**MATE robots simplifying my work: benefits and socio-ethical implications**

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Abstract—With the increasing complexity of modern industrial automatic and robotic systems, an increasing burden is put on the operators, who are requested to supervise and interact with very complex systems, typically under challenging and stressful conditions. To overcome this issue, it is necessary to adopt a responsible approach based on the anthropocentric design methodology, such that machines adapt to the humans capabilities, and not vice versa. Moving along these lines, in this paper we consider an integrated methodological design, consisting in devising complex automatic or robotic solutions that measure current operator’s status, adapting the interaction accordingly, and providing her/him with proper training to improve the interaction and learn lacking skills and expertise. Accordingly, a MATE system is intended to be easily usable for all users, thus meeting the principles of inclusive design.

Using such a MATE system gives rise to several ethical and social implications, which are discussed in this paper. Additionally, a discussion about which factors in the organization of companies are critical with respect to the introduction of a MATE system is presented.

I. INTRODUCTION

Modern industrial automatic and robotic production systems are becoming increasingly complex in order to comply with market demands and competitiveness. Thus, workers are requested to be more and more skilled to be able to operate such systems. As a resulting drawback, an increasing burden is put on the operators, who are requested to supervise and interact with very complex systems, typically under challenging situational conditions, such as noisy environment, tight time constraints, fear of job loss, and/or psychological pressure due to the presence of supervisors. Such stressing conditions are amplified when vulnerable users, such as those cognitively or physically impaired, elderly and low educated operators, are involved in the interaction. In typical operative scenarios, these classes of workers are prevented from job positions that require high attentional skills to interact with a robot or a complex plant, or, in the case they are granted any of such positions, their responsibilities and duties are very limited.

To invert such a policy, it is needed to reverse the design of complex production systems and adopt a responsible approach based on the anthropocentric design methodology. This consists in the process of ensuring that people’s needs are met, that the resulting system is understandable and usable, that it accomplishes the desired tasks, and that the experience of use is positive and enjoyable [1]. In the context of industrial production, this amounts to reverse the paradigm from the current belief that “the human learns how the machine works” to the future scenario in which “the machine adapts to the human capability” accommodating to her/his own time and features [2], [3]. Indeed, interaction systems typically used in industrial environment do not provide any possibility of controlling the amount of displayed information, or its form. Hence, while the human operator is flexible and adaptable, the system is not. In particular, the control systems applied to industrial processes typically respond in a specified way, without regard as to whether the flow of information is low or extremely high, or the level of expertise of the user is good or bad [4]. The human operator is then typically the only element that needs to adapt her/his behavior based on the situation. Namely, the operator needs to be sufficiently flexible, to be able to cope both with common activities and unpredictable situations, such as in the presence of dangers. This can cause significant difficulties for the operators, decreasing working performance and job satisfaction, and preventing less skilled operators from using complex systems. To overcome these limits, and to change the design approach, it becomes advantageous to add the user in the feedback loop during the use of the system and her/his interaction with it, thus instantaneously modulating such interaction on the basis of her/his current psychophysical status. Specifically, we refer to the need to take into account the physical and cognitive overload induced by the working task and use such information to adapt the interaction accordingly, with the ultimate aim of relieving user’s stress and affect.

A. MATE approach

A first attempt to implement this new paradigm is achieved by approaches based on affective computing and robotics, which rely on measuring user’s physiological parameters that are known to be related to mental strain, and adapting the interaction with the robotic system accordingly [5], [6]. Moving along these lines and extending the concept of affective computing, we aim at introducing an integrated methodological approach for the anthropocentric design of human-machine/robot systems. We call such approach MATE, i.e., Measure, Adapt and TEach since it relies on three pillars: measurement of human capabilities and skills, adaptation of the interaction system, training and support for less skilled
users. The rationale behind the MATE approach is that not only is current operator’s status measured to adapt the interaction accordingly, but also she/he is properly trained to permanently improve the interaction and learn lacking skills and expertise. Moreover, a more tailored adaptation of the interaction tasks and training support can be achieved by thoroughly characterizing the worker in terms of working skills, perceptive and cognitive capabilities in addition to mood and affect, thus extending measurements proper of affective computing. Thus, while the immediate goal of a system based on the MATE methodology is that of improving the performance when interacting with the system, the ultimate goal is that of possibly enhancing the skills of operators, especially the vulnerable ones, in order to attenuate their adverse condition. Given its features, a MATE system is intended to be easy to use and usable for all users, thus meeting the principles of inclusive design [7]–[9].

A first example of such a MATE approach is being developed in the framework of the European project INCLUSIVE [10], [11]. The goal is to devise a methodology for the design of complex interaction systems that profile the user by measuring her/his cognitive and perceptive capabilities (offline) and sustainable cognitive burden (on-line) and adapt the presentation of information and the interaction accordingly, providing adequate teaching support. Further details about the INCLUSIVE system can be found in [10].

B. Social and ethical impacts

However, while most of the research on the use of collaborative solutions has focused on factors that have a direct influence on collaboration, such as motion and safety, limited research has focused on the anthropological impact. The social impact of the introduction of industrial and collaborative robots on factory workers has been discussed, for example, in [12], [13]. In [14] it is reported that social problems stemming from the introduction of robots in factories are, first of all, loss of jobs and unemployment, and this is confirmed by interviews to factory workers reported in [13]. Thus, the goal of having robots that support, rather than supplant, people in workplaces [15], [16] has not been reached yet. Moreover, the use of robots and the topic of human-robot interaction give rise to several anthropological and ethical issues, which become even more prominent when vulnerable users are involved. To this end, frameworks for incorporating ethics in the design of robots have been proposed [17]. These started from care robots and have been extended to service robots. However, considering the quick growth of industrial collaborative robots, such frameworks should be properly adapted to account also for industrial working scenarios. In this regard, the term roboethics has been recently introduced, referring to a set of tools useful to promoting the development of robotics, while preventing its misuse and any harm to humans [14]. Specifically, roboethics addresses the need to consider ethical issues related to the use of robots, meant as intelligent devices that can make decisions on humans’ behalf or conflicting with humans’ will, thus tending to enhance or, on the contrary, replace humans. This should not be confused with coding ethics or morals into robotic systems in order to make robots conscious beings [15], which is out of the scope of MATE systems.

Moving along these lines, when considering a MATE robotic or automated system, such as the INCLUSIVE system, that adapts to its users in order to facilitate the interaction, social and ethical implications cannot be neglected, especially (but not only) when users with special needs are involved. Indeed, the risks of stigmatization must be properly tackled, and further issues arise since a proper adaptation relies on accurate measurement of the user. Thus, the aim of this paper is twofold. First, in Sec. II a set of high-level recommendations for the anthropocentric design of MATE working interaction systems are provided. Such recommendations stem from the collection of technical requirements as well as requirements related to socio-ethical implications and roboethics principles. Second, the feasibility of the implementation of such requirements with respect to status quo of companies is analyzed in Sec. III in order to estimate the impact that the use of a MATE system would have on the current organization of companies.

II. ANTHROPOCENTRIC ANALYSIS OF REQUIREMENTS

As for any complex system, the development of a MATE system requires the definition of a set of specifications that provide a description of the main characteristics that the system has to fulfill. Following a standard system engineering approach [18], such specifications are derived from a set of requirements, which describe the desired behavior of the system from the users’ perspective.

While system specifications depend on the specific application under consideration, the requirements can be defined from a universal point of view, for MATE systems in general. Such requirements are derived based on an anthropocentric approach, focusing on the users’ needs.

Moving along these lines, technical requirements were first considered, but they were complemented by additional requirements, as well necessary, regarding social and ethical implications of the system. Fig. 2 shows how the different
classes of requirements were derived; all the requirements, which have general validity, serve as inputs to the definition of the technical specification for a given system.

Further, Table I summarizes the proposed design recommendations, in terms of technical requirements and requirements for Ethical, Social and Legal Implications (ELSI) and roboethics, which will be discussed in detail hereafter.

A. Technical Requirements

In a first attempt to derive the design requirements, we started from a thorough understanding of users and the analysis of their needs. Specifically, we focused on three specific industrial case studies, which are representative of a wide area of interest for industry in Europe:

Use case 1: machinery for woodworking, typically used in small companies run by elderly artisans;
Use case 2: robotic solutions to automatize the assembly of appliances, currently done manually;
Use case 3: bottling automatic machines used in industrial plants.

Such use cases have been analyzed in detail, with specific respect to precise working scenarios and those tasks involving interaction between the human operator and the machine [19]. The current interaction with standard automation and robotics systems was firstly studied, to understand the limitations and pitfalls that reduce operator’s working performance [19]. Particular attention was given to vulnerable users, since they are the most affected by complexity in interaction. To this end, we consider as vulnerable users not only those who have physical or cognitive impairments, but also elderly, who might be not familiar with advanced technological and computer solutions, and low educated people. Their vulnerability is related to the fact that they are the most likely to lose their job, and the less likely to be re-trained and re-employed. This is due either to the difficulty in effectively utilizing complex modern computer aided manufacturing equipments, or to physical impairments that prevent some activities.

Therefore, a list of users’ needs has been derived, as summarized in Table II. These are expressed with respect to current human-machine systems, in terms of limitations and drawbacks perceived by operators. In particular, the users’ needs highlight the fact that current interaction modality involves a significant effort from users, especially from vulnerable ones, thus often resulting in additional working stress. A simplification of the interaction is sought, by means of guidance in procedural tasks and easy to use interaction modes. From such users’ needs, a first set of requirements, which are listed in the left column of Table I, can be derived. Basically, they translate users’ needs in technical hints for design, in order to improve traditional approaches to interaction.

It is worthwhile noting that such technical requirements hold true for any inclusive interaction system and do not depend on the considered use cases, although they have been derived from specific users’ needs that are related to these use cases. Moreover, they have been devised as additional requirements to overcome the limitations of traditional systems, and thus are not the only technical requirements to consider in design (e.g., task specific requirements, safety requirements, etc.).

B. ELSI Requirements

In addition to the technical requirements driven from the use cases, other design recommendations come from the analysis of implications on ethics and social and legal issues related to the use of such an adaptive MATE human-machine system. This analysis leads to the definition of ELSI requirements. Specifically, in order to develop an ELSI concept related to the design of smart interaction systems for automated production machines, we have combined the approach based on the so called Model for the Ethical Evaluation of Socio-Technical ARrangements (MEESTAR) [20], which considers ethical problems, with the context specific legal issues for occupational systems, as well as societal needs of the considered vulnerable users [19].

The MEESTAR approach is a three-dimensional evaluation tool that guides users on how to reflect ethically and form judgements on the use of appropriate assisting systems. The model focuses on negative effects, requiring that the system causes little or no harm to the user. The model aims at identifying ethically problematic effects in a structured way and, on that basis, develop appropriate solutions. Specifically, as shown in Fig. 3, it decomposes the analysis in three main components, which, considered jointly, allow for a comprehensive ethical evaluation of a social-technical arrangement. The first dimension refers to ethical core values, such as care, autonomy, safety, justice, privacy, participation and self-conception. In the second dimension it considers three levels of observation, namely
TABLE I
DESIGN RECOMMENDATIONS FOR A MATE SYSTEM: TECHNICAL AND ELSI REQUIREMENTS FOR THE INCLUSION OF VULNERABLE USERS AND PRINCIPLES PROPOSED BY DEBATE ON ROBOETHICS [15].

| TECHNICAL REQUIREMENTS | ELSI REQUIREMENTS | ROBOETHICS REQUIREMENTS |
|-------------------------|-------------------|-------------------------|
| T-R1 The interface adapts to the level of skills of the operator | ELSI-R5 The system should meet all relevant safety criteria | ROBETH-R1 The operator should be protected from harm caused by the system |
| T-R2 The system can be used by low educated operators | ELSI-R7 The system should not cause injuries by means of inductive measuring technology | ROBETH-R2 The operator has the right to refuse to be cared by the system |
| T-R3 The system can be used by physically and cognitively impaired operators | ELSI-R3 The system uses collected data not for any disadvantage for the employee | ROBETH-R3 The operator liberty when using the system should be protected |
| T-R4 The system can be used by people with low computer skills | ELSI-R4 The system depicts relevant user requirements and prevents discrimination | ROBETH-R4 The operator should be protected from any privacy breaches committed by the system |
| T-R5 The system enforces the correct procedures | ELSI-R2 The system considers anonymized personal data | ROBETH-R5 The operator personal data processed by robots should be protected |
| T-R6 The operator feels satisfied from the interaction experience | ELSI-R6 The system should not distract the operator | ROBETH-R6 The operator should be protected against the risk of manipulation by the system |
| T-R7 Interaction with the system generates a low level of stress for the operators | ELSI-R1 The system prevents inducing strain itself | ROBETH-R7 The dissolution of social ties should be avoided |

As regards the legal implications, we consider data protection, safety and health at work, as addressed by the EU regulations, namely the Machinery Directive 2006/42/EC, the Council Directive 89/391/EEC and the General Data Protection Regulation 2016/679.

Finally, social requirements risen from the considered vulnerable users, who are supposed to have limited skills in perception, cognition and motion, refer to the need for equal treatment and integration in the working process.

C. Roboethics Requirements

The ELSI requirements presented above still do not provide a complete analysis of the design recommendations from the ethics point of view. Indeed, since we are dealing with vulnerable users and are considering a system that measures human capabilities and performance, ethical issues must be dealt with in detail and with specific concern. Additional ethical principles for the design, production and use of robots have been proposed in the framework of roboethics [15]. Although they are quite general, such roboethics requirements well suit the considered MATE methodology, highlighting some further issues that are not covered by ELSI analysis. The requirements proposed by roboethics are reported in the last column of Table I. Two roboethics requirements (ROBETH-R1 and ROBETH-R5) overlap with ELSI principles (ELSI-R5 and ELSI-R2, respectively), namely the fact the system should not harm the operator, and that anonymous personal data should be considered.

Then, roboethics empathizes the fact that the worker should always keep the control of the interaction (ROBETH-R2 and ROBETH-R3), dismissing it whenever she/he does
not feel confident with the system. Thus, the use of a MATE system should be conditioned to the true will of the operator, who, in case of shame, should be always let free to use standard interaction approaches, although this choice would incur in lower performance.

Requirement ROBETH-R6 refers to one of the biggest risks of the use of MATE systems in the context of industrial applications, that is the risk of stigmatization that might come from the use of a system that measures worker’s skills and performance. This may be critical for both the worker, who might feel frustrated from the outcomes of the assessment, and her/his supervisor or employer. Although this risk is in part mitigated by prescriptions about data protection, it requires special attention when considering MATE approaches.

As regards social relationships, while these are inherently undermined by the introduction of robots, the introduction of a MATE system aggravates this risk only to a minor degree, per se. Indeed, the only reduction that can be seen in social ties among colleagues refers to the fact that operators using the MATE system will ask for less help or support to their colleagues, since the system is supposed to support them. However, the social value of these exchanges of information is debatable, since they mostly give rise to competition and stigmatization. Additionally, the use of a MATE system is expected to increase operator’s confidence in the use of the machine or robot, thus making her/him less ashamed and more prone to interact with colleagues.

The requirement ROBETH-R8 refers to the fact that, for professional users, difficulties in accessing robotic technologies may stem from a lack of confidence in, or knowledge of, robotics [15]. The MATE approach aims at reducing these barriers, relying on an inclusive design. Thus, this requirement is intrinsically satisfied when considering a MATE system.

Finally, as regards the last roboethics requirement, we believe that it has a marginal application to MATE systems. Indeed, this requirement refers to the fact that, by the use of advanced robotic solutions, humans might lose the perception of their actual abilities and feel empowered by attributing robot’s skills to themselves [15]. However, the first step of a MATE system is measurement of human skills: thus, although stigmatization will be prevented, operators will unavoidably be faced with their limitations, measured by the system, as discussed with respect to requirement ROBETH-R6.

III. IMPACT OF THE MATE APPROACH IN THE ORGANIZATION OF COMPANIES

In this section, the feasibility of the implementation of such requirements is considered, in order to estimate the impact that the use of a MATE system would have on the current organization of companies. Indeed, satisfying the general recommendations discussed above requires that, on the one side, the design of novel robotic or automatic solutions follows the technical requirements and the principles of inclusive design; these apply differently depending on the specific characteristics of any given application. On the other side, it is necessary that some concrete actions are taken at a broader level, considering companies organization and goals: an infrastructure is needed to support the introduction of a MATE system, while preserving operators’ interests.

To address this point, we explored how the ELSI analysis affects the organization of companies. Thus, the following ELSI dimensions have been derived in [19], studying the intersection between the MEESTAR approach with the legal and social requirements, as for the ELSI requirements described in Sec. II-B. Further details are in [19]. Such ELSI factors are:

- occupational health,
- occupational safety,
- data protection,
- ergonomic workplace design,
- equal opportunities,
- reintegration.

These factors represent the main organizational dimensions that are affected by the introduction of MATE systems in a real industrial setting. Thus, we firstly analyzed how companies are currently organized with respect to these dimensions, aiming at understanding the corresponding successful measures already taken and companies predisposition to invest on these soft skills. Then, we estimated how a MATE system would affect such dimensions. Moreover, in [19] we already discussed the related potential of improvement and risks following the introduction of a MATE interaction approach.

Such pieces of information were gathered by means of a questionnaire that aimed at investigating the appropriateness of the identified dimensions in the scenario of MATE systems accessible to special user groups with special needs and requirements. The questionnaire was organized in two parts: first the status quo of companies was investigated, with respect to the identified ELSI dimensions. In the second part, the estimated impact of a MATE system on such dimensions was considered. The questionnaire was administrated to 13 employees of management staff of companies operating in the following diverse sectors: information technology and software development (2 companies located in Germany), technology transfer (2 in Italy), industrial automation (4 in Italy and 1 in Greece), white goods (1 in Italy), packaging and bottling (2 in Italy), and machine manufacturing (1 in Germany).

A. Status quo of companies with respect to the ELSI dimensions

Fig. 4 shows an overview of the number of companies currently including a management system for each of the ELSI dimensions, among those involved in the questionnaires. Data show that, amongst participants, most commonly implemented management systems are occupational safety and health management systems and data protection divisions. It was also found that companies use to employ more people on average in these sections.

Additionally, Fig. 5 shows the mean value of the estimated overall relevance of each dimension for the companies in-
TABLE II

Users’ needs derived from the analysis of the limitations of the current human-machine systems.

| 1) Inclusion of all users |
|---------------------------|
| 1.1) The system should be effectively usable by inexperienced operators |
| 1.2) The system should be effectively usable by operators with different age |
| 1.3) The system should be effectively usable by operators with different level of work experience or education |
| 1.4) The system should be effectively usable by operators with physical impairments |

| 2) User-oriented organization of information |
|--------------------------------------------|
| 2.1) Procedures should adapt to the operator’s skills |
| 2.2) The system should provide guided procedures for ordinary operations |
| 2.3) The system should guide the operator according to common practice solutions |
| 2.4) Specific prior training and studying the manual should not be necessary |
| 2.5) Operations should be performed in the correct sequence, according to the manual |
| 2.6) The system should suggest the operator what parameters need to be changed, based on the desired result |

| 3) Prioritization of human factors |
|-----------------------------------|
| 3.1) The system should be comfortable for all the users |
| 3.2) The stress level during the use of the system should be low |
| 3.3) The intervention of supervisors to assist the operators should be avoided |
| 3.4) Operators should feel confident when using the system |

| 4) Enhancement of operator’s performance |
|-----------------------------------------|
| 4.1) The number of errors should be reduced |
| 4.2) The execution time should be improved |
| 4.3) The correct operational mode and the correct value for critical parameters should be automatically selected |
| 4.4) The choice of wrong options should be prevented |
| 4.5) The HMI should depict the actual equipment and state of the machine |

| 5) Advanced technological solutions |
|------------------------------------|
| 5.1) Hands-free interaction should be possible |
| 5.2) Portable interfaces should be available, to guide the operators in the working area |

Involved in the questionnaire. Relevance was rated on a scale from 1 (very negative) to 10 (very positive). Occupational safety (average relevance 7.6 ± 2.7), data protection (7 ± 2.5) and occupational health (6.9 ± 2.9) were assessed most relevant. The relevance of the other factors was related below mean: it was 5.6 ± 3.3 for ergonomic workplace design, 5.2 ± 2.7 for equal opportunities and 5.2 ± 3.0 for reintegration. It is worthwhile noting that, since some companies do not implement a management system for some of the considered ELSI dimensions, it was not possible to assess the corresponding relevance for all companies. Thus, results in Fig. 5 were averaged on a different number of study participants, as shown in the figure. Further, answers to the questionnaires highlighted that successful measures already implemented by the considered companies with respect to the ELSI factors include, for example, periodic health monitoring, psychological support, internal physiotherapists, fitness programs, reintegration of handicapped people and reintegration after long illness.

B. MATE impact on ELSI dimensions

The second part of the questionnaire considered a working scenario where affective computing is applied to an industrial human-machine system, thus measuring operator’s mental workload, stress and induced anxiety by recording some physiological signals. Specifically, the questionnaire included questions regarding the following MATE scenario: “The working machines are equipped with sensors that are able to track strain of a working person by real-time measurement of her/his physiological parameters, e.g. heart rate, blood pressure, etc. If the measured strain indicators are too high, the system adapts to the situation resulting in a lower stress..."
level.”

Participants were firstly asked whether a potential of improvement or risks in measuring strain of a working person as described in the scenario above could be found. Results are summarized in Fig. 6. Most subjects reported potential of improvement in occupational health (12 out of 13), ergonomic workplace design (11 out of 13) and occupational safety (9 out of 13) by means of the considered system. Occupational health, however, was also rated with the highest potential risks (6 mentions), while 5 subjects out of 11 mentioned a potential risk with respect to data protection, ergonomic workplace design and equal opportunities (2 did not answer the corresponding questions). For data protection and equal opportunities, the estimated risk (5 mentions each) overcomes the potential of improvement (3 and 4 mentions, respectively), thus confirming the fact that discrimination of vulnerable users is a critical issue to be addressed in the use of MATE systems, as pointed out also by the requirement ELSI-R4. In particular, data protection reported the smallest number of mentions for potential of improvement, which is clearly explained by the mission of a MATE system. Risks for occupational safety were mentioned by 4 users, and the smallest risks (3 mentions) were reported for reintegration.

Moreover, we asked each participant how positively the impact of strain measurement was considered for each dimension of the ELSI concept. A scale from 1 (very negative) to 10 (very positive) was considered and the achieved results are reported in Fig. 7. The responses to the questionnaire showed that the impact of strain measurement according to each dimension was mostly rated positively above 6 points, except for two dimensions: data protection (4.9±1.9) and equal opportunities (4.8±2.0). The influence of strain measurement on occupational health (7.0±1.4) was rated highest. The impact of stress measurement on occupational safety was rated 6.7±2.6, on ergonomic workplace design was 6.8±2.2; the impact on reintegration was rated 6.3±2.0.

IV. DISCUSSION AND CONCLUSION

In this paper we considered a novel human-centred approach, based on affective robotics and computing, to the design of advanced automatic or robotic systems. The resulting system, which we call MATE, measures the operator’s skill, performance and stamina and then adapts itself to facilitate the interaction. Also, some teaching support is provided to the operator, in order to train her/him about lacking skills. Such a system is intended to be easy to use and usable for all users, also the most vulnerable ones, thus meeting the principles of inclusive design.

In this paper, we analyzed the social and ethical implications related to the use of MATE systems. Specifically, we derived the requirements that should drive the MATE design. Technical requirements have been discussed together with ethical, legal and social recommendations and principles inspired by roboethics.

Moreover, we considered the impact that the use of a MATE system has on the organization of companies. Specifically, several organizational factors have been identified that are affected by the use of MATE systems. We then investigated how companies are currently organized in terms of such factors and what measures are already taken to implement them.

Results show that more than 50% of the participating companies implement occupational health, safety and data protection management systems, but that there is still a lack of implementation in ergonomic workplace design, equal opportunities or reintegration, though estimated relevance for all ELSI dimensions was rated positively. On the other hand, Fig. 5 also shows that relevance was rated highest for those ELSI dimensions that are already implemented in practice and well known. Since the here discussed MATE approach aims at supporting elderly, impaired and unskilled workers during machine and robotics operations, it thereby has the potential to create changes in the awareness of equal opportunities and reintegration in the companies in the future. This assumption consolidates with regard to the estimated impact, which was rated high for health, safety, ergonomics and reintegration.

The impact on data protection was rated surprisingly low, as shown in Fig. 4 although potential risks were expected to be greater than improvement potential, as shown in Fig. 6. Also equal opportunities only plays a minor role compared to the other dimensions. Moreover, the highest potential of improvement is seen in health, safety and ergonomics.
which is the general objective of MATE systems. All these dimensions were rated with relatively low risks for the implementation of a MATE system.

As regards the currently less implemented dimensions, namely equal opportunities and reintegration, they were rated with the lowest potential of improvement and with the highest risk if compared to potential improvement. Hence, a MATE system cannot only retrieve better awareness for ELSI questions, as concluded earlier, but also should consider to pay special attention towards dimensions that might have higher risk than potential of improvement, when implemented in industrial environment.

Finally, the reliability of these results has to be verified and these issues have to be inspected more in detail in further investigations. Specifically, the proposed design recommendations and requirements will be reconsidered by assessing the real impact on concrete use cases brought by the MATE systems built in the framework of the INCLUSIVE project. The foreseen risks and improvements and possible side effects of strain measurement will be verified and updated, since possible other risks might arise, thus leading to further counter measures to be considered in the design process.

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