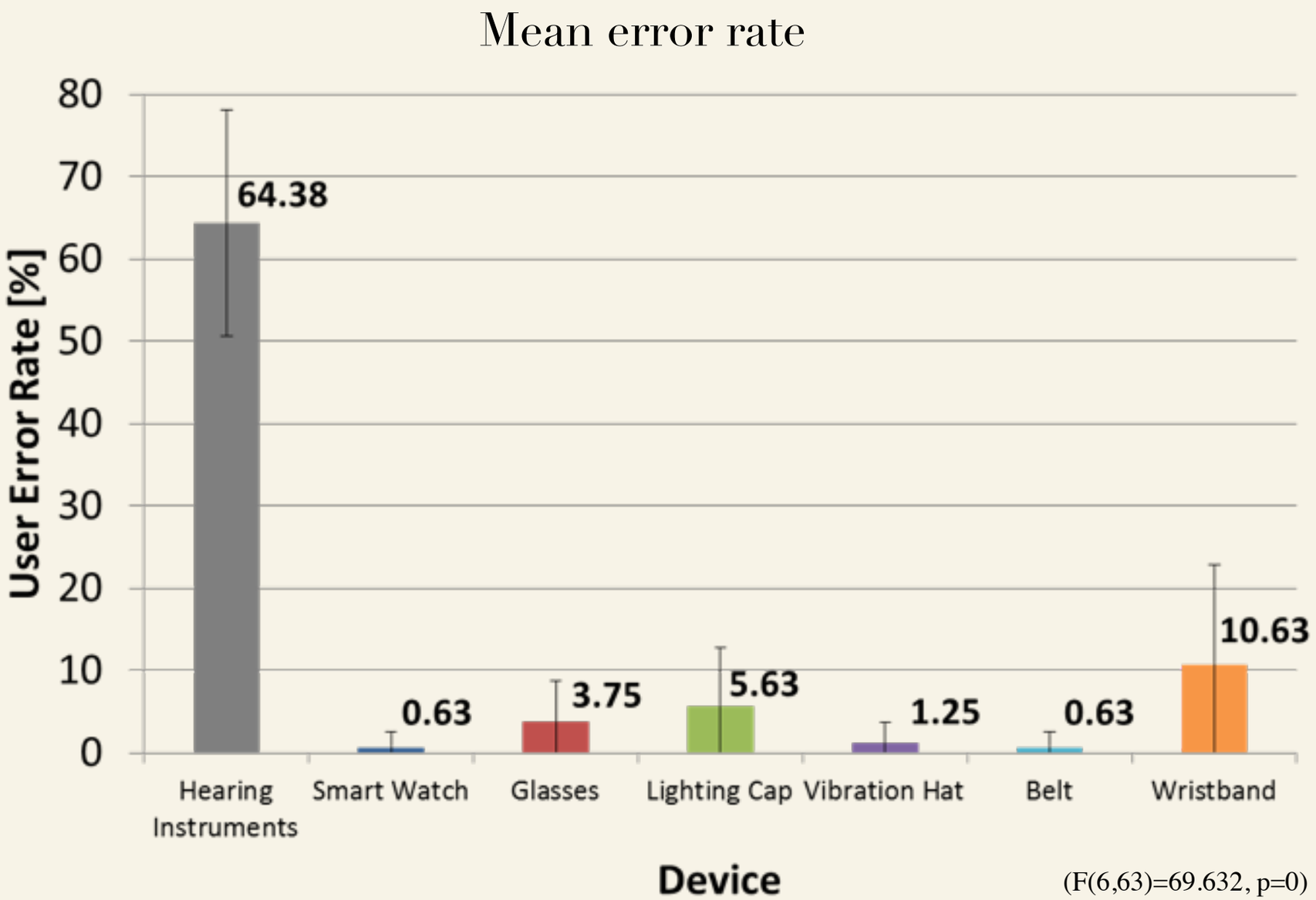
Experiment 2: Result



(F(6,63)=69.632, p=0)

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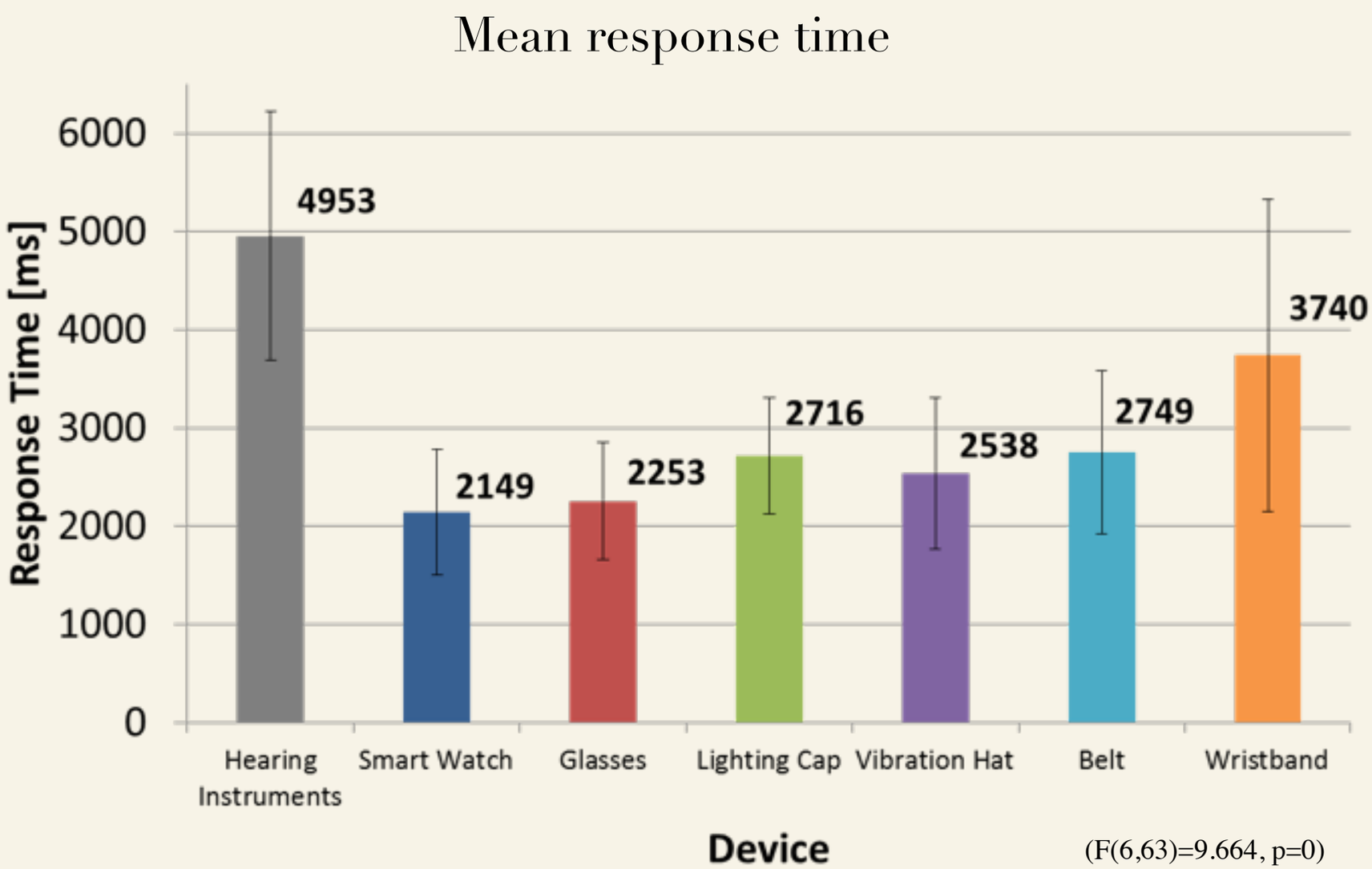
Experiment 2: Result



(F(6,63)=9.664, p=0)

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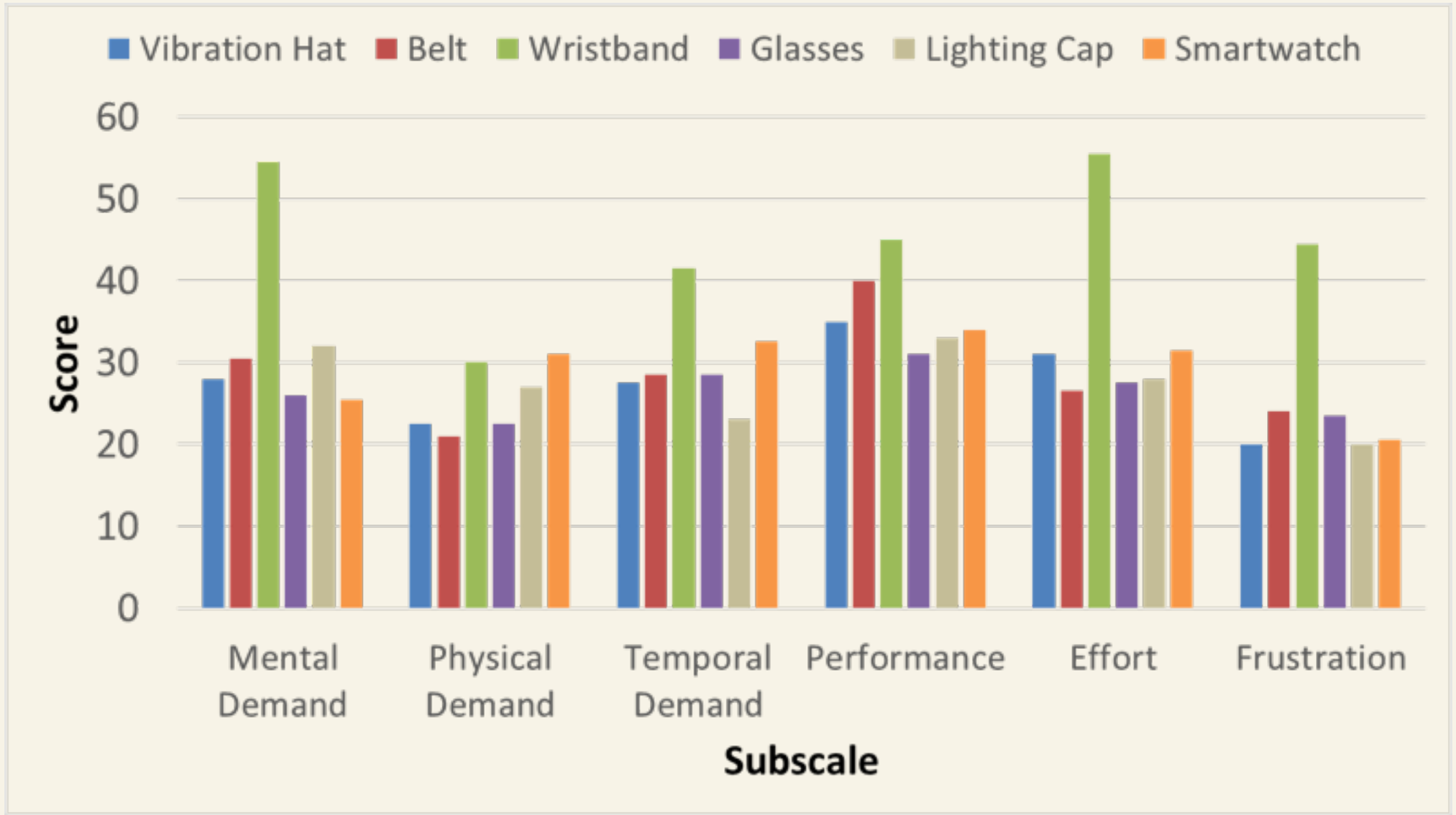
Experiment 2: Result

Mean score of NASA Task Load Index for each device



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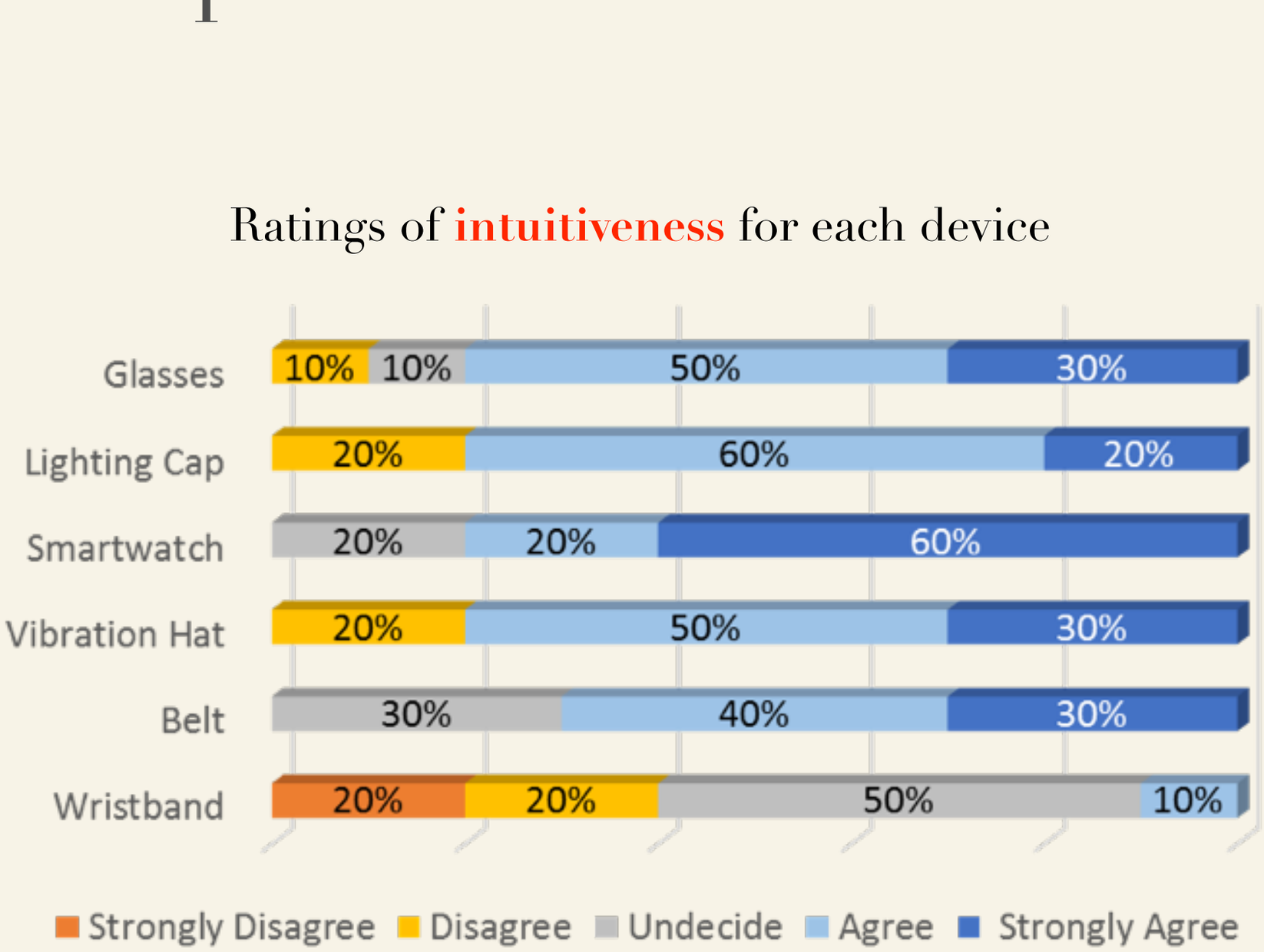
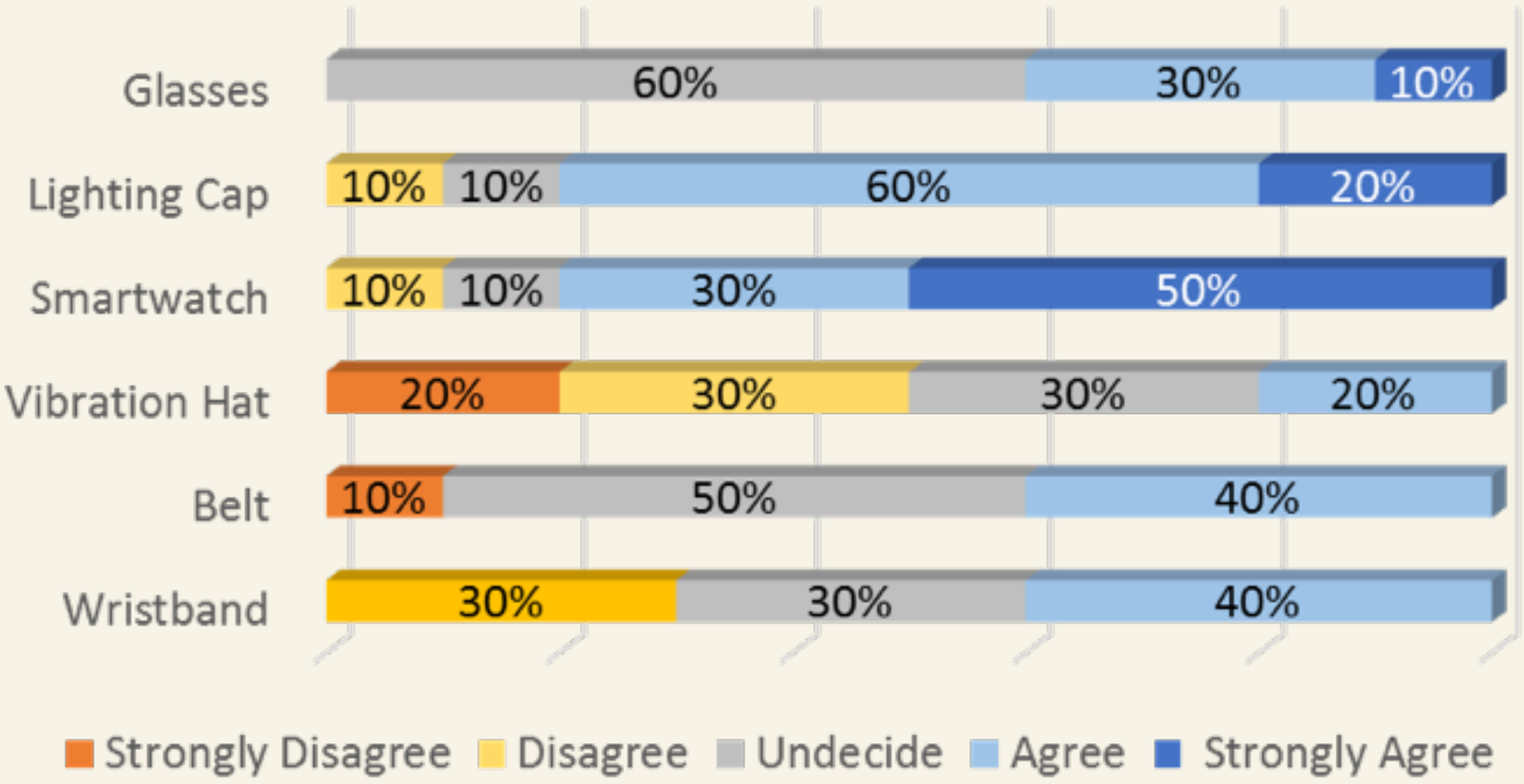
Experiment 2: Likert Scale



Experiment 2: Likert Scale

Ratings of **comfort level** for each device



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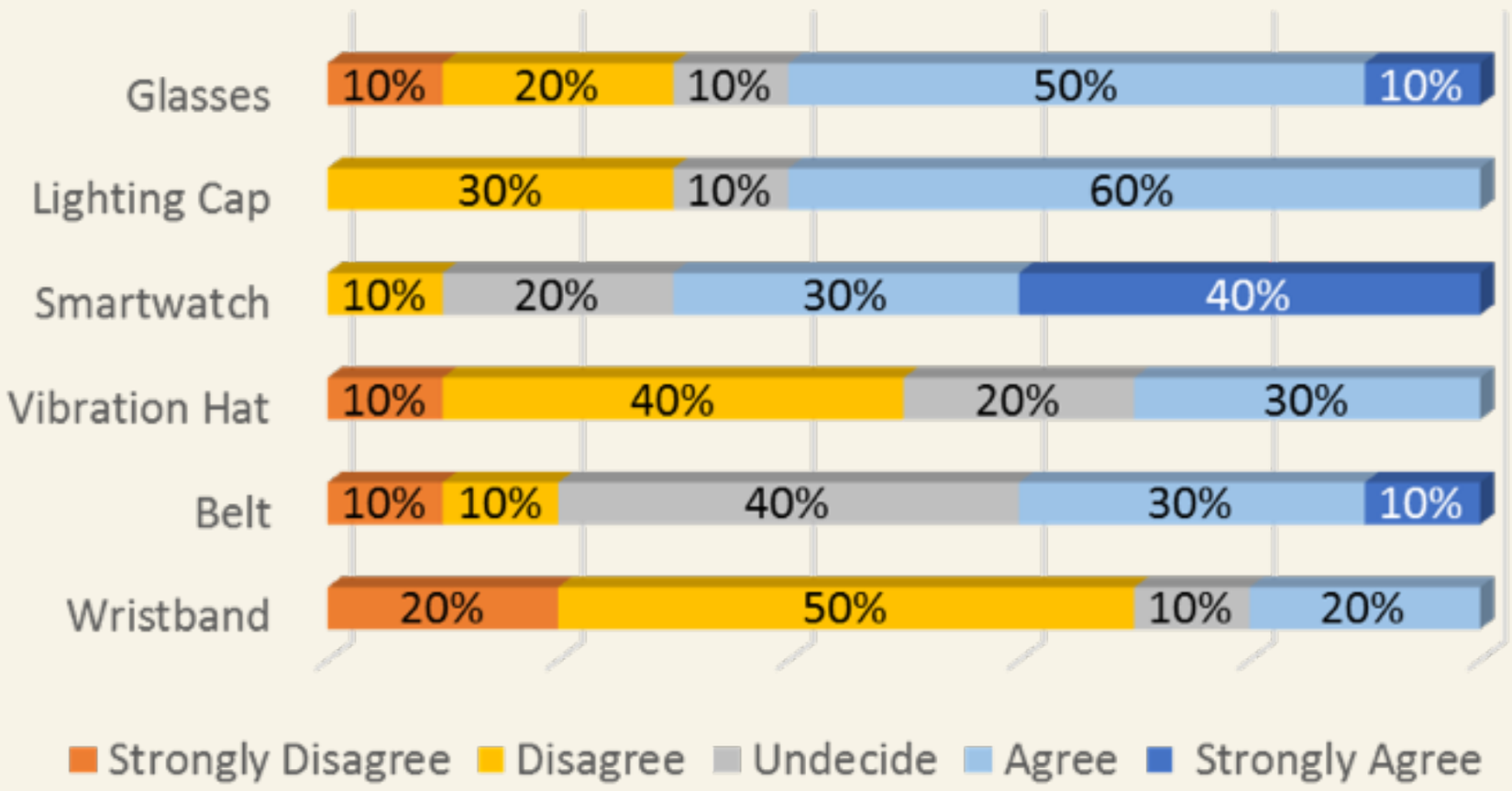
Experiment 2: Likert Scale



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Experiment 2: Conclusion

- The lack of accuracy is significantly higher than when the devices are worn ($p<.00001$).
- Among all devices, smartwatch has the highest efficiency, comfort level, and preference to user.
- Vibration hat and belt both have similar performance to smartwatch, however the comfort level and user preference is low.
  - *"Vibration causes interference to hearing aids."*
- Wristband received the lowest score in all aspects.

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Overview

- Background of Research
- Introduction
- Related Work
- Type of Accessories
- Prototype and Pattern Design
- Experimentation
- Conclusion and Discussion
- Future Research
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Conclusion and Discussion

- It is possible to use wearable visual and tactile feedback devices to improve deaf people's acoustic awareness regarding to sound locationing.
- Overall, users preferred using visual feedback devices instead of tactile devices.
- Using imagery representations are able to display information more clearly and intuitively. i.e. smartwatch
- The surface (contact) area on certain body location is unable to display complex tactile information. e.g. wrist and arm

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Future Research

- Using heads-up display to perform imagery information directly
- Studying methods of feedbacks on different types of characteristics of sound
- Implementing sound recognition techniques to distinguish and prioritize sound source with feedbacks

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