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The Development and Evaluation of the SmartAbility Android Application: Detection of Reduced Physical Abilities through Smartphone Sensors

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http://hci.bournemouth.ac.uk/project/smartability/

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Overview

- Assistive Technology research conducted by the Human Computer Interaction (BUCHI) Research Group, Faculty of Science & Technology
  - Received publicity in Auto Express, Bournemouth Echo, BBC South Today and Radio Solent
  - Research published in IEEE Transactions on Human Machine Systems and at 10 international conferences
- Introduction to SmartAbility Framework
- Development and evaluation of the SmartAbility Android Application
- Suggestions for future SmartAbility work and related research proposals

BBC South Today – November 2018

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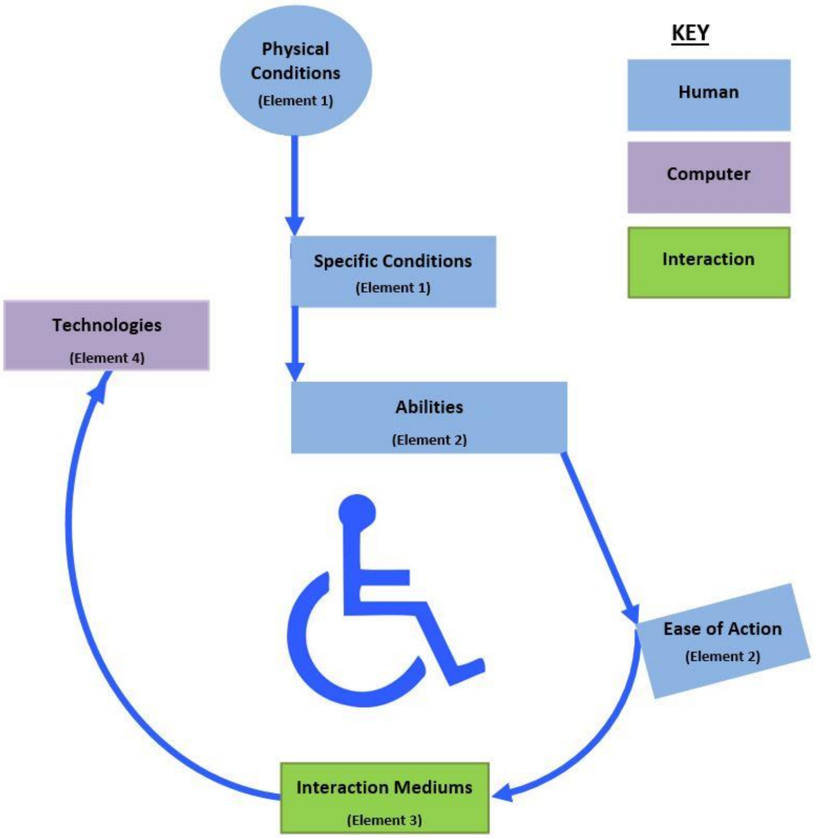
SmartAbility Framework

- Recommends Assistive Technologies (AT) based on user abilities
- Conceptual model aligns with internationally recognised disability symbol
  - Highlights alignment to Human Computer Interaction



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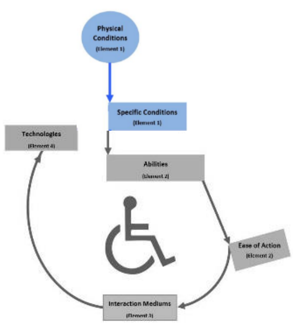
Physical Conditions

- Identifies the conditions associated with specific disabilities to filter the range of disabilities into generic physical conditions
  - Conditions and mappings obtained from the ICF Framework [1] and Downton fall risk assessment scale [2]



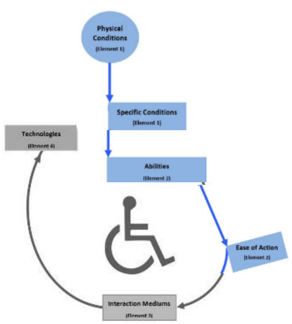
	Acquired			
Associated Components	Brain Injury	Multiple Sclerosis	Muscular Dystrophy	Osteoarthritis
Partial neck movement	✓			✓
Partial shoulder movement	✓			✓
Partial elbow movement	✓			✓
Partial wrist movement	✓			✓
Partial finger dexterity	✓			✓
Partial ankle movement	✓			✓
Joint hypermobility				
Joint dislocation				
Scoliosis				
Contractures	✓	✓	✓	
Dyskenesia		✓		
Atrophy		✓	✓	✓
Paraplegia	✓	✓	✓	✓
Quadraplegia / tetraplegia	✓	✓		
Hemiparesis	✓			
Visual	✓	✓		
Cataracts			✓	
Dizziness	✓			
Speech	✓			

Physical Conditions element extract

[1] World Health Organization (WHO), 2001. *International Classification of Functioning, Disability and Health* [online]. Geneva: WHO.
[2] Downton, J.H., 1993. *Falls in the elderly.* Sevenoaks: Edward Arnold, 128-130.

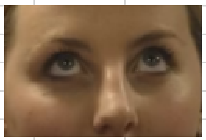
Abilities

- Considers how the specific condition of the user affects their 'ease of action' in terms of Easy, Difficult or Impossible
  - Categorised into the associated regions of the body and graded using a traffic light style system

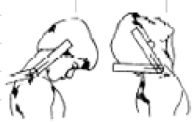


[1]

[2]



Physical Abilities	Target Ranges (iv)	Ease of Action		
		Easy	Difficult	Impossible
HEAD AND SENSES				
Head [3](ii)				
Tilting head upwards	>20°			
Tiliting head downwards	>20°			
Turning head left	80°			
Turning head right	80°			
Eye [2]				
Gazing upwards	Y/N			
Gazing downwards	Y/N			
Gazing left	Y/N			
Gazing right	Y/N			
Blinking	Y/N			
Seeing	6:6			



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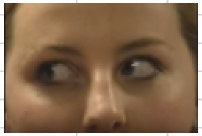

[2]

Abilities element extract

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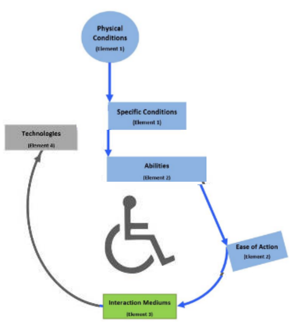
Interaction Mediums

- Describes the relationship between different interaction mediums and the required abilities for the interaction between users and technologies
- Mandatory abilities are required for successful interaction



Ability:

- ● Mandatory
- ○ Optional

Physical Abilities	Interaction Mediums				
	Arm [10]	Brain [8]	Chin [4]	Eye [2]	Fingers [4]
Head [3]					
Tilting head upwards	○	○	●	○	○
Tilting head downwards	○	○	●	○	○
Turning head left	○	○	●	○	○
Turning head right	○	○	●	○	○
Eye [2]					
Looking upwards	○	●	○	●	○

Interaction Mediums element extract

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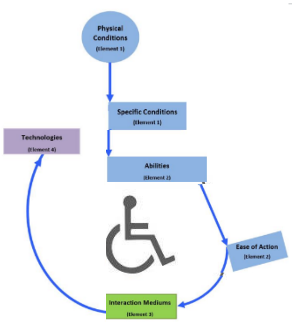
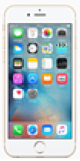
Technologies

- Identifies specific Assistive Technologies operated through each interaction medium
- Symbols devised for agility, acuity and clarity
  - Based on Quality Function Deployment



Interaction Mediums	Technologies						
	Smartphone [1]	Tablet [2]	Head Mounted Display [3]	Eye Tracker [4]	Head Tracker [6]	Electroencephalogram [9]	Switch [10]
Arm	■	□	■				□
Brain						■	
Chin							□
Eye	▲	▲	▲	▲	▲	▲	△
Fingers	■	■	■				□
Foot							□
Hand	■	□	■				□
Head					■		□
Sip n Puff	■	■					■
Tongue						■	■
Voice	◆	◆	◆				

Actions		
Using	■	High agility
	□	Low agility
Seeing	▲	High acuity
	△	Low acuity
Speaking	◆	High clarity
	◇	Low clarity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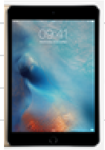
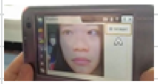
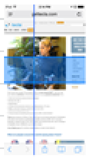
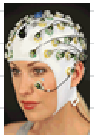

[2]


[3]


[4]

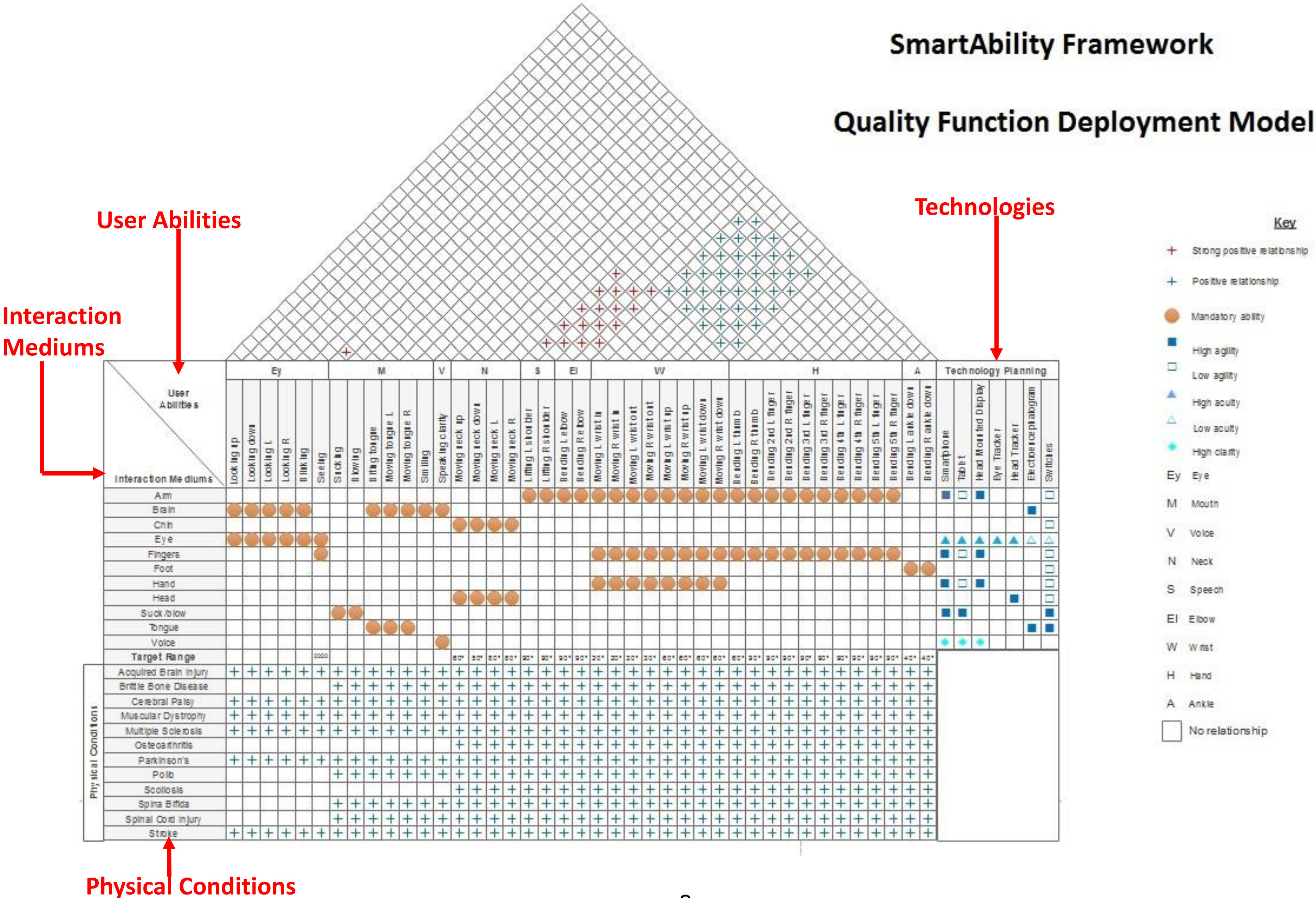





[9]

SmartAbility Framework

Quality Function Deployment Model



Mapping User Abilities to Smartphone Sensors

User Abilities	Required Sensors	Compatible Operating Systems and Algorithms
Tilting Head Upwards and Downwards	*Accelerometer and Gyroscope*	*Android Face Detection (Orientation) getEulerZ()*
Turning Head Left and Right	*Accelerometer and Gyroscope*	*Android Face Detection (Orientation) getEulerY()*
Blinking	*Face Tracking*	*Android Face Detection (Activity) getIsLeftEyeOpenProbability() getIsRightEyeOpenProbability()*
Smiling	*Face Tracking*	*Android Face Detection (Landmarks) getIsSmilingProbability()*
Speaking	*Microphone*	*Android Voice to Text Translator*
Lifting Shoulders, Moving Wrists and Bending Ankles	*Accelerometer and Gyroscope*	*iOS Significant Motion Sensor Android Significant Motion Sensor*
Bending Elbows	*Accelerometer and Gyroscope*	*iOS Significant Motion Sensor Android Significant Motion Sensor*
Bending Fingers and Thumbs	*Gesture Detector*	*iOS Gesture Detection Android Gesture Detection*
Walking	*Step Counter*	*iOS and Android Step Counter*

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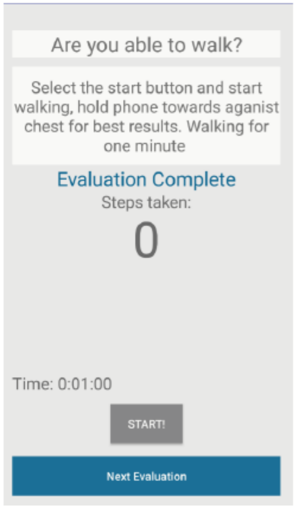
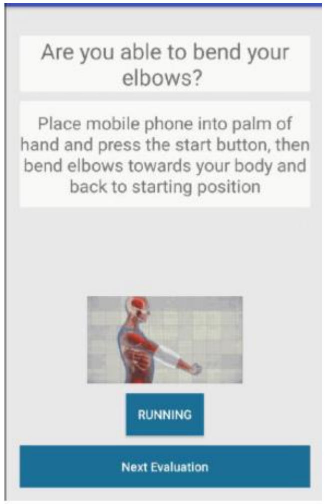
SmartAbility Application Version 1

- Based on a prototype Android Application requiring manual input of abilities through checkboxes
- Android offered greater capabilities to detect user abilities via built-in sensors on smart devices and associated APIs:
  - Accelerometer to detect movements (shoulder, elbow, wrist and ankle)
  - Step sensor to detect walking ability
  - Face detection for head movements, blinking and smiling ability
- Minimal manual input required
  - Some abilities entered manually due to necessary sensors not currently available, e.g. tongue movements
- Administrative features to add/remove Assistive Technologies





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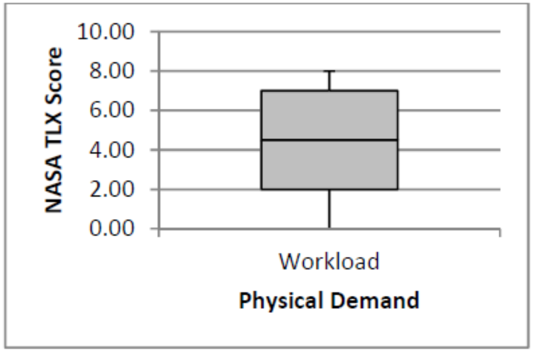
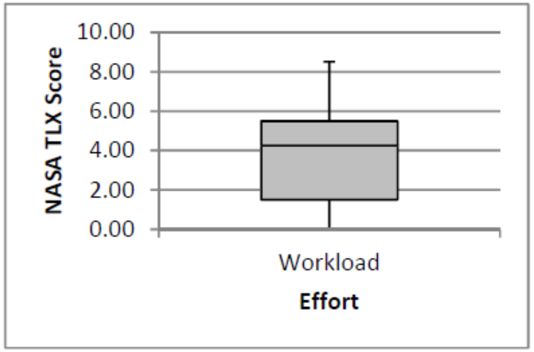
Usability Evaluation

- Evaluation conducted at Victoria Education Centre
  - 18 participants, aged 15 to 19 with varying physical conditions, e.g. Autism, Cerebral Palsy, Muscular Dystrophy
- Usability assessed through System Usability Scale (SUS), Adjective Rating Scale and NASA Task Load Index (TLX)
- 89% of participants found SmartAbility Application easy to use without requiring support
- Application achieved an SUS score of 72.5/100 (‘Good Usability’) and medium levels of Physical Demand and Effort
- Areas of improvement suggested:
  - Larger buttons and text on interfaces
  - Reduce some task durations, e.g. walking task from 40 seconds to 20 seconds
  - Facility to skip tasks
  - Compatibility with third party input devices, e.g. joysticks
  - Audible questions for users with difficulty reading





SmartAbility Application Version 2 Demo

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Future Work

- SmartAbility has received interest from charities, e.g. Ace Centre and Remap
- Disseminate the Application to charities, special educational needs schools, NHS Dorset CCG and NIHR Wessex Clinical Research Network, Assistive Technology providers, All-Party Parliamentary Group for Assistive Technology
- Conduct further usability evaluations
  - Implement any suggested improvements
- Disseminate SmartAbility on the Google Play Store as a free Application
- Anticipated evolvement into a product promotion tool
  - Increase awareness of Assistive Technologies available
  - Develop customisable versions for Assistive Technology providers

NHS Dorset Clinical Commissioning Group

Livability Victoria Education Centre

AceCentre

Remap making things possible

Local Clinical Research Networks

All-Party Parliamentary Group for assistivetechnology

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Conclusions

- SmartAbility recommends Assistive Technologies based on user abilities
- Android Application developed to automatically detect user abilities
  - Utilisation of built-in sensor technologies
- Dissemination of the Android Application to charities, schools, NHS Dorset CCG and NIHR Wessex Clinical Research Network
- Anticipated to enhance the development of Assistive Technologies and an independent quality of life
- Submitted funding bids for future Assistive Technology research based on SmartAbility
  - Development of an 'AT4Ed' toolkit to provide Continuing Professional Development training on the use of Assistive Technology in the classroom, for teachers and teaching assistants at mainstream and special educational needs schools

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Previous Publications (1)

Whittington, P., Dogan, H. and Phalp, K., 2015a. Evaluating the Usability of an Automated Transport and Retrieval System. The 5th International Conference on Pervasive and Embedded Computing and Communication Systems, Angers, France, 11-13 February 2015. 59-66. Science and Technology Press, Lisbon, Portugal. Available from: http://ieeexplore.ieee.org/document/7483733/

Whittington, P., Dogan, H. and Phalp, K., 2015b. SmartPowerchair: to boldly go where a powerchair has not gone before. Ergonomics & Human Factors 2015, Daventry, UK, 13-16 April 2015. 233-240. CRC Press, London, UK. Available from: http://www.crcnetbase.com/doi/abs/10.1201/b18293-46

Whittington, P. and Dogan, H., 2015c. SmartPowerchair: A Pervasive System of Systems. The 10th International Conference on System of System Engineering, San Antonio, TX, USA, 18-20 May 2015. IEEE Press, New York, NY, USA. Available from: http://ieeexplore.ieee.org/document/7151932/

Whittington, P. and Dogan, H., 2015d. Improving life for people with disabilities. *The Ergonomist, 542, 12-13.* Available from: http://www.ergonomics.org.uk/wp-content/uploads/2015/05/542-August.pdf

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Previous Publications (2)

Whittington, P. and Dogan, H., 2016a. SmartDisability: A smart system of systems approach to disability. The 11th International Conference on System of System Engineering, Kongsberg 12-16 June 2016. New York, NY: IEEE Press. Available from: http://ieeexplore.ieee.org/document/7542943/

Whittington, P. and Dogan, H., 2016b. Improving user interaction through a SmartDisability Framework. British HCI 2016 Conference, Bournemouth 11-15 July 2016. Available from: http://ewic.bcs.org/content/ConWebDoc/56884

Whittington, P. and Dogan, H., 2016c. A SmartDisability Framework: enhancing user interaction. British HCI 2016 Conference, Bournemouth 11-15 July 2016. Available from: http://ewic.bcs.org/content/ConWebDoc/56902

Whittington, P. and Dogan, H., 2016d. SmartPowerchair: Characterisation and Usability of a Pervasive System of Systems. *IEEE Transactions on Human Machine Systems.* Available from: http://ieeexplore.ieee.org/document/7707466/

Ki-Aries, D., Dogan, H., Faily, S., Whittington, P. and Williams, C., 2017. From Requirements to Operation: Components for Risk Assessment in a Pervasive System of Systems. The 4th International Workshop on Evolving Security and Privacy Requirements Engineering, Lisbon, Portugal 4 September 2017. Available from: http://ieeexplore.ieee.org/document/8054834/

Previous Publications (3)

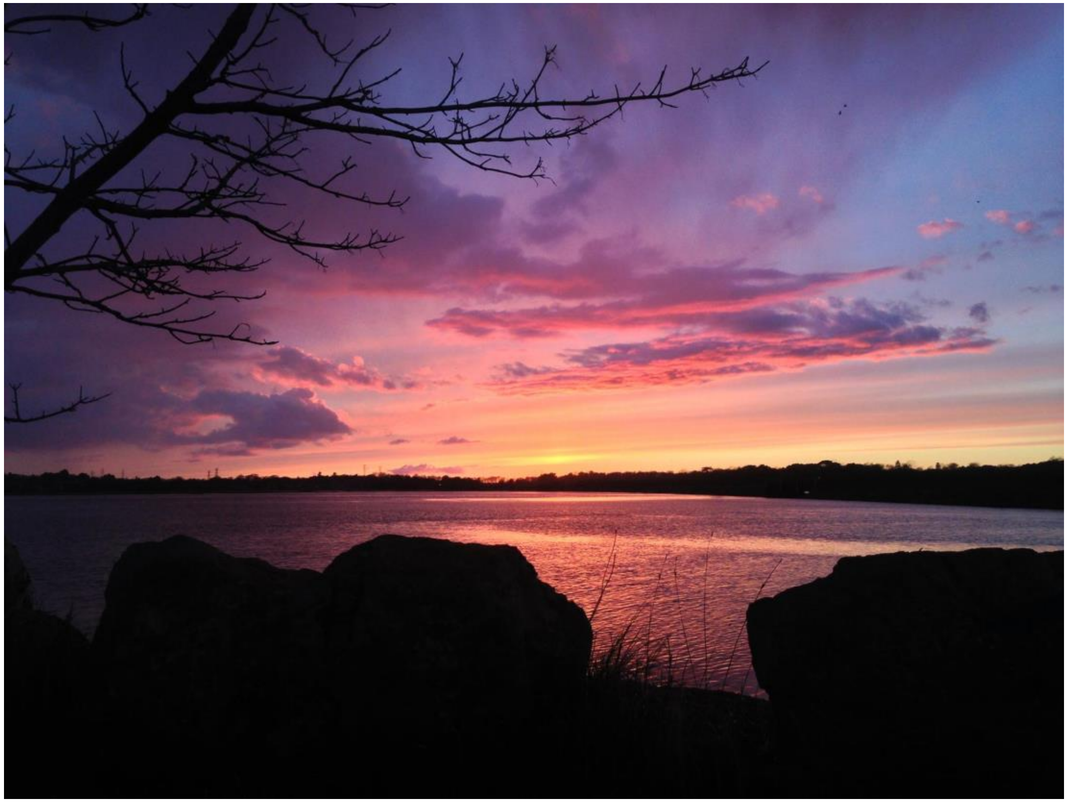
Cox, M., 2017. Disability cars and driving aids: the new tech helping disabled people get behind the wheel [online]. London: Dennis Publishing Ltd. Available from: http://www.autoexpress.co.uk/car-news/101188/disability-cars-and-driving-aids-the-new-tech-helping-disabled-people-get-behind-the

Eckersall, F., 2017. New technology to help people with disabilities [online]. High Wycombe: Newsquest Media Group Ltd. Available from: http://www.bournemouthecho.co.uk/news/16196363.Here__39_s_how_Bournemouth_University_is_helping_people_to_find_their_independence_through_assistive_technology/

Whittington, P., Dogan, H., Phalp, K. and Jiang, N., 2018. Automatic Detection of User Abilities through the SmartAbility Framework. British HCI 2018 Conference, Belfast, 2-6 July 2018. Available from: https://dl.acm.org/citation.cfm?id=3301065

Whittington, P., Dogan, H., Phalp, K. and Jiang, N., 2019. The Development and Evaluation of the SmartAbility Android Application to Detect Users' Abilities. CHI 2019 Conference, Glasgow, 4-9 May 2019. Available from: https://arxiv.org/abs/1904.06138

Thank you for listening
Any Questions?



Sunset over Holes Bay, Poole (April 2016, Dr Paul Whittington)

http://hci.bournemouth.ac.uk/project/smartability/