Next-Generation Hand Prostheses: What is next?

Prospects about the Machine-Human Interaction

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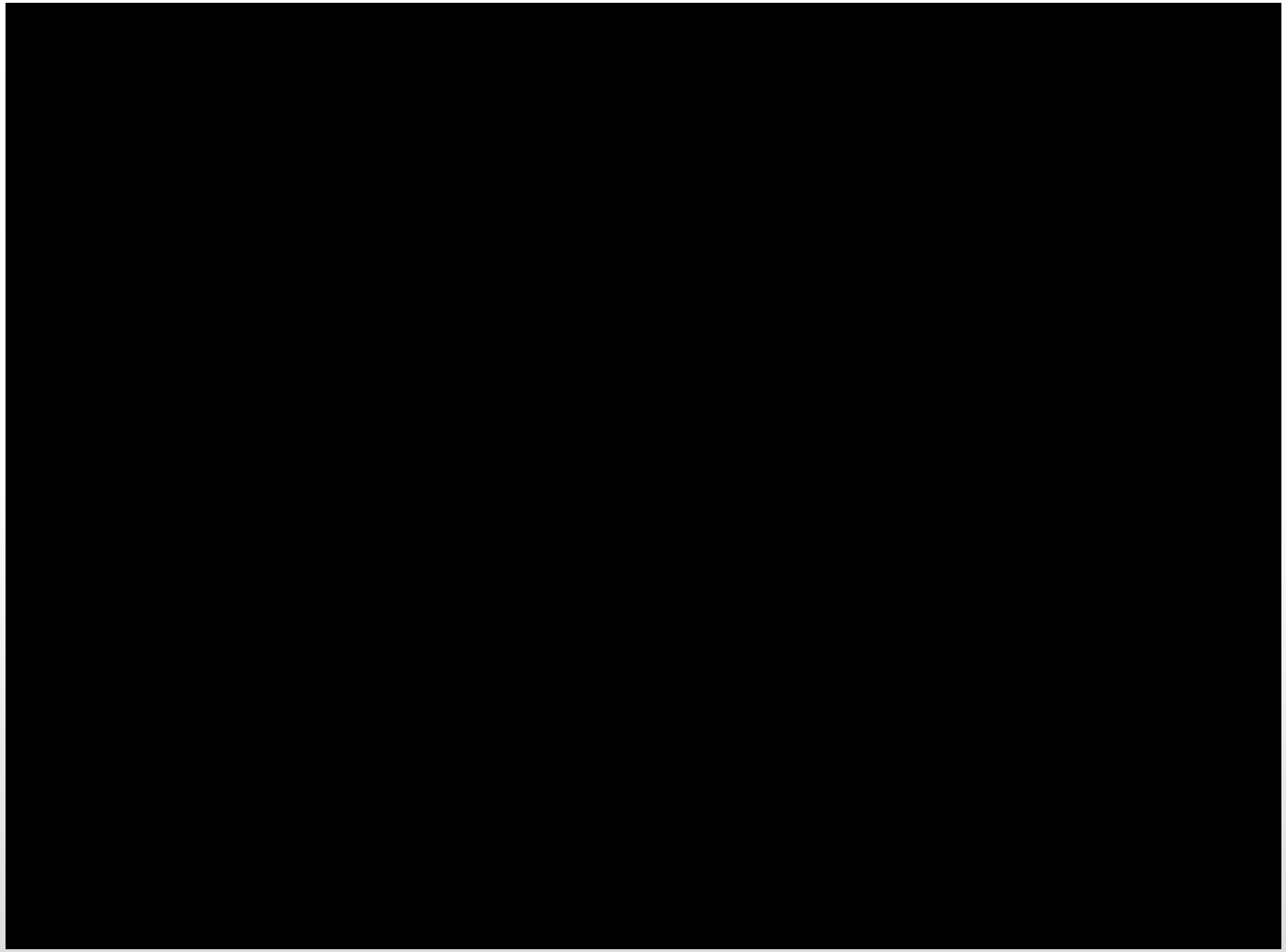
Information on possible conflicts of interest

Marco Controzzi is founder and hold shares of "Prensilia", the spin-off company commercializing robotic hands.

Wireless Brain-Connect inteRfAce TO machineS: B-CRATOS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 965044



The Potato Show | The French Chef Season 1 | Julia Child

The **(re)integration** of an individual with a disability **into society** by enhancing **existing capabilities** or by providing **alternative means**.

(Robinson, *Rehabilitation Engineering, Science, and Technology, 1993*)

Prosthetics deals with the **replacement of motor functionality and cosmesis**

Prosthesis, noun - *An artificial device used to replace a missing body part*

30% - 50% of the users abandon their prostheses!!!

~650 needs

P. Borracci et al "Organizing and prioritizing user needs for upper limb prostheses" ICORR2025 accepted

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216 Categories

50 Needs

- Lightweight
- Easy to wear
- Thermal comfort
- Ergonomy
- Quite

- Affordable
- Cost-effective
- Purchase condition
- Assistance

- Precision & stability
- Power
- Operating time
- Usability & Versatility
- Feedback

- Rubustness
- Durability – Mantainance
- Cleanable
- Anatomically proportionate
- Safety

- Aesthetically pleasing
- Anatomically prop.

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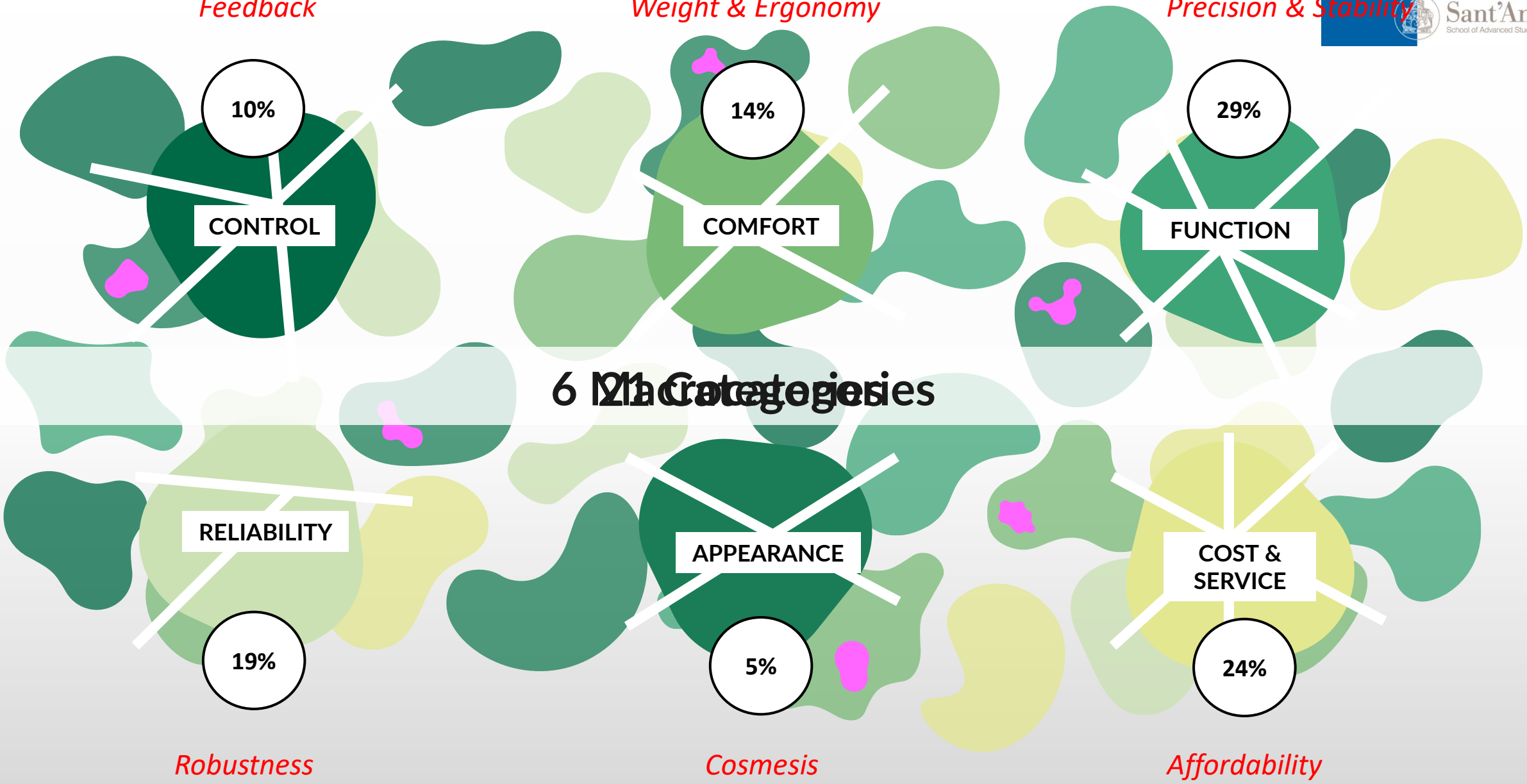

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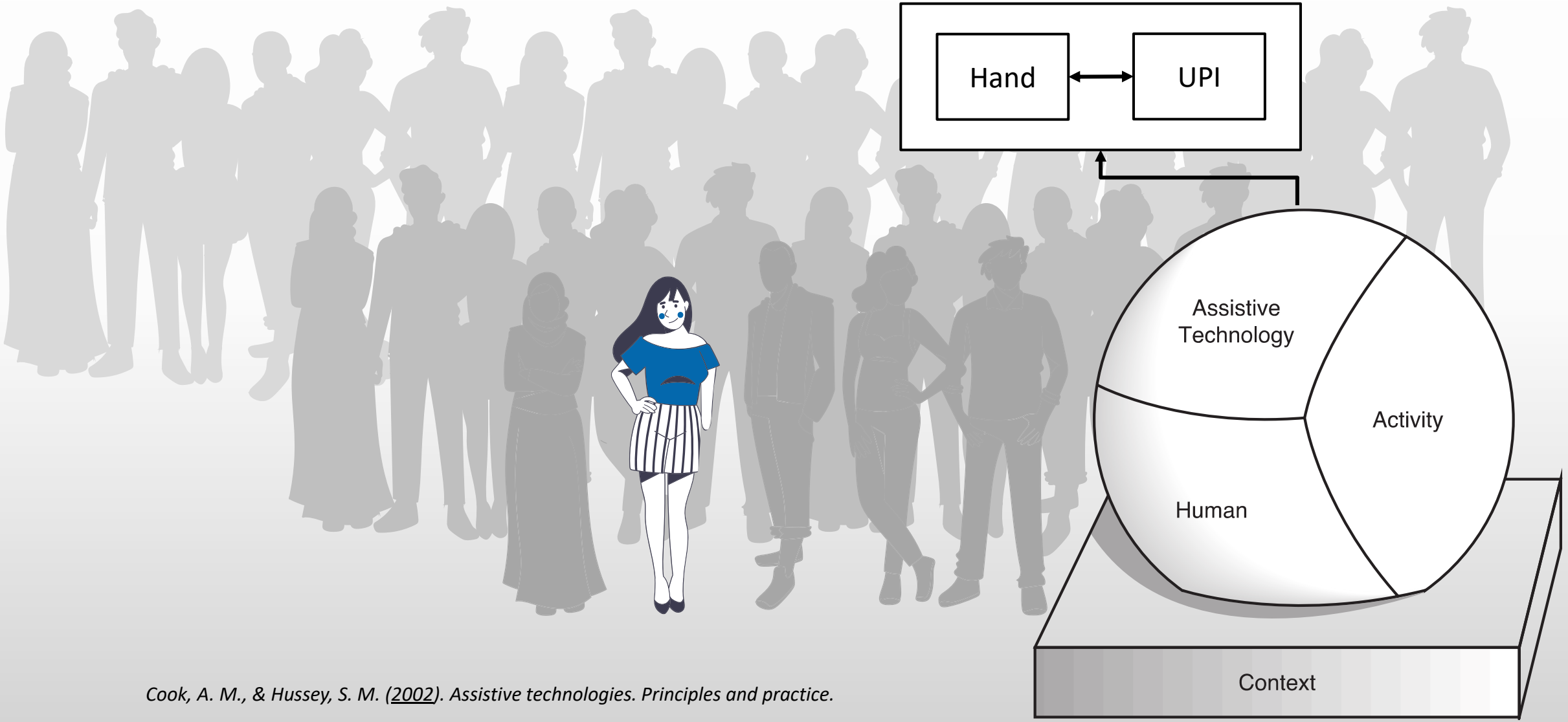
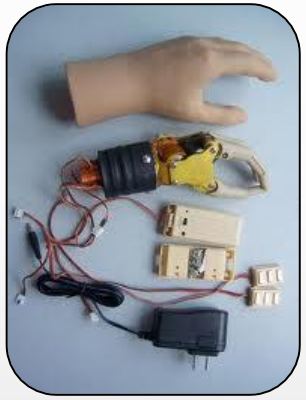


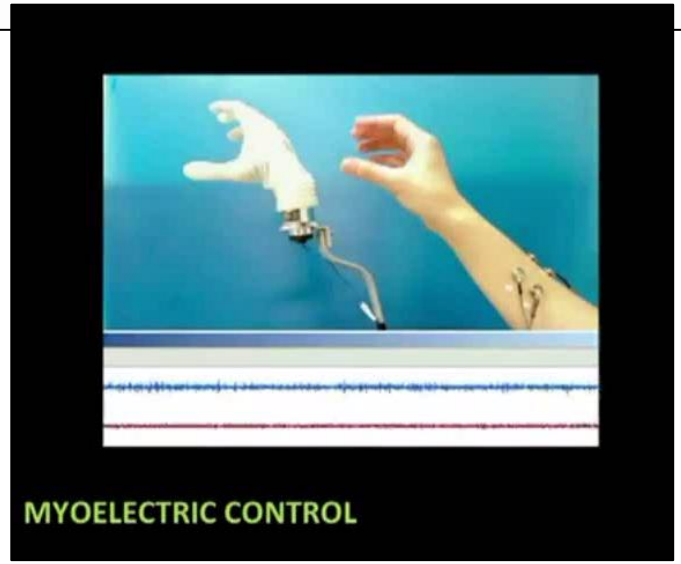
Cook, A. M., & Hussey, S. M. (2002). Assistive technologies. Principles and practice.

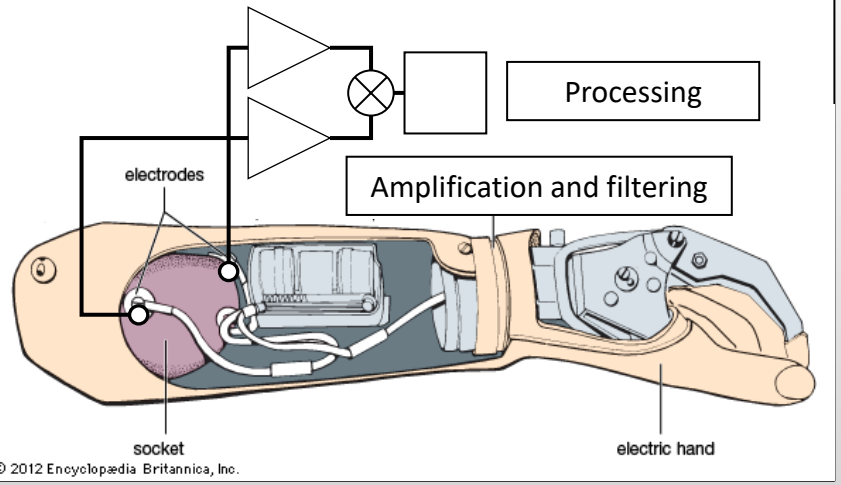
Prosthetic Hands

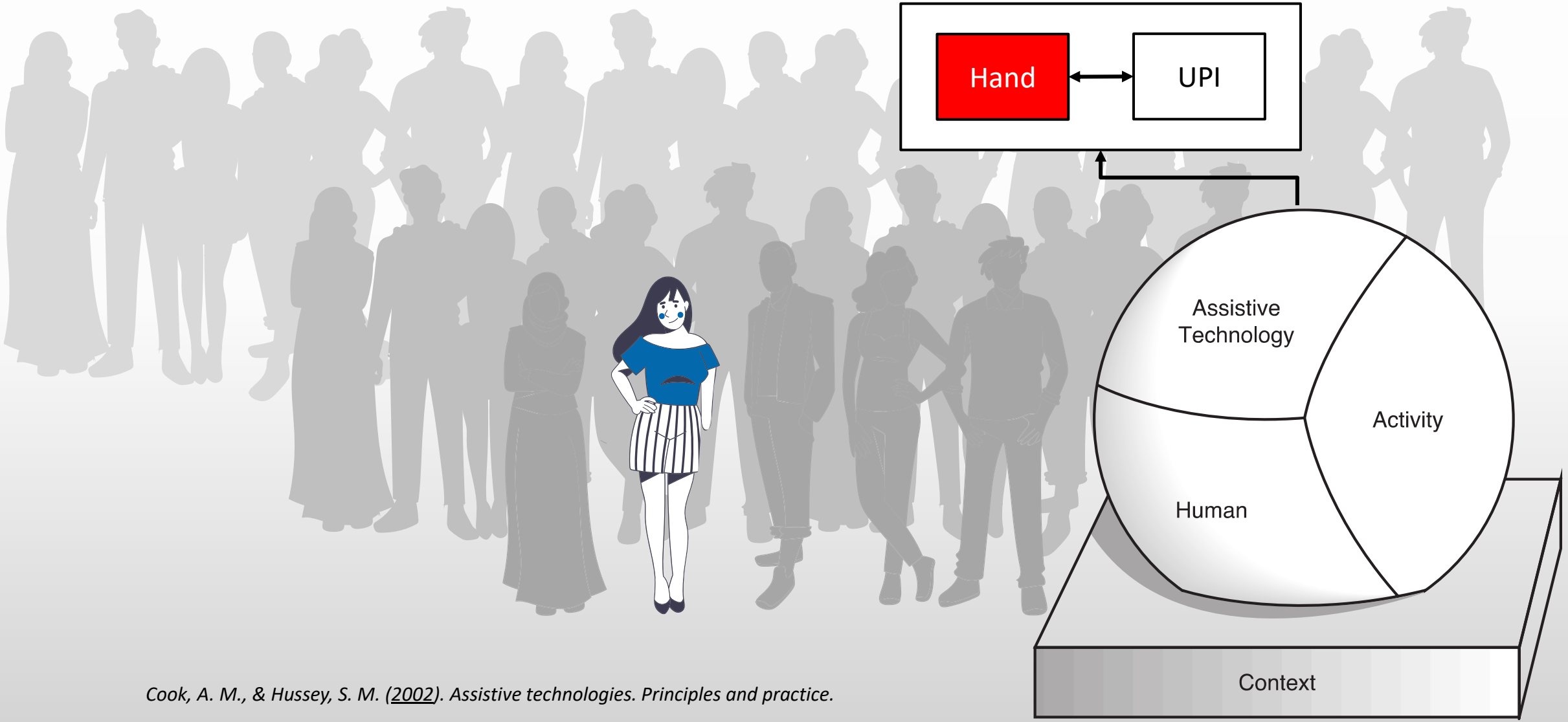
- Passive
  - Cosmetic
  - Tools
- Active
  - Body-powered
  - Myoelectric



User Prosthesis Interfaces







Cook, A. M., & Hussey, S. M. (2002). Assistive technologies. Principles and practice.

MIA HAND PROSTHESIS

3 PILLARS

Optimal functionality

Over 80% of daily activities

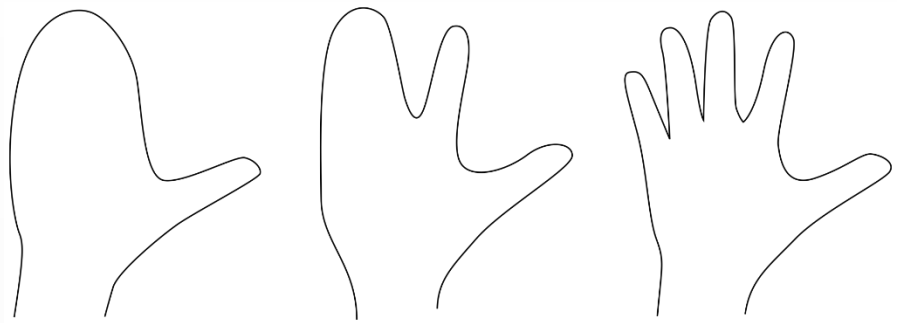
Affordable for everyone

The best cost:performance alignment

Design and customisation

Stop hiding the disability, proud to show

Controzzi, M., Clemente, F., Barone, D., Ghionzoli, A., & Cipriani, C. (2016). The SSSA-MyHand: a dexterous lightweight myoelectric hand prosthesis. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *25*(5), 459-468.



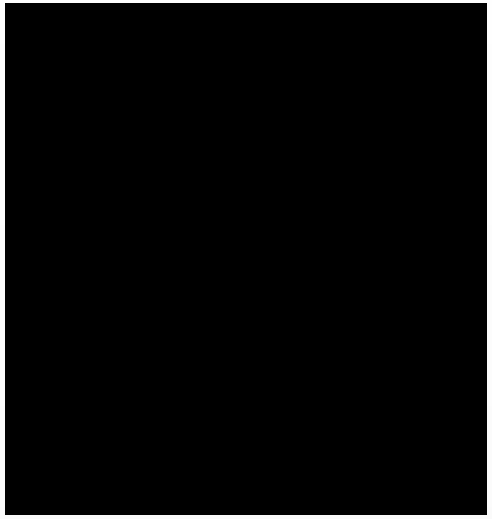
Split hook device

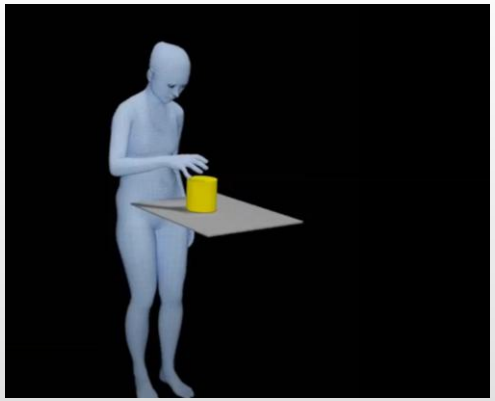
Prehensile function

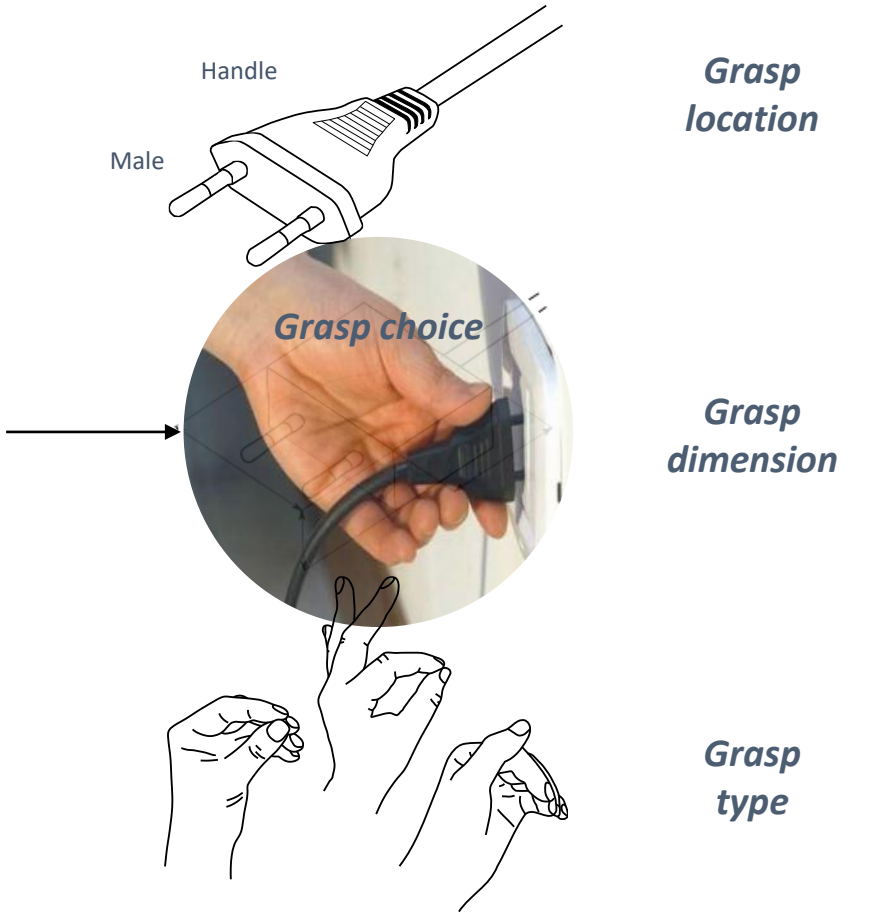
Robustness

Multi-DoF hand

Montagnani, F., Controzzi, M., & Cipriani, C. (2016). Independent long fingers are not essential for a grasping hand. *Scientific Reports*, *6*(1), 35545.





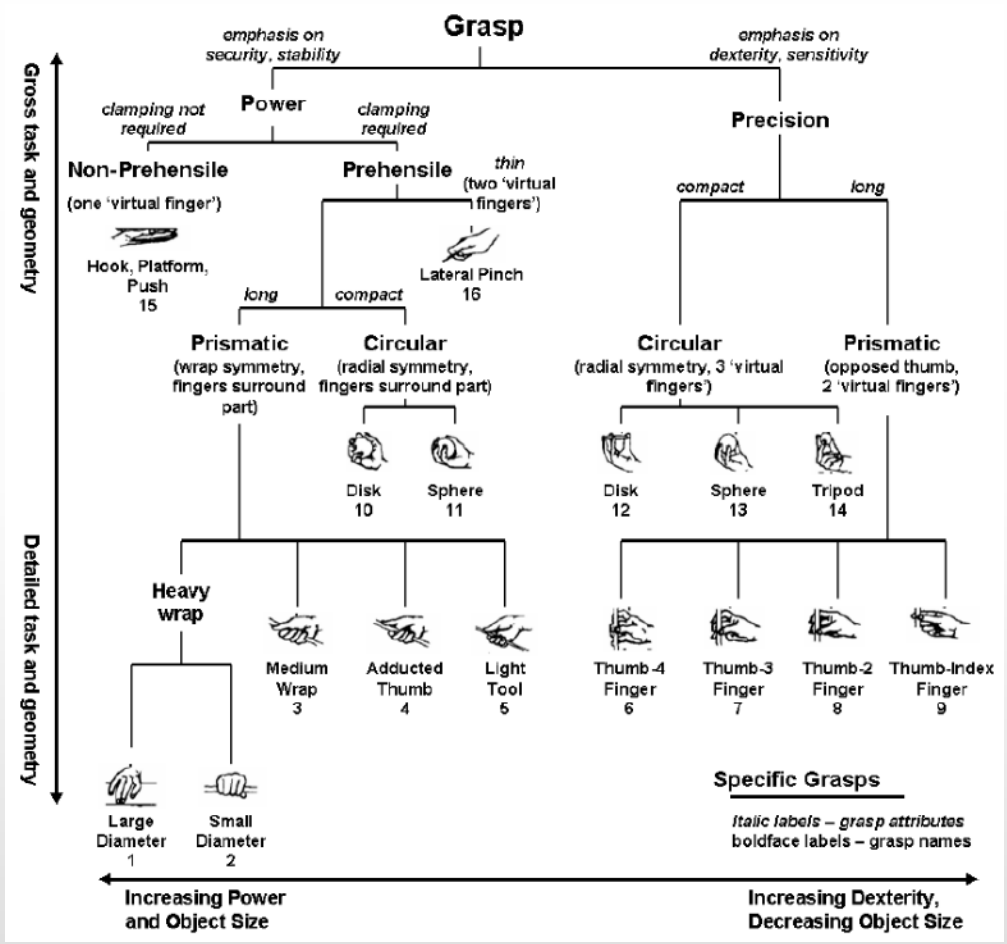


Cini, F., et al. "On the choice of grasp type and location when handing over an object." *Science Robotics* 4.27 (2019): eaau9757.

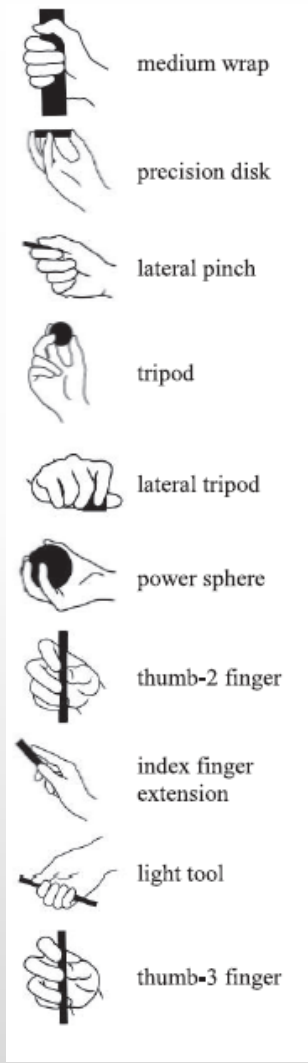
Taheri, Omid, et al. "GRAB: A dataset of whole-body human grasping of objects." *European conference on computer vision*. Springer, Cham, 2020.

Ansuini, C., Santello, M., Massaccesi, S., & Castiello, U. (2006). Effects of end-goal on hand shaping. *Journal of neurophysiology*, *95*(4), 2456-2465.

Sartori, L., Straulino, E., & Castiello, U. (2011). How objects are grasped: the interplay between affordances and end-goals. PloS one, 6(9), e25203



Cutkosky M. R., "On grasp choice, grasp models, and the design of hands for manufacturing tasks", IEEE Trans. RA, vol. 5, no. 3, June 1989.



Most frequently used grasps during ADLs

Grasp Frequency and Usage in Daily Household and Machine Shop Tasks

Ian M. Bullock, *Student Member, IEEE*, Joshua Z. Zheng, Sara De La Rosa, Charlotte Guertler, and Aaron M. Dollar, *Member, IEEE*

MIA HAND AT A GLANCE

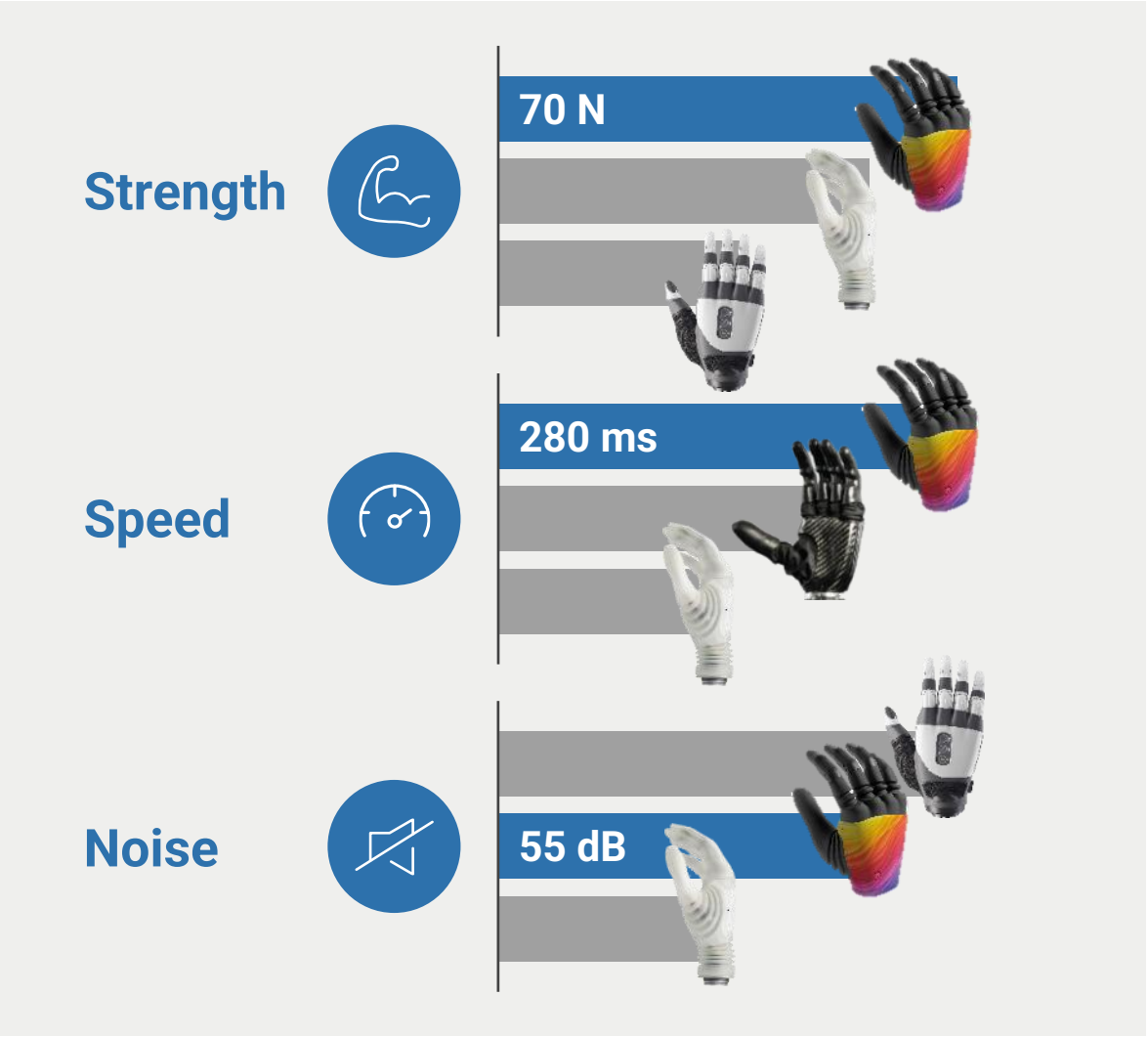
Available grasps and gestures*

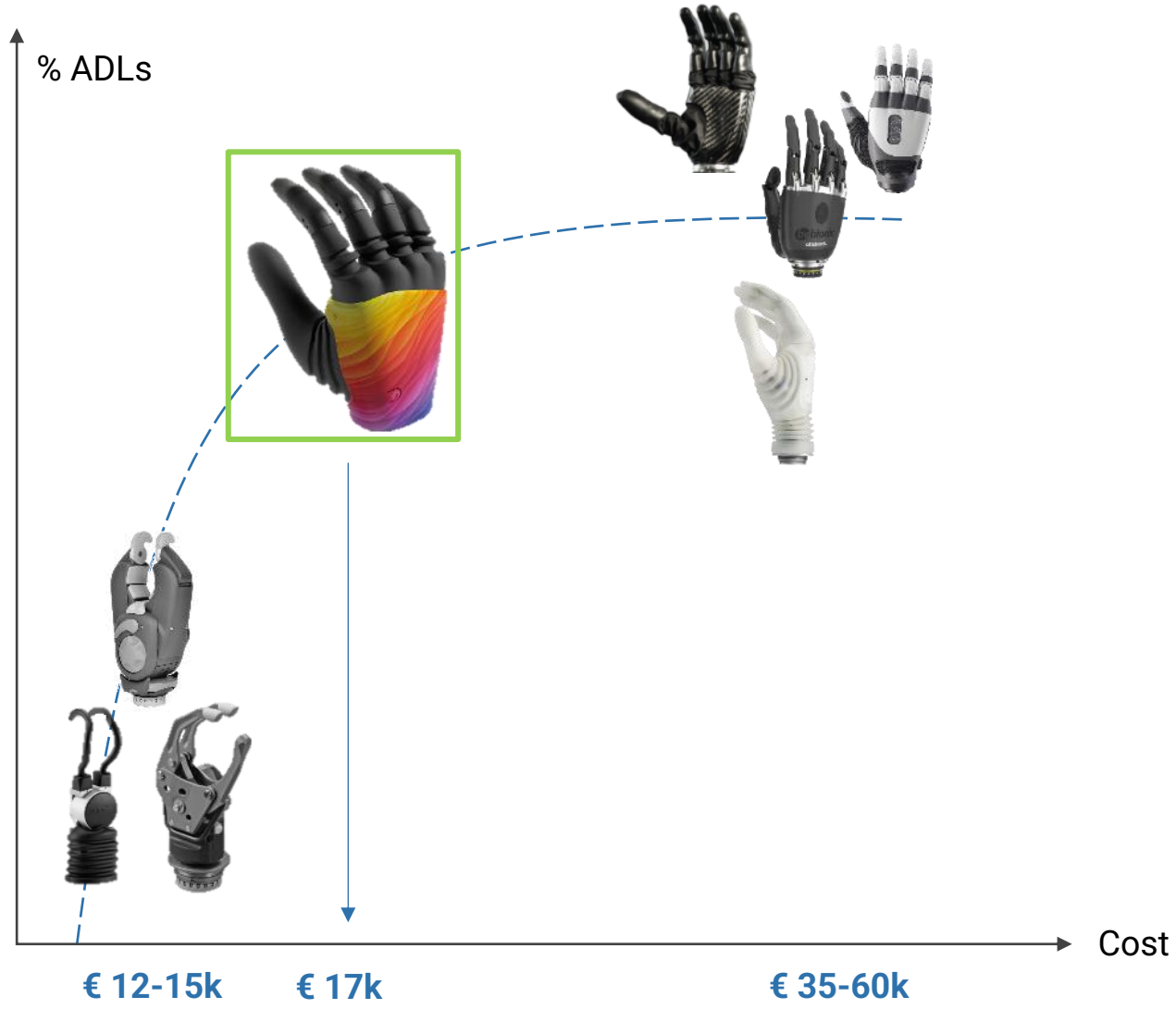
Lateral | Pointing down* | Pointing up* | Power | Precision

Controzzi, M., Clemente, F., Barone, D., Ghionzoli, A., & Cipriani, C. (2016). The SSSA-MyHand: a dexterous lightweight myoelectric hand prosthesis. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *25*(5), 459-468.

THE SOLUTION: MIA HAND PROSTHESIS

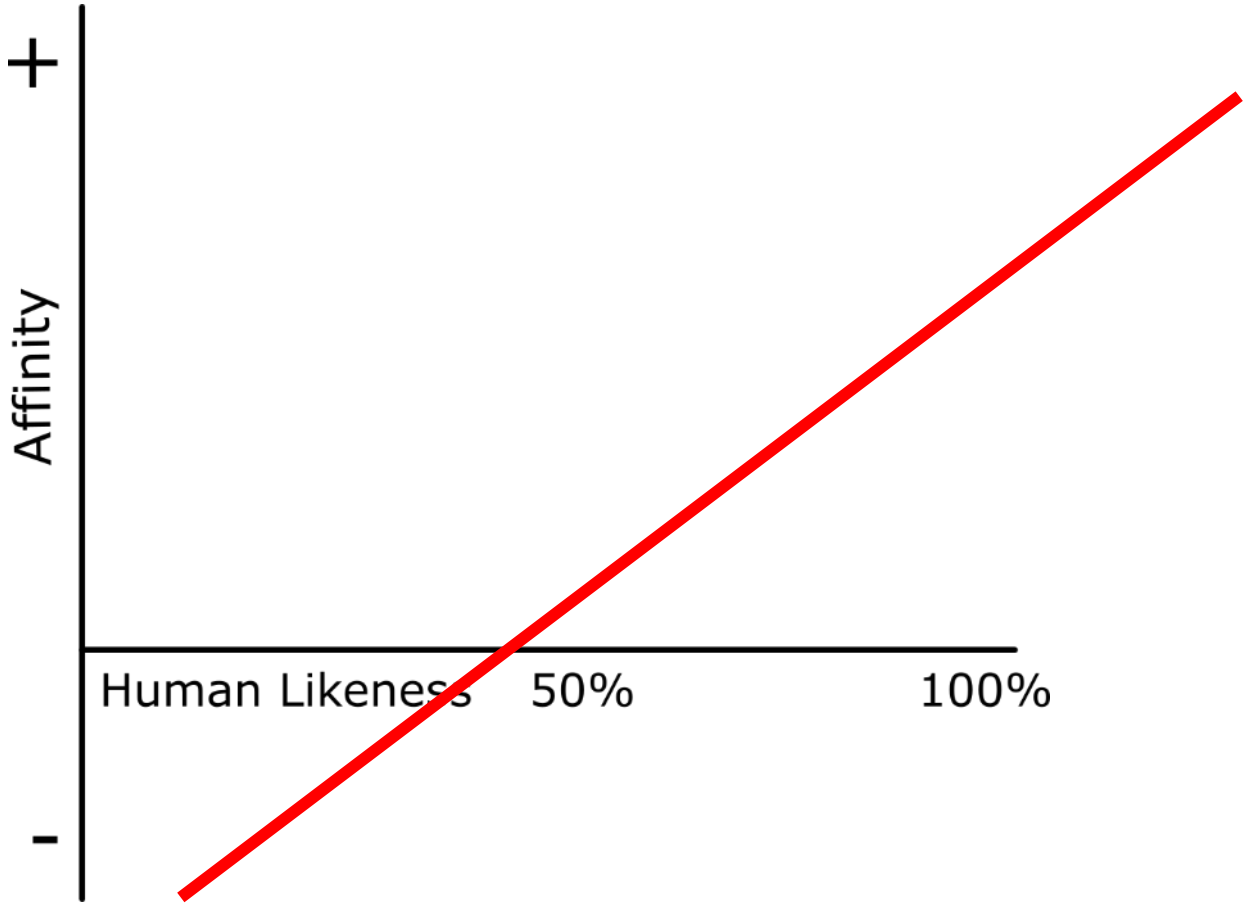
Less in number, yet more performing grasps. Quality, not quantity, is key in manipulation.





ABOUT COSMESIS

The uncanny valley

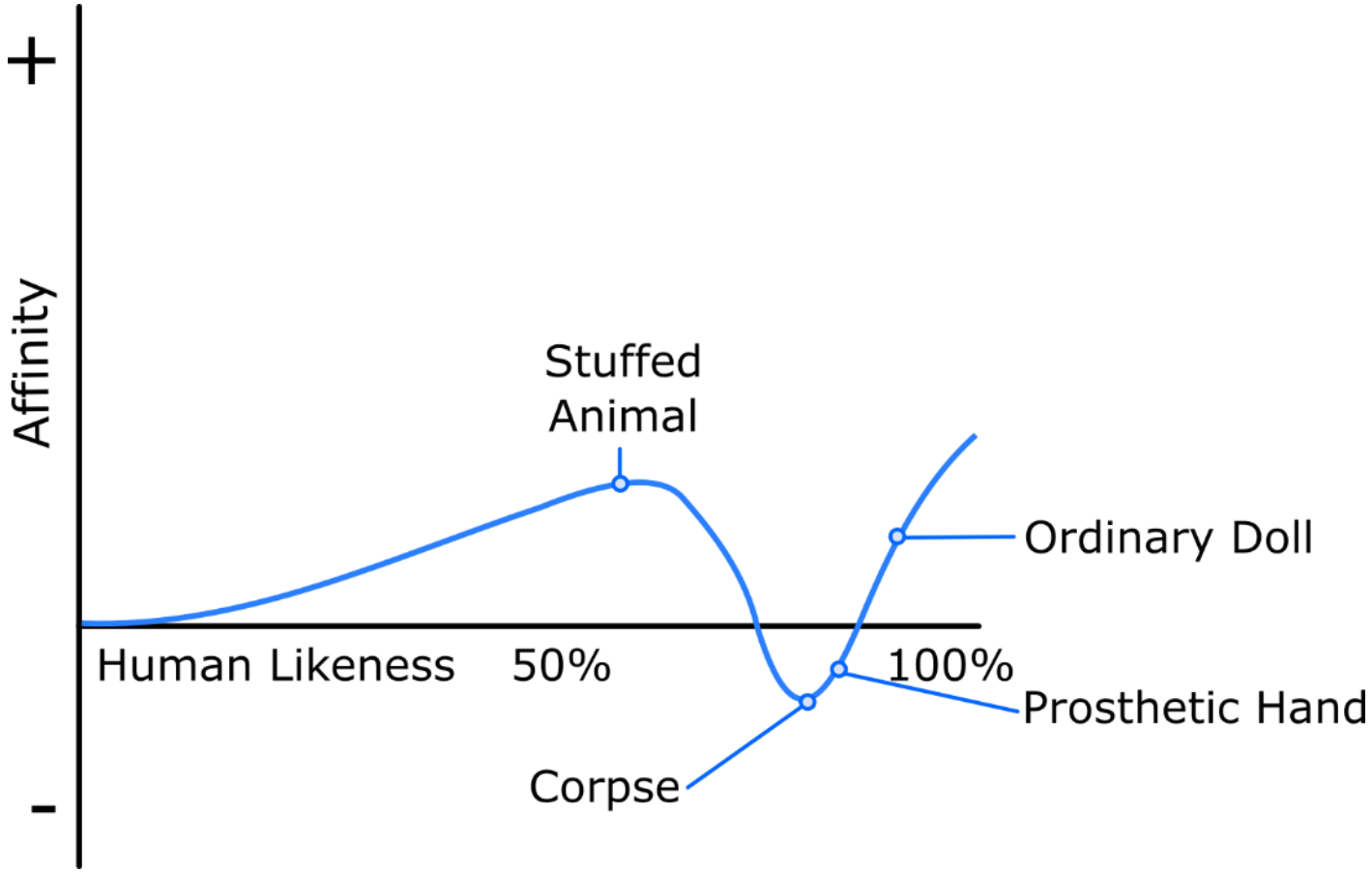


Nelson Mandela

Lady Diana

ABOUT COSMESIS

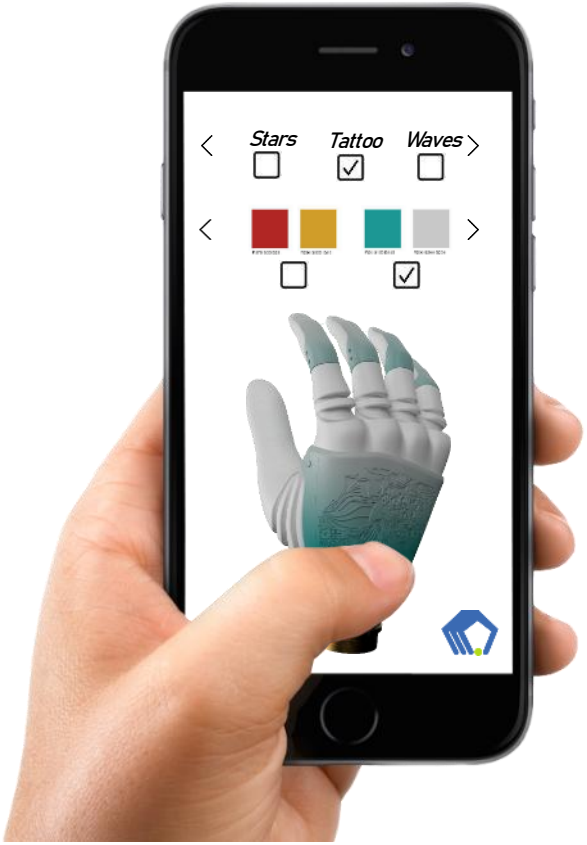
The uncanny valley

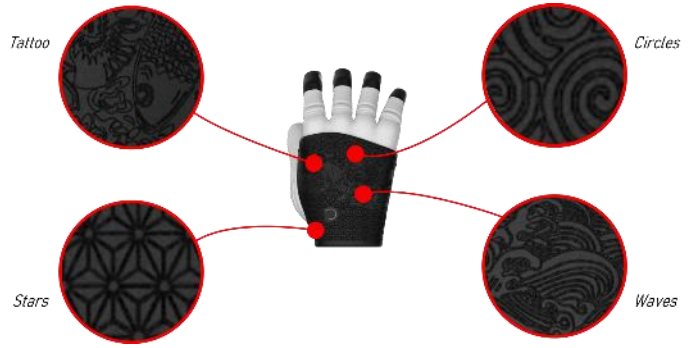


Mori, Masahiro. "The uncanny valley: the original essay by Masahiro Mori." *Energy* (1970).

MIA HAND PROSTHESIS

Customization





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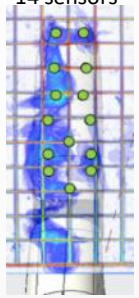
reddot award 2019
winner

Enabling force and contact location feeback

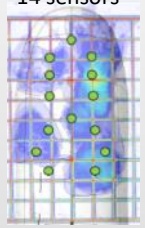
Index/Middle

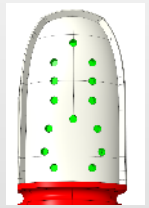
14 sensors



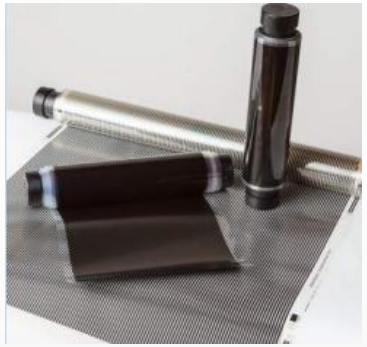
Thumb

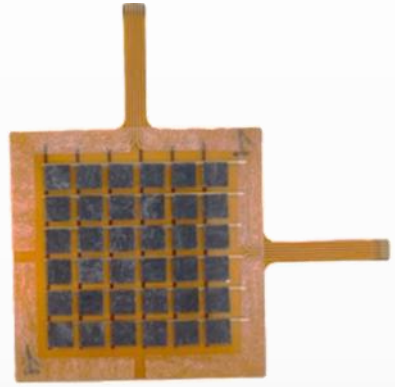
14 sensors



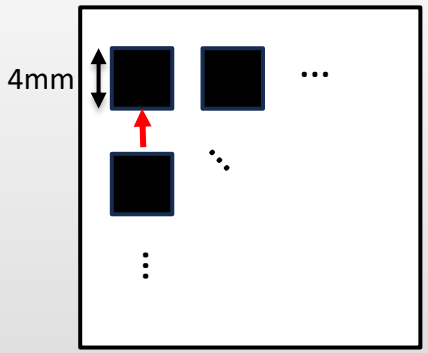


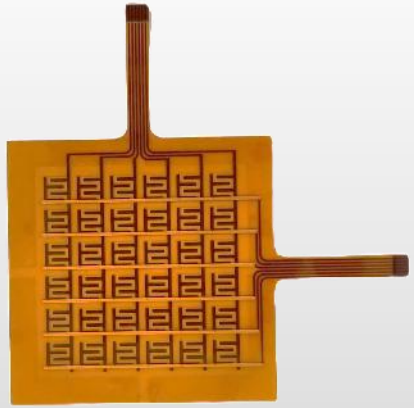
XactFSR





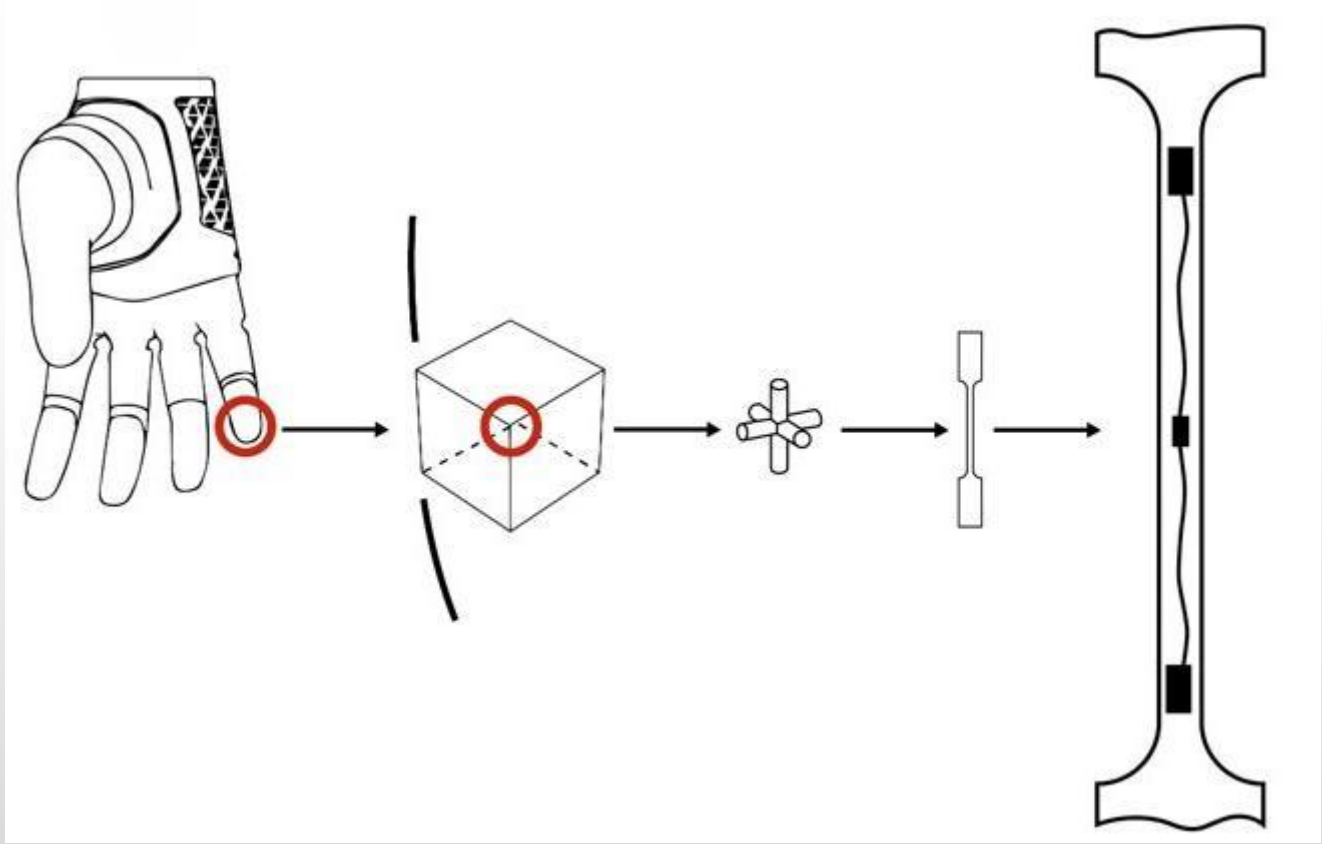
Mylar





Guachi, R., Napoleoni, F., Kabashi, B., & Controzzi, M. (2024, September). Mechanical Integration of a Sensorized Skin in an Anthropomorphic Hand: Design pipeline and tests. In *2024 10th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob)* (pp. 345-351). IEEE.

Exploiting lattice structure (AM) to reduce weight



What are we missing?

The multi-grip and standard myoelectric hand prosthesis compared: does the multi-grip hand live up to its promise?

Nienke Kerver[1*†], Verena Schuurmans[2†], Corry K. van der Sluis[3] and Raoul M. Bongers[4]

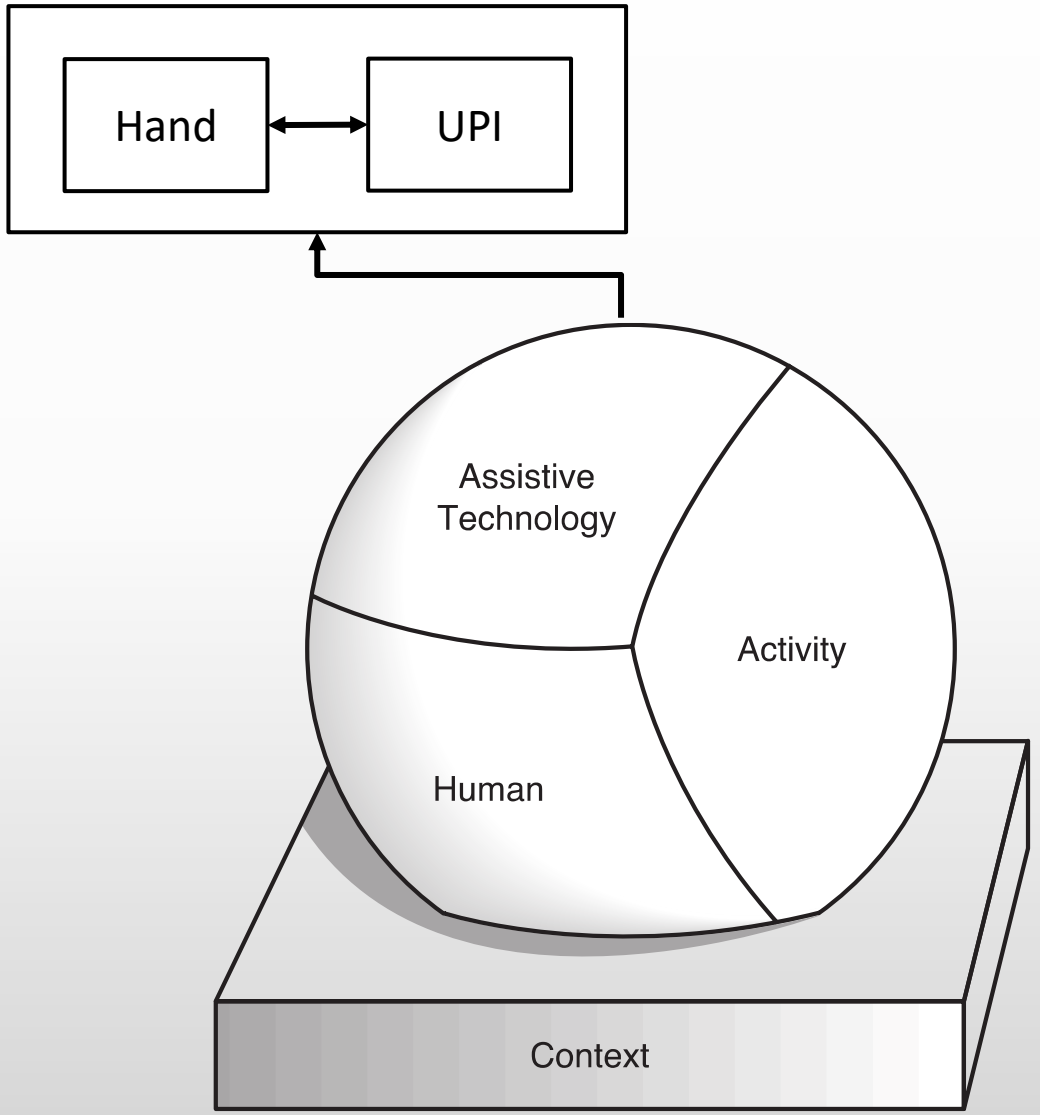
Abstract

Background Multi-grip myoelectric hand prostheses (MHPs), with five movable and jointed fingers, have been developed to increase functionality. However, literature comparing MHPs with standard myoelectric hand prostheses (SHPs) is limited and inconclusive. To establish whether MHPs increase functionality, we compared MHPs with SHPs on all categories of the International Classification of Functioning, Disability, and Health-model (ICF-model).

Methods MHP users (N = 14, 64.3% male, mean age = 48.6 years) performed physical measurements (i.e., Refined Clothespin Relocation Test (RCRT), Tray-test, Box and Blocks Test, Southampton Hand Assessment Procedure) with their MHP and an SHP to compare the joint angle coordination and functionality related to the ICF-categories 'Body Function' and 'Activities' (within-group comparisons). SHP users (N = 19, 68.4% male, mean age = 58.1 years) and MHP users completed questionnaires/scales (i.e., Orthotics and Prosthetics Users' Survey—The Upper Extremity Functional Status Survey /OPUS–UEFS, Trinity Amputation and Prosthesis Experience Scales for upper extremity/TAPES-Upper, Research and Development-36/RAND-36, EQ-5D-5L, visual analogue scale/VAS, the Dutch version of the Quebec User Evaluation of Satisfaction with assistive technology/D-Quest, patient-reported outcome measure to assess the preferred usage features of upper limb prostheses/PUF-ULP) to compare user experiences and quality of life in the ICF-categories 'Activities', 'Participation', and 'Environmental Factors' (between-group comparisons).

Results 'Body Function' and 'Activities': nearly all users of MHPs had similar joint angle coordination patterns with an MHP as when they used an SHP. The RCRT in the upward direction was performed slower in the MHP condition compared to the SHP condition. No other differences in functionality were found. 'Participation': MHP users had a lower EQ-5D-5L utility score; experienced more pain or limitations due to pain (i.e., measured with the RAND-36). 'Environmental Factors': MHPs scored better than SHPs on the VAS-item holding/shaking hands. The SHP scored better than the MHP on five VAS-items (i.e., noise, grip force, vulnerability, putting clothes on, physical effort to control) and the PUF-ULP.

Conclusion MHPs did not show relevant differences in outcomes compared to SHPs on any of the ICF-categories. This underlines the importance of carefully considering whether the MHP is the most suitable option for an individual taking into account the additional costs of MHPs.



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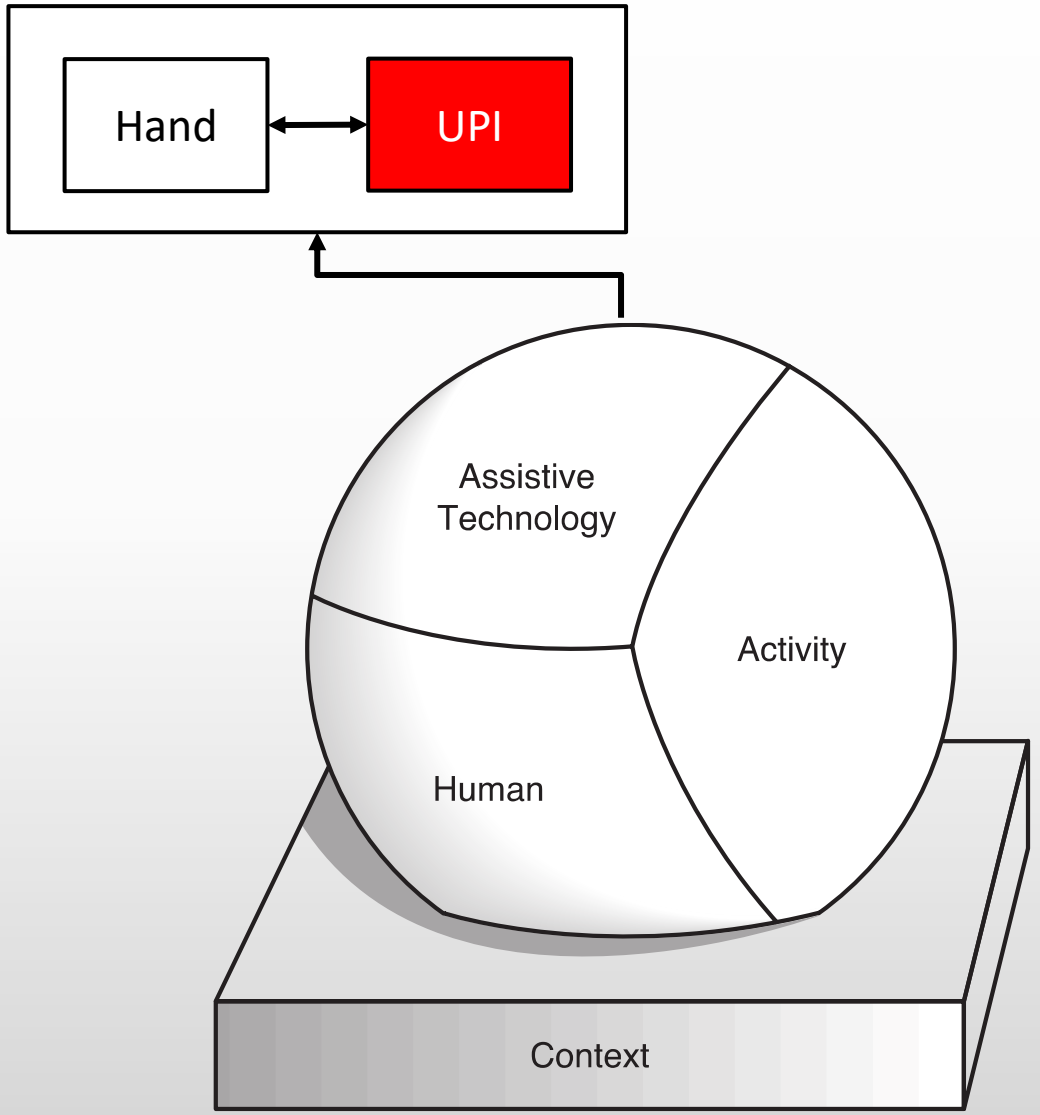
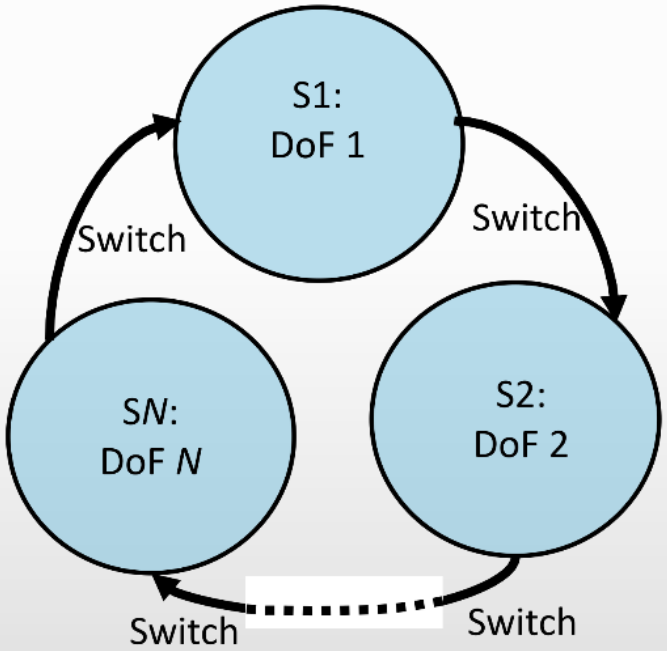


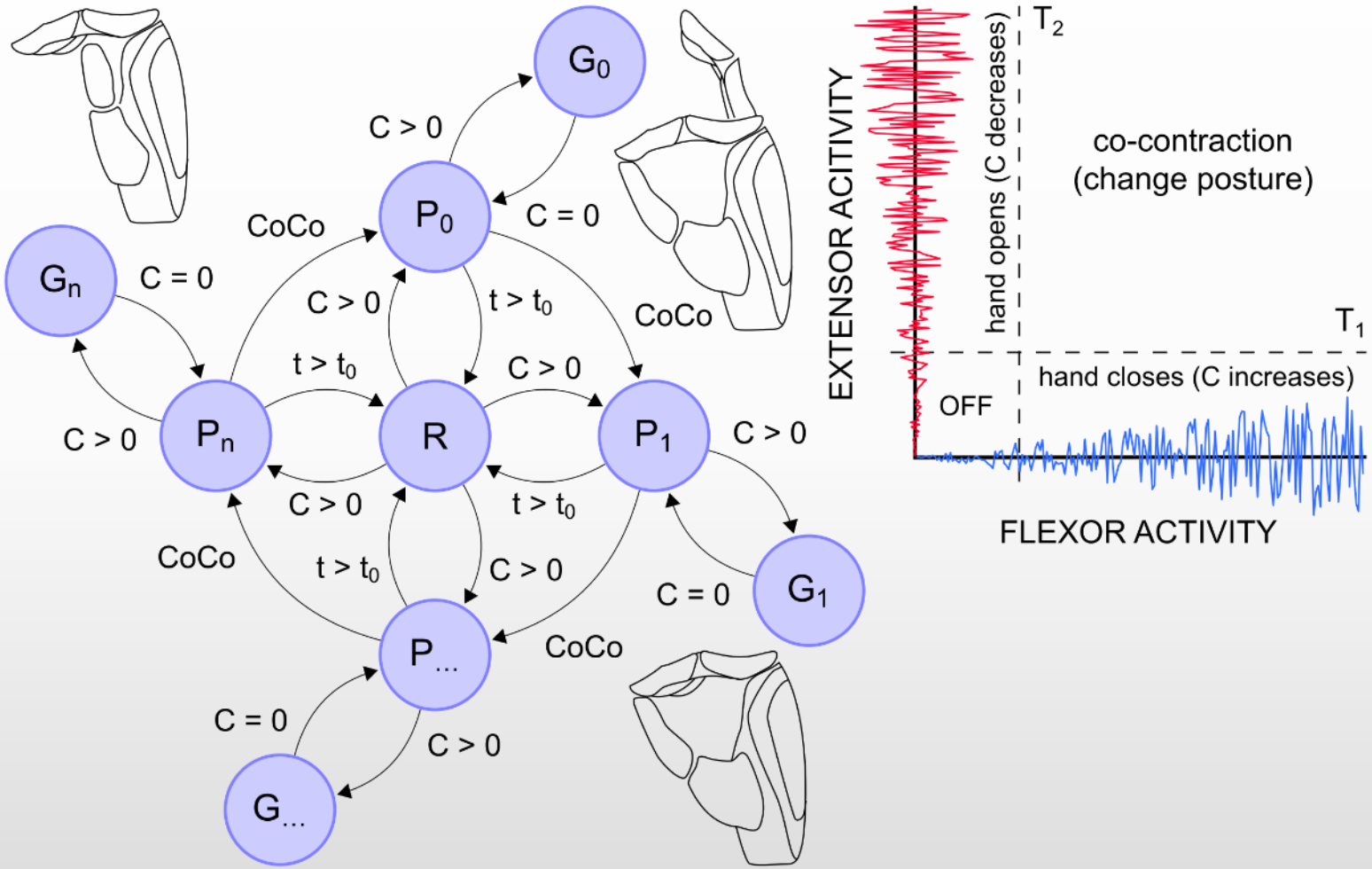
What are we missing?

Control limitations

- Limited number of control sites
- Impossibility to control multiple DoFs independently
- Impossibility to control multiple DoFs simultaneously



Parker, P., et al.. "Myoelectric signal processing for control of powered limb prostheses." *Journal of electromyography and kinesiology*, 2006.
Salminger, Stefan, et al. "Current rates of prosthetic usage in upper-limb amputees–have innovations had an impact on device acceptance?." *Disability and Rehabilitation*,2020.



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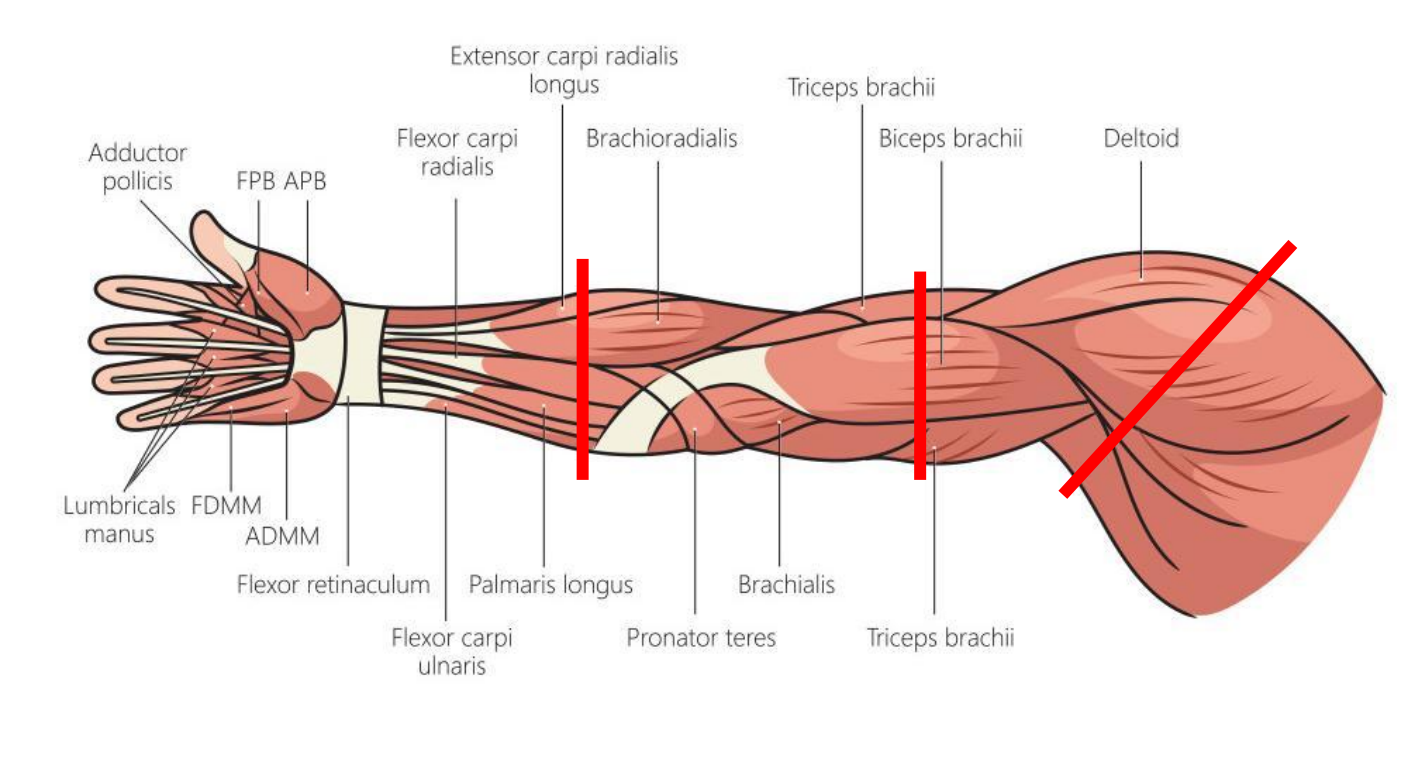
The paradox

… the more proximal the amputation, the fewer input sources are available, yet the greater the number of DoFs the user must control.



DeTOP
Dexterous Transradial Osseointegrated Prosthesis with neural control and sensory feedback

Ortiz-Catalan, M., Zbinden, J., Millenaar, J., D'Accolti, D., Controzzi, M., Clemente, F., ... & Brånemark, R. (2023). *A highly integrated bionic hand with neural control and feedback for use in daily life*. *Science Robotics*, *8*(83), eadf7360.

THE BIOROBOTICS INSTITUTE

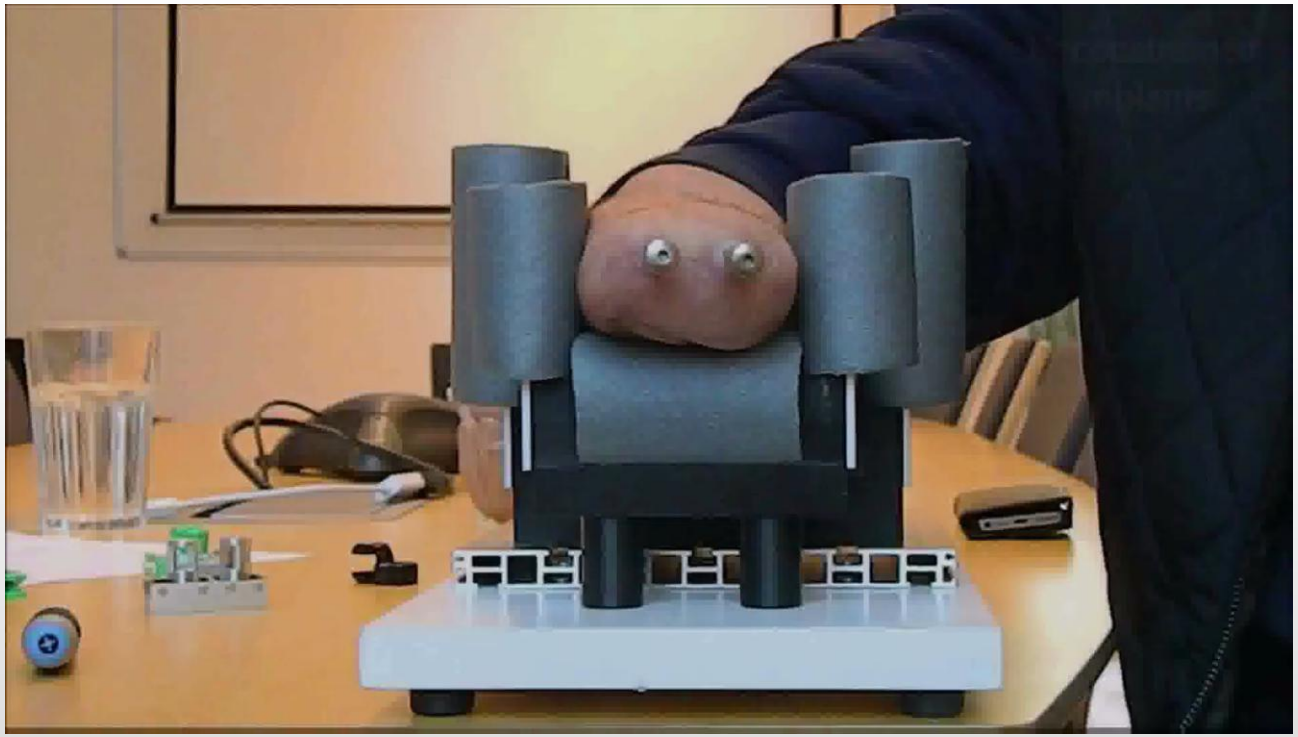
CRATOS

HEARLIGHT

nemobmi

DeTOP

Dexterous Transradial Osseointegrated Prosthesis with neural control and sensory feedback



Impact of preserved forearm rotation by bone-anchoring implants and an artificial wrist joint on activities of daily living

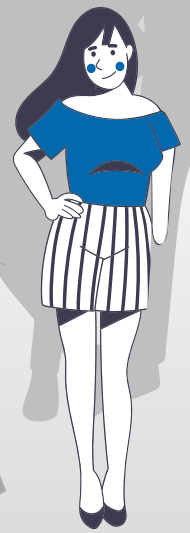
Boni, I., Millenaar, J., Controzzi, M., & Ortiz-Catalan, M. (2018). Restoring natural forearm rotation in Transradial Osseointegrated amputees. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 26(12), 2333-2341.

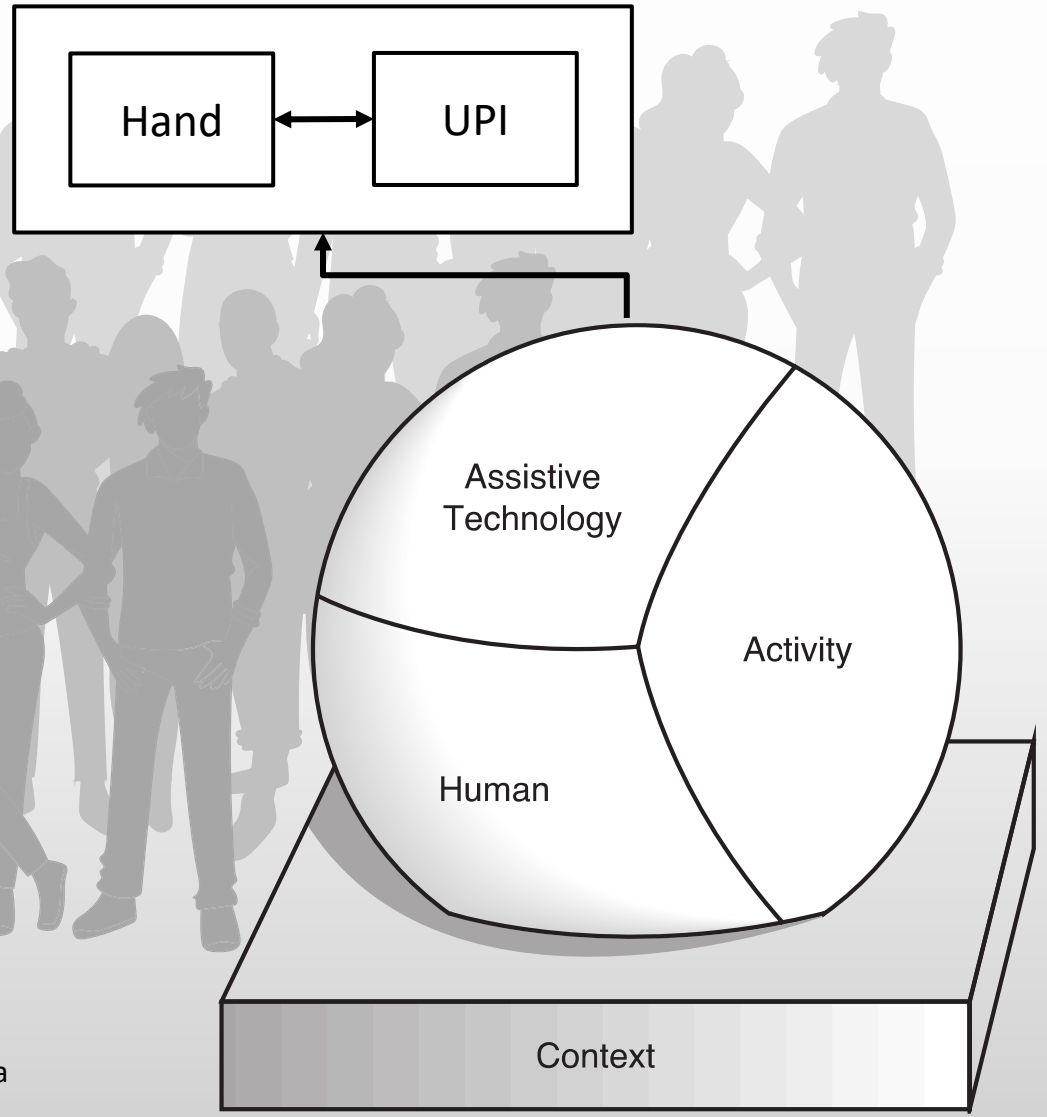
F. Montagnani, M. Controzzi, C. Cipriani, "Is it finger or wrist dexterity that is missing in current hand prostheses?, *IEEE in Transactions on Neural Systems & Rehabilitation Engineering*, 23 (4), 2015.

What's next?

Hand
- Personalization
- Actuators
- Battery

UPI
- Shared autonomy
  - *Mixing other inputs*
  - *Contextual informations*
- Learning





Thank you for your attention!

marco.controzzi@santannapisa.it