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ARIVE Lecture Series
XR: Virtual and Augmented Reality

# Engaging Human Augmentation

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# INTRODUCTION

# Artificial Intelligence (AI)

- Computer systems that perform tasks normally requiring human intelligence
- AI systems are world champion in games such as Chess, Jeopardy or Go
- AI systems play a major role in financial trading, computer assisted diagnosis, recommendations or self-driving cars
- But, AI lacks qualities like
  - experience
  - creativity
  - leadership
- Humans still leading in innovation or design


https://www.nature.com/nature/volumes/529/issues/7587


https://www.youtube.com/watch?v=AVxTm7RsVkM

# AI and humans

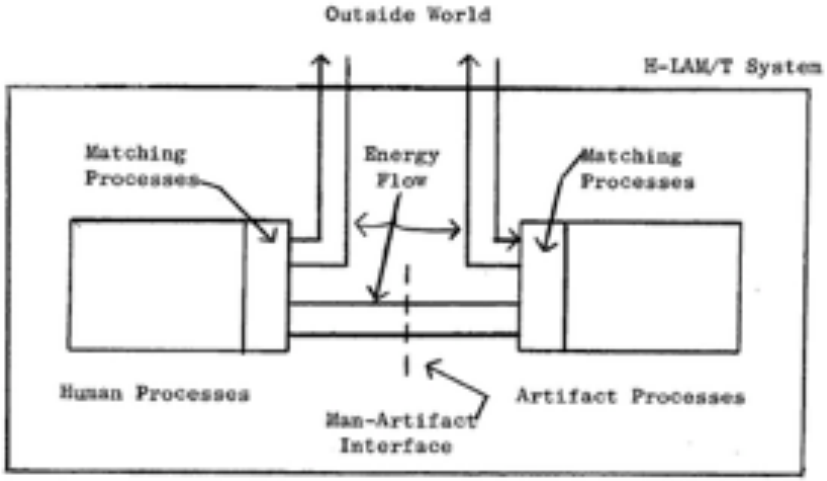
- Combine artificial and human intelligence
- Use AI for sensor-based machine perception
- Create human-centred intelligent systems and intelligent user interfaces
  - Affective systems
  - Empathic systems
- Amplify existing or create new human skills and capabilities


Iron Man 3


Title page, The Six Million dollar Man, ABC

# Augmented Intelligence

- Use AI to augment human intelligence
- Increase the effectiveness of processes resulting in human time and productive thought
- Increase the capability of a human to approach a complex problem situation
  - Gain comprehension
  - Derive solutions
- Use of AI in real-life situations



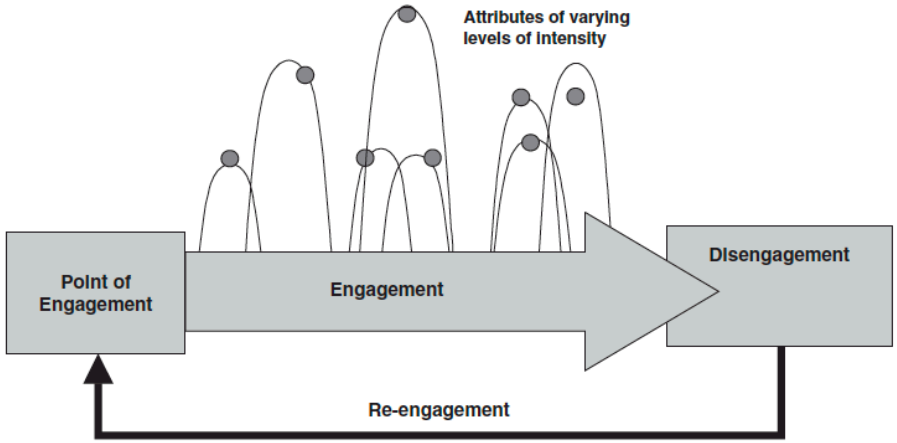

Engelbart, D. C., Augmenting Human Intellect: A Conceptual Framework, Stanford Research Institute, Stanford Research Institute, 1962
Bates, A., Augmented Mind: AI, Superhumans, and the Next Economic Revolution, Neocortex Press , 2018

# Augmented Humans

- Do not limit human augmentation to intellectual abilities
- Shift from human-computer-interaction to human-computer-integration
- Augment human abilities by human-computer-integration
  - Enhance and create new experiences
  - Foster engagement

Rekimoto, J., From augmented reality to augmented human, IEEE International Symposium on Mixed and Augmented Reality (ISMAR), 2013, 2013, 1

# Model for user engagement




**Point of Engagement Attributes**
- Aesthetics
- Novelty
- Interest
- Motivation
- Specific or experiential goal

**Period of Engagement Attributes**
- Aesthetic and Sensory Appeal
- Attention
- Awareness
- Control
- Interactivity
- Novelty
- Challenge
- Feedback
- Interest
- Positive Affect

**Disengagement Attributes**
- Usability
- Challenge
- Positive Affect
- Negative Affect
- Perceived Time
- Interruptions

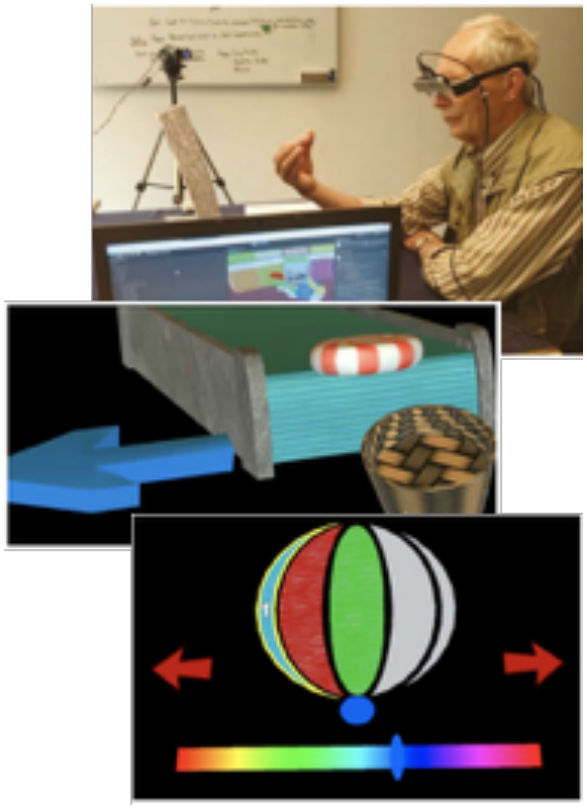
O'Brien, H. L. & Toms, E. G., "What is user engagement? A conceptual framework for defining user engagement with technology", *Journal of the American Society for Information Science and Technology, Wiley Online Library,* **2008***, 59*, 938-955

# HEALTH

# Augmented Reality Games to Assess Upper Extremity Motor Dysfunctions

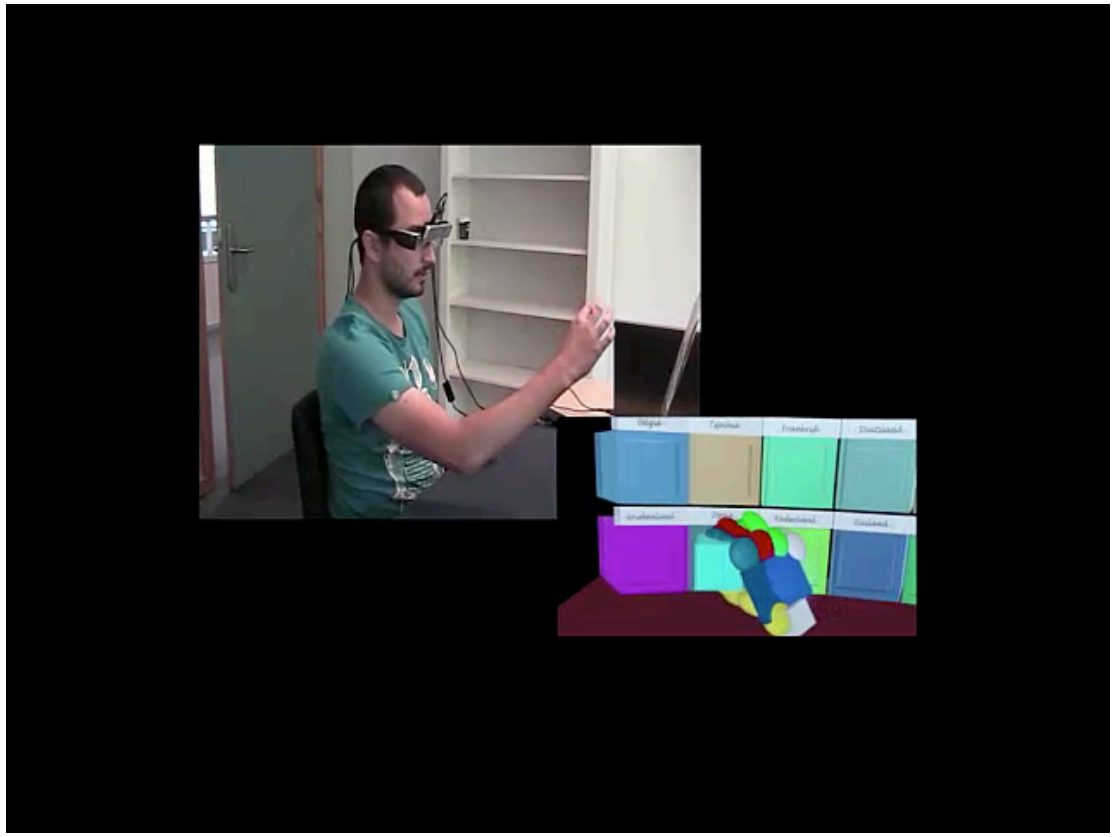
- Question: How to design AR games for an engaging, patient-friendly, objective, quantitative, valid and efficient tool to assess upper extremity motor dysfunctions?

- Approach: Iterative patient-centered design of AR games
  - Post Office Trouble
  - Candy Factory
  - ChiroChroma
  - Balloons, Melody Cubes, Hungry Squirrel



Cidota, M. A.; Lukosch, S. G.; Dezentje, P.; Bank, P. J.; Lukosch, H. K. & Clifford, R. M., Serious Gaming in Augmented Reality using HMDs for Assessment of Upper Extremity Motor Dysfunctions, i-com – Journal of Interactive Media, Special Issue on Smartglass Technologies, Applications and Experiences, 2016, 15, 155-169
Cidota, M. A.; Bank, P. J.; Ouwehand, P. E. W. Ouwehand & Lukosch, S. G., Assessing Upper Extremity Motor Dysfunction Using an Augmented Reality Game, IEEE International Symposium on Mixed and Augmented Reality, IEEE Computer Society, 2017 , 144-154

# Game impressions



# System Usability Scale (SUS)

| | Strongly disagree | | | | Strongly agree |
|---|---|---|---|---|---|
| 1. I think that I would like to use this system frequently | 1 | 2 | 3 | 4 | 5 |
| 2. I found the system unnecessarily complex | 1 | 2 | 3 | 4 | 5 |
| 3. I thought the system was easy to use | 1 | 2 | 3 | 4 | 5 |
| 4. I think that I would need the support of a technical person to be able to use this system | 1 | 2 | 3 | 4 | 5 |
| 5. I found the various functions in this system were well integrated | 1 | 2 | 3 | 4 | 5 |
| 6. I thought there was too much inconsistency in this system | 1 | 2 | 3 | 4 | 5 |
| 7. I would imagine that most people would learn to use this system very quickly | 1 | 2 | 3 | 4 | 5 |
| 8. I found the system very cumbersome to use | 1 | 2 | 3 | 4 | 5 |
| 9. I felt very confident using the system | 1 | 2 | 3 | 4 | 5 |
| 10. I needed to learn a lot of things before I could get going with this system | 1 | 2 | 3 | 4 | 5 |

Brooke, J., Jordan, P. W.; Thomas, B.; Weerdmeester, B. A. & McClelland, A. L. *(Eds.),* SUS: A "quick and dirty" usability scale, *Usability Evaluation in Industry, Taylor and Francis,* **1996**

# Game Experience Questionnaire

- Modular structure consisting of:
  - core questionnaire
  - social presence module
  - post-game module

- Assesses game experience as scores (0 – 4) on seven components:
  - competence
  - immersion
  - flow
  - tension
  - challenge
  - positive and negative affect

| | |
|---|---|
| 1 | I felt revived |
| 2 | I felt bad |
| 3 | I found it hard to get back to reality |
| 4 | I felt guilty |
| 5 | It felt like a victory |
| 6 | I found it a waste of time |
| 7 | I felt energised |
| 8 | I felt satisfied |
| 9 | I felt disoriented |
| 10 | I felt exhausted |
| 11 | I felt that I could have done more useful things |
| 12 | I felt powerful |
| 13 | I felt weary |
| 14 | I felt regret |
| 15 | I felt ashamed |
| 16 | I felt proud |
| 17 | I had a sense that I had returned from a journey |

IJsselsteijn, W. A.; de Kort, Y. A. W. & Poels, K., The Game Experience Questionnaire, *Technische Universiteit Eindhoven, Technische Universiteit Eindhoven,* **2013**
Law, E. L.-C.; Brühlmann, F. & Mekler, E. D., Systematic Review and Validation of the Game Experience Questionnaire (GEQ) - Implications for Citation and Reporting Practice, *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play, ACM,* **2018**, 257-270

# Results

- AR games have potential for assessing motor impairments in patients with neurological conditions
- Design recommendations
  - Use a first-person perspective to keep relation to the real world
  - Make games adaptable to the patient's physical and mental condition
  - Make game features are relevant and meaningful for assessment
  - Game controls need not to interfere with the natural movements
  - Provide large interaction space with guidance towards virtual objects
- Future work
  - Improve accuracy of measurements
  - Explore continuous fine-grained adaptation of game interaction
  - Explore application in clinical practice

# SAFETY & SECURITY

# Human Augmentation for Distributed Situational Awareness

- Question: How to design human augmentation to improve distributed situational awareness between local and remote investigators, policemen, and firemen?
- Approach: Create virtual co-location of local and remote experts
  - Use AR to augment crime scene with relevant information
  - Allow local and remote expert to annotate scene
  - Share annotation between organisations

Lukosch, S.; Lukosch, H.; Datcu, D. & Cidota, M., Providing Information on the Spot: Using Augmented Reality for Situational Awareness in the Security Domain, Computer Supported Cooperative Work (CSCW), 2015, 24, 613-664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POLITIE
POLITIE

# Techniques to assess situational awareness

- **Self-rating** techniques
  - subjective assessments of SA
  - administered post-trial
  - easy non-intrusive application

- **Freeze probe** techniques
  - SA related queries during 'freezes'
  - task is randomly frozen
  - responses are compared to the state of the system at the point of the freeze
  - may negatively affect performance

- **Real-time probe** techniques
  - experts as SA related queries on-line
  - no freeze of the task under analysis
  - query response time indicator for SA

- **Observer rating** techniques
  - experts observe participants during task and rate SA
  - non-intrusive

Salmon, P. M.; Stanton, N. A.; Walker, G. H.; Jenkins, D.; Ladva, D.; Rafferty, L. & Young, M., Measuring Situation Awareness in complex systems: Comparison of measures study, *International Journal of Industrial Ergonomics,* **2009***, 39*, 490 - 500

# Situation Awareness Rating Technique (SART)

- Self-rating technique
  - 10 dimensions
  - 7-point Likert scale: 1 = low, 7 = high
- Applicable, if
  - SA content is not predefined
  - task is dynamic, collaborative, and changeable
  - task outcome is not known (e.g. real world tasks)
- Administered post-trial
- SART score is: U−(D−S)
  - U is the summed understanding
  - D is the summed attentional demand
  - S is the summed attentional supply

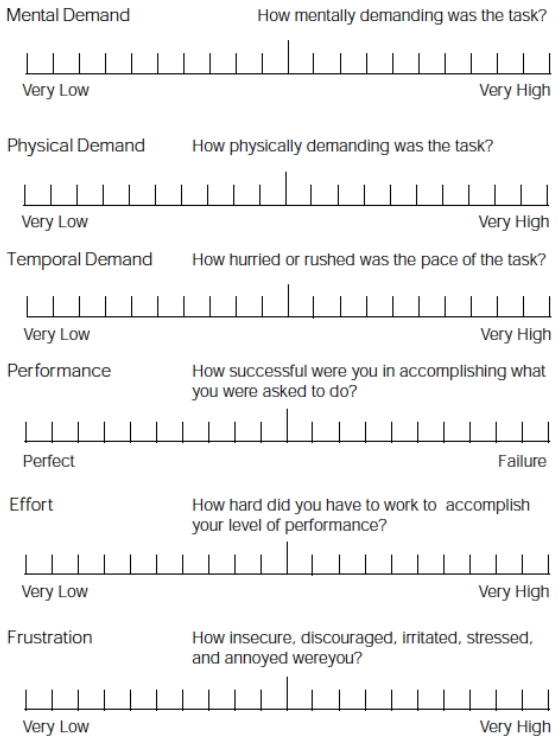
Taylor, R., Situational awareness rating technique (SART): The development of a tool for aircrew systems design, *Situational Awareness in Aerospace Operations, Advisory Group for Aerospace Research & Development (AGARD),* **1990**, 3/1-3/17

# SART questionnaire

- SART questionnaire – Understanding
  - Information Quantity: How much information have you gained about the situation? Have you received and understood a great deal of knowledge (High) or very little (Low)?
  - Information Quality: How good is the information provided about the situation? Is the communicated knowledge valuable (High) or not (Low)?
  - Familiarity with Situation: How familiar are you with the situation? Do you have a great deal of relevant experience (High) or is it a new situation (Low)?
- SART questionnaire – Attentional demand
  - Instability of Situation: How changeable is the situation? Is the situation highly unstable and likely to change suddenly (High) or is it very stable and straightforward (Low)?
  - Variability of Situation: How many variables are changing within the situation? Are there a large number of factors varying (High) or are there very few variables changing (Low)?
  - Complexity of Situation: How complicated is the situation? Is it complex with many interrelated components (High) or is it simple and straightforward (Low)?
- SART questionnaire – Attentional supply
  - Arousal: How aroused are you in the situation? Are you alert and ready for activity (High) or do you have a low degree of alertness (Low)?
  - Spare Mental Capacity: How much mental capacity do you have to spare in the situation? Do you have sufficient to attend to many variables (High) or nothing to spare at all (Low)?
  - Concentration of Attention: How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (High) or focussed on only one (Low)?
  - Division of Attention: How much is your attention divided in the situation? Are you concentrating on many aspects of the situation (High) or focussed on only one (Low)?

# NASA Task Load Index (TLX)

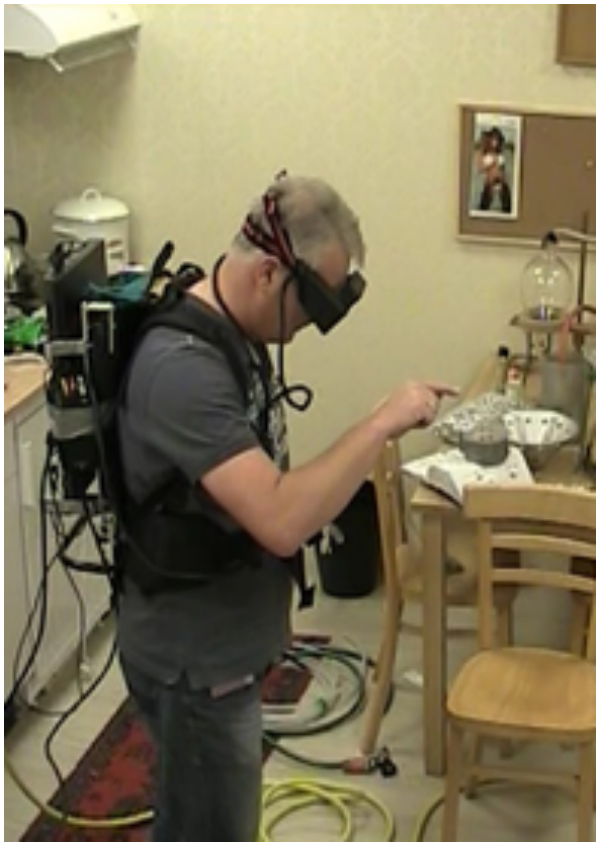
- Subjective workload assessment tool
- Focus on users working with human-machine systems
- Multi-dimensional rating procedure
- Overall workload score based on a weighted average of ratings on
  - Mental Demands
  - Physical Demands
  - Temporal Demands
  - Own Performance
  - Effort and Frustration
- Weights for subscales user defined




Hart, S. G. & Staveland, L. E., Hancock, P. A. & Meshkati, N. *(Eds.),* Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research , *Human Mental Workload, Amsterdam: North Holland Press,* **1988**

# Results

- Team situational awareness increased with AR
- Design recommendations
  - Use AR to create a shared visual space between local and remote
  - Use AR to enrich crime scene with information
  - Use remote colleagues as advisor in stressful situations
  - Use virtual co-location to increase presence of remote experts at local scene
- Future work
  - Explore other scenarios and modalities
  - Adapt information to current user context, e.g., environment, emotional state, task, …



# SUPERHUMAN SPORTS

# Superhuman Sports Society

# Superhuman Sports

- Question: How to design mixed reality games that motivate and engage users in physical activity?

- Approach: Augment human capabilities in sports and games
  - Augment senses
  - Augment the body
  - Augment the playing field

Kunze, K.; Minamizawa, K.; Lukosch, S.; Inami, M. & Rekimoto, J., Superhuman Sports: Applying Human Augmentation to Physical Exercise, IEEE Pervasive Computing, 2017 , 16 , 14-17

# Augment the senses

- Perceive something that no normal person can
  - "Spider sense" (a way to detect if one is in danger)
  - X-ray vision to
  - Clairvoyance
- Map the "invisible play world" onto existing senses
- Sensory augmentation, substitution, and supplementation
- Change the properties of one sensory modality into stimuli of another sensory modality

Rebane, K.; Shijo, R.; Schewe, T.; Jiang, J. & Nojima, T., Augmented Dodgeball, *Proceedings of the First Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities, ACM,* **2018**, 5:1-5:5

# Augment the senses

Chernyshov, G., Ragozin, K., Chen, J. and Kunze, K., Dubhap: a sensory substitution based superhuman sport. In Proceedings of the First Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities (p. 4). ACM. 2018

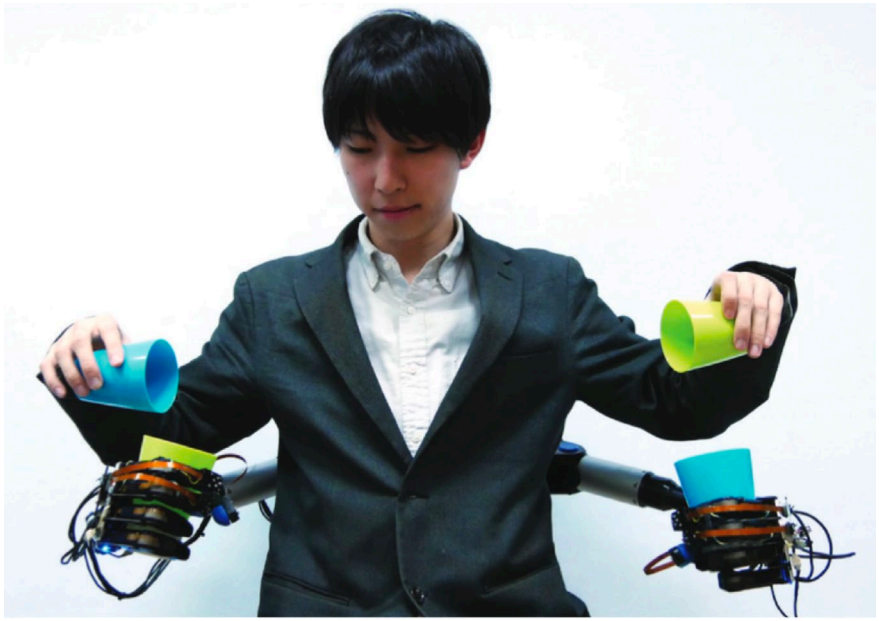
Sasaki, T., Liu, K.H., Hasegawa, T., Hiyama, A. and Inami, M., Virtual Super-Leaping: Immersive Extreme Jumping in VR. In Proceedings of the 10th Augmented Human International Conference 2019 (p. 18). ACM 2019.

# Augment the body

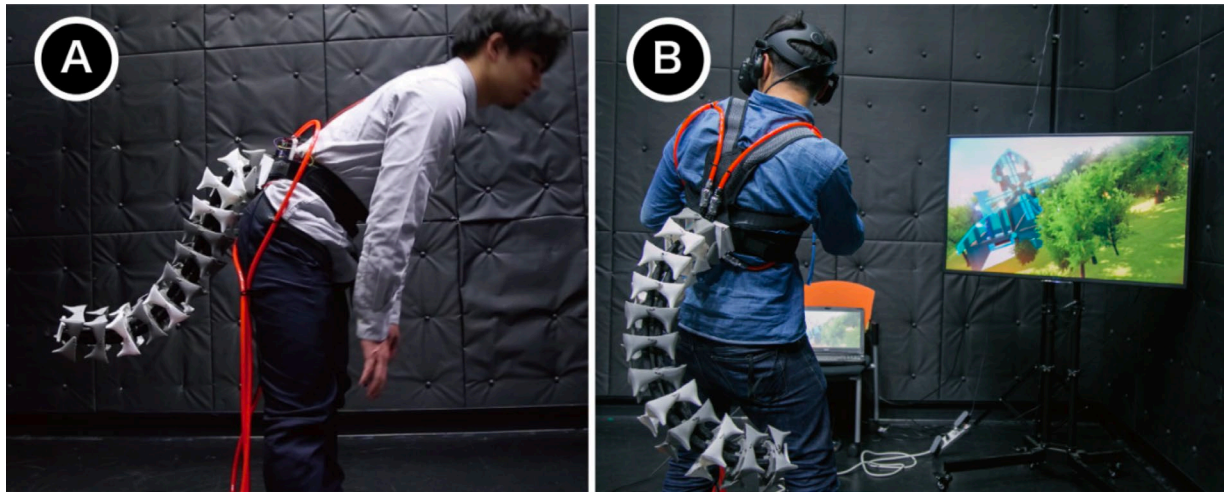
- Expert athletes aim at a state of flow and "becoming one with their equipment"
- Provide equipment as a natural extension of the body
- Create wearable computing systems that "feel" integrated with the  body
- Create new Superhuman Sports with body extensions

Kishishita, Y.; Ramirez, A. V.; Das, S.; Thakur, C.; Yanase, Y. & Kurita, Y., Muscleblazer: A Wearable Laser Tag Module Powered by PGM-induced Force-feedback, *Proceedings of the First Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities, ACM,* **2018**, 2:1-2:6

# Augment the body



Saraiji, M. H. D., Sasaki, T., Kunze, K., Minamizawa, K., & Inami, M. MetaArmS: Body remapping using feet-controlled artificial arms. In The 31st Annual ACM Symposium on User Interface Software and Technology (pp. 65-74). ACM 2018.




Nabeshima, J., Saraiji, M. H. D., & Minamizawa, K. Prosthetic Tail: Artificial Anthropomorphic Tail for Extending Innate Body Functions. In Proceedings of the 10th Augmented Human International Conference 2019 (p. 36). ACM.

# Augment the playing field

- Re-design existing sports by adding virtual elements
- Create new sports by creating the "impossible"
  - Challenge physics
  - Add new equipment
  - Add new opponents
- Train in a safe environment
- Make sports more interesting and enjoyable to play

Tiator, M.; Geiger, C.; Dewitz, B.; Fischer, B.; Gerhardt, L.; Nowottnik, D. & Preu, H., Venga!: Climbing in Mixed Reality, *Proceedings of the First Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities, ACM,* **2018**, 9:1-9:8

# Play your run!


van Zon, M.; Lukosch, S. G.; Jansen, A. J. & Greidanus, A. J., Play your run! A Superhuman sports running game in mixed reality, *Science and Engineering Conference on Sports Innovation,* **2017**

# League of Lasers


Miedema, N. A.; Vermeer, J.; Lukosch, S. G. & Bidarra, R., Superhuman sports in mixed reality: the multi-player game League of Lasers, Proceedings of the IEEE VR Workshop on Superhuman Sports, 2019

# WizARds


First team to get 3 points wins
Press Trigger to shoot.
Look out for the golden snitch too!
Your Team Score: 0
Red Team Score: 0

# User Experience Questionnaire (UEQ)

- Measures the user experience of interactive products
- 2 antonyms at the ends of  a seven step scale (e.g. annoying and enjoyable)
- Six aspects:
  - Attractiveness:
    - Overall impression of the product. Do users like or dislike it? Is it attractive, enjoyable or pleasing?
  - Perspicuity:
    - Is it easy to get familiar with the product? Is it easy to learn? Is the product easy to understand and clear?
  - Efficiency:
    - Can users solve their tasks without unnecessary effort? Is the interaction efficient and fast? Does the product react fast to user input?
  - Dependability:
    - Does the user feel in control of the interaction? Can he or she predict the system behaviour? Does the user feel safe when working with the product?
  - Stimulation:
    - Is it exciting to use the product? Is it fun to use?
  - Novelty:
    - Is the product innovative and creative? Does it capture users' attention?

Laugwitz, B.; Held, T. & Schrepp, M., Construction and Evaluation of a User Experience Questionnaire, *HCI and Usability for Education and Work, 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society, USAB 2008, Graz, Austria, November 20-21, 2008. Proceedings,* **2008**, 63-76

# Results

- Augmenting senses, body or playing field
  - Encourages physical activity
  - Allows for new (sport) experiences
  - Conceived as engaging
- Keep it simple, less is more
- Foster audience participation
- (Longer-term) evaluation of engagement and human factors

# CONCLUSIONS

# Conclusions

- Health
  - games suitable for motor assessment
  - human augmentation needs to be adaptive and meaningful
- Safety & Security
  - human augmentation improves situational awareness
  - increases task load
  - changes work processes
- Sports
  - human augmentation encourages physical activity

# Future work

- Advanced displays: high FOV, high resolution
- Equipment: light, ergonomic, ubiquitous, non-invasive
- Real-time space capture and tracking: 3D scanning, stitching, segmentation
- Multimodal interaction: natural gesture interaction, tangible interaction, speech, emotion sensing, fusion
- Embedding of virtual content in the real world
- Model and design guidelines for engagement