

Enhancing Surgical Team Collaboration and Situation Awareness through Multimodal Sensing

Arnaud Allemang--Trivalle

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**MAX PLANCK INSTITUTE
FOR INTELLIGENT SYSTEMS**



IMT Atlantique
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École Mines-Télécom

Lab-STICC

Surgery: a stage for vital collaboration

- **Team effort:** Surgeons, anesthesiologists, and nurses collaborate actively
- **Critical, complex and stressful situation**



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Surgery: a stage for vital collaboration

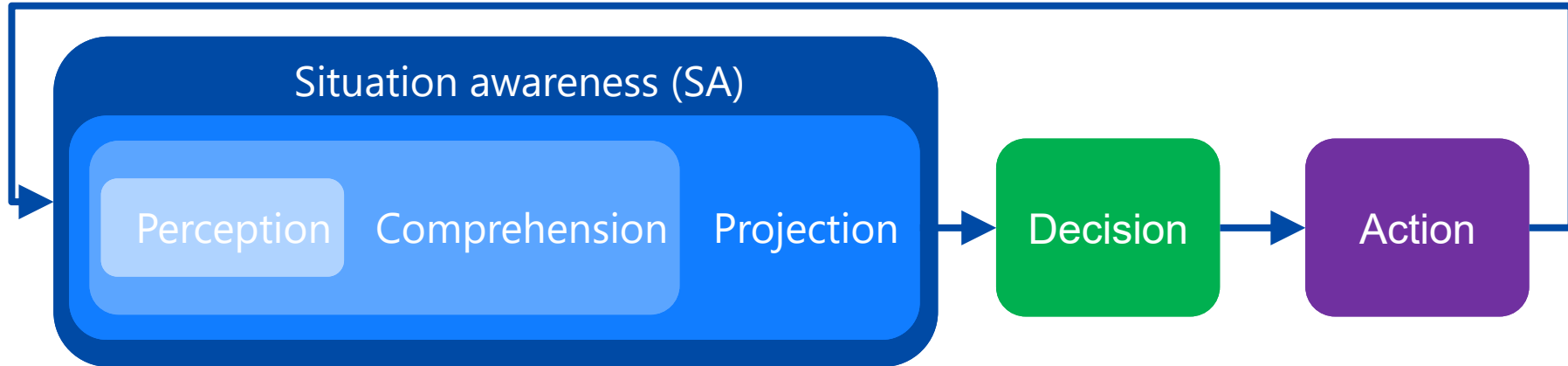
Surgical errors are affected by situation awareness (SA) and collaboration

(A. A. Gawande, 2003) :

- Stress, mental workload (33% surgical errors)
- Collaboration issues (43% surgical errors)

Collaboration and SA

Feedback on state of the environment



"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (M. Endsley, 1995)

Collaboration and SA

In the operating room (OR):

- Responsibilities and knowledge of the situation are shared (B.M. Gillespie, 2013)
- Team processes (coordination, communication) to integrate information and knowledge about the environment and situation of each team member (N.J. Cooke, 2001).

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→ Quantifying the situation using multimodal data to reduce errors

Research questions

(RQ1) How to manage ethical and technical challenges in OR multimodal data collection?

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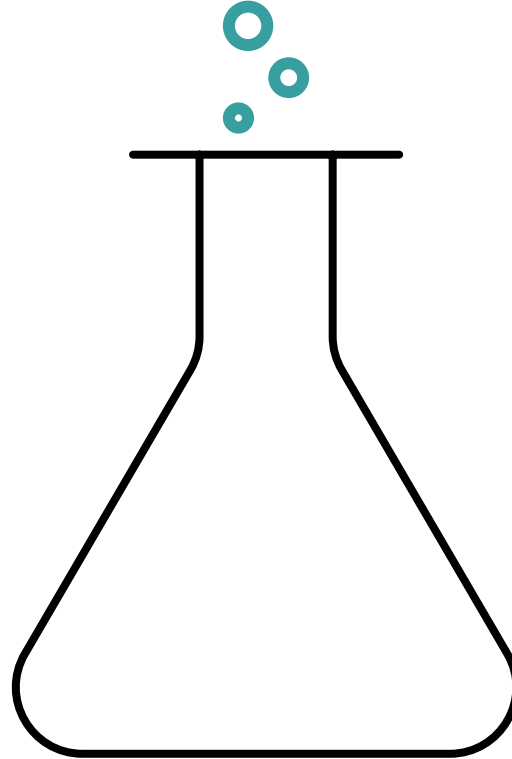
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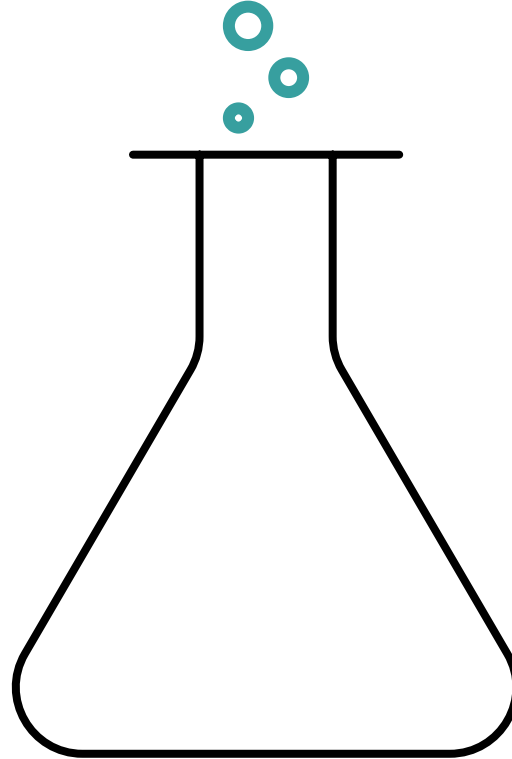
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(RQ5) How to build AI that predicts errors and adverse events in surgery?

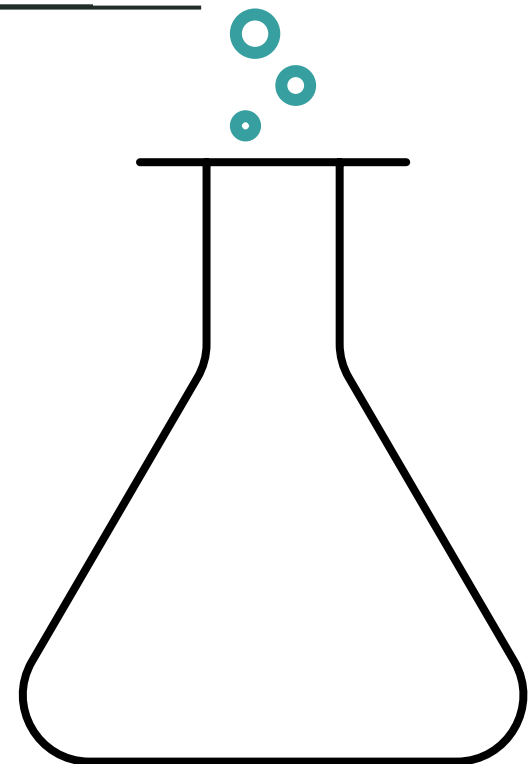
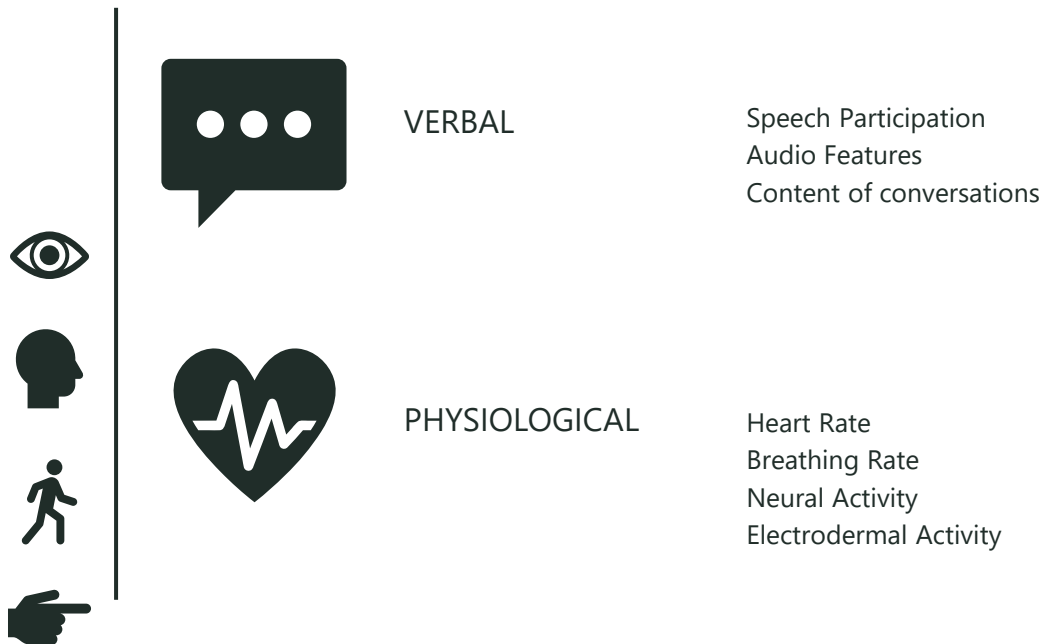
(RQ1) Collaborative tasks are complex



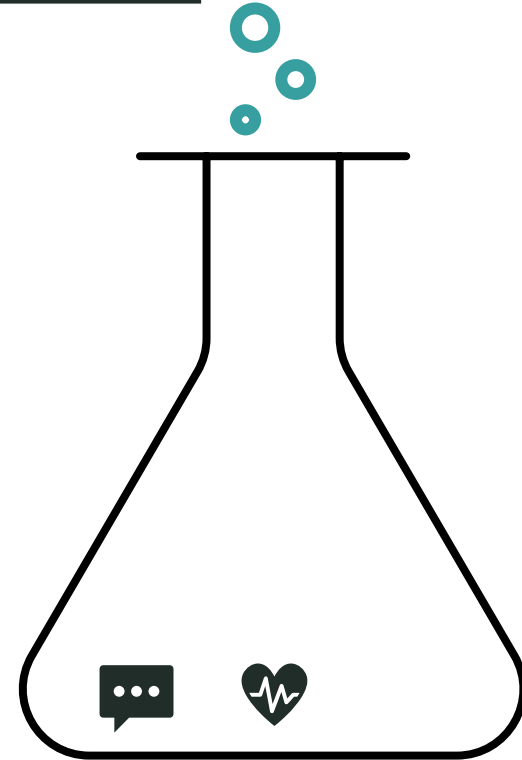
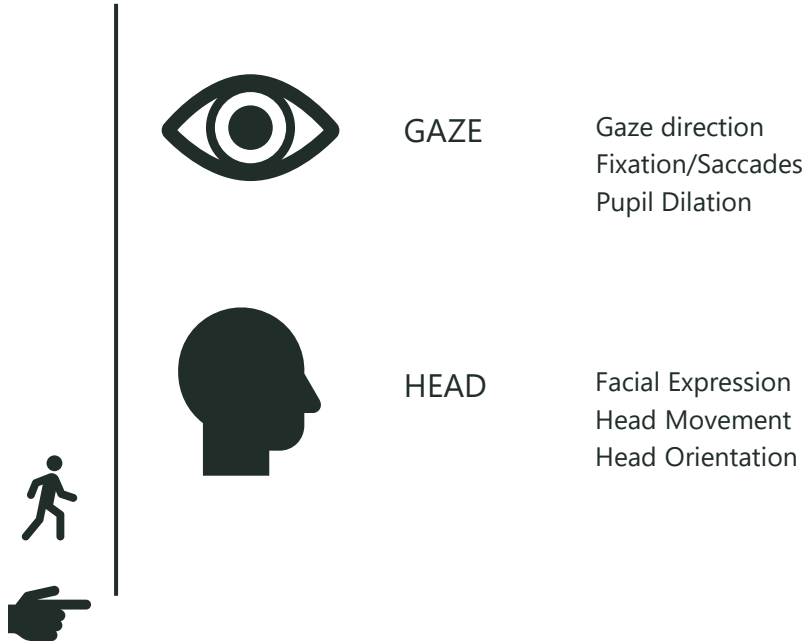
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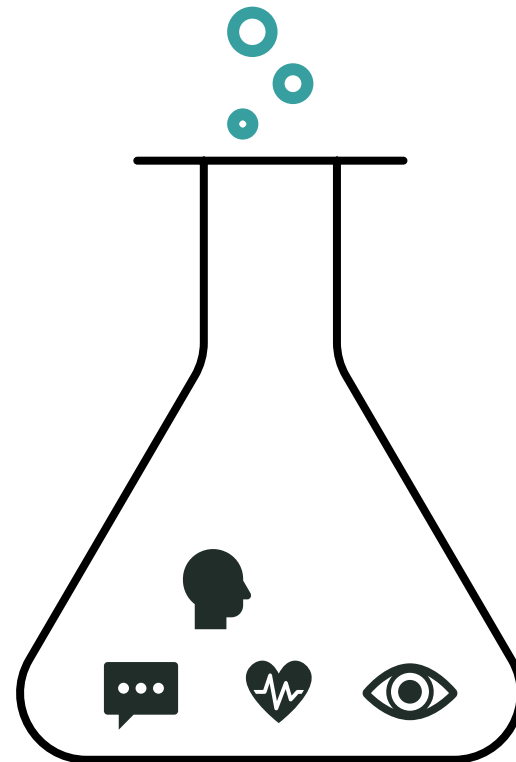
BODY

Hand Gesture
Location
Body Language

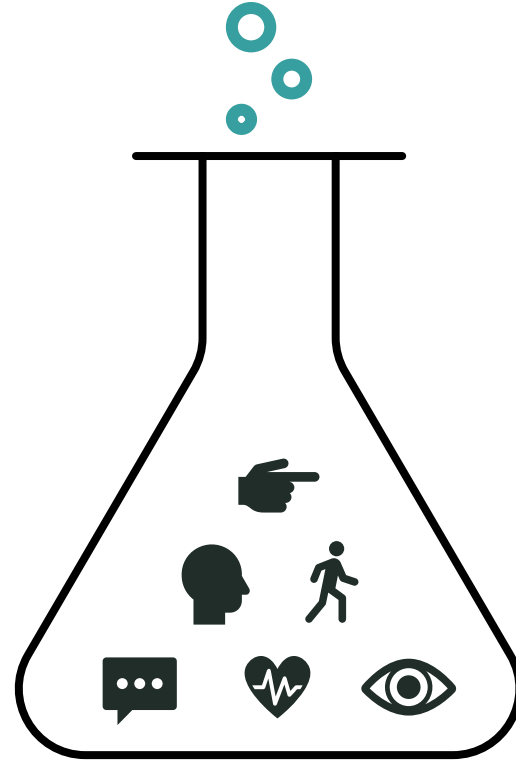


ACTION

Writing
Task-Related Action



(RQ1) Too many modalities



(RQ1) Many OR constraints

- Need a non-invasive and comfortable setup
- Must comply with sterility constraints
- Not allowed to use the power sockets in the OR




OR n°3 Centre Hépatobiliaire Paul Brousse

(RQ1) Setup (☑)

Machine-readable

Wearable sensors



1 Lavalier microphone

2 Physiological garment

3 Tracking tag

4 Audio transmission system


5 Wi-Fi router

6 Computer (Microsoft PSI)

(RQ1) Setup (☑)

Machine-readable

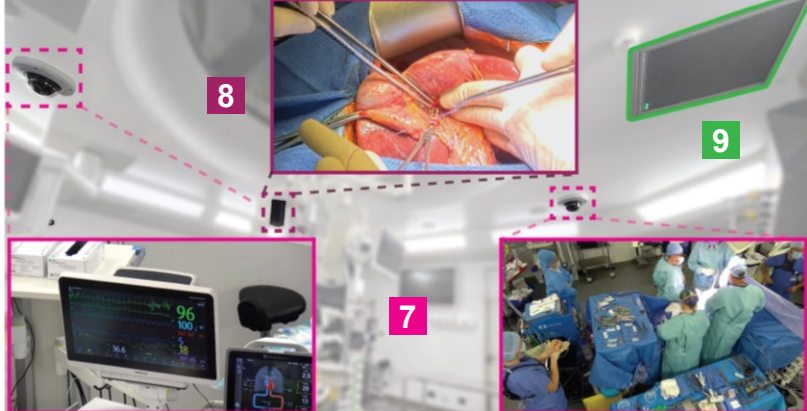
Wearable sensors



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Human-readable

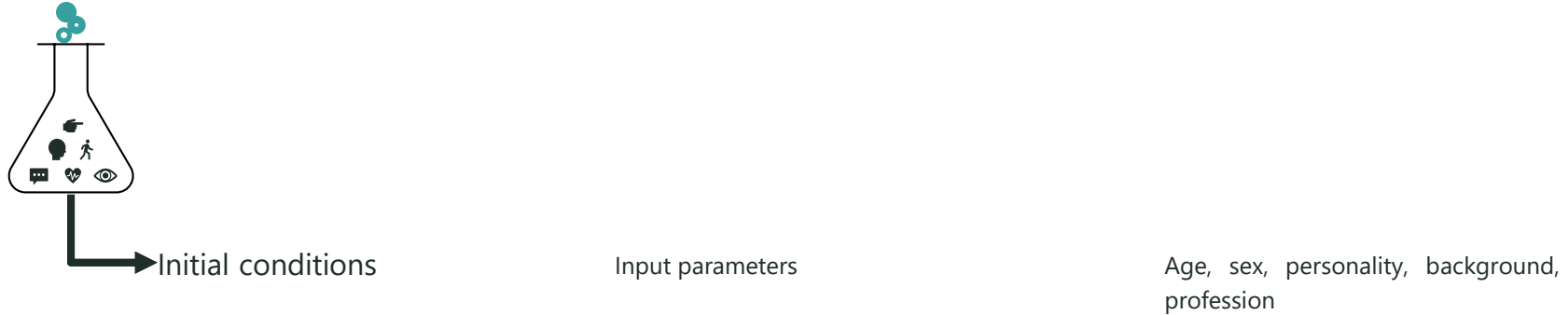
Operating room sensors



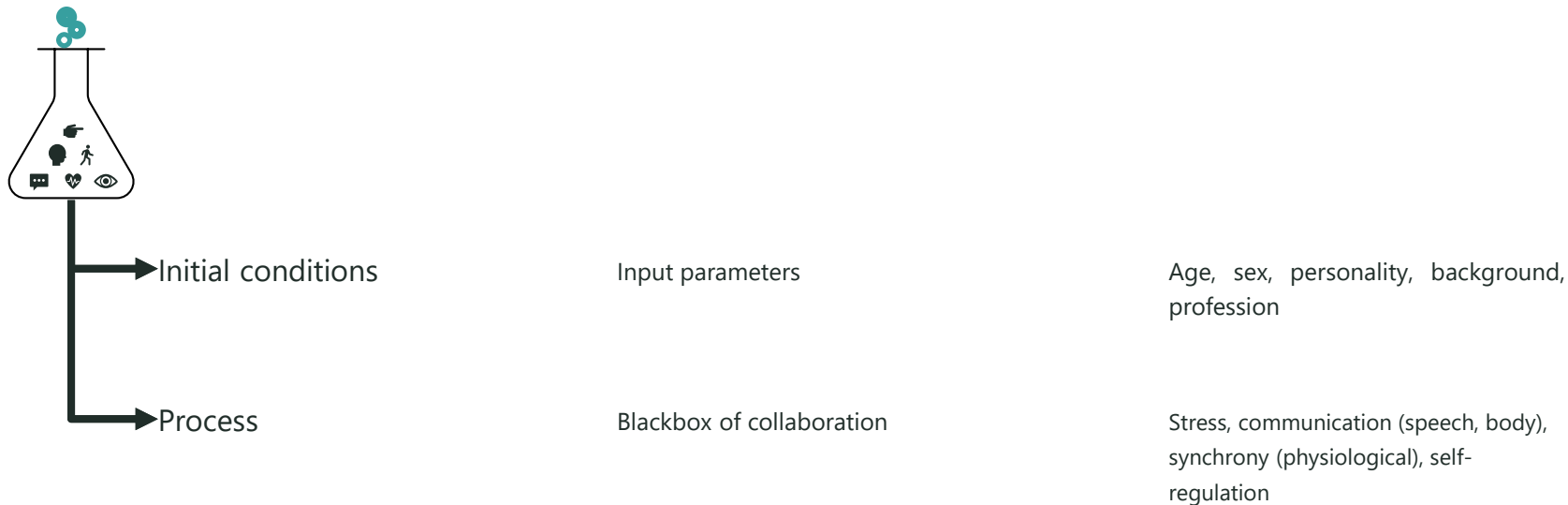
OR n°3 Centre Hépatobiliaire Paul Brousse

7 PTZ cameras	8 Surgical camera	9 Ceiling microphone
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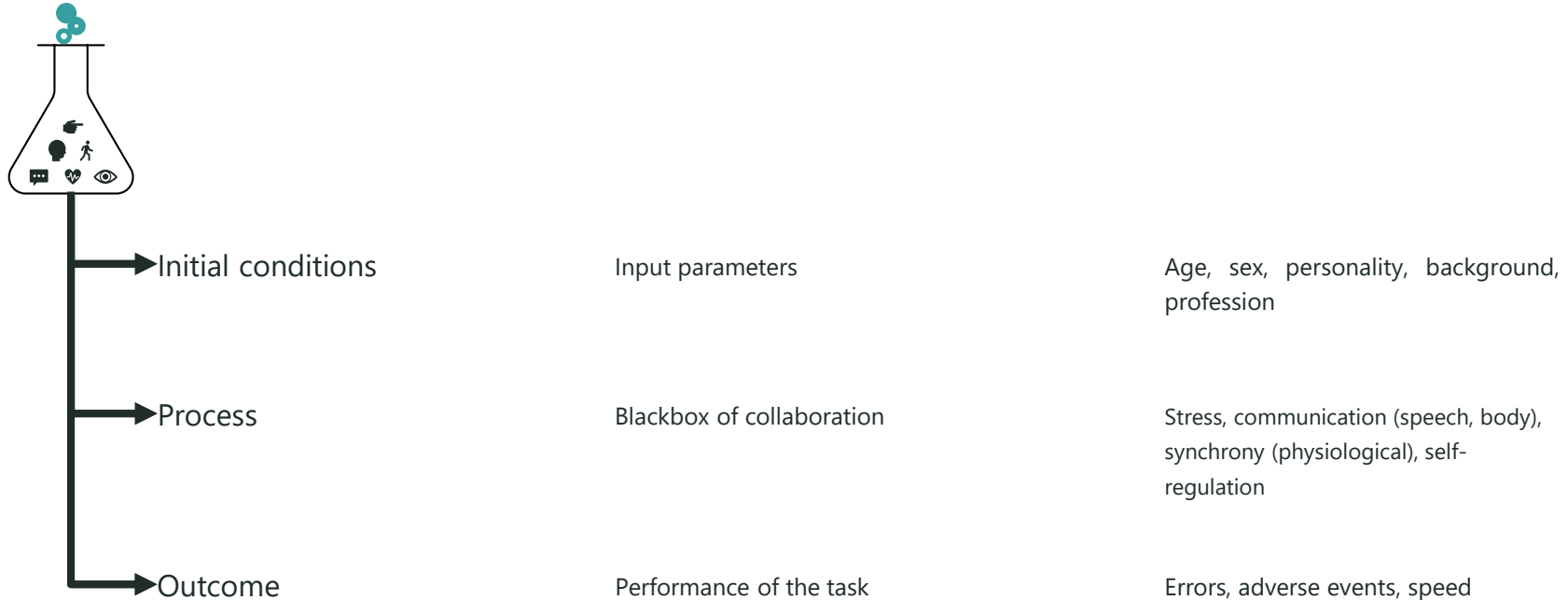
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Questionnaires

Get to know the people:

- **Background:** e.g., age, gender, job, role, experience
- **Conditions:** e.g., quality of sleep, time since last meal
- **Relationships:** familiarity with other team members

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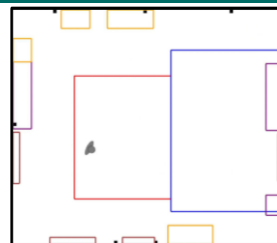
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Metrics

- 1 **Speech**
- 2 **Physiological data**
- 3 **Localization**



User

- Speech flow
- Stress and mental workload
- Proximity to areas of interest

Team

- Overlapping speech
- Physiological synchrony
- Proximity to team members

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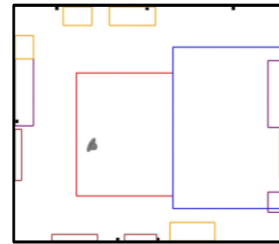
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Surgical context

Annotations made by surgeons using ELAN:

- **Surgical steps and phases:** e.g., incision, suture, ligation, intraoperative ultrasound
- **Errors:** e.g., cognitive error, communication error, technical error, teamwork error
- **Adverse events:** e.g., bleeding injury, thermal injury, ischemic injury

(RQ3) Augment surgical context (future)

How do you identify moments of interest?

Current OR black box interface (Caresyntax)



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Youtube ©[icahn School of Medicine]



The Mount Sinai Surgical Film Atlas: Cervical Endarterectomy

(RQ3) Augment surgical context (future)

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Current OR black box interface (Caresyntax)



Youtube ©[icahn School of Medicine]



Augmenting the timeline

Stress



Voice activity



Activity level (motion)



(RQ4) Actionable feedback (future)

For learning

Share relevant findings: e.g., nurses who continue to communicate verbally under high-stress conditions enhance patient outcomes in x% of scenarios

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For learning

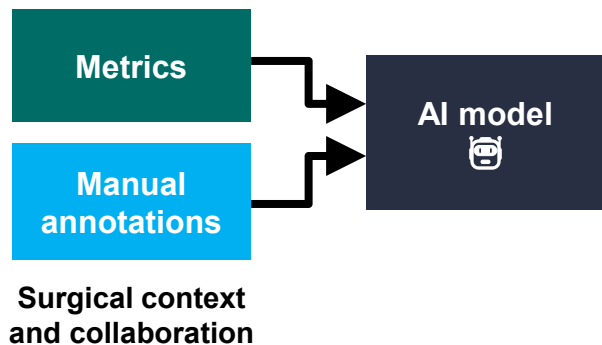
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During surgery

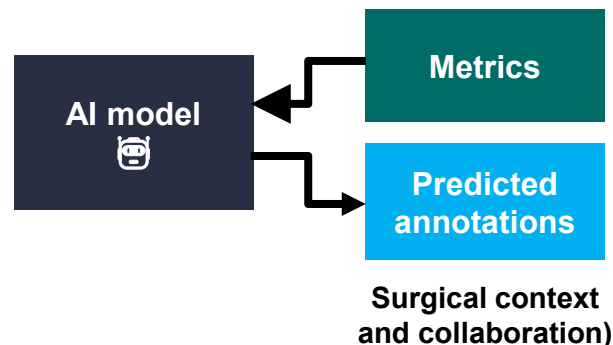
- **Report anomalies:** e.g., team member who does not react to changes in situation
- **Suggest actions:** e.g., the team is overwhelmed; it is recommended to replace X

(RQ5) AI (future?)

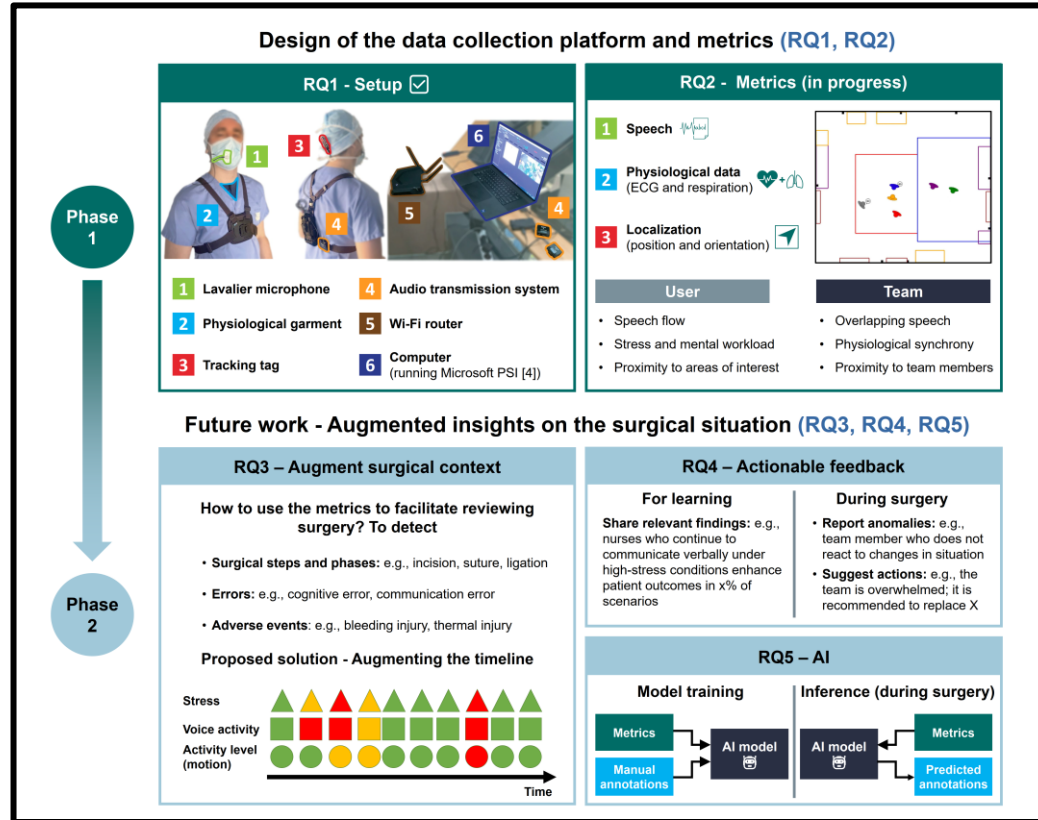
Model training



Inference (during surgery)



Summary



Acknowledgments

- **Doctoral supervisors:** Caroline G.L. Cao, Mathieu Chollet and Katherine J. Kuchenbecker
- **Surgical collaborators:** Eric Vibert, Nesrine Mekhenane and Clément Cormi
- **Intern:** Moaz Hudhud Mughrabi
- **And many others:** Cédric Dumas, Bernard Javot, Joey Burns, Aurélien Milliat, Karine Callement...



References

- **Publications:**

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- Gillespie, B. M., Gwinner, K., Fairweather, N., & Chaboyer, W. (2013). Building shared situational awareness in surgery through distributed dialog. *Journal of Multidisciplinary Healthcare*, 6, 109–118.
- Cooke, N. J., Stout, R. J. R. J., & Salas, E. (2001). A knowledge elicitation approach to the measurement of team situation awareness. *New trends in cooperative activities: Understanding system dynamics in complex environments*, 114–139.
- Gawande, A. A., Zinner, M. J., Studdert, D. M., & Brennan, T. A. (2003). Analysis of errors reported by surgeons at three teaching hospitals. *Surgery*, 133(6), 614–621.

- **Software:**

- Microsoft PSI: <https://github.com/microsoft/psi>
- ELAN: <https://archive.mpi.nl/tla/elan>
- Caresyntax: <https://caresyntax.com/>

- **Illustrations:**

- [ihorvsn] /Adobe Stock
- The Mount Sinai Surgical Film Atlas: Carotid Endarterectomy, Icahn School of Medicine, Youtube

Thank you.

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Paper

