Exploring Multimodal Interactions with a Robot Assistant in an Assembly Task: A Human-Centered Design Approach

Simona D'Attanasio[a], Théo Alabert, Clara Francis and Anna Studzinska[b]
Icam School of Engineering, Toulouse Campus, 75 av. de Grande Bretagne, CS 97615, 31076 Toulouse Cedex 3, France

Keywords: Human-Robot Interaction, Multimodality, Human-Centered Design, Bidirectional Interaction, Robot Assistant.

Abstract: The rise of collaborative robots, or cobots, has opened up opportunities for shared operations between humans and robots. However, the transition to true human-robot collaboration faces challenges depending on the context and on the implemented interactions. This article aims to contribute to the evolving field of Human-Robot Interaction by addressing practical challenges in real-world scenarios and proposing a comprehensive approach to bidirectional communication between humans and robots. In particular, our research focuses on an elemental operation during an assembly task, observed in real SMEs (Small and Medium Sized Enterprises). We propose a multimodal bidirectional approach incorporating voice, gesture, visual, haptic, and feedback cues. The study involves a Wizard of Oz series of experiments with test subjects to evaluate user satisfaction, and the overall feeling of interaction, among other aspects. Preliminary analysis supports hypotheses related to the effectiveness of multimodality, the positive reception of simple interactions, and the impact of feedback on user experience.

1 INTRODUCTION

Collaborative robotics is spreading thanks to the availability of collaborative robots, also known as cobots. Those robots are designed to safely operate alongside humans in a shared workspace. In the industrial environment, the cobot manipulators available today allow SMEs (Small and Medium Sized Enterprises) to implement robotics, offering flexible solutions and reducing the integration costs. Cobots are in fact easily reprogrammable by an operator by means of an intuitive programming interface. Depending on the application, the installation of physical barriers can be avoided and cobots can be moved from one place to another. These factors make it possible to adapt them to small batch sizes and facilitate their integration, which are both important constraints for SMEs. In addition, cobots integrate force sensing technology that evaluate and limit the force exerted by the robot. This allows as already mentioned the sharing of the working space (coexistence), but also the execution of a whole new set of operations where robots and humans can work together, not only interacting one next to the other (cooperation), but also jointly on the same task (collaboration).

Even if the technology is available to create interactions with cobots, few real industrial applications exist that accomplish a real human-robot collaboration (Kopp et al., 2020; Michaelis et al., 2020). Since the introduction of robot manipulators in manufacturing, there has been a clear physical separation by design between robots and humans and consequently between tasks allocated to each of them: automated tasks are for robots and manual operations are for humans. Many processes are not designed to be collaborative and applications of cobots are mainly limited to automation solutions, as if they were (not collaborative) robots, exploiting only the advantages mentioned above: ease of programming and flexibility in the installation process. According to (Michaelis et al., 2020), cobot applications should be seen from a worker perspective. Therefore, as stated by the authors, the design of cobots needs to be reframed "to be viewed as augmented supports for human worker activity with an on-board capacity for responding to human action and intent". (Kopp et al., 2020) state that the worker perception of a robot as a

---

[a] https://orcid.org/0000-0002-8595-836X
[b] https://orcid.org/0000-0002-7694-4214

D'Attanasio, S., Alabert, T., Francis, C. and Studzinska, A.
Exploring Multimodal Interactions with a Robot Assistant in an Assembly Task: A Human-Centered Design Approach.
DOI: 10.5220/0012570800003660

In *Proceedings of the 19th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2024) - Volume 1: GRAPP, HUCAPP and IVAPP*, pages 549-556
ISBN: 978-989-758-679-8; ISSN: 2184-4321

trustworthy (affective) supporting device is also considered to be an important factor, which heavily influences acceptance.

Following similar guidelines, industry 5.0 pushes towards a human-centered approach of industrial processes (Adel, 2022) and in particular towards human-robot coworking requiring human-robot interaction (HRI) (Alves et al., 2023), where personal preferences, psychological issues and social implications among other factors should be considered during the design (Demir et al., 2019).

In this context, HRI plays a key role in the accomplishment of a truly collaborative task. The following paragraph proposes related works in the area.

1.1 Related Works

The state of the art is full of very interesting research in the field of HRI. (Kalinowska, 2023) and (Strazdas et al., 2022) propose an exhaustive description of the available modalities, such as gesture, vocal, haptic, vibrotactile, augmented or virtual reality feedback, eye tracking, and many more.

In HRI, multimodality is often implemented to obtain a more effective interaction. As an example, the use of a haptic device is explored by (Alegre Luna et al., 2023) which illustrates the development of a glove for a robot assisting a surgeon, integrating an accelerometer to recognize gestures. The system also integrates the possibility to control a robot with vocal commands using predefined words, each corresponding to a specific action. Another glove is tested by (Rautiainen et al., 2022) also for gestural analysis. The Data Glove is studied in (Clemente, 2017): force and vibration feedbacks are provided to control a robot hand with the assistance of AR (Augmented Reality) in a clinical scenario. Real time eye tracking is performed with glasses in the research conducted by (Penkov et al., 2017). In this experience, an operator is wearing AR glasses with an eye tracking device and a camera. The goal is to achieve a "natural exchange" with the robot, in the sense that the robot will detect which tool the human needs. Also, the robot knows the plan that the operator is executing, so it can anticipate which tool will be needed. More recently, (Villani, 2023) proposes wrist vibration feedback together with light feedback. The challenge is the recognition of vibration patterns and tests are carried out in a simulated industrial environment to perform a collaborative assembly task. In a study by (Male and Martinez Hernandez, 2021), a cobot collaborates with a human in an assembly task by proving the components needed at the right moment, without having to explicitly ask for them. The collaborative actions are predicted by an AI-based cognitive architecture, using inertial measurements to estimate human movements and a camera for environment perception.

Overall, the state of the art shows a big variety of methods and devices and some general conclusions can be drawn with respect to two main issues. The first one is the *context issue*. Few studies propose an experimental set-up related to a real use-case. Most of them are proof of concepts tested in the laboratory environment, that don't always consider all the constraints of a real working environment, such as noise or vision related problems (obstruction, lightning conditions). This means that although human-centered design should be at the very core of HRI research, efforts still need to be made to consider user needs and psychology. Moreover, the experimental set-ups often concern the execution of a predefined sequence of steps to which the robot can contribute in more or less intelligent way.

The second one is the *interaction issue*. Even if the integration of technology to foster bidirectional communication between a robot (or an agent in general) and a human, to "improve mutual understanding and enable effective task coordination" (Marathe, 2018) is studied, research is more focused on the robot's ability to understand the human (Wright et al., 2022). Multimodality is often implemented, but the number of patterns and modality can rapidly add complexity to the interaction and, paradoxically, end up contributing to the human workload. Moreover, interactions between the human and the robot are rarely designed to explicitly manage failure (errors of the robot) and misunderstanding.

1.2 Research Objectives

The research proposed in this article by a team of engineers and of psychologists aims to improve the understanding concerning the above two issues, by designing a multimodal bidirectional interaction for an elementary operation in an assembly task.

To explore the context issue, we consider the operation "bring me that / put it away" without referring to a particular sequence of operations. We carried out informal observations in two SMEs, a manufacturing plant and a cabinetmaker, and found that workers spent a significant proportion of their time looking for tools and other materials. It is difficult to produce a proper quantified analysis and no data could be found in the literature, but they move several times per hour, depending on the particular task. In the case of the cabinetmaker, the task is always different. The idea is to explore the added value of the assistance from a robot in an elementary operation that is widely applicable in any SME context and type, as well in a variety of service environments (e.g. medical, or assistance in general).

To explore the interaction issue, we made the choice of testing multimodal bidirectional interaction implementing simplified patterns providing:

- Voice control through a limited set of words, perceived as a natural way of communicating, especially useful when hands are not free.
- Simple gesture control through a laser pointing device, to offer an alternative to voice control failures, due to noisy environment or to difficulty of the available technology in recognizing accents.
- Control through a tactile device, to provide a well known, smartphone-like interaction device.
- Haptic feedback through vibration, to prevent the operator that the robot is approaching.
- Visual feedback through a moving light spot, to visualize the robot's understanding of the instruction.
- Simple visual feedback of the robot state (happy/unhappy) to communicate to the operator the understanding by the robot of the instruction.

A Wizard of Oz (WoZ) series of tests have been designed (scenario and test protocol) and conducted on a set of trial users, also called test subjects in the paper. Feedbacks from the users have been collected and a preliminary analysis has been performed. The hypotheses that we test with our research are the following:

- Multimodality contributes to higher satisfaction and lower frustration in accomplishing the task.
- Simple interaction is positively and not poorly considered.
- Feedbacks and error recovery improve the "feeling of interaction" and thus the user experience.

The rest of the paper is organized as follows. The next section presents in details the experimental set-up: the implemented interactions, the scenario, and the test protocol. The Results and Discussion section presents the preliminary analysis of the user's feedbacks. The Conclusion section concludes the paper illustrating the next steps of our research.

2 EXPERIMENTAL SET-UP

The experimental set-up, shown in the diagram of Figure 1, proposes to carry out an assembly operation with the help of a robot assistant, whose task is to bring and put away the tools needed for the assembly. The robot is a UR5 cobot from Universal Robots, a 6 degrees-of-freedom industrial manipulator having a reach radius of 850mm and a payload of up to 5Kg. Tools are stored on a vertical wall out of reach of the human within plastic boxes, while the robot's workspace covers the wall and part of the assembly table, allowing the human to reach the robot's end-effector. The implemented interactions allow bidirectional communication between the robot and the human. The scenario is controlled by human WoZ operators. The interactions, the scenarios and the test protocol are detailed in the following paragraphs.

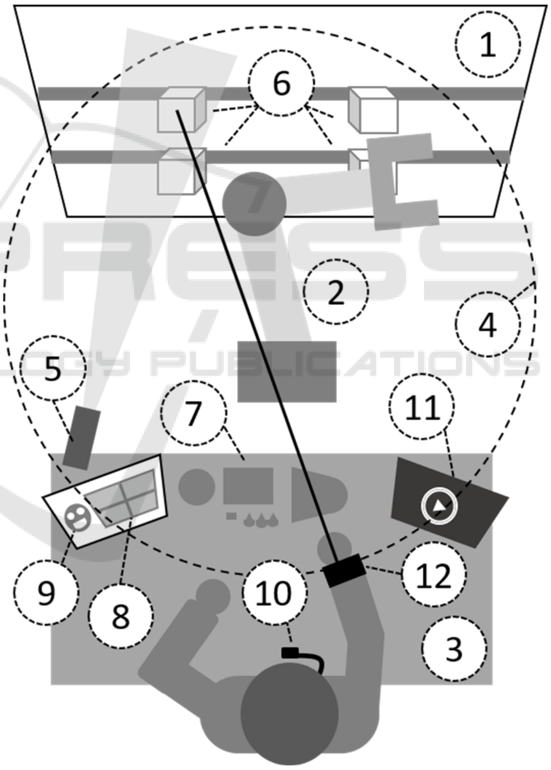

Figure 1: The diagram of the experimental set-up showing the following components: 1) vertical wall, 2) UR5, 3) assembly table, 4) robot workspace, 5) light spot, 6) tool boxes, 7) material for the assembly, 8) touch screen, 9) robot state, 10) tie microphone, 11) video with the assembly instructions, 12) wristband with laser pointer and vibration motor.

2.1 The Interactions

The interactions implemented in the experimental set-up are summarized in Table 1 and are described hereafter.

Table 1: List of the interactions with the corresponding technologies. The table is divided into 2 sections: the control commands from human to robot in the upper part; the feedbacks from the robot to the human in the lower part.

Interaction type	*Technology*
From human to robot (control)	
Voice	A tie microphone connected to 2 Picovoice AI engines
Gesture	Laser pointer
Visual	Touch screen
From robot to human (feedback)	
Haptic	Vibration motor
Visual	Moving light spot
Visual	Robot state images on a screen

2.1.1 From Human to Robot (Control)

The voice control is implemented using Picovoice, an end-to-end voice AI (Artificial Intelligence) powered platform. Two engines of the platform are used: the Porcupine wake word and the Rhino speech-to-intent. The first one allows the voice control to be started using the wake words “U R five”. The second one infers user intents from utterances. Table 2 summarize the intents that have been used to train the AI model. The voice control allows the control of the robot assistant.

Table 2: The following table illustrates the intents that are coded in Rhino speech-to-intent engine. Each intent is an expression made of several slot words and macros that form phrases. The addition of words like “the”, “a”, “an” in the phrase is possible. As an example, the phrase “Bring the scissors” is recognized as a valid intent. Each macro can contain synonyms that are equally processed. All the words are translations of the original French words.

Macros (synonyms)	*Slot Tools*
Bring me (the) Bring (the) Get me (the) Get (the)	Screwdriver Small key Big key Scissors
Put back (the) Put away (the)	
Slot Answer	*Slot Corrections*
No	Right Left Up Down
Yes	

The gesture control is a laser pointer integrated into a wristband, illustrated in Figure 2, that was custom-made using a 3D printer. The laser is constantly switched on during the test. By pointing the laser at a tool on the wall, the human asks the robot to pick the tool.

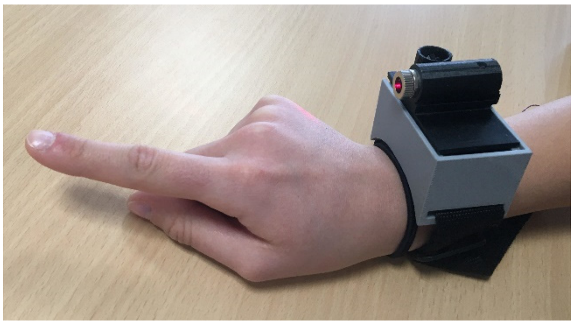

Figure 2: A picture of the wristband integrating the vibration motor and the laser pointer.

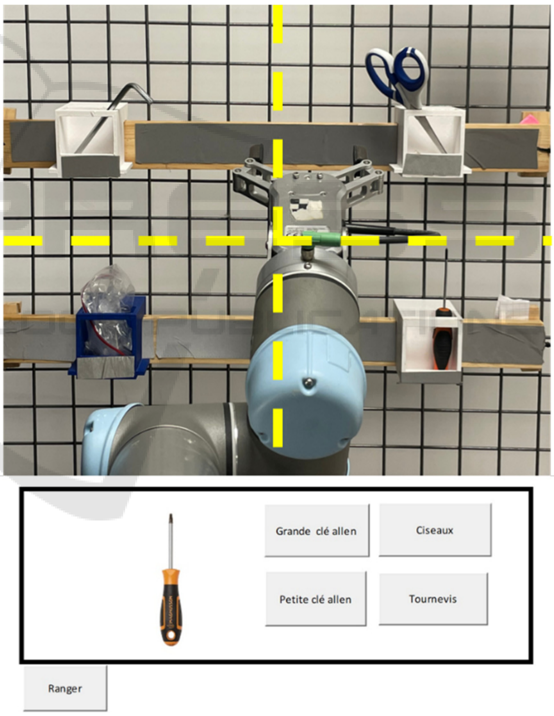

Figure 3: A picture of the touch screen and of the wall where tools are stored. The division in 4 areas is highlighted by the dotted yellow lines. The buttons on the screen are positioned in the same way. A fifth button allows to put away the tool.

The visual control consists of a touch screen displaying four buttons, allowing to select a corresponding area where a tool is stored. The position of the button corresponds visually to the area where the tool is stored, as shown in Figure 3. The effect of the touch screen on the robot is the same as that of the laser pointer.

2.1.2 From Robot to Human (Feedback)

The haptic feedback consists of a 3V mini-vibration motor of 1cm diameter integrated in the same wristband containing the laser pointer. It is activated manually by a WoZ operator as the robot approach the half of the workspace in the test subject's direction.

The visual feedback consists of a light spot that points towards the tool selected by the test subject. This feedback allows the human to correct the command in case of misunderstanding of the robot. For the experimental the spot is manually controlled by the WoZ operator.

The second visual feedback consists of a smiley that appears on the same screen used for touch control. Two types of smileys are available: happy and unhappy. The happy smiley is displayed when the spot points to the right tool if the human answer is "yes" or when a voice intention is recognized. The unhappy smiley is displayed when the spot points to the wrong tool or when the voice control is unsuccessful. This feedback is controlled by a WoZ operator.

2.2 The Scenario

The complete scenario consists of performing an assembly operation that needs four different sets of tools and consists of 5 steps, with a total duration of about 15 minutes. The step sequence is shown on a video displayed on a screen on the assembly table. The test subjects can pause the video and perform any step at their own rhythm. The material for the assembly is available on the same table. Only the tools are stored on the vertical wall in front of the subject. The robot is installed between the table and the wall. The scenario layout is illustrated in Figure 4 and in Figure 5. Two WoZ operators are hidden from the test subject that sits on a chair in front of the assembly table in an isolated environment (without other people).

A WoZ operator receives the Picovoice output and the touch screen selection and executes the corresponding robot movement through the teaching pendant. For this experimental set-up, it is important to use a real voice control interaction to be as close as possible to actual conditions of use. The WoZ operator, that has a view of the vertical wall, can also control the robot following the laser pointer, as well as the robot state on the touch screen. A second WoZ operator controls the light spot and the vibration motor. All the robot movements are pre-recorded and executed at reduced speed for safety reasons. In fact, we don't take speed into account at this stage of the research because we considered that this aspect is not a priority.

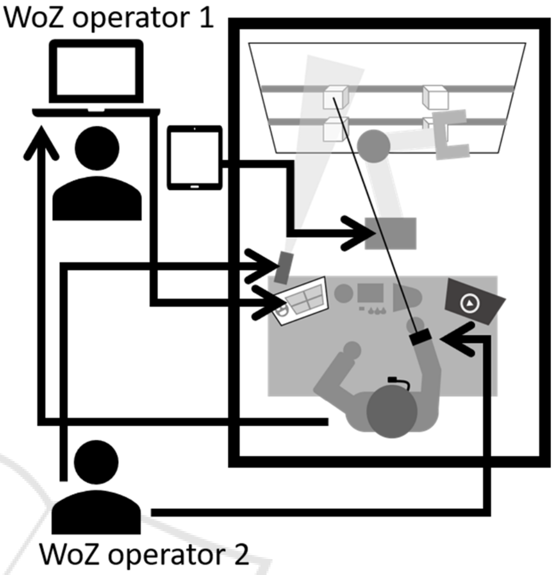

Figure 4: A diagram of the scenario showing the position of the two WoZ operators (in black in the diagram).

Figure 5: A picture of the scenario layout taken from above.

2.3 The Test Protocol

The study subject group was composed of N=20 students and employees of an engineering school (10 female and 10 male test subjects, including 13 students and 7 employees, as shown in Table 3).

Nobody knew about the experiment in advance. They were all confident with technology and have already seen an industrial robot in action. During the second half of the assembly operation, a sound of people's voices was produced on a loudspeaker to simulate a noisy environment disturbing voice control. At the end of the assembly operation, the subjects filled out a questionnaire inspired by the System Usability Scale (Brooke, 1995) and the USE

Usefulness, Satisfaction and Ease (Lund, 2001). The questionnaire is composed of 27 questions divided into 5 parts to evaluate the usability, the ease of use, ease of learning, global satisfaction, and multimodality interactions (intuitiveness and usefulness). Each item is evaluated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Each subject could comment freely on the interaction.

Table 3: The following table shows the age distribution of all the test subjects to the experiment. It is divided into two sections: the students and the employees. Each section is divided into two further sections: male (M) and female (F).

Age categories (years old)	*Students*		*Employees*	
	M	*F*	*M*	*F*
21-25	6	7	-	
31-35	-		3	1
51-55	-		0	1
61-65	-		1	1

3 PRELIMINARY RESULTS AND DISCUSSION

Tables 4 and 5 show the mean scores of the questions of the questionnaire.

The assistant robot was positively evaluated. The highest scores are recorded for the items in the ease of learning category, confirming the low workload associated with the use of the interactions. The lowest score concerns the perception of the need of the assistant robot, while its usefulness has a fair score of 3,1. We think that a reason for the score is that the proposed assembly operation is too simple, as there are too few tools and assembly steps to manage and it is hard to justify the use of a robot in this context. This hypothesis is confirmed by some free comments made by the test subjects. Moreover, although assembly time was not measured, the subjects had to wait for the robot to make the movements and found this waiting time annoying.

Concerning interaction modalities, most subjects preferred screen-related modalities: the touch screen was often preferred to the laser pointer as an alternative control modality to voice command in the event of failure; feedback on the robot's state was judged to be clearer than other feedback modalities. Nevertheless, we believe that the advantage of using an alternative to the screen could be better perceived in a more realistic dynamic working configuration, where there is no space on the assembly table to install a screen. From direct observation, we noticed that voice control was always the first choice for interaction, even though it generated a lot of frustration due to the poor results obtained mainly during the noisy second half of the tests. In this case, it was appreciated to have an alternative way of controlling the robot. The vibration motor was seen more as a safety feature that simply added information that was already known: in fact, the subject was always looking at the robot while waiting for the tool when the motor started to vibrate. Moreover, test subjects were invited to freely comment on the following statements:

Table 4: The following table shows the mean scores of the 15 questions of the questionnaire aiming to evaluate usability, ease of use, ease of learning, and global satisfaction. For each part, the overall mean value is calculated.

Question	*Mean score*
Utility	
I save time by using the multimodal interface	3,3
The system is useful for assembly work	3,1
The robot and its multimodal interface correspond exactly to my needs	3,2
The feedback is useful	3,9
Overall score for utility	**3,3**
Ease of use	
The system is intuitive to use	4,3
I need little effort to use the system	4,3
There are no inconsistencies in use	4,1
I can correct any misunderstandings in the robot quickly and easily	3,7
Overall score for ease of use	**4,1**
Ease of learning	
I learnt to use the system very quickly	4,4
I remember how to use each modality before each use	4,6
The interactions are easy to learn	4,5
Overall score for ease of learning	**4,5**
Satisfaction	
I am satisfied with the use of the system	4,0
I would recommend the use of the system	3,9
I think I need this assistant robot	2,6
The system is pleasant to use	4,1
Overall score for satisfaction	**3,6**

Table 5: The following table shows the mean scores of the evaluation of the intuitiveness and of the usefulness of the interaction modalities.

Modality	*Intuitive*	*Useful*
Laser pointer (gesture control)	3,9	3,3
Vibration (haptic feedback)	4,1	3,6
Touch screen (tactile control)	4,5	4,4
Robot state (visual feedback)	4,2	4,3
Voice control	3,9	3,9
Light spot (visual feedback)	3,7	4,0

1) Multimodality contributes to greater satisfaction and reduces frustration.
2) A simple interaction is interesting and preferable to a more complex interaction (richer in information).
3) The presence of feedback improves the 'feel' of the interaction (user experience).

All the subjects agreed unanimously with the statements. For example, concerning multimodality and simple interactions, we could record the following quotes: “I think multimodality offers the user choice, which reduces frustration”, “Above all, multimodality allows me to adapt to different situations”, or “The simpler it is to operate, the faster and more pleasant it is to run”. They considered that feedback is very important for a successful and satisfactory collaboration. An additional comment was made that simple feedback is important, but the content of the information to be provided should not be reduced because of that: “Simple feedback is important, but in the event of an error other than non-comprehension, adding a corresponding interaction seems interesting”.

3.1 Limitations of the Study

The goal of this paragraph is to discuss the main limitations of our study. First of all, the number of test subjects is too small. In order to have more significant results, a higher number of subjects is necessary for future works. More in particular, to be able to truly evaluate multimodality, comparative tests and analysis should be performed.

Secondly, we didn’t measure the following parameters: the duration of the assembly task, the subjects’ errors, and the subjects’ level of comfort. Consequently, the efficiency was not evaluated. And even if all the subjects successfully finished the task, the effectiveness was also not evaluated. The main reason is that the current use-case does not completely reflect a real working situation, even if it is meant to implement elementary real operations. The study is at a preliminary stage and can be defined as a theoretical one, contributing to the comprehension of multimodal HRI.

Finally, the proposed assembly task was also not always adapted to the goal of evaluating multimodality. As an example, the presence in the sequence of unwanted waiting times was detrimental to the assessment of the haptic feedback and of the user experience in general.

4 CONCLUSIONS

In this study, we have explored the complexities of HRI in the context of a collaborative assembly task with a robot assistant. In particular, we focused on the elementary yet widely applicable operation “bring/put away”, very common and very often performed in SMEs and service contexts. Our experimental set-up, featuring a UR5 robot, allows voice, gesture and visual control and provides visual and haptic feedbacks. A series of Wizard of Oz tests were carried out with twenty test subjects, implementing an assembly operation scenario, with the objective of exploring the potential of simple multimodal interaction for enhancing the feeling of interaction and the user experience. The preliminary results indicate positive feedbacks, with test subjects expressing satisfaction with the simplicity and the intuitiveness of the interactions. The inclusion of feedback mechanisms, incorporating mainly visual but also haptic cues, contributes to a more immersive and satisfying collaborative experience. The findings from this preliminary study offer valuable insight for further research. The experiment not only highlighted the ease of use and effectiveness of the different interaction modalities, but also underlined the importance of feedbacks in shaping the overall user experience.

Future work should strive to develop more realistic scenarios, bridging the gap between laboratory proof-of-concept and real-world use cases, taking greater account of user needs, psychological factors, and the dynamic nature of the working environment. This will allow us to plan a longitudinal research to assess long-term effectiveness. In addition, a more integrated multimodality, proving that content is still simple but richer, needs to be designed and tested with more precise test protocols. In further research, different types of interaction configuration will be established and tested in order to assess one, two or three modalities at a time. However, robot feedbacks are assumed essential and will be evaluated in all configurations. Following the new test protocol, there will be one questionnaire for each test configuration, adjusted to quantify the efficiency and effectiveness. Behavioural analysis will be needed to make a more accurate evaluation of the user experience.

REFERENCES

Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. In *Journal of Cloud Computing* 11, 40.

Alegre Luna, J., Vasquez Rivera, A., Loayza Mendoza, A., Talavera S., J., Montoya, A. (2023). Development of a Touchless Control System for a Clinical Robot with Multimodal User Interface. In International Journal of Advanced Computer Science and Applications (IJACSA), 14(9).

Alves, J., Lima, T.M., Gaspar, P.D. (2023). Is Industry 5.0 a Human-Centred Approach? A Systematic Review. In *Processes* 2023, *11*, 193.

Brooke, J. (1995). SUS: A quick and dirty usability scale. In *Usability Evaluation in Industry* 189, 4-7.

Clemente, F., Dosen, S., Lonini, L., Markovic, M., Farina, D., Cipriani, C. (2017). Humans Can Integrate Augmented Reality Feedback in Their Sensorimotor Control of a Robotic Hand. In *IEEE Transactions on Human-Machine Systems*, 47(4): 583-589.

Demir, K.A., Döven, G., Sezen, B. (2019). Industry 5.0 and Human-Robot Co-working. In *Procedia Computer Science*, 158: 688-695.

Kalinowska, A., Pilarski, P. M., Murphey, T. D. (2023). Embodied Communication: How Robots and People Communicate Through Physical Interaction. In *Annual Review of Control, Robotics, and Autonomous Systems* 6:1, 205-232.

Kopp, T., Baumgartner, M., Kinkel, S. (2020). Success factors for introducing industrial human-robot interaction in practice: an empirically driven framework. *In the International Journal of Advanced Manufacturing Technology*, 112(3-4): 685-704.

Lund, A.M. (2001). Measuring Usability with the USE Questionnaire. In Newsletter of the society for technical Communication, October 2001, Vol 8, No. 2.

Male, J, Martinez Hernandez, U. (2021). Collaborative architecture for human-robot assembly tasks using multimodal sensors. In *Proceeding of the International Conference on Advanced* Robotics, ICRA 2021, Ljubljana, Slovenia.

Marathe, A.R., Schaefer, K.E., Evans, A.W., Metcalfe, J.S. (2018). Bidirectional Communication for Effective Human-Agent Teaming. In: Chen, J., Fragomeni, G. (eds) *Virtual, Augmented and Mixed Reality: Interaction, Navigation, Visualization, Embodiment, and Simulation. VAMR 2018. Lecture Notes in Computer Science*, vol 10909. Springer, Cham.

Michaelis, J. E., Siebert-Evenstone, A., Shaffer, D. W., Mutlu, B. (2020). Collaborative or simply uncaged? understanding human-cobot interactions in automation. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*.

Penkov, S., Bordallo, A., Ramamoorthy, S. (2016). Inverse eye tracking for intention inference and symbol grounding in human-robot collaboration. In *Robotics: Science and Systems Workshop on Planning for Human-Robot Interaction, 2016.*

Rautiainen, S., Pantano, M., Traganos, K., Ahmadi, S., Saenz, J., Mohammed, W.M.; Martinez Lastra, J.L. (2022). Multimodal Interface for Human–Robot Collaboration. In *Machines*, *10*, 957.

Strazdas, D., Hintz, J., Khalifa, A., Abdelrahman, A.A., Hempel, T., Al-Hamadi, A. (2022). Robot System Assistant (RoSA): Towards Intuitive Multi-Modal and Multi-Device Human-Robot Interaction. In *Sensors*, 22(3), 923.

Villani, V., Fenech, G., Fabbricatore, M., Secchi, C. (2023) Wrist Vibration Feedback to Improve Operator Awareness in Collaborative Robotics. In *Journal of Intelligent and Robotic Systems* 109: 45.

Wright, J., L., Lakhmani, S., G., Chen J., Y., C. (2022). Bidirectional Communications in Human-Agent Teaming: The Effects of Communication Style and Feedback. In *International Journal of Human–Computer Interaction*, 38:18-20, 1972-1985.