Introducing Assistive Assembly: Reducing cognitive workload, unlocking efficiency

André Cardoso[1]

andre.cardoso@dps.uminho.pt

Supervisor(s): Ana Colim[2], Estela Bicho[1], Ana Cristina Braga[3]

1. Algoritmi Research Centre/ LASI, University of Minho, Guimarães, Portugal
2. Digital Transformation Colab and Algoritmi Research Centre/ LASI, University of Minho, Guimarães, Portugal

MIT Portugal 2023 Annual Conference

1 INTRODUCTION

- In today's fast-paced and competitive Industry, **assembly tasks** often **demand high levels** of **concentration**, **precision**, and **cognitive effort** [1].
- These challenges can lead to **mental fatigue**, **errors**, and **decreased efficiency** among workers [2].
- **Assistive Assembly** may represent the perfect **synergy** between **human dexterity** and **cutting-edge technology.**
- Integrating **ergonomics** and **robotics** together, may offer invaluable **support** to assembly line workers, **empowering** them to **achieve their best performance effortlessly** [3].
- This work is a **proof-of-concept** to assistive assembly, where we further will attempt **to develop** an **assistive-adaptative workstation** composed of a worker, a collaborative robot, and a video-camera system.

2 OBJECTIVE

Compare the **cognitive workload** experienced by workers between **assistive** and **non-assistive manual assembly.**

3 METHODOLOGY

Assembly of **3 types of windows,** with the following dimensions:
- 400mm x 500mm
- 400mm x 600mm
- 500mm x 600mm

This task is **cognitively demanding** as:
- there are several possible parts and orientations for assembling the different windows.
- each window have parts in common with the others.

1. **Hinges assembly**
2. **'L' frames assembly**
3. **Merging 'L'-frames into a window**

Windows assembly

Simulated assembly task

C1: Non assistive
- Parts delivered when the participant asked, pointing to the desired part;
- Parts always delivered in a predefined orientation;
- Parts delivered within the participant's normal reach.

C2: Assistive
- Parts delivered as the subject needed them (without asking);
- Parts delivered in the correct assembly orientation;
- Parts delivered on the respective mounting side.

Randomly between participants

Statistical analysis

During each condition
- Type of errors
  - Choosing the wrong part;
  - Assembling in the wrong orientation

Registration of the number of errors.

End of each condition

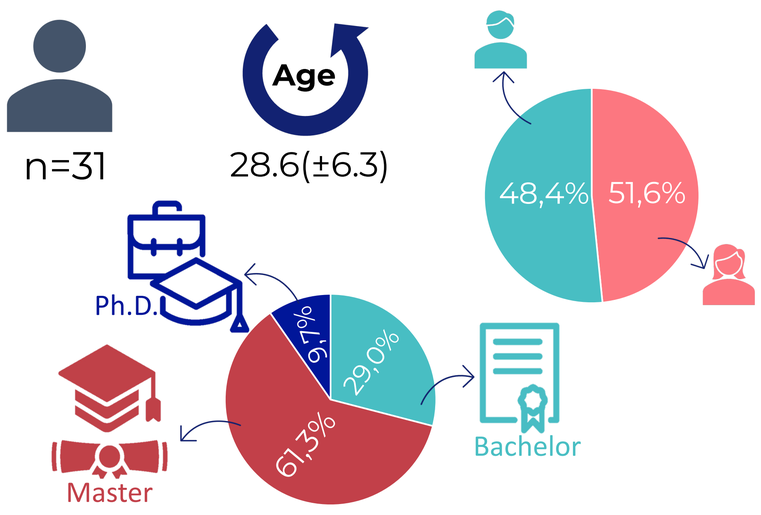
100 / 0

NASA Task Load Index application [4].

Perceived subjects' ratings on these six dimensions.
- Mental Demand
- Physical Demand
- Temporal Demand
- Performance
- Effort
- Frustration

4 RESULTS AND DISCUSSION

4.1. Sociodemographic characterization



4.2. Perceived cognitive workload

- The **perceived cognitive workload** reported by the subjects is **statistically lower** in the **assistive condition.**
- The main **contributors** for this score are the **mental demand**, the **performance** and the **effort**.

This points out, that **assistive assembly** may reduce the mental and perceptual activity required, increase the satisfaction and make it easier to assemble a window.

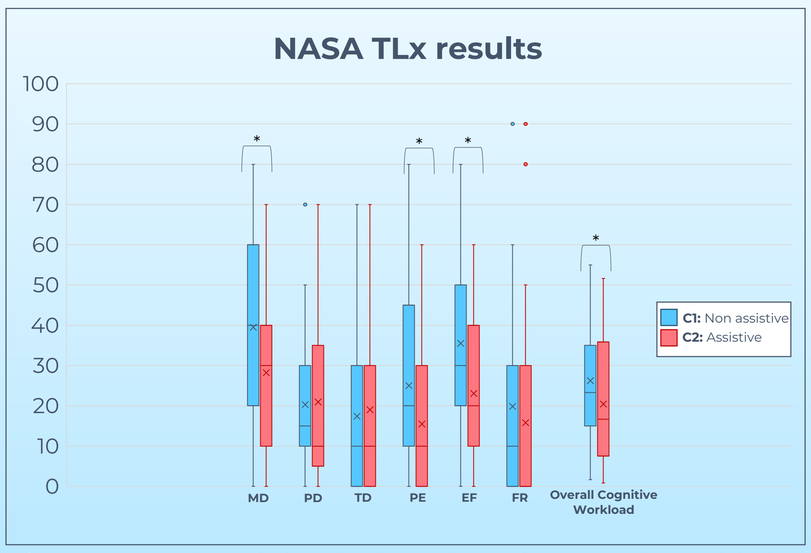


Figure 1: Box-plots of the six dimensions of NASA-Task Load index (NASA TLx) and Overall Cognitive Workload for both conditions (C1: Non-assistive; C2: Assistive). Significant results ($p<0.05$) are marked with *. MD –Mental Demand; PD – Physical Demand; TD – Temporal Demand; PE-Performance; EF –Effort; and FR – Frustration.

4.3. Number of errors

- The results of this study indicate that there is a **statistically significant difference** ($p<0.05$) between the mean test scores of the non-assistive and the assistive conditions.
- A t-test revealed a **t-statistic of 2.78**, which means a **decrease in the number of errors** from condition 1 to condition 2.

Table 1: Mean (SD) number of errors of non assistive (C1) and assistive conditions (C2).

C1: Non assistive	C2:Assistive
0,90 (±1,29)	0,29(±0,21)

t Stat = 2,78; *p* (0.004) <0.05

Note: the performance scale is inverted. A lower value means that performance was better [4].

5 CONCLUSIONS

- **Assistive condition** compared with Non assistive condition:

Decrease on Mental Demand. | Increase on Performance. | Decrease on Effort. → Statistically Significant

Overall conclusions

Decrease on Cognitive Workload. | Decrease on number of errors.

6 FUTURE WORK

Although the **promising results**, further development and testing is needed:
- Use of more accurate techniques for direct measurement of mental workload.
- Development of a computer vision system endowed with a framework for real-time ergonomic assessment of the cognitive status of the worker.
- Integrate the vision system into the robot architecture.
- Map of the robotic actions according to the results of the framework.
- Conduct user studies in real human-robot collaborative tasks and assess the worker's cognitive workload and the dyad's efficiency.

7 REFERENCES

Funded by:

Fundação para a Ciência e a Tecnologia

MIT Portugal

This work also received support from *FCT Project I-CATER (ref. PTDC/EEI-ROB/3488/2021), R&D Unit Project Scope UIDB/00319/2020, and DTx CoLAB under the Missão Interface of the Recovery and Resilience Plan, integrated in the notice 01/C05-i02/2022.*

under the Doctoral Grant SFRH/151365/2021 | Digital Transformation in Manufacturing