Trends of Creatively Intelligent Wearable Technology

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Content

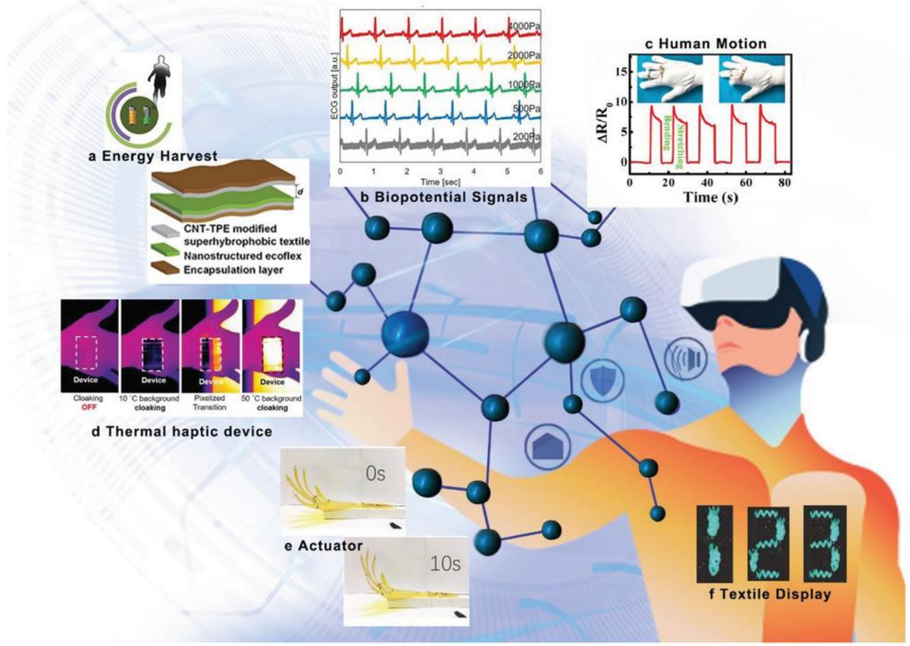
- Research Institute for Intelligent Wearable System (RI-IWEAR)
- Smart Textiles and Apparel
- Case: Smart Insole System for People with Parkinson’s Disease

Research Institute for Intelligent Wearable System (RI-IWEAR)

Research Objects

- Intelligent materials & devices
- Microelectronics
- Fiber structure
- Artificial intelligent (AI) wearable systems

→ A platform for communication among human, machine and environment

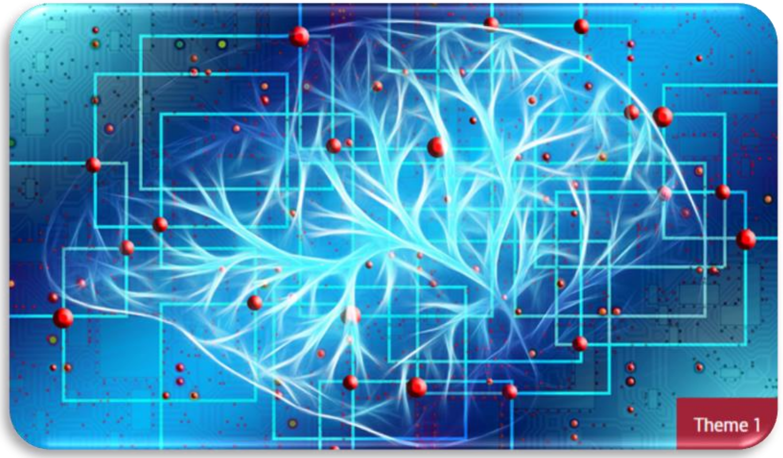


Characteristics

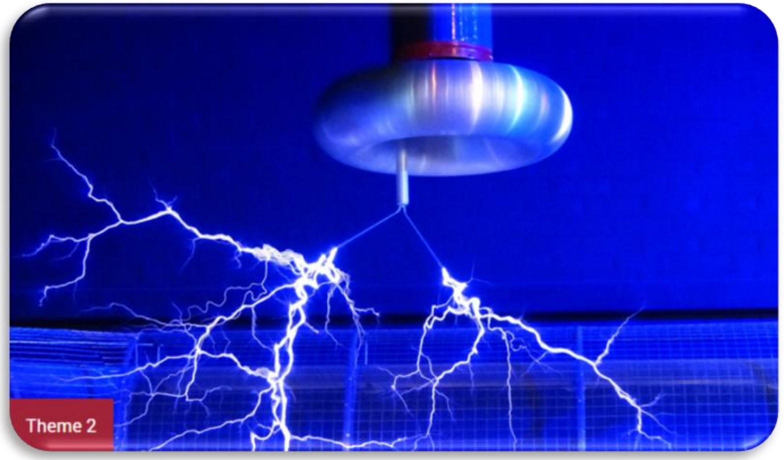
- Multi-sensing and multi-actuating ;
- High intelligent (e.g. learning, thinking, memorizing and analysing abilities);
- Sustainable self-powering and self recovering;
- High communication ability;
- Wearable: light-weight, large area, flexible, comfortable.

Research Institute for Intelligent Wearable System (RI-IWEAR)

Brief introduction



IWEAR System Applications



System Integration and Evaluation

Fibre-based and Flexible Devices

- Cooperation among 13 disciplines
- Total funding: HK$ 130 m
- RI-IWear Subsidizing: 18 projects
- Professors: 48
- Postgraduates and researchers: 280

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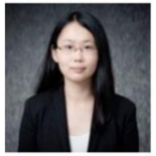

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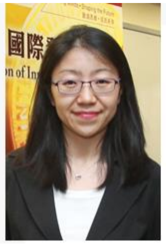

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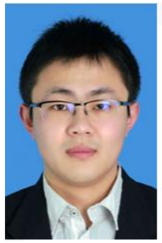

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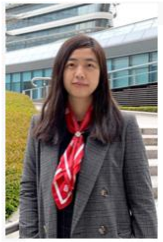

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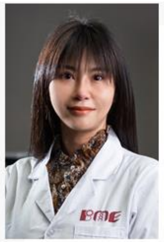

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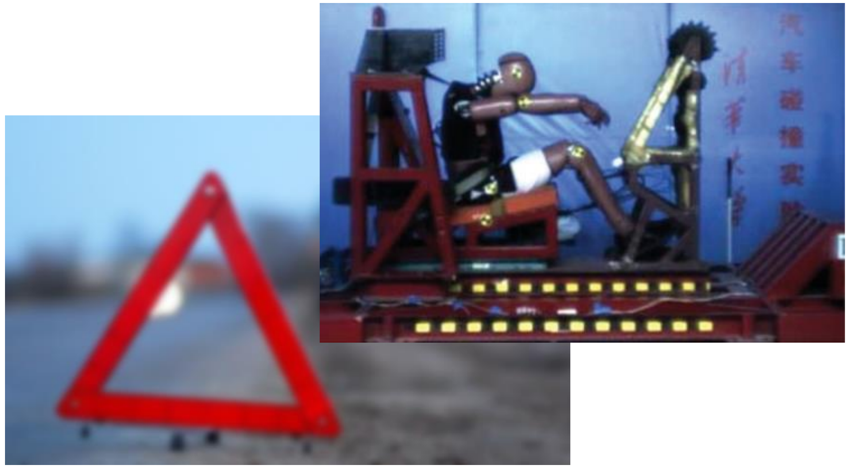
Research Institute for Intelligent Wearable System (RI-IWEAR)

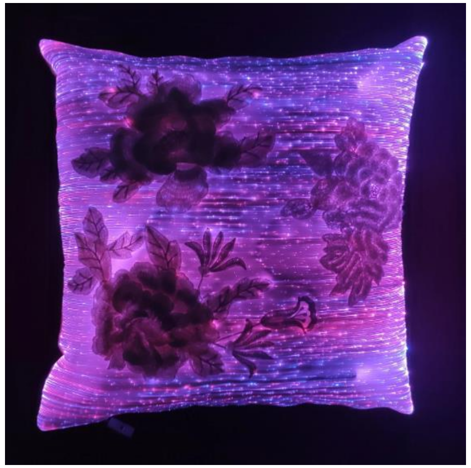
Initiative health & sports

- Wearable technologies for sports and health
- Wearable systems for fast exercise recovery

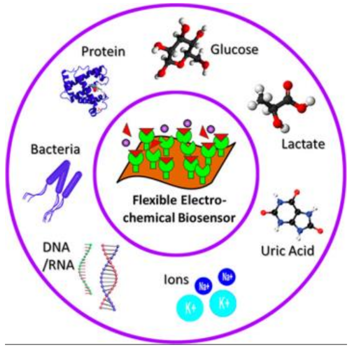
Traffic safety



Fabrics technology



Detection by sensors



Big data & AI medical care

Gait rehabilitation assisting treatment systems

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- Research Institute for Intelligent Wearable System (RI-IWEAR)
- **Smart Textiles and Apparel**
- **Case: Smart Insole System for People with Parkinson's Disease**

Smart Textiles and Apparel

- The textiles and apparel that have capacity of **sensing, actuating, adapting, communicating, self-healing, self-powering, memorizing, learning** etc., like living beings.
- Reaction upon external stimuli or pre-programmed.

Activity sensing

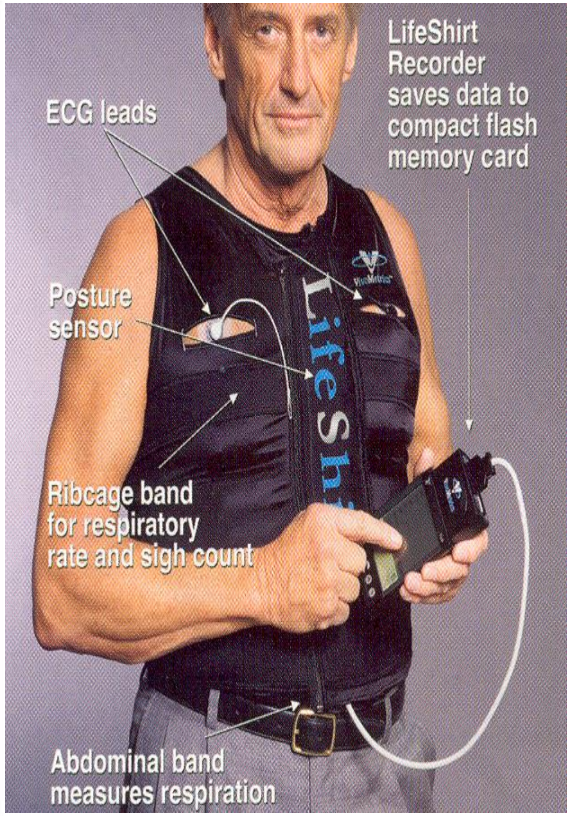
Characteristics of smart textiles and apparel

- ✓ Highly flexible
- ✓ Large deformation
- ✓ Light weight
- ✓ Large area
- ✓ Wearable and real-time
- ✓ Fashionable and comfort

Disruptive technology

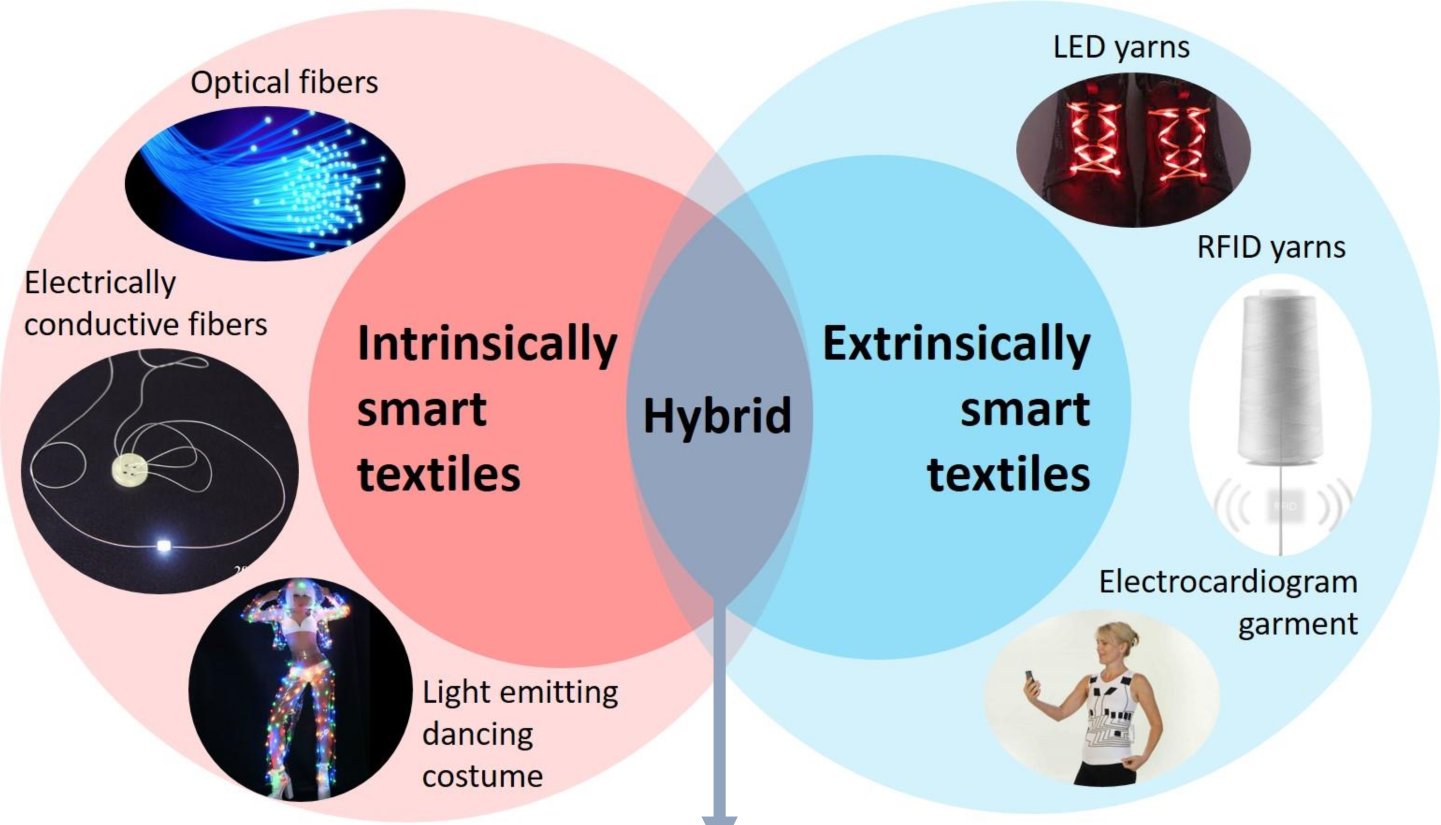
https://www.youtube.com/watch?v=dcAzvtCQCbI&t=5s

Applications of smart textiles



Intrinsically and Extrinsically Smart Textiles

Some textiles have their own sensors or actuators or both of them. They are intrinsically smart textiles. These are the study subjects for **material scientists** and **textile technologists**.



Extrinsically smart textiles haven't their own sensors or actuators. When the sensors or actuators are attached or embedded to them, they can become smart textiles. These are the subjects of **textile technologists** and **microelectronic engineers**.

Hybrids are mixed with intrinsically and extrinsically smart textiles.
- Example: Cooling vest

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- **Case: Smart Insole System for People with Parkinson's Disease**

1. People suffering from Parkinson's disease (PD)

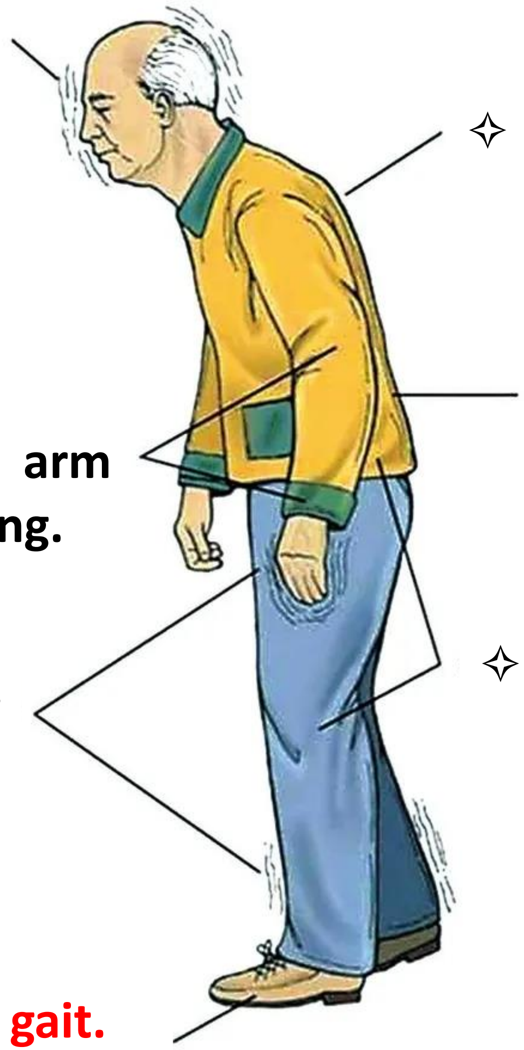


Fig. 1 Schematic diagram of a patient with Parkinson's disease

- > 10 million people.
- A high prevalence of fall incidence (38% ~ 68%) occurs when a PD patient enters the moderate stage of PD.
- The fall incidence is mainly associated with **freezing of gait (FoG).**
- FoG is likely to appear at the initiation of gait when approaching narrow spaces, turning, and even during walking, especially when performing a concomitant simultaneous activity.

1. People suffering from Parkinson's disease (PD)

Fig. 2 Illustration of degenerate gaits of PD patients. These photos captured in the trials show that the toe and the outer edge of the forefoot can be the main region for supporting.

- PD patients are likely to strike the ground using the forefoot firstly when they walk with the torso leaning forward.
- On turning, PD patients may turn left/right in short steps using the inner/outer border of the forefoot as the supporting region.

2. Current wearable systems detecting freezing of gait (FoG)

- Wearable systems can provide real-time gait measurement and detect the occurrence of FoG, such as wearable inertial sensors and pressure sensing units.

- Currently, response time of wearable inertial sensors is often delayed up to several or even dozens of seconds in identifying the occurrence of FoG episodes.

- Besides, most pressure sensing units have a low fatigue resistance for long-term use and limitation of real-time wireless transmission due to vast amount of generated data.

3. Key issues on intelligent wearable system (IWS)

- The sensing and data processing devices used in IWS are bulky, obtrusive, of poor performance, especially, in fatigue resistance.
- Short-duration FoG is surprisingly difficult to be seen in clinics, although it is a common disabling feature in everyday circumstances.
- Poor accuracy of real-time detection.
- Cueing operations should be diversified and meet individual needs. For example, someone likes visual cueing, auditory cueing, or both.
- Continuous cueing is confined in training sessions as they interfere normal activities. Thus, on-demand cueing can be a better choice in real life.

4. Structure and functions of intelligent wearable system (IWS)

- Therefore, a new reliable IWS is designed and fabricated, which can detect the FoG occurrence accurately and real-time automatically, and provide timely cueing options.
- The IWS is featured with a novel binary pressure-sensing technology that substantially reduces the amount of data to be transferred and processed.

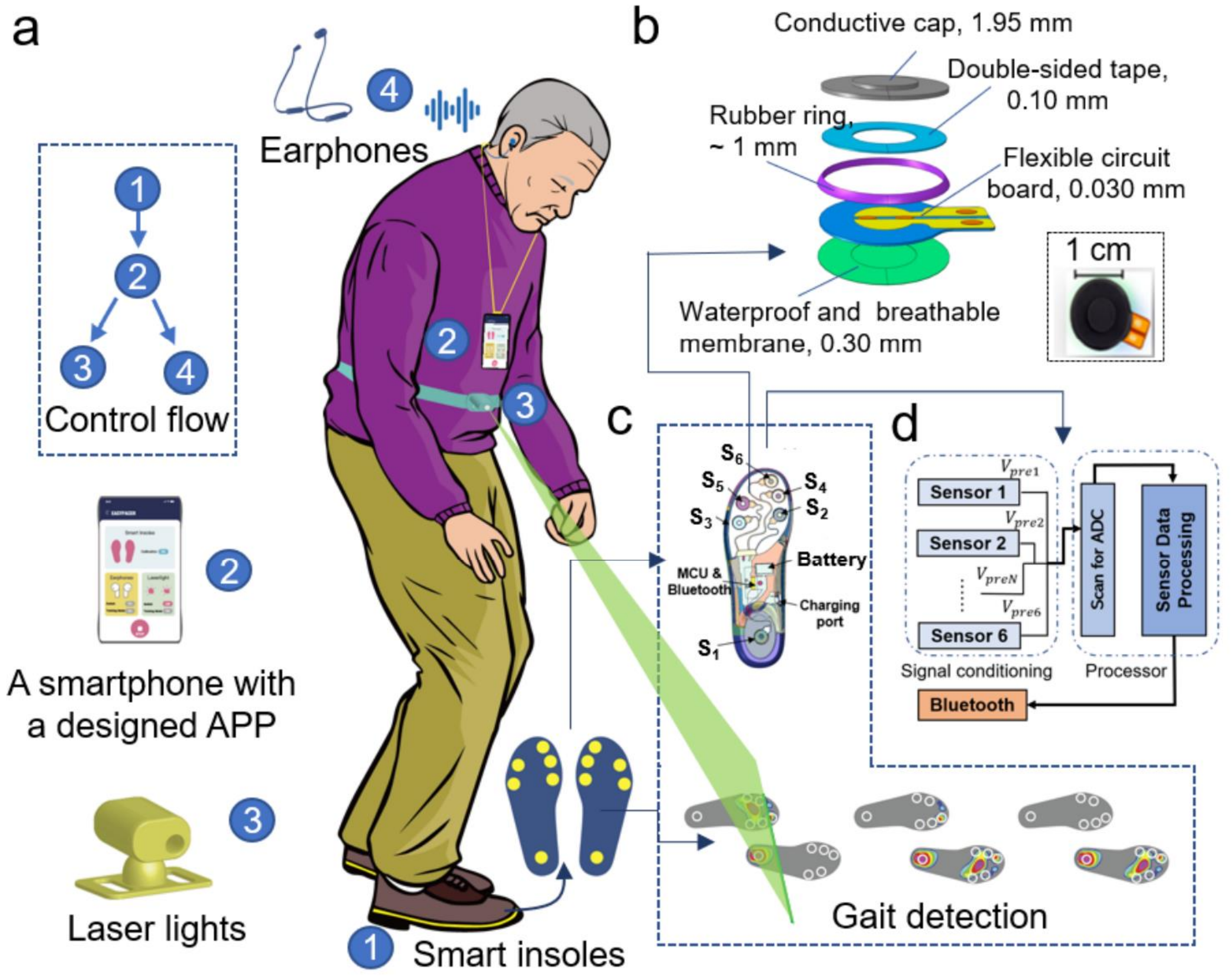


Fig. 3 a. Illustration of the IWS worn by an individual with PD. **b.** Explored view schematic of a planter pressure sensing unit. **c.** Schematic of the inner structure of a smart insole. **d.** Block diagram of smart insoles.

4. Structure and functions of intelligent wearable system (IWS)

Plantar pressure sensing unit (PSU)

- ➢ The flexible printed circuit board (FPCB) has two copper electrodes right under the center of the cap concave.

Pressure	Resistance across the electrodes	Binary code
Under threshold pressure	Infinity	0
Over threshold pressure	Several Ohms	1

- ➢ Comparing other pressure sensors, this sensor is unique as it compresses a large amount of pressure-time data into a simple set of binary serial codes 1 and 0 with a predefined pressure threshold value.

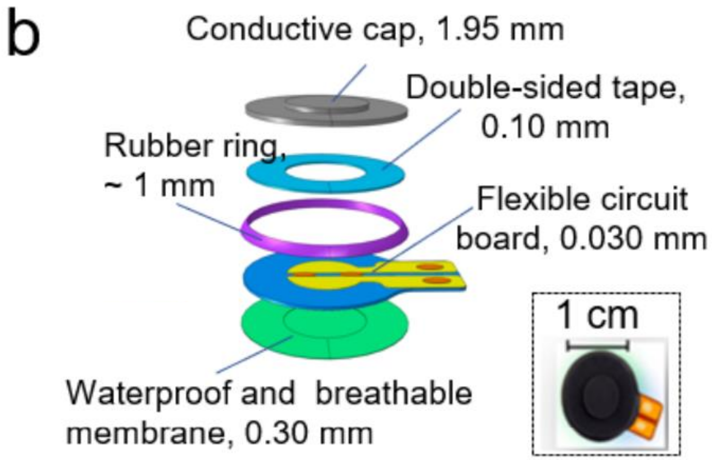


Fig. 3 b. Explored view schematic of a planter pressure sensing unit.

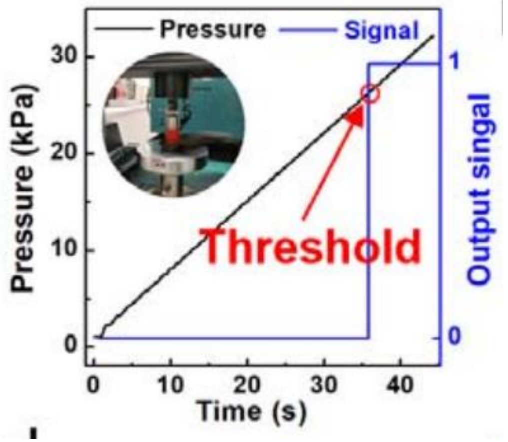


Fig. 4 Illustration of the pressure threshold of the PSU embedded in smart insoles. When the applied pressure reaches the threshold, the output of the PSU changes from 0 to 1.

4. Structure and functions of intelligent wearable system (IWS)

- In Fig. 3c., the smart insole has a compact design, including a flexible sensing network with six PSUs, a microcontroller unit (MCU) and Bluetooth for data pre-processing and transmission, a lithium battery with a power management module, and a charging port.
- In Fig. 3d., smart insoles are responsible for receiving, preprocessing, pre-storing sensor data, data transmission as well as network management. After signal conditioning of the sensors, the signals are digitized in the embedded A/D converters. The scanned data are then pre-processed in a processor like a microcontroller unit (MCU) and sent to the Bluetooth module for timely transmission to the smartphone installed with a specially designed application (APP).

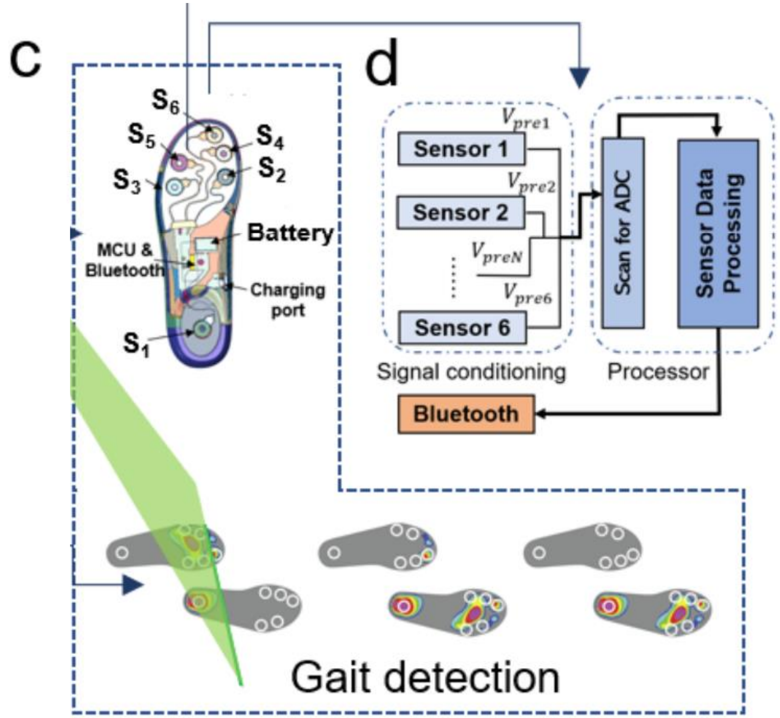


Fig. 3 c. Schematic of the inner structure of a smart insole. **d.** Block diagram of smart insoles.

4. Structure and functions of intelligent wearable system (IWS)

- The functions of the APP in this system:

  (1) to manage the smart insoles,

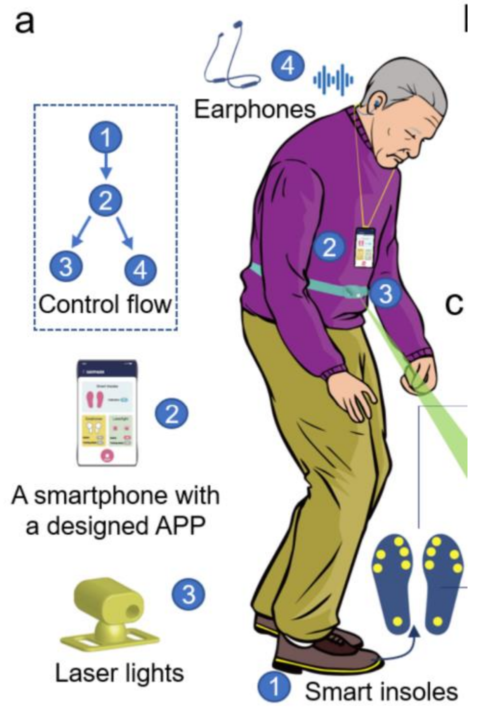
  (2) to collect and store data from smart insoles,

  (3) to process data,

  (4) to monitor gait,

  (5) to detect FoG,

  (6) to control earphones and laser light generators.



- These wireless-cueing devices can be controlled based on two modes.

(1) **Continuous cueing mode** provides continuous cueing regardless of the gait signals, which can be utilized to help PD patients familiar with the cueing.

(2) **Automatic cueing mode** is utilized to control the cueing devices upon signals received from the smart insoles, which can provide on-demand cueing.

5. Enhancement of mobility

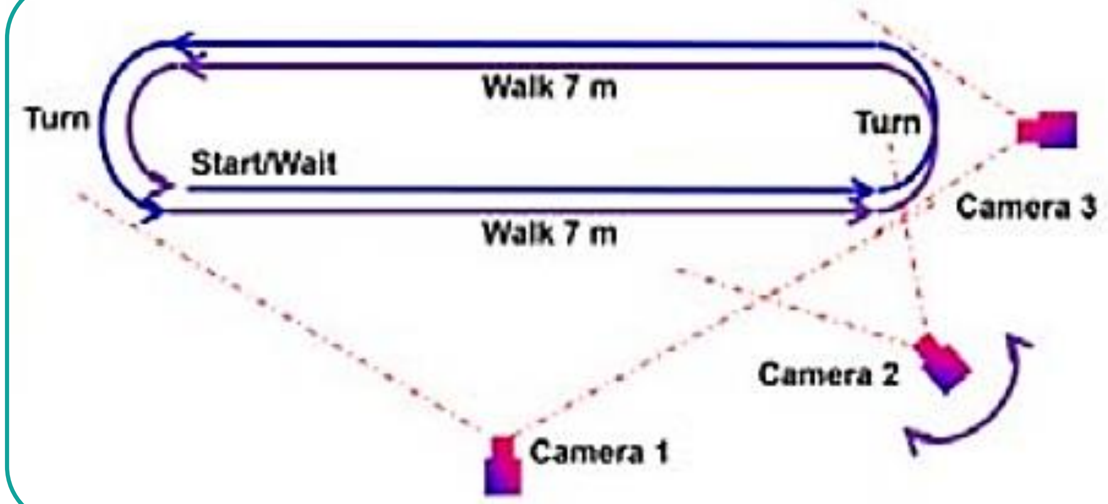


Fig. 5 Schematic of the walking experimental setup for collecting the data from this IWS and videos taken from three cameras. The walking track includes four straight-line walks and four turns. Three cameras are utilized for recording the gait

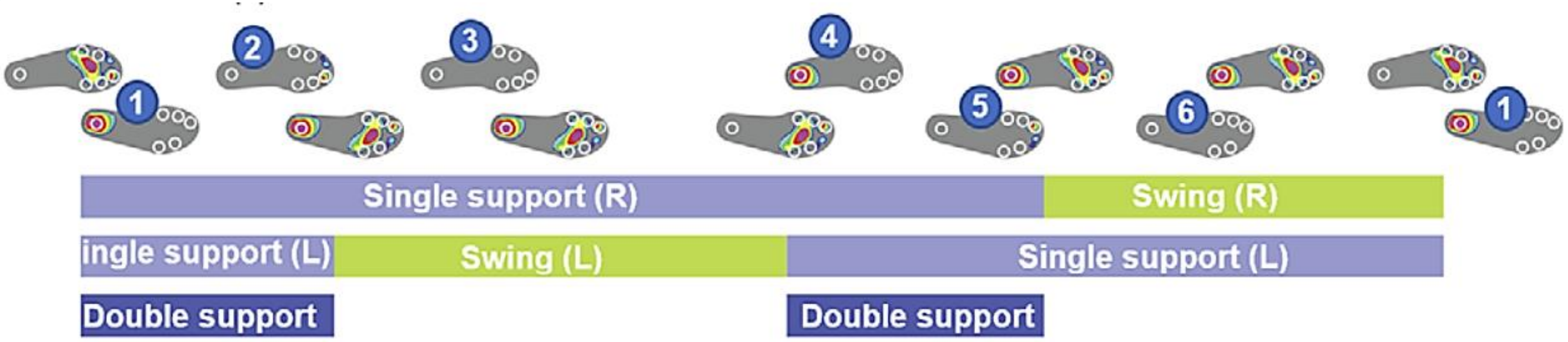
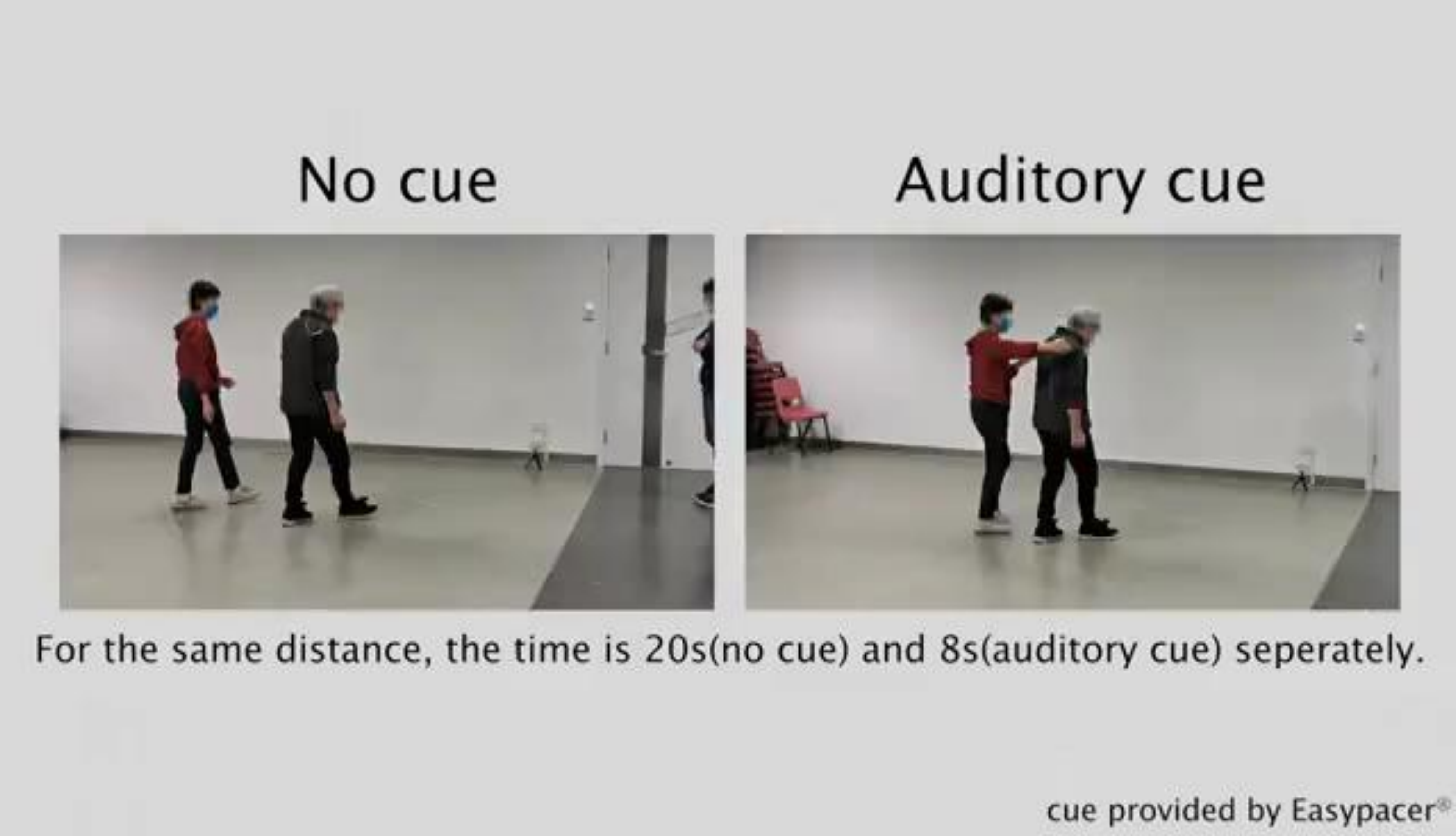
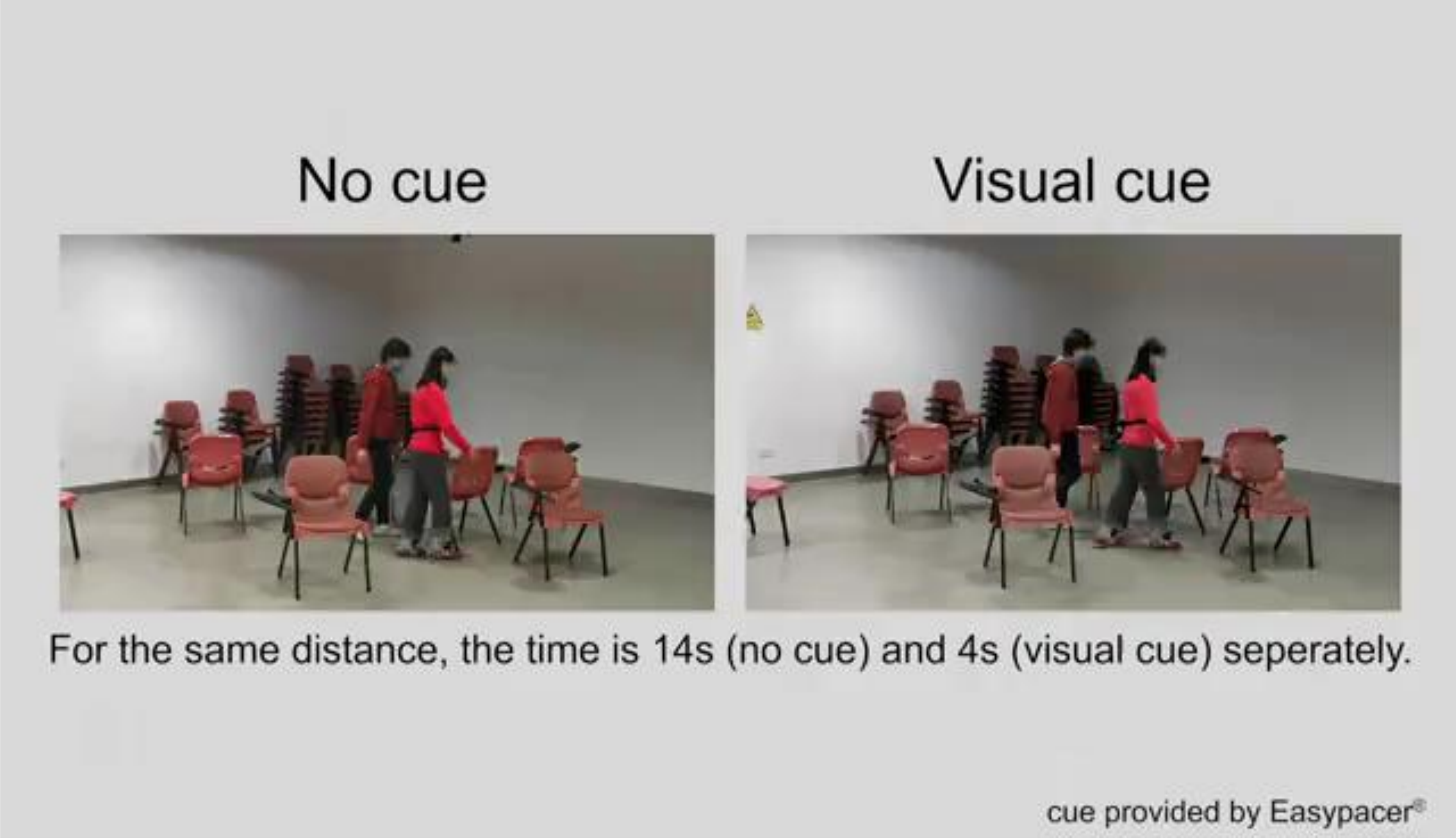


Fig. 6 Schematic of six phases of normal gait including heel strike of the right foot, toe-off of the left foot, mid-standing of the right foot, heel strike of the left foot, toe-off of the right foot, and mid-standing of the left foot and key parameters of single support, swing and double support.

5. Enhancement of mobility



5. Enhancement of mobility



5. Enhancement of mobility

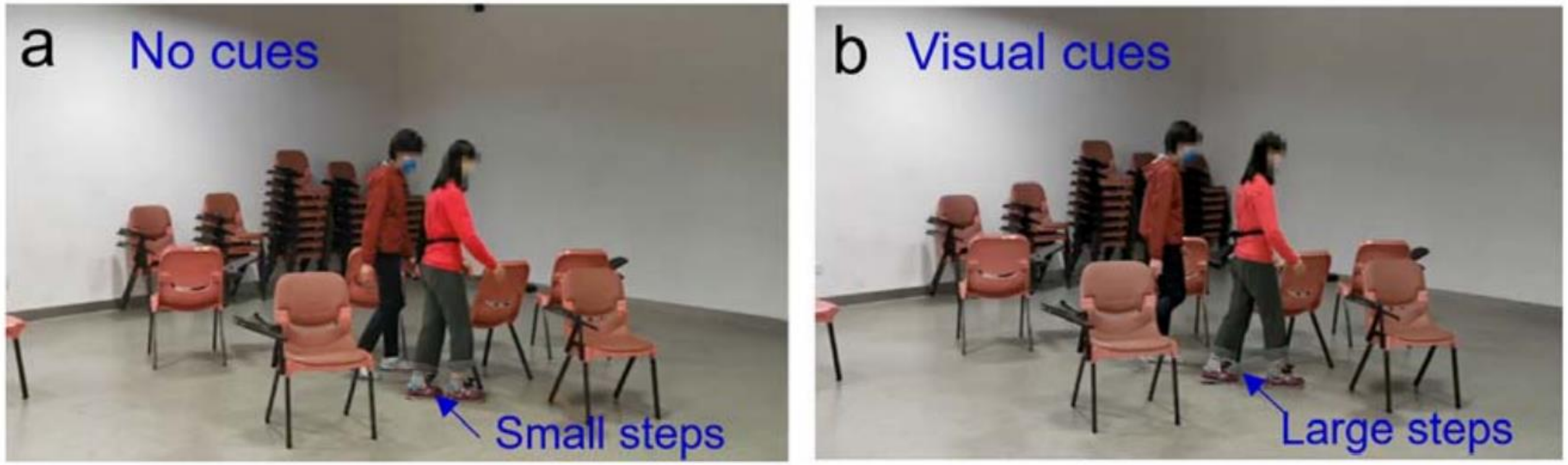
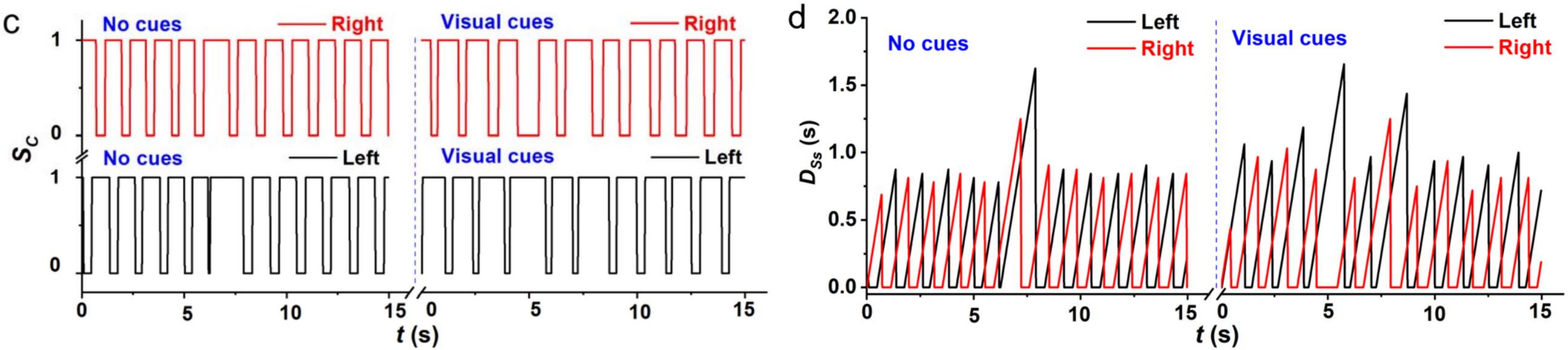


Fig. 7 a. & b. Comparison between walking through a narrow path without and with visual cueing. The corresponding gait phases and parameters: **c.** Combined signal (S_c) of smart insoles, **d.** Duration of single support (D_{Ss}).



6. Response time and user satisfaction

- **The PSU response time is less than 2 ms for loading and 20 ms for unloading**, which is neglectable in comparison to hundreds of ms for the gait feature durations of double support, swing, and stance.

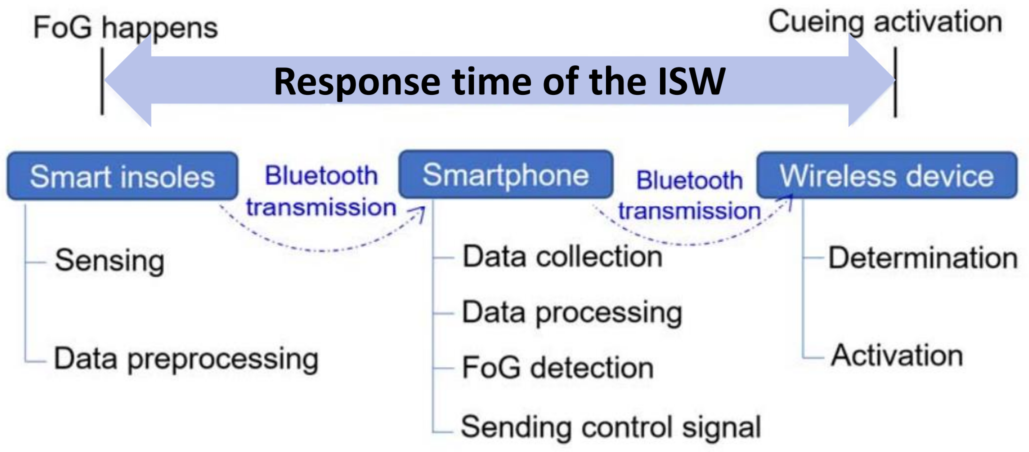


Fig. 8 Schematic of the response time from the onset of FoG to provision of cueing.

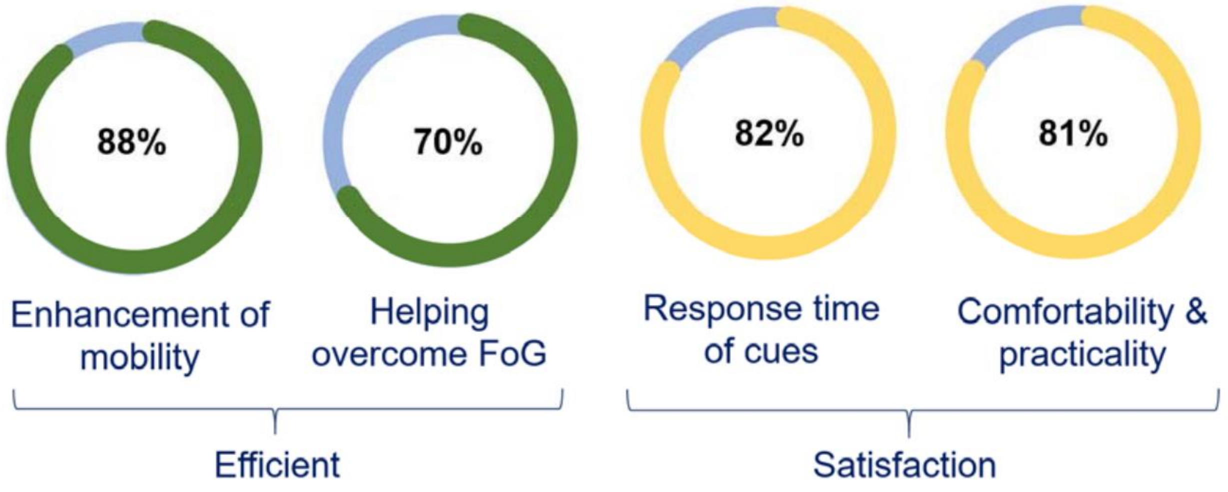


Fig. 9 Overview of IWS through questionnaire from 16 participating PD patients. Efficient and user satisfaction of IWS, including enhancement of mobility, helping overcome FoG, satisfaction on the response time of cues, and comfortability & practicality. The comfortability & practicality includes comfortable of the insoles, the fixing position and the weight of laser light devices, and ease to wear and use the APP.

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Acknowledgement

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