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OPERATORVIS

DESIGN AND RECOMMENDATIONS FOR THE UNDERSTANDABILITY OF DATA BY OPERATORS 4.0.

Dissertation in the context of the Master in Design and Multimedia advised by Professor Paula Alexandra Silva and PhD Ricardo Melo and presented to Faculty of Sciences and Technology / Department of Informatics Engineering.

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in Design and Multimedia
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Glossary

AICOS — Assistive Information and Communication Solutions
i4.0 — Industry 4.0
IoT — Internet of Things
IT — Information Technology
CPS — Cyber-Physical Systems
KPI — Key-Performance Indicators
AR — Augmented Reality
Robo-Mate — Wearable Exoskeleton
IPA — Intelligent Personal Assistants
CoBots — Collaborative Robots
PD — Participatory Design
HCI — Human-Computer Interaction
PMTS — Predetermined Motion Time Systems

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Resumo

Nos últimos anos, o mundo tem-se vindo a preparar para a quarta revolução industrial, vulgarmente referida como Indústria 4.0. Apesar de existirem várias abordagens e teorias distintas quanto à visão Indústria 4.0, a característica comum que caracteriza melhor essa revolução é a simbiose entre o Homem e a máquina. As diferenças geradas por esta nova revolução podem identificar-se através de Sistemas Ciber-Físicos, Internet das Coisas, Realidade Aumentada e Realidade Virtual. São tecnologias como estas que se espera que integrem futuros chãos-de-fábricas e que trabalhem em cooperação com os trabalhadores destes locais. É esperado que esta cooperação melhore a produtividade, gere um crescimento de receitas, reduza as perdas de tempo e melhore o controlo de danos. Para atingir esse objetivo, já foram consideradas múltiplas estratégias a serem integradas e adaptadas em fábricas. Uma das estratégias mais importantes para acompanhar e seguir os chãos-de-fábricas e os trabalhadores é receber feedback dos mesmos em tempo real. Existem, atualmente, tecnologias que se mantêm a par das tarefas, da informação relativa à saúde e outras métricas. Nestas tecnologias, é importante que essa informação seja compreensível para todos os utilizadores das mesmas, desde operadores de chão-de-fábrica a responsáveis de turno ou área.

Assim sendo, o foco principal desta dissertação debruça-se sobre a interação entre os trabalhadores e a tecnologia, bem como a devolução de informação e necessária compreensão por parte dos trabalhadores das métricas acima mencionadas (tarefas, atividade, saúde, entre outros). Apoiada nas áreas de Interação Humano-Computador e Visualização, o objetivo principal desta dissertação é gerar soluções de visualização de dados para a aplicação a desenvolver pela Fraunhofer AICOS, bem como prototipar, testar e validar essas soluções. O processo de trabalho incluiu observação, entrevistas e sessões de co-criação junto dos trabalhadores da Bosch, do IKEA e da OLI, a prototipagem e validação das soluções junto de peritos das áreas de Interação Humano-Computador, Design de Comunicação e Design de Produto. Este processo permitiu o desenvolvimento de diretrizes preliminares para a representação de dados em contextos de chão-de-fábrica. Estas diretrizes preliminares, permitirão uma leitura e compreensão facilitadas por parte dos trabalhadores e servirão para informar o design e o desenvolvimento de tecnologia nestes contextos.

Abstract

In the last few years, the world has been preparing for the fourth industrial revolution, commonly mentioned as Industry 4.0. Even though there are different approaches and visions of Industry 4.0, what characterises it is the symbiosis between man and the machine. The changes that have taken place in this new revolution can be identified through Cyber-Physical Systems, Internet of Things, Augmented Reality or Virtual Reality. Technologies such as these are expected to integrate shop floors and to cooperatively work with operators in the near future. It is expected that this cooperation will increase productivity, generate revenue growth, reduce time loss and improve damage control. In working towards achieving this goal, multiple strategies to adapt factories and the future workplace have been considered. One of the most important strategies is to keep continuous tracking of shop floors and operators, and to constantly receive real-time feedback from operators. To receive information, there are technologies that allow the tracking of tasks, health related information and other metrics. In these technologies, it is important that information is understandable for everyone, from operators to shift or area supervisors.

Hereby, the main focus of this dissertation leans on the interaction between operators and technology as well as the return of information and necessary comprehension from workers of the metrics mentioned above (tasks, activity, health, and so on). Supported by Human-Computer Interaction and Visualization, the main goal of this dissertation is to generate visual solutions for the application to be developed by Fraunhofer AICOS, as well as to prototype, test and validate those solutions. The work plan includes observation, interviews, and Co-Design sessions with workers from Bosch, IKEA, and OLI, prototyping, and validation of those solutions with experts from the areas of Human-Computer Interaction, Communication Design and Product Design. This process allowed the development of preliminary guidelines for data representation in shop floor contexts. These preliminary guidelines will allow for the ease of readability and comprehension from workers and will inform the design and development of technology in these contexts.

Keywords

Industry 4.0, Operator 4.0, Human-Computer Interaction, Visualisation, User-Centred Design, Self-Tracking, Health Monitoring.

1. Introduction

Industry 4.0 has grown “under the pressure of an increasingly competitive economic scenario enabled (and pushed) by technological levers” (Mercier-Laurent & Monsone, 2019), e.g. Cyber-Physical Systems (CPS), Internet of Things (IoT), the cloud, and Artificial Intelligence (AI). These technologies are meant to improve the productivity of factories, collaborating with workers, preventing errors and assisting tasks. To that end, it is considered important to improve the relationship between humans and machines. This improvement will allow factories to obtain a bigger success rate, increase productivity and improve the work environment.

This dissertation is intended to contribute to that improvement, by generating visualization solutions for industry 4.0 environments, through contextual studies, and developing, testing and validating prototypes for that technological solution. This will enable the development and definition of guidelines to display information in factories so that information is understandable in a shop floor context, to inform the design and development of technologies in that context.

The first chapter of this dissertation provides contextual insight to what has been developed in this academic year. First, there is a brief introduction about Fraunhofer-Gesellschaft, an explanation of the project in which this dissertation is inserted, the scope and motivation of this dissertation, the goals and contributions of this research and an explicitation of the document’s structure.

1.1 Fraunhofer-Gesellschaft

The Foundation Fraunhofer[1]-Gesellschaft is a non-profit organization that was born in March 1949 in Munich, in honor of the successful researcher Joseph von Fraunhofer. It is known that this foundation was built "as part of a program to reorganize and expand Germany's research infrastructure" (1949-1954, n.d.). Throughout the years, the organization has evolved, developing solutions in many different areas such as health, physics, automation, and Human-Computer Interaction.

Nowadays, Fraunhofer-Gesellschaft is considered to be a major research organization in the world. With seventy-four units and research institutes only in Germany, Fraunhofer-Gesellschaft works in cooperation with units of investigation all around the globe. Fraunhofer Portugal - AICOS (Assistive Information and Communication Solutions) is located in Porto, Portugal and was founded in 2009 through a partnership between Fraunhofer-Gesellschaft, the Foundation for Science and Technology (FCT) and the University of Porto (UP). With expertise in a broad range of areas such as heath, agriculture, retail or energy, AICOS has consolidated its competences in the following groups: Human-Centred Design, which focuses on the conceptualisation, design, and evaluation of technologies with a focus on the users; Intelligent Systems, which focus on areas such as Signal & Image Processing, Artificial Intelligence, and Cognitive Computing; and Connected Things, which fathers expertise in electronics, telecommunications, and software engineering for the development of hardware, firmware, and software solutions.

(1) Joseph von Fraunhofer, born in Germany in 1787, was a physicist who studied the fields of light and optics. These studies, as an apprentice, lead him to a deeper investigation on this area that sooner made him an independent investigator with great honor. The "Fraunhofer lines" were what made him win great acclaim from the industry and the government at the time.

1.2 Augmented Humanity Project

This dissertation is part of a project that is currently ongoing at Fraunhofer AICOS “Augmented Humanity” (a project funded by ANI under the program “Programas Mobilizadores PT 2020”. This project addresses three main challenges: 1) the improvement of the efficiency of industrial processes, as well as the respective reduction of emissions; 2) the development and suitability of productive processes, in accordance with the characteristics of the active population; 3) the preparation of human resources of a new industrial reality (i4.0).

The work developed in the context of this dissertation will contribute for the activities planned in the PPS5 of the project: “HR 4.0: Tools for better and healthier workers in i4.0 environments”, namely activity 29: “Research and development of workers’ companion and visualization system in the context of Industry 4.0, with the objective of the development of a Worker Companion that will gather and display data concerning the worker and the workplace, creating a holistic picture of the worker, their competence and wellbeing. This Worker Companion will enable better models concerning the worker’s physical and mental health and allow for a rich understanding of the worker within the context of an i4.0 workplace. This solution envisions the optimization of human efficiency and productivity for a better and healthier work environment. It is expected that this solution will afford workers the possibility to track their performance, evaluate their exposure to health risks, and report their general well-being. Moreover, this solution aims to improve employees’ engagement with the organization through their cooperation in decision-making.

In the context of this dissertation, the responsibilities include user research, Co-Design , and evaluating methods, in order to create visualization solutions for industry 4.0 environments. These visualization solutions are expected to contribute to the development of the application (Worker Companion), in particular in workers’ data representation. My responsibilities, in specific, are to generate a concept, create prototypes, test and validate those prototypes. To accomplish this goal, it is necessary to develop a set of activities to guide the research. At first, it is planned to elicit requirements and analyse them, including user profiles, and their context. Then, it is necessary to capture user information and confirm the previous requirements elicitation. Besides this, there will be the development of prototyping, testing solutions in real-world scenarios. Lastly, it will be essential to refine the developed solution.

The Augmented Humanity project is estimated to last until 2023, allowing the team of researchers involved in the project to analyze users, the context and explore the problem exhaustively, implement the most adequate methods adapting to their background, values, goals and availability and test the solution in cooperation with them.

1.3 Scope and Motivation

The industrial world is about to witness it's fourth revolution. This revolution is intended to create the perfect "human-automation symbiosis" (Romero et al., 2015). In many ways and at various moments, it has been proved that machines are capable of improving factories' performance, increasing productivity and auxiliating the workforce in an extraordinary way.

Through tracking operators' health and monitoring workers' tasks, factories are able to improve performance. However, this is a field to explore and, in the development of this dissertation, there were no studies found about the acceptance of visualization solutions in shop floor environments.

This dissertation intends to study the context of workers from factories expected to integrate Industry 4.0. Besides that, it is also intended to study the technological solutions already available. These studies will allow the generation of a concept for the visual representations in the application to develop.

Through those studies and after reaching the concept, the author will develop, test and validate prototypes for the technological solution. As a result of this research, it is expected to reach guidelines to assure the readability of displayed information. Readability, hereby defined according to the Cambridge dictionary as “the quality of being easy and enjoyable to read”. The goal is to find solutions that make information easily understandable to shop floor workers.

For a better understanding of the problem, it was necessary to review previous research on Industry 4.0, Operator 4.0, and the estimated alterations and innovations that they brought. In addition, it was necessary to investigate about the more adequate User Research Methods in the shop floor context, as well as take into consideration possible changes or needed adaptations to be applied remotely given the pandemic situation, as a result to Covid-19, that severely restricted the workfield to execute. The possibilities to develop this user research are being continuously studied and possible changes and adaptations are considered.

1.4 Goals and Contribution

The main goals of this dissertation are the generation of visual representations that are understandable for shop floor workers and useful for the development of the application to be developed by Fraunhofer AICOS. These visualizations' concept, development, testing and validation of those visualizations' prototypes for the Worker Companion were elaborated working in collaboration with end-users. The accomplishment of these goals enabled the development and definition of preliminary guidelines that ensure the readability of information displayed while monitoring operators in Industry 4.0. In order to accomplish these goals, it was important to understand the values, needs, goals, tasks, and risks of Operator 4.0.

Developing qualitative user research, a Human-Centred Design approach was implemented through the following methods: Observation, Individual Interviews, Stakeholder and Journey Mapping, Co-Design Workshops, Lo-fi Prototyping and Validation. These methods are detailed in chapter 4 of this dissertation, "Project Development", where the goal of each stage of development is explained.

The research developed through those methods resulted in two types of contributions: an empirical contribution that led to a theoretical contribution. A theoretical contribution consists of "new or improved concepts, definitions, models, principles, or frameworks."(Wobbrock & Kientz, 2016). This theoretical contribution, in specific, is focused on defining guidelines to display information in the Worker Companion to integrate factories in Industry 4.0.

To accomplish this goal, it was essential to develop a set of activities that guided this research. This set of activities was developed as an empirical contribution. The empirical contribution of this research results from the methodology which counts with Observation, Individual Interviews, Personas, Stakeholder and Journey Maps, Co-Design Workshops, Prototypes, and Evaluation.

1.5 Document's Structure

This dissertation is organized in seven chapters.

Chapter 1 is the Introduction of the work. This chapter introduces the host institution of my internship — Fraunhofer Portugal — AICOS, the project where this dissertation is being developed, the motivation, scope, goals and the contributions expected from this research. It also includes this particular section where the structure of the document is presented.

Chapter 2 includes the State of the Art and Literature Review. In this chapter, Industry 4.0 is deeply explored, from the economical, to the geographical, technological and human perspectives. Besides reviewing those topics, chapter 2 also highlights the importance of Health Monitoring within the shop floors of Industry 4.0. Besides this, the two main subjects of this dissertation are introduced: Human-Computer Interaction and Visualization. There is, also in this chapter, an exploratory analysis of some of the technological solutions already available according to HCI and Visualization principles.

Chapter 3 presents the Research and Design Approach of this dissertation. In this chapter, the Human-Centred Design approach, the timeline and the different stages of development planned and effectively done a.

Chapter 4 explains the Project Development, the different stages of development of this research and the explanation of each stage.

Chapter 5 presents the Preliminary Guidelines found as a result of the research and explains each of them.

Chapter 6 presents the Conclusion and Final Remarks of this dissertation as well as the Discussion and Future Work that will give continuity to the work that has been developed.

Chapter 7 lists the References that guided this dissertation.

2. Literature Review and State of the Art

This chapter addresses Industry 4.0, including its economical, geographical, and technological perspectives as well as the Human Perspective and Operator 4.0. Besides this, chapter 2 also addresses Health Monitoring, its importance and advantages.

2.1 Industry 4.0

Industry has been constantly evolving over the years. This evolution allowed a significant growth of the manufacturing sector, now reaching its fourth revolution. While trying to define Industry 4.0, Carsten Wittenberg (2016) recalled the preceding innovations that allowed the sprout of this new era of manufacturing. From steam and water power, to band conveyors, and programmable logic controllers, Industry 4.0 is now introducing Cyber-Physical Systems (CPS). This revolution brings a new perspective of improvement and growth, through a symbiosis of humans and machines.

This chapter introduces and contextualizes the different perspectives of Industry 4.0 as well as their characteristics, compromises and concerns. In doing so, this chapter first introduces Industry 4.0 from an economical perspective, to then pass through its geographical and technological perspective and finally provide a view on the human perspective of Industry 4.0.

2.1.1 Economical Perspective

There is a general concern about how Industry 4.0 will affect the economy, the changes it might bring to employment, and the impact it might have in the world in general. In fact, the skills required to integrate industry 4.0 are distinct to the ones required for a person to integrate factories nowadays. According to The Boston Consulting Group, introducing collaborative machines on the shop floor of factories will result in a productivity increase and improved performance, where after a year, these companies are estimated to originate revenue growth (Lorenz et al., 2015). This growth will allow companies to create thousands of new positions to perform tasks required in the new work environment, such as “jobs requiring flexible responses, problem solving, and customization”(Lorenz et al., 2015). However, Lorenz et al. also expect a decrease in jobs that require physical assistance or mechanical repetitive work.

Consequently, it is imperative to encourage governments and companies to adapt and integrate Industry 4.0 models, so that the offer and demand for jobs and skills remain coordinated. It is essential to “engage in strategic workforce planning” (Lorenz et al., 2015) categorizing the multiple types of jobs, grouping them. This will allow education systems to create and provide wider skill sets, preparing future generations for this new industrial era.

2.1.2 Geographical Perspective

A study involving different countries around the world explored their visions for Industry 4.0 and concluded that the focus of these perspectives can diverge depending on the country (Ruppert et al., 2018).

Germany is considered the major influence of European industrialization while promoting the "computerization of manufacturing" (Ruppert et al., 2018). China, on other hand, has a different approach. "Made-in-China 2025" was announced in 2015 and, envisioning the most modern Information Technologies (IT), its strategic plan is to increase competitiveness among multiple industries. Whereas, the United States has admitted to consider "reindustrialization" policies to reinvigorate its manufacturing industry"(Ruppert et al., 2018), Japan has presented the "New Robot Strategy" as an attempt to accelerate the development of cooperative robots, and revolutionize the robot industry. The "New Industrial France", the "High-Value Manufacturing Strategy Of The UK" and "The Advanced Innovators' Strategy Of South Korea" focus on cyber-physical systems (CPS) and their common goal is to integrate the supply chain[2].

While each country has a distinct approach, one aspect is consensual: all around the globe, industry is evolving towards a symbiosis between humans and machines. Humans and technology are envisioned as cooperative workers, committed to improve productivity, increase competitiveness and fight time loss and stagnation.

(2) The supply chain is defined as "a series of steps and operations (procurement, production, inventory, transportation) that transforms raw materials into consumable products" (Chwif et al., 2002)

2.1.3 Technological Perspective

Factories integrating Industry 4.0 are expected to introduce new technologies in the shop floors. These technologies are meant to help workers, complement the workflow, and make production more efficient and adaptable. The wide range of technologies can go from cyber-physical systems (CPS), Internet of Things (IoT), Bio-data sensors, Wearable Trackers to Collaborative Robots, and Augmented Reality. However, there is evidence that the predominant use of technology will rely on “the use of IoT technologies, followed by CPS and mobile devices'' (Fettermann et al., 2018).

According to (Lee et al., 2015), Cyber-physical systems are “defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities”. Hence, CPS allows broad communication networks in a system, through autonomous and cooperative elements, e.g. robots, capable of connecting every element present in the workforce. It can be challenging trying to define the Internet of Things (IoT). However, after deep consideration on multiple theories, (Lynn et al., 2020) concluded that IoT may acquire two different perspectives: “a purely technical and a socio-technical perspective”, that has the “potential to transform how society operates and interacts”. Ergo, IoT allows the operators, machines, and objects to connect with the internet, and exchange data through software, trackers, or sensors. These technologies and devices create what is called a “smart factory”.

2.1.4 The Human Perspective and Operator 4.0

In manufacturing, as in other areas, there are multiple kinds of workers, while some of them perform tasks resorting to their strength, others mostly perform repetitive tasks and calibrate machines. Nowadays, these workers — referred to as "operators" as someone who operates a machine or works in collaboration with one — are assisted by technology and in Industry 4.0 this assistance will be even more notorious. It is important to consider that not all industries have the same types of technologies and operators and it is not necessary to have all of them to consider a factory complete.

A previous review (Romero et al., 2016), has identified eight types of operators expected to integrate Industry 4.0: the Super-Strength Operator, the Augmented Operator, the Virtual Operator, the Healthy Operator, the Smarter Operator, the Collaborative Operator, the Social Operator, and the Analytical Operator.

Different types of operators

"THE SUPER STRENGTH OPERATOR" refers to operators who may use wearable exoskeletons to help them reduce physical stress and give them support in harder tasks related to strength. An example of this type of assistant is "Robo-Mate"[3]. This exoskeleton has both active and passive support for workers which means that it can both give stability and support for a worker that spends many hours in the same position or help the movements and strength of a worker that spends most of his time carrying or lifting things.

"THE AUGMENTED OPERATOR" can be assisted by Augmented Reality, head-gears, smartphones, or tablets in their field of view. These integrations in the field provide operators real-time feedback, important indications, and digital assistance through the projection of graphics, video, or sound. There are multiple advantages in the integration of these technologies in their tasks, such as the reduction of human errors or faster cycle times. In fact, this can also be more eco-friendly since there will be less need for printed instructions and manuals.

(3) https://www.robo-mate.eu/

“THE VIRTUAL OPERATOR” can count on the presence of “immersive interactive multimedia and computer-simulated reality” (Romero et al., 2016) that is capable of simulating a manufacturing environment, design, or assembly. The operator is expected to interact with these simulations and work in cooperation with the information given by them.

“THE HEALTHY OPERATOR” uses wearable trackers, bio-data sensors, and exploits personal analytics. This can prevent threats to the health of these operators “monitoring health-related metrics and workloads and alert decision-makers” (Romero et al., 2016). Great examples of these trackers are Apple Watch and MiBand. They both are able to monitor personal data such as heart-rate and the number of steps someone gave whilst wearing those watches.

“THE SMARTER OPERATOR” is helped by Intelligent Personal Assistants (IPA). These assistants can also be mentioned as conversational agents, smart speakers, or voice-controlled agents. These assistants can be activated by voice or typing and their goal is to respond to the users’ needs by giving them the information they need. These assistants can have different hardware, design, and types of tasks but their network architecture is similar. They receive the user’s input (usually, a request), access web-hosted services, like the cloud, and return the answer that responds to what has been asked by the user. Good examples of these assistants are Apple Siri, Amazon Alexa, or Google Assistant.

“THE COLLABORATIVE OPERATOR” works with Collaborative Robots, or “CoBots”[4], that assist operations and support workers. There are many advantages in working in cooperation with these robots, such as flexible automation, the ease to transport and reprogram them, and capacity of performing dangerous tasks allowing the workers not to put their lives at risk.

“THE SOCIAL OPERATOR” is envisioned to be connected to other team members to keep real-time communication. This allows a faster response to danger, necessity or request. This type of dynamic is already integrated in companies like LinkedIn, where workers use their own product — the social network LinkedIn — to communicate internally.

(4) https://www.universal-robots.com/products/collaborative-robots-cobots-benefits/

“THE ANALYTICAL OPERATOR” is assisted by interactive dashboards and real-time alerts and information. Like the Social Operator, the Analytical Operator is connected to other applications. However, this operator is connected to applications related to data analytics to control metrics and key-performance indicators.

The Worker Companion to be developed in the “Augmented Humanity” project is mostly focused on the “Healthy Operator” through the register and representation of health information and metrics. However, it will also approach some of the “Smarter Operator” issues through the access of relevant information, and some of the “Collaborative Operator” and the “Social Operator” issues through communication tools.

Health Monitoring for Operators 4.0

According to (Chiang et al., 2012), “knowledge of prior behavior is necessary for understanding the potential risk on the long-term system performance”. In the context of Industry 4.0, health monitoring emerges as a particularly interesting topic, since there are multiple advantages in monitoring the health of operators in an industrial context. Gathering the health of workers’ information through monitoring solutions assures multiple advantages such as damage control and risk prevention. Damage control can be guaranteed by the integration of smart alerts and notifications, attention to the values of indicators, and the evaluation of metrics. Through analysing the information displayed, it is possible to prevent risks, such as work related injuries or accidents. Besides this, monitoring information allows the user, in an industrial context, to evaluate if someone is performing an adequate task, adjusted to their health conditions.

Smart watches are great examples of an integration that successfully transmits health related information to users. According to Bieber et al. (2012), smart watches can be described as “wrist worn devices with computational power, connectivity to other devices or Internet and an integrated clock”. These watches, among others, allow for activity and gesture recognition and heart rate measurement. In industrial scenarios, these measures can be used to evaluate stress and sedentary levels. Usually, these metrics are displayed on a watch or app that connects the watch to a mobile device, such as a smartphone or a tablet. These functionalities allow the user to receive notifications or smart alerts through sound, image or vibration in the watch or in a mobile device, which alerts the user in case a situation requires attention.

Figure 1 — Example of smart watches, namely a Fitbit (left) and an Apple Watch (right).

How will operators adapt to this new era?

In "Towards a Human-Centred Reference Architecture for Next Generation Balanced Automation Systems: Human-Automation Symbiosis", (Romero et al., 2015) described the importance of adapting operators to the new industrial era. Romero (2015) highlights that Industry 4.0's plans to bring new machines, robots and cyber-physical systems to the shop floors must be followed by plans to adapt workers to this integration.

In addition, Mercier-Laurent and Monsone (2019) also stresses that, while managing systems of Industry 4.0, it is required the "deep comprehension of the interrelations between all components including people and environment" (Mercier-Laurent & Monsone, 2019).

Smart factories must create and adapt plans for workers that are apprentices, aging, or disabled, so that these people can integrate into the new work environment, remain in their jobs, or return to them. It is expected that apprentices will be able to receive professional training which includes the tasks integrated in the new system of operations. This allows the future apprentice to perform tasks with efficiency and without difficulty, from the beginning. For older workers, Romero presents two possible scenarios. The first scenario predicts a rise of automation elements present in a shop floor to compensate for the operator's age-related limitations. The second scenario anticipates the adaptation of the plant of shop floors to reduce the number of automation machines so that the operator is able to perform tasks and feel integrated in the workflow. In case of disabled operators, factories will possibly avail of "adaptive physical and cognitive automation" (Romero et al., 2015) to include operators in ordinary tasks.

2.3 Human-Computer Interaction and Visualization

Departing from the two main areas of this research: Human-Computer Interaction and Visualization, this section presents and reviews already existing solutions able to inspire the Worker Companion to develop in the context of Industry 4.0.

2.3.1 Human-Computer Interaction

Reading the term “Human-Computer Interaction”, it might seem easy to conclude that this discipline studies the interaction between humans and computers. However, in 2004, Alan Dix reflected on Human-Computer Interaction, its foundations, its design process and its models. Then, he clarified that “when we talk about Human-Computer Interaction, we do not necessarily envisage a single user with a desktop computer” (Dix, 2004). Here, the use of the word “human”, can refer to a single person or a determined group of people. The word “computer” refers to a technology or artifact used in the work. At last but not least, “interaction”refers to any kind of communication between the human and the computer, representing an attempt to accomplish something. This communication can happen in many different ways, for example, through movement, dialogue, the use of image, sound or sensors.

In this research, HCI is mainly focused on the interaction between humans and the technologies that display useful information, in the context of factories in Industry 4.0. There are multiple HCI design principles that could guide this study: Don Norman’s Design Principles, Ben Shneidermann’s Eight Golden Rules for Interface Design, Alan Dix’s Design Rules, and Bruce Tognazzini’s First Principles of Interaction Design.

Ben Shneidermann’s Eight Golden Rules for Interface Design (Shneiderman et al., 2017) provide good starting points to develop web and mobile applications. They include: Strive for consistency, seek universal usability, offer informative feedback, design dialogs to yield closure, prevent errors, permit easy reversal of actions, keep users in control and reduce short-term memory load.

Alan Dix's Design Rules (Dix, 2004) are divided into three major areas: learnability, flexibility, and robustness. Inside each of these areas, there are five sub-categories that support the major ones. Dix listed predictability, synthesizability, familiarity, generalizability, consistency as pillars for learnability. Dialogue initiative, multi-threading, task migratability, substitutivity, and customizability as pillars to flexibility. Lastly, observability, recoverability, responsiveness, and task conformance as pillars to robustness.

Bruce Tognazzini (Tognazzini, 2014) identified sixteen principles of Interaction Design. These principles include anticipation, autonomy, color blindness, consistency, defaults, efficiency of the user, explorable interfaces, fitts' law, human interface objects, latency reduction, learnability, metaphors, protect users' work, readability, track state, and visible navigation.

Each and every one of these sets of principles and rules are relevant and could be detailed. However, the message is that there is a considerable overlap. So, to assure clarity and simplicity, in this dissertation, the principles of design that will lead the exploration of platforms are Don Norman's Design Principles. As mentioned in his book, "The Design of Everyday Things: Revised and Expanded Edition" (Norman, 2013) , the seven principles include:

1. "**Discoverability.** It is possible to determine what actions are possible and the current state of the device.
2. **Feedback.** There is full and continuous information about the results of actions and the current state of the product or service. After an action has been executed, it is easy to determine the new state.
3. **Conceptual model.** The design projects all the information needed to create a good conceptual model of the system, leading to understanding and a feeling of control. The conceptual model enhances both discoverability and evaluation of results.
4. **Affordances.** The proper affordances exist to make the desired actions possible.
5. **Signifiers.** Effective use of signifiers ensures discoverability and that the feedback is well communicated and intelligible.
6. **Mappings.** The relationship between controls and their actions follows the principles of good mapping, enhanced as much as possible through spatial layout and temporal contiguity.
7. **Constraints.** Providing physical, logical, semantic, and cultural constraints guides actions and eases interpretation."

These principles assure focus points of an analysis from a Human-Computer Interaction point-of-view. However, this dissertation not only focuses on that perspective but also concerns Visualization issues. Thus, it is pertinent to present the Visualization principles that will guide the analysis of the solutions from a Visualization point-of-view.

2.3.2 Visualization

Matthew O. Ward described Visualization as “the communication of information using graphical representations” (Ward et al., 2015). According to Tamara Muzner, Visualization “is suitable when there is a need to augment human capabilities rather than replace people with computacional decision-making methods” (Munzner, 2014). Relying on this idea of representation focused on the information and the user, studies on this scientific field developed multiple approaches to Visualization.

Three of these approaches comprise: Information Visualization, Data Visualization and Visual Analytics. Gershon stated that “Visual representation of information requires merging of data visualization methods, computer graphics, design, and imagination.” (Gershon et al., n.d.). However, Mathew O. Ward did not separate Scientific Information Visualization from Data Visualization, asserting that “Both provide representations of data.” and that even though there are distinct functions of each, depending on the dimension of information, Data and Scientific Information Visualization “are allied fields” (Ward et al., 2015). Besides these perspectives, there is a third type of Visualization called Visual Analytics. The process of Visual Analytics can be best described as “a series of steps that integrate human and computational steps in an integrated fashion to meet an analytical goal” (Keim et al., 2010). In this dissertation, the visualizations developed are influenced by these three perspectives of visualization.

Taking these different perspectives of Visualization into consideration and similarly to what was done with regards to HCI principles, it is also important to define parameters to analyse and evaluate platforms into what concerns Visualization. This appraisal enables the comprehension of the state of the art platforms that will be presented and discussed in section 3.3 from a Visualization perspective.

Ben Shneiderman defined twelve task types to analyse visualization. These twelve tasks were created to “enable iterative visual analysis, including visualization creation, interactive querying, multi-view coordination, history, and collaboration” (Shneiderman et al., 2017) and are divided in three major categories: Data and View Specification, View Manipulation, and Process and Provenance.

In the first category — *Data and View Specification* — there are four task types:

- The **Visualize** task assures that the user is able to visualize data.
- The **Filter** task assures that the user is able to filter data to visualize the items the user wants to give relevance to.
- The **Sort** task is important to organize information to expose patterns.
- The **Derive** task gets information, usually numeric values, from somewhere.

In the second category — *View Manipulation* — there are four task types:
The Select task allows the user to select information to highlight, filter, or manipulate.

- The **Navigate** task allows the user to navigate through a technology to check possible high or low level detailed patterns.
- The **Coordinate** task allows the users to coordinate more than one representation of information at the same time as a way to synchronize views.
- The **Organize** task assures the possibility to see more than one screen simultaneously, to compare data or simply explore them.

In the third category — *Process and Provenance* — there are four task types:

- The **Record** task assures that the user has the possibility to record data for posterior analysis, share or review.
- The **Annotate** task is important for the user to annotate patterns to register findings.
- The **Share** task allows the user to export and share data.
- The **Guide** task gives the user the possibility to nimbly analyse information.

In the previous and present sections, there was an overview of Human-Computer Interaction and Visualization fundamental principles that will guide this dissertation and the analysis of the already existing solutions. In the next section, these principles will be used to analyse the relevant solutions found to explore in this dissertation, hereby presented and discussed.

2.3.3 Solutions' Analysis

This section presents existing technological solutions that measure and display information. These solutions include interactive dashboards, work measurement and optimization softwares. They were identified and selected because they constitute great visualization or interaction solutions or contextual insights in terms of technological advantages and disadvantages. The analysis in this section first presents each solution to then reflect on the advantages, concerns and limitations of those solutions with regards to the HCI and Visualization principles described above, that is:Don Norman's Design Principles and Ben Shneiderman's Twelve Tasks Types for Visualization.

Scoro[5]

Scoro is a collaborative dashboard with a large range of features and integrations. The main goal of this platform is to gather all the tools needed by a company as a way to improve productivity and reduce time loss. Used in every sector, from building and construction to financial services, this dashboard counts with a high-level overview of data, from general to detailed project tracking, dynamic reports, and drag and drop planners. Scoro is fully customizable, displays real-time updates, in multiple devices at the same time, and allows the user to have multiple dashboards, displaying different information in each one of them. It is possible to observe some of Scoro's screens in Figures 2 and 3.

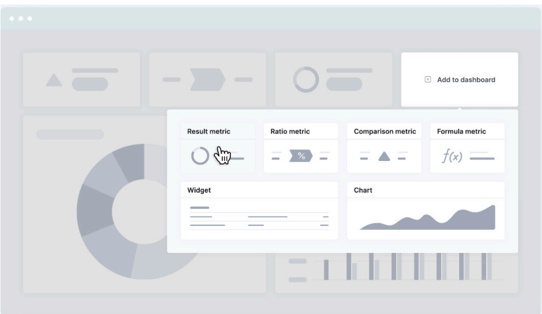


Figure 2 — Scoro's dashboard creating process.

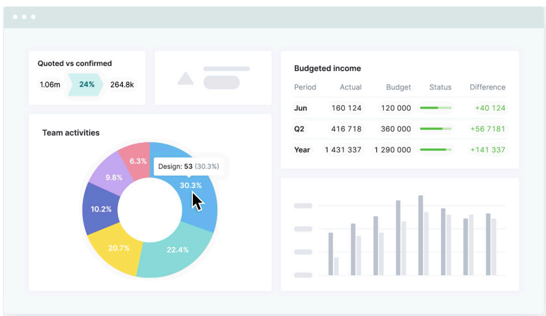


Figure 3 — Scoro's dashboard demonstration.

(5) https://www.scoro.com/

Evaluating Scoro resorting to Don Norman's Design Principles (Norman, 2013):

In terms of Discoverability, one understands what actions are possible to perform, using Scoro. Feedback in Scoro displays the current state of the device after performing a task, which makes it a good example of this parameter. The Conceptual Model of Scoro is exemplary since the design of the platform is very pleasant, informative and topical. This design allows for the understanding of the possibilities in the platform and foments the feeling of control. Scoro is strong in Affordances since the visual representations of the possible actions suggest to the users how to perform them. A good example of these affordances is the creation of a modular section and the transformation from placeholders to concrete information. Signifiers can be seen in Scoro through the animations present in the platform that represent states of the actions. Scoro follows the principles of good Mappings, for example, in the creation of a modular section on the screen and the process that leads to the creation of that section. Scoro counts with visual Constraints, helping the user to know where it is possible to introduce visualizations and how to organize and display information in each screen.

From a Visualization perspective, it is important to elicit the twelve task types for visualization, created to "enable iterative visual analysis, including visualization creation, interactive querying, multi-view coordination, history, and collaboration" (Shneiderman et al., 2017):

Scoro allows the user to select and manipulate the information she/he wants to visualize. Using Scoro, the user is able to sort the information as a way to highlight what is necessary. The information can be derived using Scoro, by extracting it from the platform. It is possible to highlight information. It is possible to navigate in Scoro's visualizations that contain information. It is also possible to access the same account of Scoro on different devices at the same time. Users are able to record and register information using Scoro. It is easy to identify patterns and annotate them. Users are allowed to share views and annotations from Scoro by exporting its data. Scoro can further be integrated with Google Calendar, Trello, Gmail, Outlook, Google Drive, Zero, Zapier, Mailchimp, and others. At last, it is possible to guide users through analysis tasks or stories using Scoro, by analyzing its visualizations and abridgements.

Bilbeo[6]

Bilbeo is a web-based analytics and key performance indicators (KPI) dashboard software. This multi-device software works as an auto-populated dashboard that notifies the user with smart alerts when needed. It also identifies the leading indicators influencing business performance at the time. Besides this, it creates custom reports from the unlimited collaborative dashboards. Bilbeo's example screens can be observed in Figures 4 and 5.

Evaluating Bilbeo according to Don Norman's Design Principles (Norman, 2013):

Looking at Discoverability, it is concluded that it is partially understandable. While some visual elements of the screen are easy to interpret, others, like the side navbar, are not so perceptible and might cause doubts and mistakes. In terms of Feedback, Bilbeo shows the user loading messages every time a visual element, like a chart or a full-screen page, is loading information. The Conceptual Model of Bilbeo is minimalist, although it displays large amounts of data. It is organized and consistent. Some elements might be weaker in terms of Affordances but, overall, the platform is easy to understand and use. Signifiers in Bilbeo are used effectively and the icons accompanying words in buttons help to complete this idea of representation of a concept. The Mappings of Bilbeo effectively help the user perform the tasks they need while selecting a control. Bilbeo's good mappings can be verified in the selection of charts to visualize. Design Constraints in Bilbeo help users organize the dashboard in a modular grid. Besides this, there are constraints adding options or criterias to a chart to help the users' process of creating a dashboard.

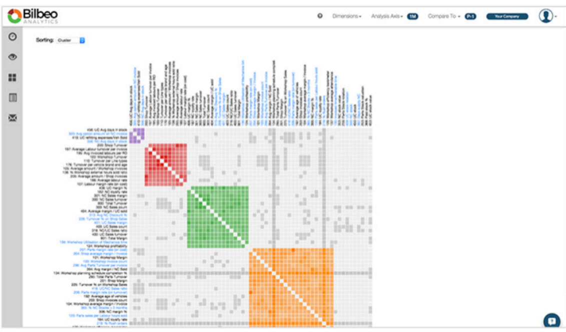


Figure 4 — Bilbeo's visual representation example.

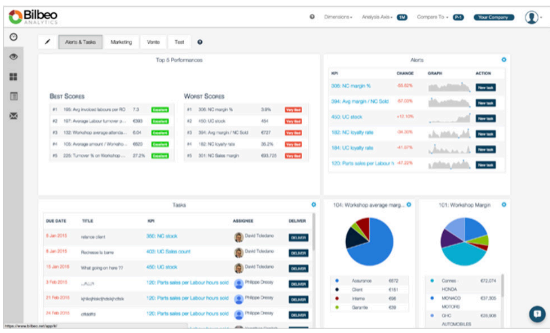


Figure 5 — Bilbeo's dashboard example.

(6) https://www.bilbeo.com/features

From a Visualization point-of-view, it is important to stress the Twelve Task Types for Visualization (Shneiderman et al., 2017):

Bilbeo is a good platform to visualize complex data making it easy to visualize and interpret. It is easy to filter information using Bilbeo, highlighting what the user wants to highlight. Bilbeo has great solutions of visualization to expose patterns while sorting information. It is possible to derive information from source data, for example machines through KPIs. It is possible to select determined values or sets of information to analyse. It is possible to navigate in Bilbeo's platform to visualize information and highlight different patterns. It is possible to visualize two or more types of information at the same time on the same device. It is possible to access the same "account" of Bilbeo on different devices at the same time. It is possible to record and register information, using Bilbeo. It is easy to identify patterns and annotate them. This software can be integrated with: Oracle, PostgreSQL, MySQL, Excel Template, Google Analytics, and CSV. It is possible to guide users through the analysis of visualizations in the platform.

UMT Plus[7]

UMT Plus is a work measurement software that does work sampling with time studies. This software can be used on multiple mobile devices, simultaneously. UMT Plus allows the user to create, edit and manage studies and metrics easily. It includes features like manual data collection, the visualization and editing of observations. Also, it is possible to add comments, photos, speed ratings and numeric codes to the observations.

(7) https://www.laubrass.com/umtplus/time-study-modules

Even though there are multiple advantages using this software, there are two limitations which can worsen the experience. The first limitation relies on programming the studies. This software offers multiple options to ease the process of programming the studies. However, the system might not be understandable or obvious for everyone. Besides this, even though it fulfils the goal of the software, the second limitation stands with the archaic design it displays. Some of UMT Plus's screens can be observed in Figures 6, 7, and 8.

Evaluating UMT Plus considering Don Norman's Design Principles (Norman, 2013):

Even though UMT Plus's design is basic, the discoverability of the platform can be difficult at first because of its lack of labels in the options available. The feedback of the platform is not exemplary. The conceptual model of UMT Plus is not exemplary since the design is not updated and the platform is not extremely clear, reducing users' control and freedom. There are good examples of affordances in UMT Plus in the options given when performing a task. These tasks can be performed by clicking at the top of the screen in "Options" while selecting a cell on the screen. These affordances include the configuration of a study. The icons in the navbar in the bottom of the screen represent a bad example of signifiers. This platform is not the best to exemplify good practices in signifiers. Since there is an archaic design with the performable options available, the controls are directly connected to the actions users want to perform. So, the mappings of UMT Plus are adequate. Even though there are multiple constraints in UMT Plus, for example, in the options available on the performable tasks, UMT Plus is not the best example of good constraints.

From a Visualization point-of-view, it is important to stress the Twelve Task Types for Visualization (Shneiderman et al., 2017):

It is possible to visualize information, using UMTPlus. Information can be filtered using this tool. The information displayed in UMT Plus can be sorted into columns and rows of different levels of information. It is possible to derive information, programming the information you want to use at the beginning or at the end of a task or activity. It is possible to select a determined piece of information, using UMTPlus. It is possible to navigate in UMT Plus as a way to visualize the different data. It is not possible to access different information in the same screen, using UMT Plus. It is possible for the user to build her/his information, organizing it from the beginning. It is possible to record UMT Plus features using the new integrations of the platform. It is possible to identify patterns and annotate them. The analysed data can be exported to Excel and other report softwares. It is possible to guide users through the analysis of graphics and charts.

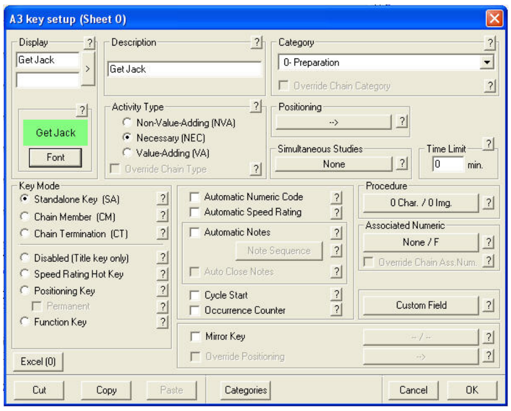


Figure 6 — UMT Plus programming tab, example A.

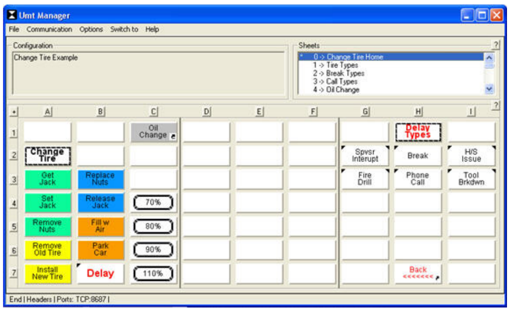


Figure 7 — UMTPlus Manage Display.

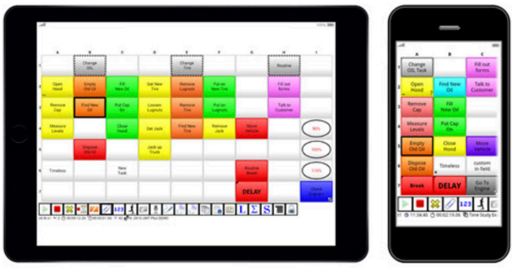


Figure 8 — UMTPlus Mobile Manage Display.

TimerPro[8]

TimerPro is a video-based measurement solution that measures, identifies and eliminates process waste to improve operation efficiency. Some advantages of this solution are: the reduction of costs; the balance of work through the number of operators and the desired production; the documentation processes. This documentation can be elaborated through man-machine charts, video storyboards, yamazumi charts, ergonomic analysis, and mixed multi model production scheduling. Also, the standard data libraries available on the software are able to help users understand their possible actions and most of the TimerPro's features. Some of TimerPro's mentioned screens are illustrated in Figures 9 and 10.

(8) https://www.acsco.com/

Evaluating TimerPro regarding Don Norman's Design Principles (Norman, 2013):

Since there are multiple options of actions to perform and they are distinctly represented, the discoverability of TimerPro is adequate. This discoverability allows users to determine what actions they are able to perform on each screen. There is real-time feedback in the platform, making it adequate for the tasks performed using TimerPro. Even though the design of the platform is archaic, the conceptual model is successful since it is understandable and minimalist. This minimalism and conceptual model makes TimerPro a good example of users control and freedom. The affordances of TimerPro are exemplary in the charts displayed. A good example of these affordances is the screen of Ergonomic Analysis. There is an effective use of signifiers in TimerPro in the platform in general and in the visualization screen in specific. TimerPro can be an example of good mapping since it assures a direct and clear relationship between controls and actions. The constraints of TimerPro allow a better organization and display of information.

From a Visualization point-of-view, it is important to stress the Twelve Task Types for Visualization (Shneiderman et al., 2017):

It is relatively easy to visualize information, using TimerPro. Information can be filtered in almost every feature. Using video in Timer Pro and its charts of information, this information can be sorted if the user selects that option on the right top of the screen. Using the video feature of TimerPro, it is possible to derive information from it. This information can transform into different types of charts, mappings and tables. It is possible to select a determined piece of information, using TimerPro. It is possible to navigate in TimerPro as a way to visualize the different data. Using TimerPro, it is possible to watch video recordings and mappings and other analytical charts. It is possible for the user to organize information, selecting what type of visualization for what type of information the user wants to see. It is possible to record and export those recordings, using TimerPro and its video features. It is possible to identify and annotate patterns. Timer Pro allows the user to export data from the video recordings, tables, and charts. Yes, it is possible to guide users through the analysis of video recordings and training.

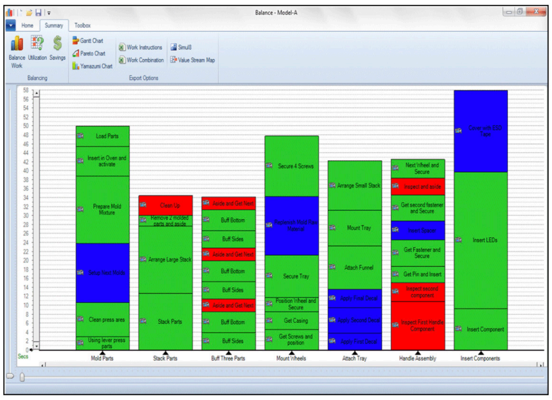


Figure 9 — TimerPro's Measurement Visualization.

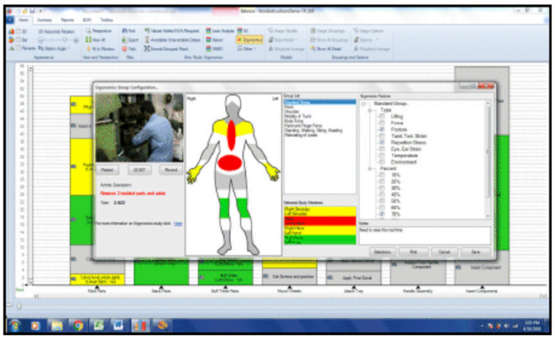


Figure 10 — TimerPro's Ergonomics Analysis Dashboard.

IBM Maximo Worker Insights[9]

IBM Maximo Worker Insights is a work measurement and improvement solution. This technology is divided by working positions — a first one that aims to notify workers and a second that notifies supervisors. Resorting to wearable trackers and environmental sensors, this technology notifies the worker, depending on his position. In case a worker is using the mobile application, this technology notifies of the risks in the workplace, with early alerts and personalized advice. In case a supervisor is using the mobile app, this technology notifies the user in case a worker is in a dangerous environment or a biometric issue. It is possible to observe some of IBM Maximo Worker Insight's screens in Figures 11, 12, 13, and 14.

(9) https://www.ibm.com/support/knowledgecenter/SSQNYQ_bas/worker-insights/overview/worker_overview.html

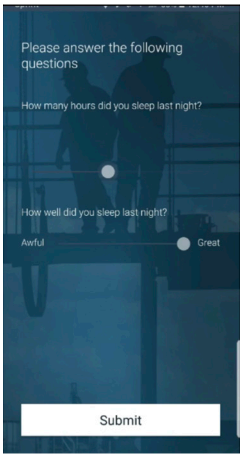
Evaluating IBM Maximo Worker Insights taking Don Norman's Design Principles into consideration (Norman, 2013):

This application is a good example of discoverability through the interaction between users, their devices and the application. Besides this, the application is clear about what kind of information it expects from users. The application gives real-time feedback and its alerts and notifications represent good examples of the well-functioning of the application. The conceptual model of IBM Maximo Worker Insights is successful, projecting all the information users need in a clear and minimalist design. The affordances of the application help users understand the information that the application is asking. Signifiers in the application are successful, for example, in the safety screen when the application is identifying devices and safety equipment. The mapping of IBM Maximo Worker Insights allows users to understand quickly the information required and given by the application. These signifiers can be visualized, for example, in the notifications' screen. The constraints of this application avoid confusing tasks. A good example of these constraints are the fact that the application gives users the possible answers they can give when receiving a notification of danger.

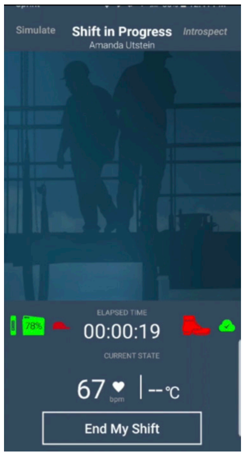
From a Visualization point-of-view, it is important to stress the Twelve Task Types for Visualization (Shneiderman et al., 2017):

Using this application, it is possible to visualize information and easily comprehend it. It is possible to filter information using IBM Maximo Worker Insights. This can help the user to visualize current and historical hazard trends and analyse them. It is possible to sort information and to derive information from the hazard patterns. It is possible to select the information to specify the view and information to analyse. It is not possible to coordinate views for linked exploration. It is not possible to organize information. It is possible to record and keep in the app's history. It is possible to annotate hazard patterns. It is not possible to share views with other applications or platforms. This application is able to guide the users through analysis tasks or stories.

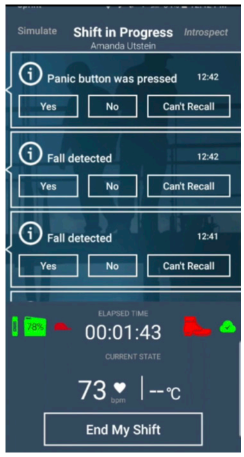
(Figure 11)



(Figure 12)



(Figure 13)



(Figure 14)

The four figures above represent screenshots from the application IBM Maximo Worker Insights.
The Figure 11 shows the screen that verifies if the worker is the safely equipped.
The Figure 12 shows the screen that asks for users' input about their tiredness.
The Figure 13 shows the general screen in which notifications appear. In this screenshot, the screen is empty.
In Figure 14, it is possible to observe the general screen with alert notifications.

2.3.4 Chapter Summary: From Human-Computer Interaction and Visualization Principles to Applications

It is important to search, explore, study and learn from the sedimentary disciplines of technology and the already existing solutions available. In this chapter, there was an introduction to Human-Computer Interaction and Visualization followed by an analysis of solutions. This analysis was supported by principles of these two disciplines which helped to understand some of the advantages and disadvantages of choices.

This analysis clarified how each technological solution can enrich the development of the future Worker Companion. With Scoro, it is possible to learn good design practices in terms of screen organization, display, typography and color. Bilbeo highlighted the need to give real-time and clear feedback to users as well as clear labels to visual elements displayed on screen. UMT Plus showed the importance of labels and descriptions, good design practices and organization by the lack of exploration in these parameters. TimerPro presents good examples of mapping, charts and visual representations, giving users different, successful and interesting interactions. Lastly, IBM Maximo Worker Insights introduces great solutions for simple, clear and quick interactions such as notifications, alerts, and device configurations.

3. Research and Design Approach

3.1 User-Centred Design

According to (Kuniavsky et al., 2012, p. 3), “User research is the process of figuring out how people interpret and use products and services”. To figure out how users think, why they act in a certain way, and what they expect from a product or service, it is important to study them and their background. User research resorts to methods that help the researcher adapt to the users’ values, needs, and goals. The methodology proposed in this research takes on a User-Centred Design approach and resorts to Participatory Design approaches to integrate certain stages of development. The influence of Participatory Design, as a “design practice that involves different non-designers in various co-design activities throughout the design process”(Sanders et al., 2010), makes the work developed in this dissertation even closer to the end-users of the application to be developed by Fraunhofer AICOS.

User-Centred Design is a process that “often demands that developers shift perspectives and spend time walking in their users’ shoes” (Kuniavsky et al., 2012). Perlman further defends that the user’s involvement in the design process is essential to accomplish a goal successfully and that “different degrees of user involvement may be implemented in order to manage expectations” (Perlman, 2002, p. 281). Even though there are usually multiple attempts to manage the user’s expectations, it is common to emerge the need to iterate the process and the product. Iteration stands as natural and necessary. Thus, Perlman mentions five principles that guide the User-Centred Design approach, the iterative aspect and the need to develop usability goals. These five principles include (Perlman, 2002):

- “User’s tasks and goals are the driving force behind the development”;
- “Users’ behaviour and context of use are studied and the system is designed to support them”;
- “Users’ characteristics are captured and designed for”
- “Users are consulted throughout the development”;
- “All design decisions are taken within the context of the users, their work and their environment”.

Considering these principles and the Participative Design influence, it was early on the development of this dissertation that the decision to work in cooperation with the final users of the “Augmented Humanity” project was made. This cooperation will allow the author to have an in-depth understanding of the user’s context, needs, values, risks and goals. The development of this dissertation led to an adaptation of the scientific term User-Centred Design to Human-Centred Design. This adaptation arises as a result of the development of this dissertation in collaboration with workers, where users are thought as people with determined characteristics and contexts and not only data sources to improve future work.

Either way, the work followed the User-Centred Design principles while developing activities with the participants. The stages of development will be described in the following section together with the timeline of each of the stages.

3.2 Research Stages and Timeline

3.2.1 Research stages

Following a User-Centred Design and Participatory Design approach, the work reported in this dissertation unfolded in six main stages of research. These stages include: Observation, Interviews, Personas, Stakeholder Map and Journey Map, Co-Design Sessions, Prototyping and Design Critique.

It started with **Observation**. This stage was necessary to introduce the context of workers, determine basic concepts, know shop floor displays, qualities and limitations.

Then **Interviews** were held to understand in-depth participants' context, tasks, values, needs, fears and goals. In this stage, there were a total of sixteen workers participating: ten from Bosch, four from IKEA and two from OLI.

After this, **Personas, a Stakeholder Map and a Journey Map** were elaborated. This stage of development was important since there was the need to organize information and comprehend previous insights.

Then, there were **Co-Design Sessions**. This stage of development was divided into two distinct sets of activities. The first set of activities was meant to inform the author about requirements and functionalities necessary to integrate in the Worker Companion. The second set of activities was meant to comprehend the workers' mental models and visual interpretations of shapes, colors, illustrations and charts.

After this, it was necessary to do **Prototyping**. This prototyping was essential to transform the information into visual representations that express the previous requirements.

Last, it was necessary to validate and iterate prototypes. This was done through a **Design Critique**. The Design Critique was a session that counted with three experts to test and evaluate the screens and the visual representations present in them.

Informed Consent and Anonymity

The stages that needed active participation from users, required Informed Consents. The document's purpose is to inform the participant about the activities, the material required, and the information that was being analysed after each session. An example of these documents can be found in the Annex A of this dissertation.

To respect participants' anonymity, workers will be mentioned as Px. P stands for Participant and x is the number associated to each participant. P1 was the first person to participate in activities integrated in the development of this dissertation, P2 was the second person to participate and so on.

3.2.1 Timeline

To structure the development of this research, a work plan was elaborated. This work plan consisted of estimating and planning the tasks, methods, and the amount of time we will need for each task. This work plan is divided into six major phases: State of the Art and Literature Review, Qualitative User Research, Ideation and Prototyping, Refinement and Evaluation, Development of Guidelines, and Writing and Dissemination. This section presents two work plans, the initial and final work plans, since due to the pandemic several changes and adaptations were required

The first section (State of the Art and Literature Review) was planned to start in the third week of September, and last until the fourth week of December. This stage of development is mostly about understanding the context of the problem. It started by searching articles, books, and dissertations to read. Then, the phase of reading and taking notes started about the topics relevant to this research, i.e.: User Research Methods, Human-Computer Interaction, Information Visualization, Industry 4.0, its shop floors and technologies, the operators, their usual tasks, and workflows. The time estimated for this stage of the work was accurate, even though some extra time was needed after the intermediate defense to accomodate for the comments and suggestion highlighted in the intermediate defense.

From October to November, there was a course on User Research Methods called "Learning From Users: User Research Methods for Technology Design". The course was led by researchers of Fraunhofer AICOS and counted with the participation of guests, also researchers, from universities from all around the world. The course included topics such as Ethnography, Observation, Cultural and Technological Probes, Participatory Design, Qualitative Data Analysis, Field Trials, Longitudinal Methods, Evaluation Methods, and Ethics. Each of these subjects was studied theoretically and applied in a practical context. This course introduced the author to methods she did not know before and added adequate references and learnings to apply in this dissertation, Participatory Design principles and Ethics.

Initially, Qualitative User Research was planned to start in the fourth week of January, and last until the third week of April. In fact, this stage of development lasted from the fourth week of January until the third week of May. This phase originally counted with Observation, Individual Interviews, Photovoice, and Journey Maps. However, given the pandemic situation, the plan needed to have some changes. It was not possible to implement the method "Photovoice" because of two difficulties. First, there was a logistical difficulty to reach workers in a pandemic situation, where it was necessary to contact factories via email and it took longer to get answers from them. Second, considering the fact that they were not allowed to use cellphones while working, it seemed inadequate to ask them to participate in this dissertation after their working hours. So, this stage of development included Observation, Individual Interviews, and the Elaboration and Validation of Personas, Stakeholder and Journey Maps. All of these methods demanded preparation, execution, and analysis. Some methods overlapped in certain moments, considering the stage of development of each method. There were moments where the finishing stage and analysis of a method overlapped with the preparation of the next method to be applied.

From the fourth week of March, to the fourth week of April, it was planned to occur the Ideation and Prototyping of the project. However, this stage lasted from the second week of April until the second week of June. In this stage of development, there were planned Co-Design Workshops, the development of Low Fidelity Prototypes, and a Design Alternatives Testing. From these three stages, the only one which needed to be adapted, eliminated and later integrated in the Co-Design Workshops was the Design Alternatives Testing.

It is important to refine the product of what has been developed and evaluate the results. The phase of “Refinement and Evaluation” was planned to start in the fourth week of April, and last until the third week of May. In fact, this stage of development lasted one week, the third week of June. This stage of development counted with a Design Critique session and iteration of prototypes.

The final stage was dedicated to the analysis and synthesis of all the information taken from the research and work developed and was used to extract and discuss conclusions for the work. This stage of development is called “Preliminary Guidelines" and was planned to occur in May 2021. However, it was only possible to execute this in the third week of June.

Writing and documenting tasks took place simultaneously. To obtain a visual overview of the timeline, consult Figures 15 and 16.

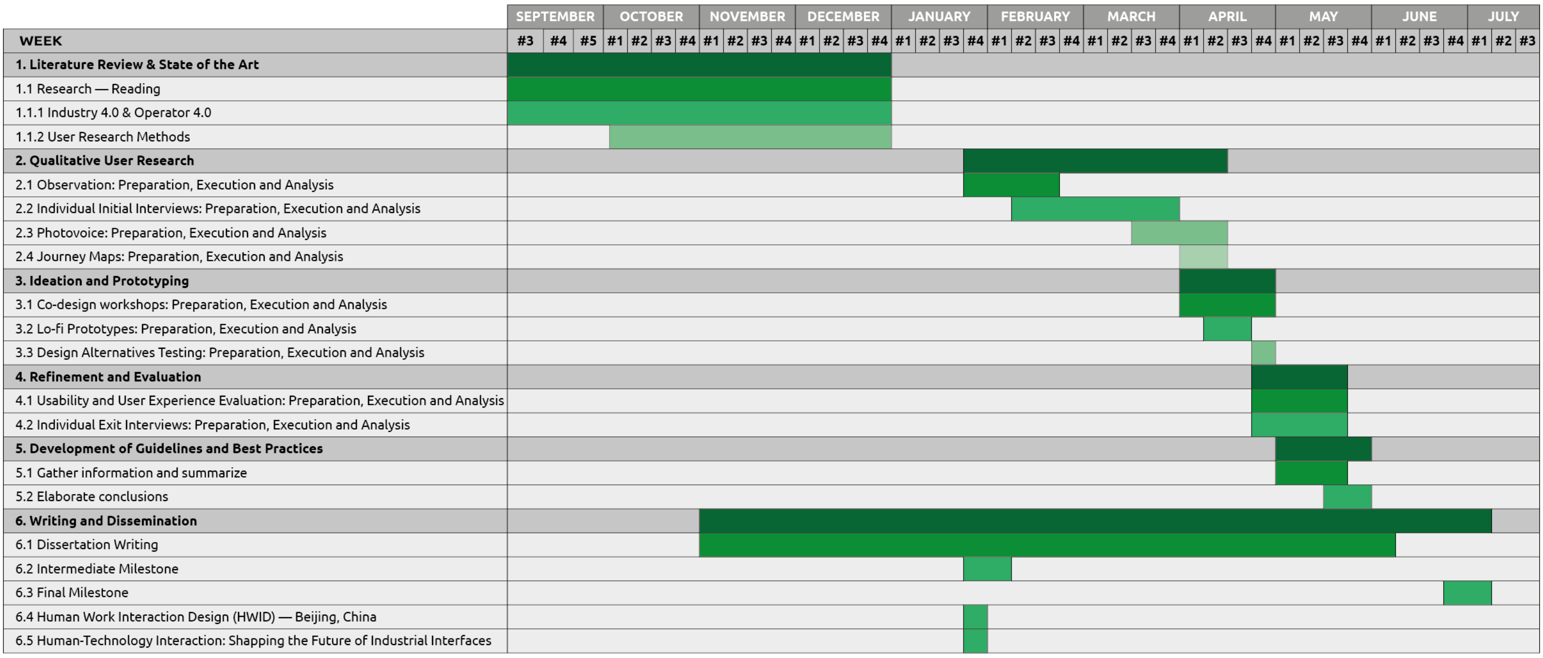


Figure 15 — The original work plan, elaborated in the first semester.

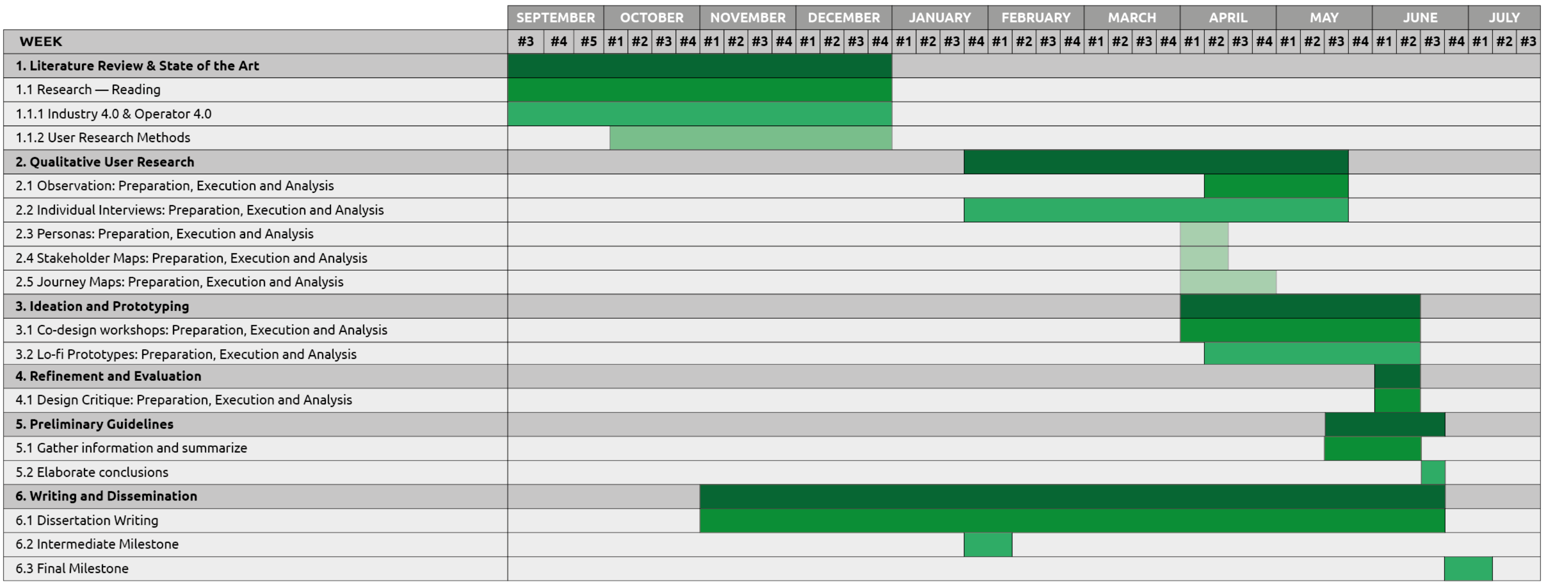


Figure 16 — The final work plan that represents the actual time spent in each task.

4. Project Development

This chapter presents and details the work that has been developed in the context of the Project Development. This work includes Observation, Interviews, Personas, Stakeholder and Journey Maps, Co-Design Sessions, Prototyping, and Design Critique. Every method includes a specification of when it was developed, how many participants it had, the context in which it occurred, what technologies or materials were used, the results and a set of key learnings from each stage of development.

4.1 Observation

From January to May, there were two moments of direct observation — “in situ” — and two of indirect observation. In April, there was the opportunity for the author to visit Bosch’s and OLI’s shop floors and in June there was a second opportunity to visit Bosch’s shop floor. As a result of several restrictions on the access to the shop floors, there were two moments where the author was not able to join on in situ observations. On those occasions, analysis was made through photographs and verbal records of the operators' context.

Context and Participants

For the observation phase, it was necessary to photograph and, if possible, record the places that were being visited. Thus, these photographs were taken with cell phones. These photographs were relevant to register the layout of the shop floors and auxiliary our ideas of the workers’ context. It was not allowed to record sound from the shop floors of the factories. However, it was possible to record interviews, explained in section 4.2 of this chapter. In every visit, there were at least two researchers and a guide — an area responsible or a technician — to explain the environment, the equipment, machines and technologies integrating these shop floors.

Procedure

Before going to these shop floors, a list of questions that had not yet been answered before would be made. Some questions were answered by direct observation, others needed to be asked to the responsibles guiding the visits. For example, the technologies integrated in each shop floor could be observed while visiting them. The number of accidents per year in each shop floor needed to be asked to the person guiging the visit.

Figure 17 — Picture of one of the visited shop floors (IKEA).

Results

The following list includes a set of insights obtained from the observation phase. These insights are called Results of Observation (RO).

RO1: There are always loud noises at shop floors;

RO2: There are certain areas of the shop floors where the temperature does not match the temperature outside.

RO3: In every factory, there are many machines working simultaneously. Some of these machines have people around them, working in cooperation and calibrating them. Others do not need any assistance from workers, excluding when they are going through maintenance;

RO4: Usually, operators are not allowed to use their cellphone while working;

RO5: The equipment differ considering the role and workstation of each worker;

RO6: In every factory, there are screens that show workers their daily levels of productivity, where people can track whether they are responding to production's goal or need to accelerate any process;

RO7: On these shop floors, it is uncommon to have workstations with seats;

RO8: At Bosch, the different areas do not have the same technological integrations; these depend on the responsible of each area.

RO9: Workers have a work ID card that they use to start and end shifts. It is with that card that they access their Hour Bank in one of the areas.

RO10: OLI has a fast-paced environment where, even on hallways, workers are required to use safety equipment, such as vests and helmets.

RO11: IKEA has information displayed in common areas. These boards can contain information relative to workers and that does not embarrass workers.

RO12: IKEA has a so-called "self-service" kiosk where people can access and browse their vacation information and hour bank.

Key Learnings

This stage of development resulted in multiple insights that allowed the author to become aware of the needs and values of shop floor workers from their working context. From the observation, it was learned that the Worker Companion to be developed by Fraunhofer AICOS had to integrate the environment or workstation category that connected their levels of productivity to their work conditions. Therefore, in this stage of development, it was acknowledged that the future Worker Companion needed to be integrated in an environment where there are loud noises, almost no seats, some computers and kiosks in the common areas, and where the cellphone is not allowed.

4.2 Interviews

Individual interviews occurred from January until April. Sixteen of these interviews had to be remotely, but there was also the opportunity to make seven of them in situ. The very first three interviews were transcribed verbatim but the research team realized that it was more effective to transcribe the remaining interviews non verbatim. This non verbatim analysis allowed the analysis of each interview in a more productive way without losing any detail of necessary data. This analysis was made through thematic analysis where the insights, pain points, observations, and conclusions from each interview were investigated. Examples of the transcripts and thematic analysis can be found in Annex B and Annex C.

Context and Participants

The participants of this stage of development included workers from IKEA, Bosch, and OLI. There were a total of sixteen workers interviewed: nine from Bosch, four from IKEA and two from OLI. The workers interviewed were Operators, Shift Responsibles, Area Responsibles, Teamleaders, Human Resources staff, Ergonomics, Health and Safety and Technologic staff.

The remote interviews were conducted via Microsoft Teams. For the success of these interviews, the participants and the interviewer needed to have a computer with wi-fi access, microphone and camera. The in situ interviews were in rooms separated from the shop floors made available by each company for the purpose and it was required to have a recording device to record the interview.

Procedure

The preparation of this phase started with the elaboration of the interview script. This script was divided into three main categories: workers' performance, well-being, and industry transformation. Questions were added while others were removed from the general interview script, depending on the role of the person that was being interviewed. The general interview script can be found in annex D.

Before starting the interviews, the participant had to consent to the recording of the interview, as explained in the procedure described in section 3.2.1. Every interview lasted about one hour and involved a primary interviewer, secondary interviewer and observer who was also a note-taker. In these interviews, the author was the primary interviewer once, with a team leader from OLI. There were three interviews where the author was the secondary interviewer: one with an area manager from OLI, one with an area manager from Bosch and one with Health and Safety and Ergonomics responsibles, also from Bosch. In the remaining interviews, the author was a note-taker, as defined by the project manager.

In the beginning of each interview, the primary interviewer introduced the team and the project and asked the participant to introduce her/himself. Completed the introductions, the interview thread along the three major categories: workers' performance, well-being, and industry transformation. The first category had three questions, all of which had sub-questions, intending to delve into the productivity, metrics and performance of workers. The second category had nine main questions. The sub-questions of this category had the intention to delve into the existing strategies of well-being in this context and the biggest challenges of this reality. The third and last category had five questions, which focused on the innovation and technological side of the work environment. At the end of each interview, the interviewer gave the rest of the team the opportunity to question the interviewee about some things that might not have been explicit before.

Results

The following list includes a set of insights obtained from the interviews with shop floor workers. This group of workers include operators, shift managers, team leaders and supervisors, HR staff from the three companies and the Technological Department staff of Bosch. Like it was mentioned in section 3.2, to maintain workers' anonymity, workers will be mentioned as Px. "P" stands for Participant while "x" is the number associated to each participant. P1 was the first person to participate in activities integrated in the development of this dissertation, P2 was the second person to participate and so on. The main insights and Results of Interviews (RI) are the following:

RI1: There are different organizational hierarchies in each company. Yet, it is possible to distinguish three major levels, common in all of them: there is an operator level, a responsible level and an administration level. Sometimes there are roles in-between the ones mentioned but these three hierarchical levels are common in all three factories. The jobs' organisational structure changes depending on the company.

RI2: Each shop floor has different workstation displays. While Bosch has a cell-line-area shop floor display, IKEA has only a position-area display and OLI differs from area to area.

RI3: In every company, the human resources staff fear the workers' resistance towards new technological solutions since they have rejected them in the past. P1 clarified that "the difficulty is always that question of openness to change and people's openness". This rejection is due to the fear that those technological integrations will be used to control them.

RI4: There were already some attempts to improve workers' motivation and work conditions but their lack of engagement did not allow the definitive integration of those technologies in the shop floors. According to P2, this lack of engagement could be improved by Human Resources staff, stating that "we have to get a way to show people that this is, actually, good for them so that they do not feel stigmatized".

RI5: There are already screens for people to keep track of information relative to productivity and work metrics.

RI6: It can be hard to distinguish between workers' well-being and motivation and productivity. When asked about previously collected information , P11 asked "Individually, about a person in specific or about the team's performance?". This question was also made by several other interview participants and the answer was repeatedly about productivity an notwell-being metrics.

RI7: Workers feel the need to improve the communication between colleagues. This improvement can be between shifts and between co-workers in general. This suggestion was made by participants of different factories such as IKEA and Bosch.

RI8: Safety is a first level priority for everyone, regardless of the role in the company.

RI9: It was mentioned in most of Bosch's interviews that workers consider training and polyvalency as an advantage.

RI10: Most of the workers' frustrations working on shop floors are related to the quality of manufacturing material and consequent productivity.

RI11: Workers are influenced by the screens present on shop floors displaying levels of productivity and values of machines. This influence can change the workers' well-being, stress and anxiety, just like P9 mentioned when stating that "if we are delayed, we have the stress that says we have to accelerate and that, yes, creates stress".

RI12: At Bosch, workers know that they have access to different technologies, depending on the area they work.

RI13: For some workers, like P10, health conditions impact and are impacted by their work conditions.These workers need to receive treatment or even be medicated to perform tasks in the workstations they usually work. This happens because of injuries, sometimes taking place in working context, and they do not want to change workstations because they fear being considered less efficient or incompetent.

RI14: In certain occasions, information is not clear and accessible to everyone.

RI15: When asked about what could be improved in the context of her/his work, P10 answered "more experienced people", stating that shifts are unevenly distributed in terms of training, with shifts composed only of polyvalency workers and shifts composed only of temporary and less experienced workers.

RI16: The most demanding tasks are "clearly, the weights", according to P3, who also stated that repetitive movements make every task more demanding.

Key Learnings

A set of new insights emerged from the different interviews. First of all, these insights demonstrated the need to integrate a technology that is accessible and understandable to everyone. This technology could prevent miscommunication and alert workers to some factors that they needed to be reminded of, like the importance of wearing safety equipment. These interviews also elucidated the author about the importance of training to perform different tasks in shop floors. So, the technology could have a section where the different levels of training done and required could be displayed. Lastly, it was also in these interviews that the author understood the need to inform workers, supervisors and the responsibles about the health and injuries of each worker. This information could help diagnose ergonomic and safety flaws and improve workers' work conditions.

4.3 Personas, Stakeholder Map, Journey Map

The development of personas, a stakeholder map and a journey map started in March and lasted until April. These tools were used to organize, and synthetize information collected in the two previous stages of development (Observation and Interviews). In these phases there were no participants, even though the Journey Map was later validated alongside the workers.

Personas

As mentioned by Alan Cooper, “Personas are the main characters in a narrative, scenario-based approach to design.” (Cooper et al., 2007). In the context of the “Augmented Humanity” project, it was important to define personas to understand the behavioral and mental models of the people that will interact with the Worker Companion developed by Fraunhofer AICOS. Defining each persona, it is possible to perceive their occupation, their level of education, their values, needs, goals and fears. This definition was developed and refined, resorting to the interviews made with workers from the three companies integrated in the project: Bosch, IKEA and OLI. The names and ages of each persona are not real , the quotes and the remaining information is. The three distinct personas represent three groups of people: shop floor workers, supervisors and the administration staff. Administration staff are represented by Maria Silva (Figure 17 — “Persona 1”) and include HR staff, Ergonomic and Safety Department staff, Technological Department staff, and other administrative positions. Supervisors are represented by José Santos (Figure 18 — “Persona 2”) include shift and area responsibles. The name of this position differs from one company to another. Shop floor workers are represented by Ana Marques (Figure 19 —“Persona 3”) and include people working in any workstation or position in a shop floor of one of the three companies. The development of personas was, also, made using Figma and the open source plug-in “Humaaans for Figma” by Pablo Stanley.

Figure 18 — Persona 1.

Name: Maria Silva
Age: 34
Quote: “Some people are more receptive to innovation than others.”

Education: Master’s Degree
Department/Sector: Administration
Work position: HR Coordinator

Values: Privacy policy accessing information.
Needs: Overview of the real-time and past situation in the company.
Goals: Develop a processes’ facilitator.
Concerns/Fears: “It is complicated to maintain the workers’ engagement in technological integrations.”

Technology level: Very Good.

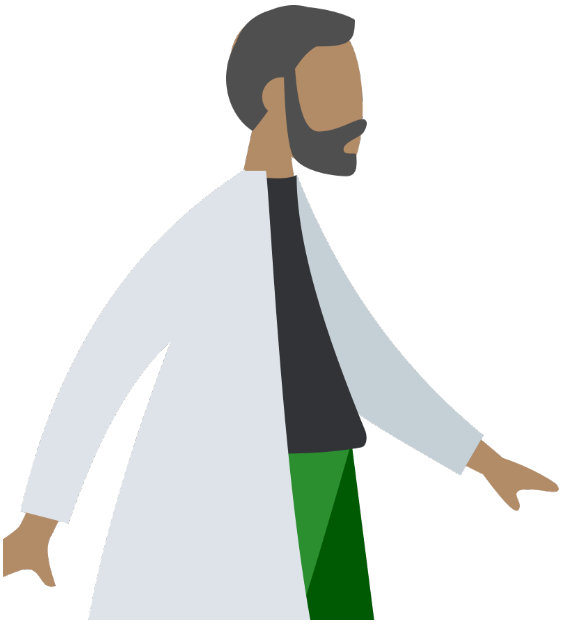


Figure 19 — Persona 2.

Name: José Santos
Age: 48
Quote: “I’ve tried to integrate some innovations before but they’ve failed.”

Education: Bachelor’s Degree
Department/Sector: shop floor
Work position: Area/Shift Responsible

Values: Transparency communicating with the workers. Safety of the workers comes first. Is important to keep workers motivated.
Needs: Assure the results of productivity, keeping the workers in the first place of priorities.
Goals: Ease the communication between supervisors and workers. Automatize some of the processes.
Concerns/Fears: Will this be trustworthy?

Technology level: Very Good.

Figure 20 — Persona 3.

Name: Ana Marques
Age: 56
Quote: "I am polyvalent."

Education: High School
Department/Sector: shop floor
Work position: Operator

Values: Avoid problems and intrigue. Keep a good relationship with the colleagues.
Needs: Nice communication in-between shifts. Good-quality material to manipulate.
Goals: Easier access to information.
Concerns/Fears: "Was this made to control me?"

Technology level: Good.

Stakeholder Map

Stakeholders are the people “affected directly or indirectly by a system” (Dix, 2004). Even though this dissertation will not result in a final system, it seemed important to map the stakeholders involved.

One of the goals of this project of Fraunhofer AICOS is to develop a Worker Companion that assists shop floor workers in improving their health, work and environment conditions. Thus, as illustrated in Figure 21, the primary stakeholder of this map is the shop floor worker. Even though this Worker Companion is thought to help and improve the life of the shop floor worker, there might be other people involved in the usage of the solution. These people are Shift/Area Responsibles, Administration staff, Human Resources staff, Ergonomics department staff, and Health and Safety staff. Lastly, there are people that are not directly affected by the Worker Companion but might be affected by the success or failure of this Worker Companion. These people include the suppliers, the transporters, the buyers, and the shops.

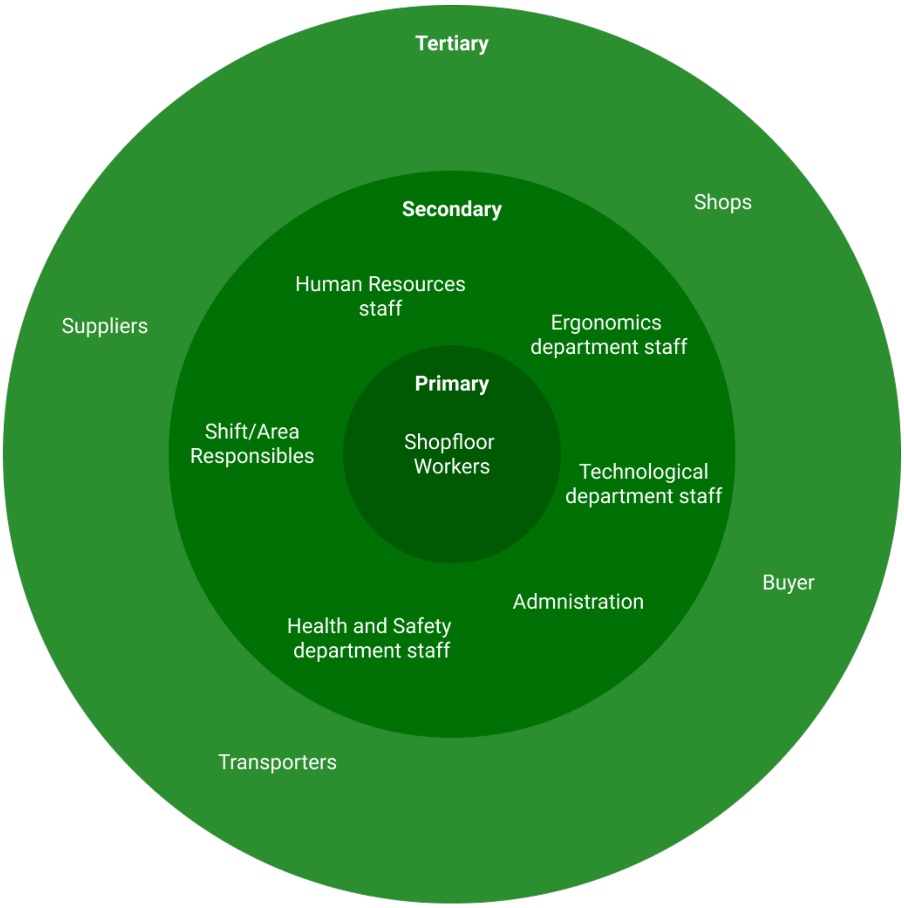


Figure 21— Stakeholder Map.

Journey Map

A Journey Map is considered to be “a visualization of the process that a person goes through in order to accomplish a goal” (Gibbons, 2018). To synthesize what was learned about the typical daily routine and behaviours of shop floor workers, it was important to build a Journey Map. This map includes:

- the stages and steps of each task;
- the time every task requires;
- an illustration of that task;
- the emotional journey;
- the channels present in each task;
- the stakeholders involved;
- the opportunities present in their daily routine.

Figure 22 illustrates the typical journey of shop floor workers that was developed based on interviews and observation. Although not all daily routines and habits are the same for everyone, there are the steps that are common to most shop floor workers; these are the steps captured in the journey map.

Usually, workers arrive at the company five to fifteen minutes before the start of their shift. This happens so that they are able to talk to the fellow worker who was working in their position in the shift before. This talk, usually, informs the worker about possible obstacles in the shift before, eventual problems on the machines, the daily productivity goal and other details that the worker should have into consideration. After this conversation, workers start their shift. To indicate the beginning of their shift, workers need to pass their working cards in the machines. As soon as they start their shifts, workers spend approximately two hours and thirty five minutes working on their position. After this, it is time for their break. They have ten minutes to eat something, go to the bathroom, drink water, check their hour bank or just hang out with other workers in the areas assigned to that purpose. To access their hour bank, workers need to pass their working card in the machines and then interact with the screens or desktops present in the shop floor. At the end of those ten minutes, workers return to their work position and continue their shift for another two hours and thirty five minutes. After this, it is time for the second break of the shift, after which the workers return to their work position and continue their job. At the end of their shift, they need to close their working day by passing their work card in the bank of hours terminal.

Along the course of the day, the workers' motivation drops in case: they have problems communicating with other workers, the materials they manipulate are of low quality, any damage appears in the pieces, or in case a machine breaks down. The tiredness increases naturally as the shift progresses and escalates if any of the examples given in the motivation occurs. The work conditions in their positions (e.g. chair and screens displaying productivity information) might also be factors to worsen their tiredness.
This Journey Map was validated with an Area Responsible later on a guided tour to Bosch, as described in section 4.1.

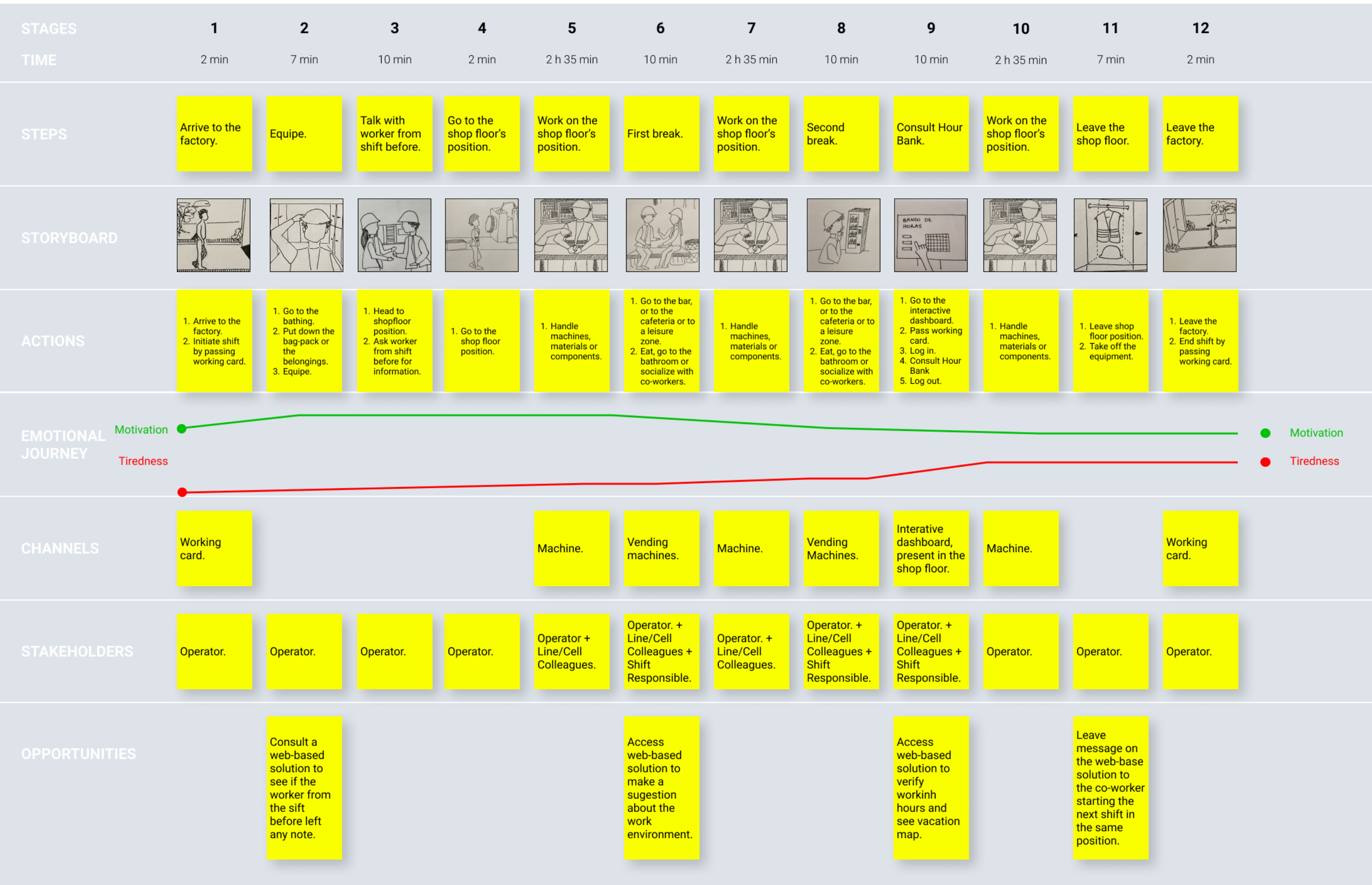


Figure 22— Journey Map.

4.4 Co-Design Sessions

Co-Design sessions can be best described as moments where there is "the creativity of designers and people not trained in design working together in the design development process" (Sanders & Stappers, 2008). These sessions allow researchers to understand and acknowledge new insights through dynamic activities developed with people they are studying. Given the pandemic situation, this stage of development only took place in May. These sessions were divided in two parts. The first part focused on validating the user's needs, values and goals and on confirming the requirements elicited and the functionalities projected for the technological solution. The second part aimed at exploring the design space of the user interface, for example, in terms of the visual meaning of components, icons, visual concepts, the connection of ideas, and the comprehension in task accomplishment. Both sessions were important to understand the mental models of participants (end-users to be).

Each set of activities was piloted with colleagues from Fraunhofer AICOS. In the first with two design researchers, one with a communication design and another with a product design background. The second set of activities was piloted with a communication designer. This validation was necessary to assure that these sessions were comprehensible for the participants focusing on the goal of the researcher.

Context and Participants

In the first set of activities, the participants were three workers from IKEA, two operators from the shop floor and a team leader. Every session of the first set of activities was held online, via Microsoft Teams and lasted about an hour.

In the second set of activities, the participants included two workers from Bosch and four workers from IKEA. The two workers from Bosch were shop floor workers. The four workers from IKEA were three shop floor workers and a team leader. The session with workers from Bosch was in situ. The other sessions were remotely. The session in situ was held in a room with the two workers simultaneously. Both in situ and remote sessions lasted about an hour.

Procedure

Before each session, emails were sent to the company to schedule appointments and to inform the participants about their role in the upcoming activities. As explained in section 3.2.1, informed consent was necessary at all times, so the email attached an informed consentment form in which the activity was described, specifying the platforms used, and explaining to participants how the information was going to be analysed. First, there was a moment to welcome participants, introduce the team that was working with them and present a brief explanation of the project. After the introductions, participants were asked to be recorded. The author read the informed consent and continued the Co-Design session, in case the participants accepted being recorded.

Every session started welcoming the participants and introducing the project, my dissertation and the activity. Also in the beginning of each session, the researcher read the informed consent and asked the participants to consent to the recording of the video-call. After an affirmative answer to the recording of each session, the researcher explained how the platform (Mural) worked and teached the participants about how to interact with it.

First Session of Activities

The first set of activities had seven exercises, like it is illustrated in Figure 23. The first four exercises of this set asked the participant to drag the colored squares — which we referred to as "post-its" — to the circles below. There were two concentric circles on the screen, one bigger than the other. Those two circles were displayed that way so that users associated them with levels of proximity to what they identified the most or the least. The post-its had suggested concepts and words to respond to each question and they could suggest others answers if they thought it was adequate. Participants were instructed to drag the post-its inside of the circles whenever the participants related to what was written in the post-its. If they relate very much to what was written in those post-its, they should drag those post-its to the center of the circles. Then, as they relate less to what was written in the post-its, they should drag them to positions more distant from the center of the image. If the participant did not relate to what was written, he/she could add another option or simply leave the post-its where they were and move on to the next exercise, in case they did not want to add anything to the current exercise.

The fifth exercise had one question and two types of post-its, the green ones and the blue ones. The question asked the participants what kind of information they felt comfortable sharing and with whom. Then, there were seven types of information in green post-its (such as "tiredness", "sadness", and "physical pain"). For each green post-it, there were seven blue post-its with groups of people. Those groups of people included: nobody, team colleagues, Human Resources, Area Responsibles, Supervisors, Medical Team, and the Administration. The task was to eliminate the post-its that did not apply to the answers they wanted to give.

The sixth exercise asked participants to fill the post-its answering the question "If I was in charge of the company for one day, what would I do first?".

The seventh question asked the participants to attribute a number to a post-it, creating the top three priorities of things they do not have in the working context and would like to have. There were some options given but participants could add suggestions if they wanted to.

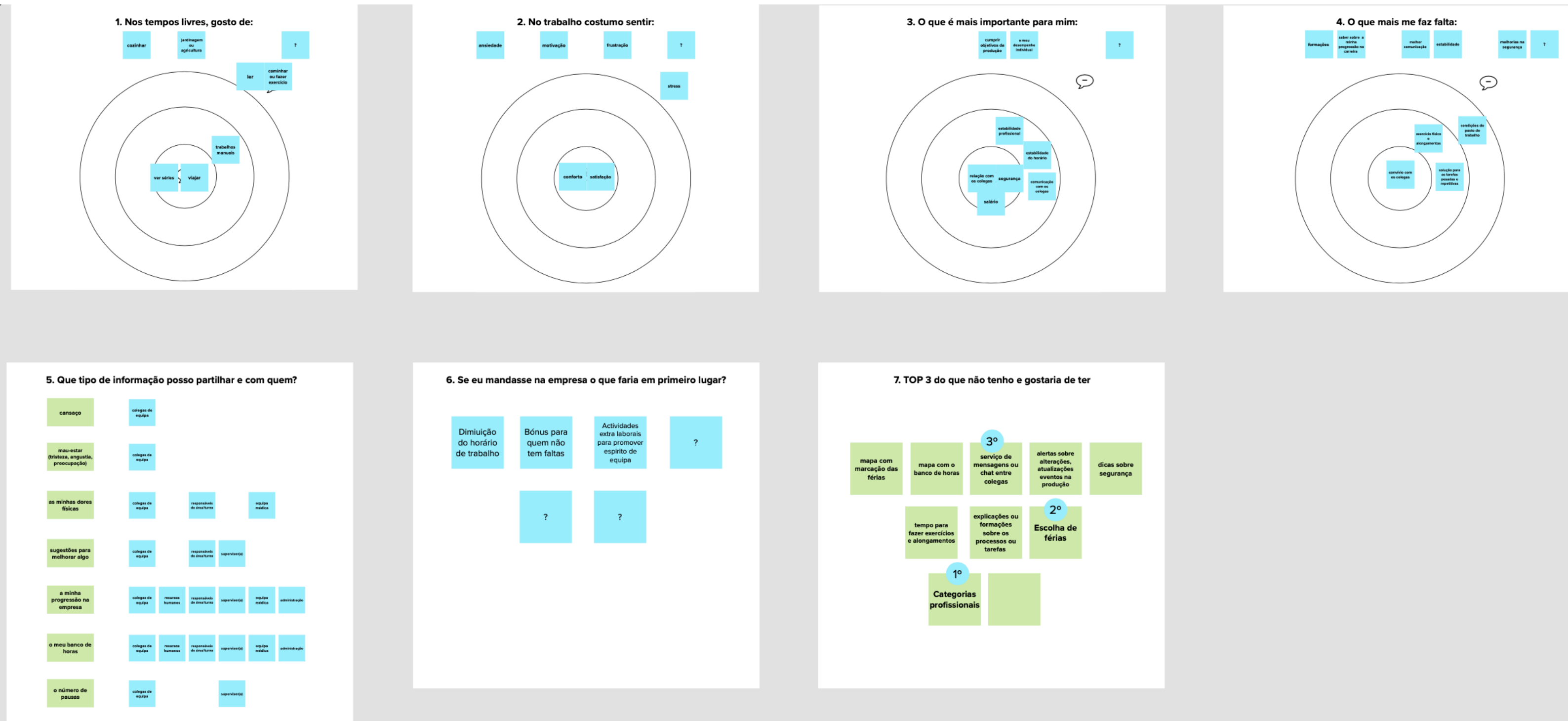


Figure 23— Example of a board of the first set of activities.

The Second Set of Activities

The second set of activities had both in situ and online sessions. Figures 24 and 25 illustrate both of the approaches. The session that was held in situ started welcoming the two participants and presenting the project. After that, participants were given an Informed Consent to sign, after which the session started. The exercises were the same as the ones in the online session. The online sessions had a procedure similar to the first set of activities, where only the activities changed. The first question asked the participants to associate an icon to a concept, dragging the image closer to the word the participant wanted to correspond. This was, probably, the exercise that took the longest time to complete in this second set of activities due to the large variety of options. The second question asked the participants to drag a color to the word that seemed to match the color. The words were "OK", "Alarm", "Danger" and "Information". The color options included red, pink, blue, green, yellow and orange. The third question was the same as the second but instead of colors, participants were asked to match the same words with geometric figures. The group of figures included a triangle with a vertex pointing up, a triangle with a vertex pointing down, a square, an hexagon, a pentagon and a circle. The fourth question asked the participants to associate a chart or figure to a concept. There were nine illustrations and nine concepts. There was also the option to add options, if the participant considered another concept to be more adequate to an illustration. The illustrations of this exercise included a person's illustration, two horizontal progression bars with different levels of progression, a bar chart, two different pie charts, a bubble cloud, and two different line charts. The fifth and last question was more abstract. This question asked the participants what they consider important to represent in a blueprint of a shop floor and how they would represent that information.

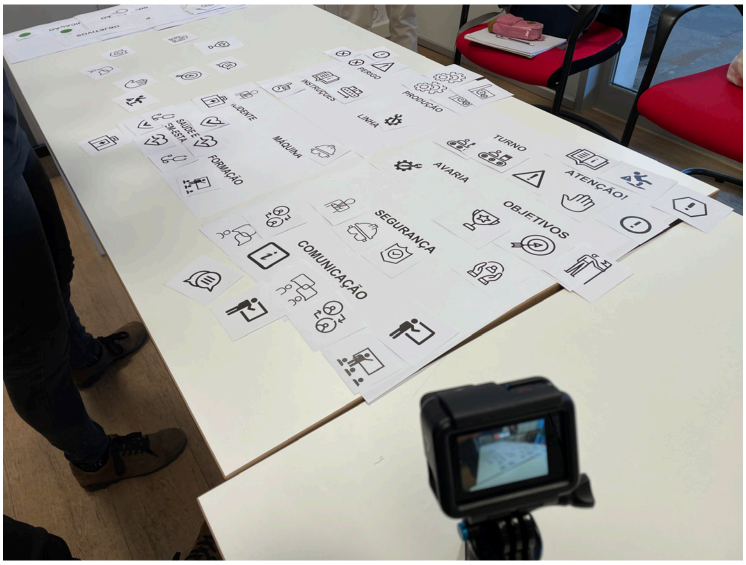


Figure 24 — Picture of the second set of activities in situ.

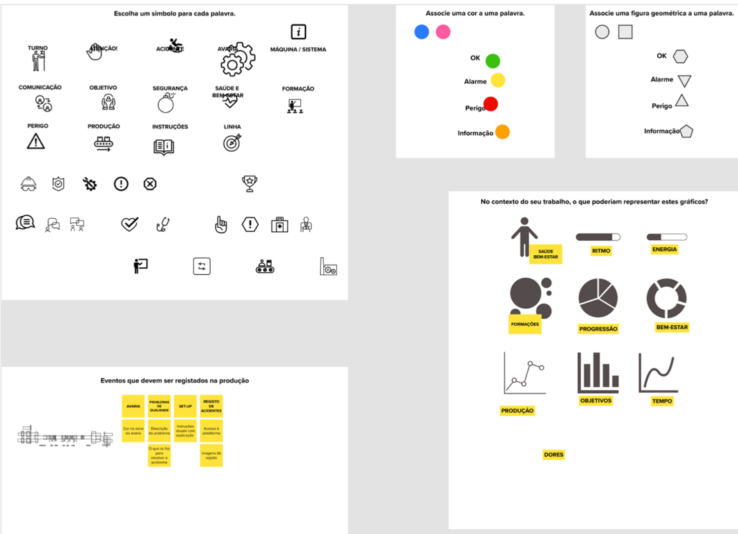


Figure 25— Example of a board of the first set of activities, remotely.

Results of the first set of activities

The following list includes a set of insights obtained from the first set of activities of the Co-Design sessions.

RCDS1—1: Safety is a priority for users.

RCDS1—2: Communication between workers from the same and different shifts is really important for them.

RCDS1—3: Training is very important but, sometimes, missing.

RCDS1—4: Sometimes people feel like superiors do not listen to them.

RCDS1—5: Documentation relative to machines and training is important and it would be useful if it was in a place where workers could get easy access to it.

Results of the second set of activities

The following list includes a set of insights obtained from the second set of activities of the Co-Design sessions.

RCDS2—1: Some people associate geometric figures to traffic signs.

RCDS2—2: People do not want to read dense texts and prefer to visualize images with brief descriptions.

RCDS2—3: The color activity clarified that the most adequate color to visualize “Ok” messages is green, the most adequate color to visualize “Alarm” notifications is yellow, the most adequate color to visualize “Danger” alerts is red, and the most adequate color to visualize information is blue.

RCDS2—4: The geometric figures activity clarified that most people associate the word “Ok” with circles, the word “Alarm” with triangles down-oriented, the word “Danger” with triangles up-oriented, the word “Information” with squares.

RCDS2—5: The icon activity showed that the different mental models workers have influence the perspective of each worker as well as her/his perception of a concept.

RCDS2—6: The charts activity clarified that most workers can relate to progressive charts. However, they might be confused when asked to associate a concept to a more abstract chart.

Key Learnings

This stage of the work enabled the research team to better understand how users' interpret information. Some people tend to avoid situations in which they have to write or draw by themselves. However, these activities let the participants more comfortable and at will to answer questions that might not be enlightened until then. Some of the assumptions made before were changed after these sessions. It was really important to validate and iterate the assumptions so that icons, colors and charts adapt participants' interpretation. These assumptions were mostly about colors, geometric figures, charts and icons.

These sessions also allowed the validation and confirmation of a list of requirements and functionalities needed in the future Worker Companion.

These requirements and functionalities include:

- A section where users can access their working schedule with their shift detailed. This will allow users to better understand their Hour Bank.
- A section where users communicate in-between shifts, so that they keep informed about the machines they use, the manufacturing materials, and other relevant information.
- A section where they access instructions, i.e. to calibrate their machines, if needed. These instructions should not be only in text but also illustrated.
- A section where they initiate their shift checking that they are safely equipped.
- A section where they can access productivity information like Time Management and the expected amount of production versus what they actually produced.
- A section where users are able to see their health related information, such as medical history and injuries.

4.5 Prototyping

Prototyping is essential to illustrate and visualize concepts and ideas. In this dissertation it was important to prototype visualizations to organize information and apply the insights gained with the previous stages of the work. The prototypes were developed using Figma.

These prototypes illustrate six categories of tasks that will be included in the future Worker Companion and the visual elements present in it. The requirements and functionalities were elicited in section 4.4, in the list below the results. Originated from those requirements, the categories to consider are: Health & Well-Being, Safety, Communication, Instructions, Shift and Productivity. The first category — Health & Well-Being — includes injuries, sick notes, medical history, work medicine and other well-being metrics. This category also has a screen for medical history and another for injuries. The second category — Safety — includes a screen where the worker is asked to check the equipment used in the shift. The third category — Communication — includes an informative screen to support communication in between shifts. The fourth category — Instructions — has screens where workers can access machines' instructions. The fifth category — Shift — allows users to access information relative to their monthly schedule and shifts. The sixth category — Productivity — allows users to access productivity-related metrics, like time management and daily goals.

Since the workers are not able to use their mobile-phones while they are on the shop floors, just like it was mentioned in RO4, these prototypes were planned to be integrated in the companies' desktops, already existing in the shop floors and common areas.

The interactable prototype that aggregates these visualizations can be found in the link below.
Link: https://www.figma.com/proto/QUGPBf0OXu6LFpOzpzTSBw/Design-Critique?node-id=1%3A2&scaling=scale-down-width&page-id=0%3A1

Colors

#E52321
R: 229
G: 35
B: 33

#40AB35
R: 64
G: 171
B: 53

#F8E923
R: 248
G: 233
B: 35

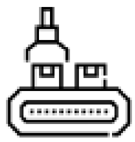
#346BB3
R: 52
G: 107
B: 179

Icons

Safety

Communication

Shift



Productivity

Health and Well-Being

Danger

Damage

Instructions

4.6 Visualization Prototypes

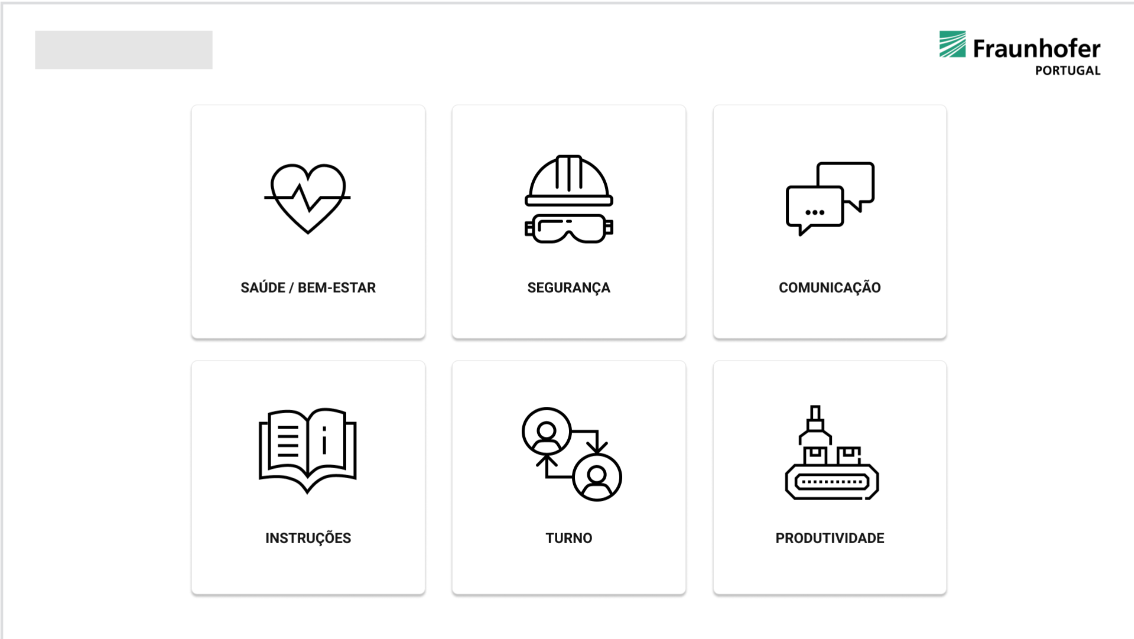


Figure 26 — Landing Page of Visual Representations.

In Figure 26, there is the screen of the Landing Page. It is this page that connects the six categories of the visual representations. From this screen, it is possible to access the six categories — Health and Well-Being, Safety, Communication, Instructions, Shift and Productivity.

Figure 27— Screen of injuries, specifically health history.

In Figure 27, it is possible to observe one of the Health and Well-Being screens where users are able to access information related to their injuries, and medical certificates.

Figure 28 — Screen of Safety Equipment checklist.

In Figure 28, there is one of Safety's screens. In this screen, users are expected to fill the checkboxes of the safety equipment they have on. The purpose of this screen is to remind users of the importance of safety.

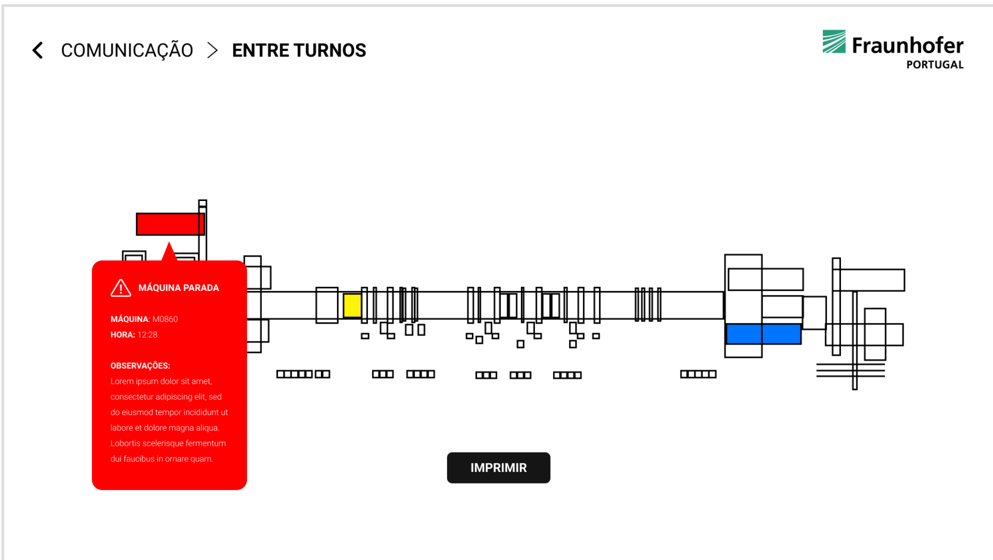


Figure 29 — Example A of the screen of Communication between shift.

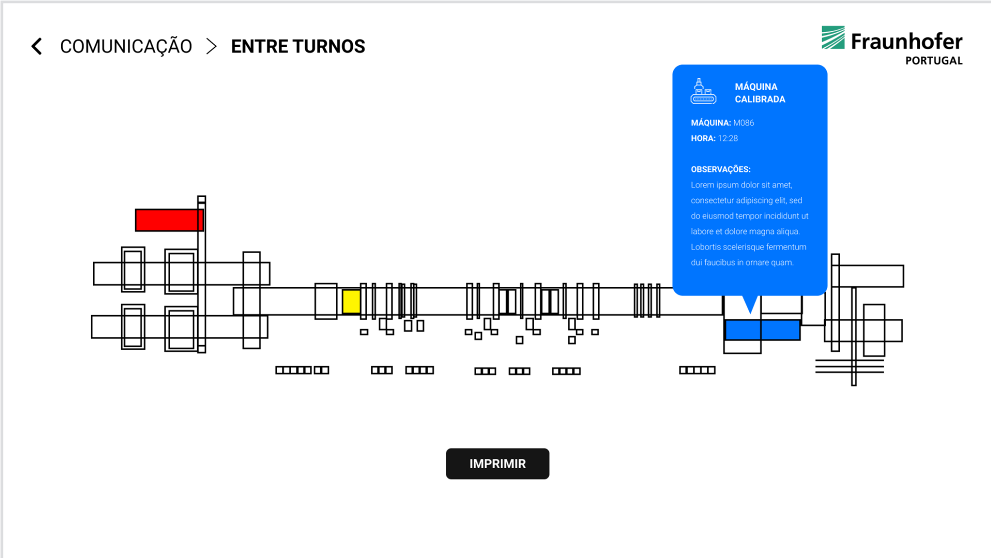


Figure 30 — Example B of the screen of Communication between shift.

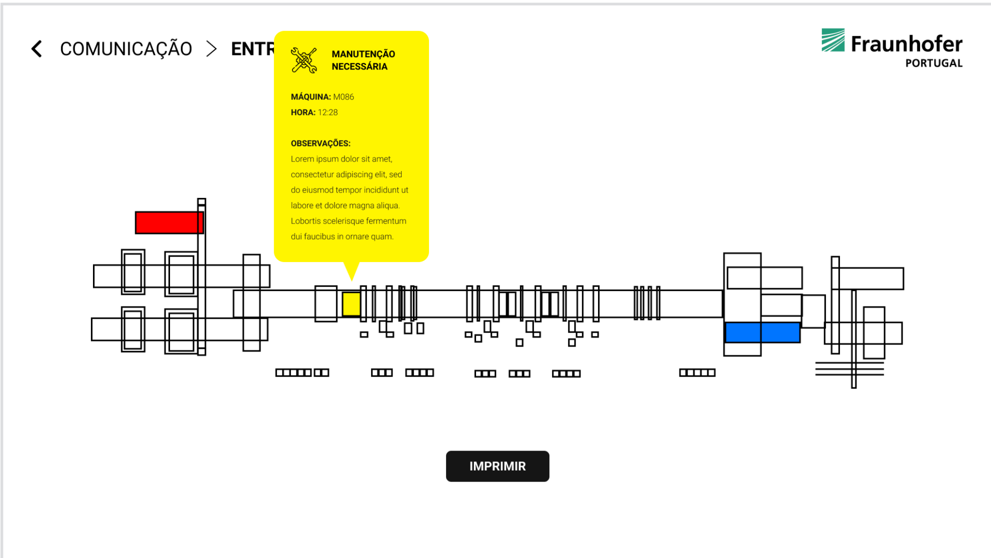


Figure 31 — Example C of the screen of Communication between shift.

In Figures 29, 30, and 31 it is possible to visualize the different types of information obtained from shifts. This screen is intended to ease the communication between workers from the same roles but different shifts.

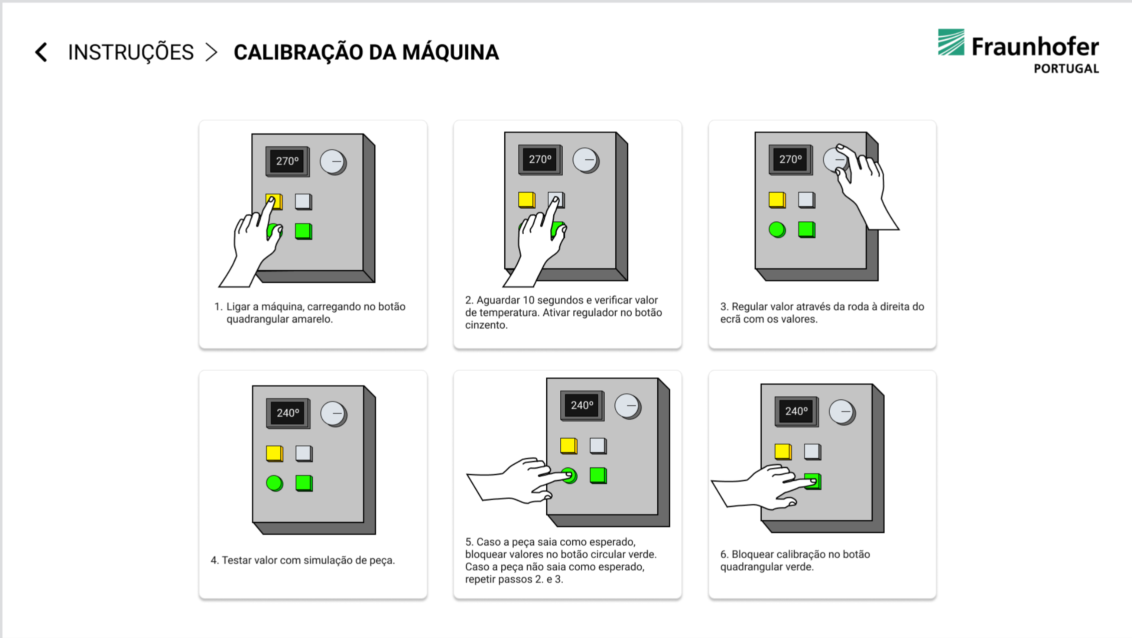


Figure 32 — Example a screen of Instructions.

The Figure 32 shows an instruction screen where workers can access information through illustrations with descriptions to facilitate their interpretation.

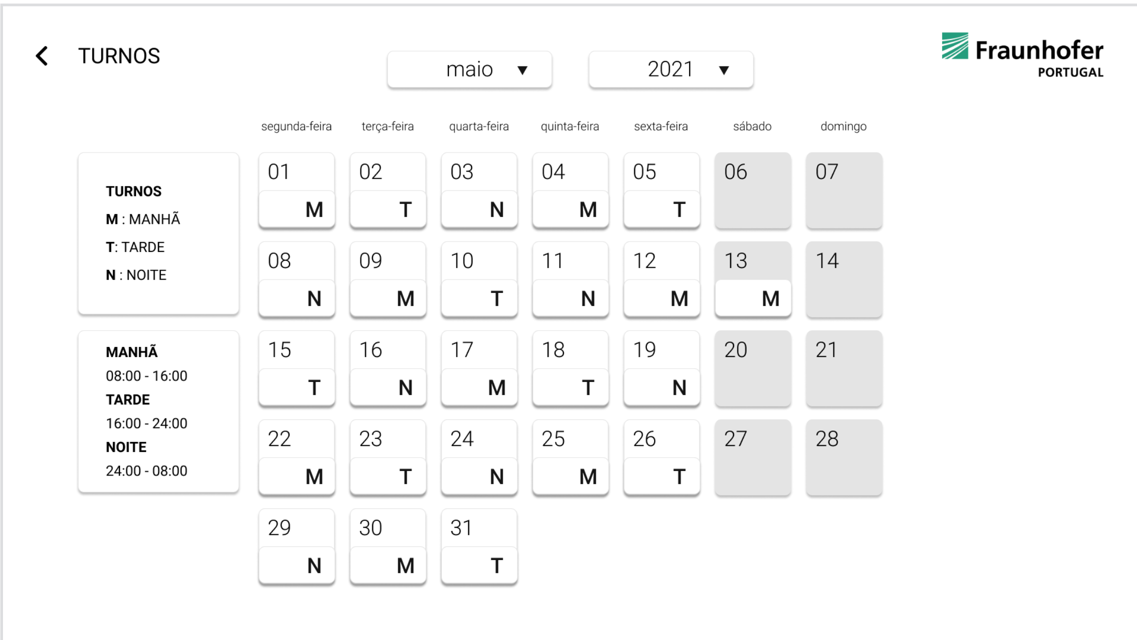


Figure 33 — Example a screen of monthly schedule.

Figure 34 — Example a screen of a shift representation.

The Figures 33 and 34 show information relative to shifts. The figure 31 displays the worker's monthly schedule and the Figure 32 displays illustrations and textual information about the worker's personal information in shifts.

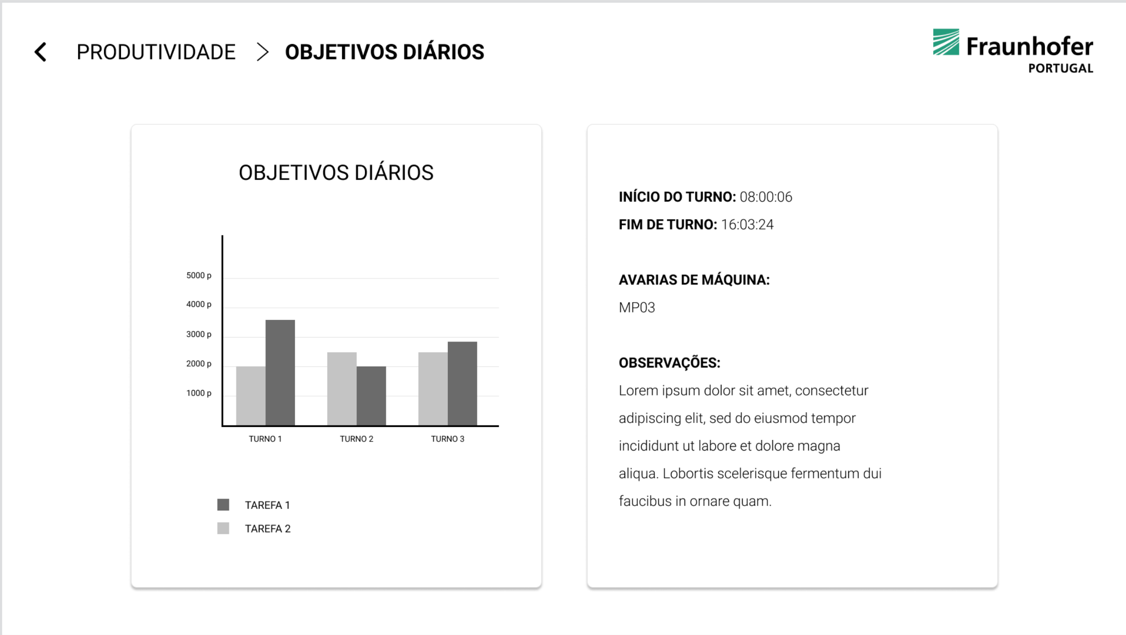


Figure 35 — Example a screen of Productivity, specifically the Daily Goals screen.

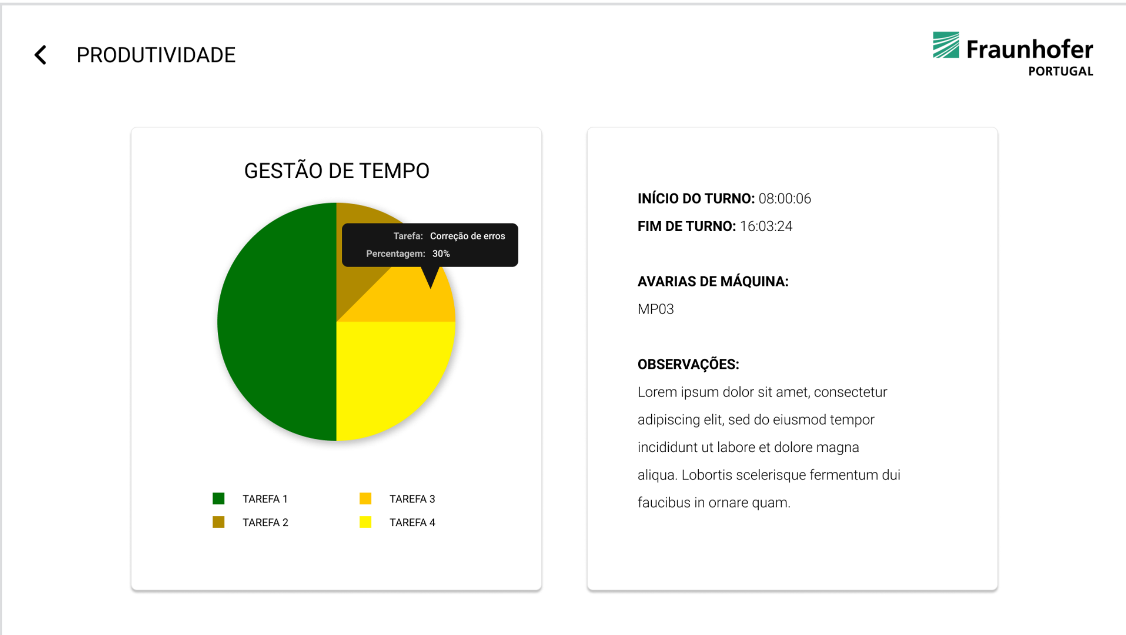


Figure 36 — Example a screen of Productivity, specifically the Time Management screen.

The Figures 35 and 36 display information relative to Productivity. This visualizations were validated with participants in the second set of Co-Design Activities. It is easier for workers to comprehend information if it is labeled. So, Figure 34 shows how this labels are idealized for users to easily interprent charts. Besides this, it is important to represent information in visual and textual representations, since there are users that prefer illustrations but there are also users that prefer textual information.

4.7 Design Critique

The method Design Critique corresponds to what is called an Inspection Evaluation Method, that consists of experts evaluating a certain technology, usually an interface. These Inspection Evaluation Methods were popularized by Jakob Nielsen between the decades of 1980 and 1990 and are commonly used as “the inspection of user interface specifications that have not necessarily been implemented yet” (Nielsen, 1994).

After prototyping, it was important to gather a group of experts to evaluate the screens and visualizations. Hence, a group of expert researchers from Fraunhofer AICOS was invited to analyse the screens and give feedback that could improve the visualization screens as well as their understandability and usability.

Context and Participants

The group of experts involved in this phase consisted of an expert in Human-Computer Interaction, a Communication Designer, and a Product Designer. Each of them gave feedback in, at least, one of these three areas — Human-Computer Interaction, Communication Design, and Product Design. The project manager of Augmented Humanity and adviser of the author was also present in this session to listen to the advice and feedback received.
The session of Design Critique was conducted online. The video call was via Microsoft Teams and lasted about an hour. The prototype was tested using Figma.

Procedure

This session started with a brief presentation about the dissertation and its goals, followed by a tour through the screens of visualization, presented in Figma. Since the participants were experts who have previously conducted user interface inspection methods no further preparation of guidance materials was needed. After this, researchers were given twenty minutes to analyse the screens. In the end, the experts were asked to give feedback and suggestions of improvement.

Results

The following list includes a set of insights obtained from the Design Critique. These insights are called Results of Design Critique (RDC).

RDC1: It is important to let the users see where they are located in the application.

RDC2: It is not necessary to plan every screen with a complete grid full of options. The different screens will not have the same number of options and it is relevant to explore options with different displays.

RDC3: The shifts' screen could be improved. Instead of having a button where the user can click to access detailed information, there could be an option where the user could see the details just by hovering the colored element on the screen. Instead, the button could export or print the information so the user could take it with her/him.

RDC4: It is important not to mention the same term to describe different information. In this case, the word "damage" was mentioned three times in different screens with dissimilar information. In one screen there was information relative to time, in the other information relative to the machine and type of damage, and in the third screen, the damage was mentioned from a productivity perspective.

RDC5: In the "Shift" screen, it would be better to keep track of the user's personal shifts, instead of the possibility to see every shift in the factory.

RDC6: It is important to remember the privacy of every user. Ergo, it is imperative to be careful about personal-public information.

RDC7: In the "Safety" screen it would be more adequate to include a checklist which the user would fill instead of dragging elements to the figure.

RDC8: In the "Training" Screen it would be pertinent to organize information by type of machine. Inside each type of machine, the user would choose the option in specific.

RDC9: It is relevant to treat elements to let the user distinguish easily the points of interaction and the ones without any interaction intention.

Key Learnings

It is considered that this session improves the visualizations in a Human-Computer Interaction perspective as well as an Interaction and Product Design perspective. This improvement focuses on the final user and bases solid acknowledgments to develop guidelines.

5. Preliminary Guidelines for the Understandability of Information

Through the development of this dissertation, there were four most important moments that contributed to the definition of these preliminary guidelines. These moments include Observation, Interviews, Co-Design Sessions and Design Critique. These stages of development informed the author about the users' context, needs, values, fears and goals that influence their interpretation of visual elements and information displayed.

This chapter presents the findings of the study, here described as Preliminary Guidelines (PG). The intention of these guidelines is to orient the process of development of the Worker Companion. Like it was mentioned in RI3, there is a general concern that workers' show some resistance towards new technological solutions since they have rejected them in the past. The Preliminary Guidelines presented in this chapter contribute for this not to happen, adapting the future Worker Companion to the workers' levels of comprehension. Every guideline has the final-user in sight and is explained so that the developers of the solution know the importance of following them.

PG1: Colors and geometric figures should match traffic signs.

An important aspect that emerged in the Co-Design sessions, specified in RCDS2—3 and RCDS2—4, and illustrated in Figures 37 and 38, was that people associate colors and geometric figures to traffic signs. It is, therefore, important to bear this in mind when developing notifications, alerts and reminders in the Worker Companion, since people associate the color red to danger, yellow to alert, green to "OK" and blue to informative messages.

This Preliminary Guideline matches Don Norman's Design Principles by adapting the conceptual model to the users and their mental models. This adaptation allows users to successfully associate previous knowledge from other learnings to the use of this technology. It also matches Ben Shneiderman's

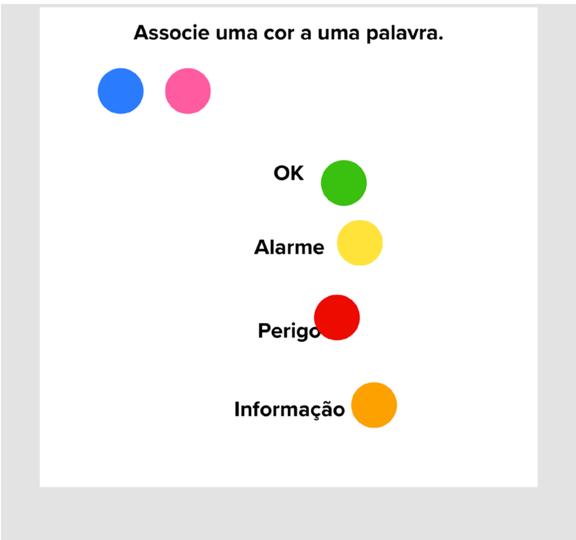


Figure 37 — Printscreen of a Co-Design Session where colors were associated with traffic signs.

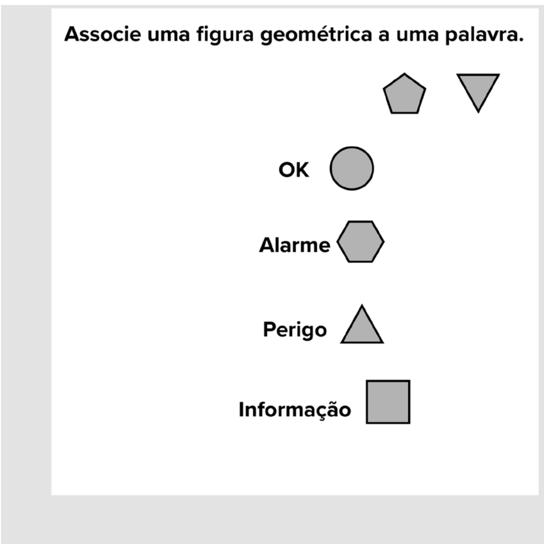


Figure 38 — Printscreen of a Co-Design Session where geometric figures were associated with traffic signs.

task types, in specific, the “Guide” task where users are able to nimbly analyse information displayed on screen.

PG2: Add labels to every element of graphics and charts.

Since people have different interpretations of visual elements, even if they work in the same context, it is important to label every element on the screen. It can be clarified in RCDS2—5 and RCDS2—6, where it is stated that the different mental models of people allow distinct interpretations of visual elements and a possible confusion when asked to associate a concept to a more abstract chart. The labeling of elements, like the one illustrated in Figure 39, will prevent possible errors and ease the comprehension of the visual representations.

This Preliminary Guideline matches Don Norman’s Design Principles through the Conceptual Model and Affordances. These labels will allow users to better comprehend visual elements and information. It also matches Ben Shneiderman’s task types through the Derive and Guide tasks, where users

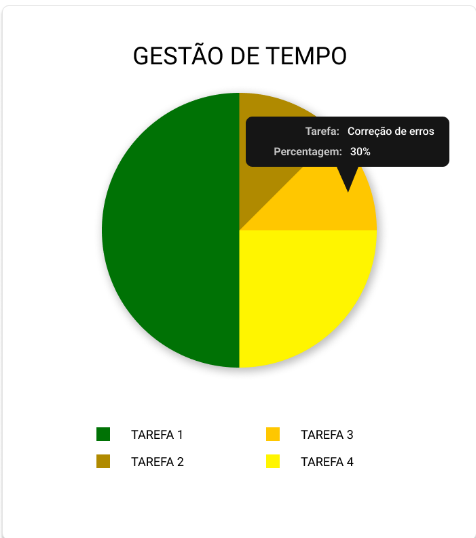


Figure 39 — Printscreen of a prototype where an element of a chart is labeled.

are able to get information, in this case from graphics and charts, and nimbly analyse it.

PG3: Graphics and charts need to be explained.

People have different levels of comprehension and interpretation. Just like it was mentioned in RCDS2—6, there might be a certain confusion for users when asked to associate a concept to a more abstract chart. Thus, it is important to detail and explain more complex information, like it is shown in Figure 40. This will assure that workers do not need to feel uncomfortable trying to understand information and, if needed, consult the same information detailed in an alternative form.

This Preliminary Guideline assures Don Norman's Design Principles through the Conceptual Model that assures that users are completely informed about the information displayed. It also matches Ben Shneiderman's task types, specifically the Visualize, Select, and Guide tasks where users are able to visualize information, select which information they want to highlight and

Figure 40 — Screen developed in the context of this dissertation, where a graphic is accompanied by a textual description.

nimbly analyse that information.

PG4: It is important to situate the user in the platform.

To give the user a feeling of freedom and control using the Worker Companion, it is important to inform users about their location in the platform. This need emerged from the result from RDC1, where it was explicit the need to inform users about their location in a technological solution. It is important so that they can leave a screen or quickly change screen, in case they need it. This guideline can easily be put into practice by creating a navigation drawer on the screen, just like illustrated in Figures 41 and 42.

This Preliminary Guideline matches Don Norman's Design Principles through Mappings and Constraints that assure users know where they are located in the technology. This PG also matches one of Nielsen's ten Usability Heuristics for User Interface Design (Nielsen, 1994) — "3. User Control and Freedom" — where it is mentioned the need to clearly mark an "emergency

Figure 41 — Suggestion developed in the context of this dissertation, as a solution to inform users about their location in a technology.

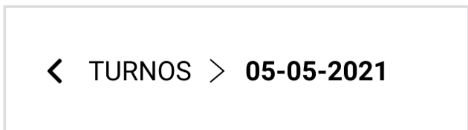


Figure 42 — Printscreen of the navigation drawer present in this dissertation's prototypes.

exit”, “to leave the unwanted action without having to go through an extended process” (Nielsen, 1994).

PG5: It is important not to mention the same term to describe different information.

Like it was presented in RDC4, before the Design Critique, the word “damage” appeared three times in different screens with dissimilar information and it might have been confusing for users to interpret correctly that verbal inconsistency. Since it might be confusing for final-users to see the same term associated with different information, depending on the screen they are on, it is important to find terms that describe information as it is, keeping a consistent language.

This Preliminary Guideline matches with Don Norman’s Design Principles and again with Jakob Nielsen’s ten Usability Heuristics for User Interface Design (Nielsen, 1994). It matches Norman’s Constraint principle through a semantic constraint and Nielsen’s heuristics through the fourth heuristic “Consistency and Standards”. Both of these matches assure the importance of a consistent language and semantic constraints to avoid communication or feedback errors and misunderstandings.

PG6: Display different purpose graphic elements differently.

Displaying distinct purpose graphic elements differently will allow the final-users to easily distinguish the points of interaction from the ones with no intention of interaction. This will avoid confusion when trying to accomplish a task, making interactions clear and straightforward as soon as the user learns how to interact with the companion. This necessity was highlighted in the Design Critique as explicit as a result of it, RDC9, when the need to make interaction obvious for users arose. This guideline can be put in practice by clearly distinguishing buttons and interaction points from informative and static elements, like it is illustrated in Figure 43.

This Preliminary Guideline matches Don Norman's Design Principles through the principles of Affordances and Constraints. These principles are assured by displaying logical constraints through the distinction of visual elements, and by making the desired actions possible distinguishable from static elements. It also matches Ben Shneiderman's Navigate and Guide task types. This guideline reflects these tasks through the possibility to navigate in the technology and improve the efficiency of performing actions while using the

Figure 43 — Screen of the prototypes where there is a clear distinction between interactive and non-interactive elements.

Worker Companion.

PG7: Give people the possibility to choose how they want to see information.

Just like it was mentioned in Co-Design Sessions, RCDS2—2, most of the people who participate in this activity do not appreciate reading dense texts. Instead, they prefer looking at images or drawings, i.e., in instructions. However, in a more general sense, some people feel more comfortable reading and others feel more comfortable looking at visual representations. It is important to let the users choose how they want to see information. This guideline can be put into practice by allowing users to choose how they want to see the displayed information, giving them both options — visual and textual.

This Preliminary Guideline matches Don Norman's Design Principles, specifically the Conceptual Model principle. The principle reflected in this PG improves the understandability of information displayed in the platform. It also matches Ben Shneiderman's task types Visualize, Filter, Select and Navigate. These four task types allow users to visualize, select and navigate through information in the platform. By choosing how they want to see information in the Worker Companion, users are able to select how they want to visualize it, while selecting which information they want to access and navigate.

6. Conclusions and Final Remarks

The final chapter of this dissertation is the culmination of the work developed in the present year as well as a reflection of the accomplishments and failures of it.

This dissertation lasted about nine months with both online and in situ stages of development. The goal of this dissertation was to define guidelines to represent information in shop floor contexts. The accomplishment of this goal was possible through a User-Centred Design and Participatory Design methodology that included Observation, Interviews, Personas, Stakeholder and Journey Maps, Co-Design Sessions, Prototyping, and Evaluation. This multiple stages of development allowed the author to learn about the different improvements that could be developed in this context, such as the improvement of communication in-between shifts, the digitalization of instructions to every machine, and the importance of health monitoring and health related information to improve participants' work conditions.

The entire process of development was enriched by the participation of multiple people, making a total of twenty five workers from the three sites: eleven from IKEA, twelve from Bosch and two from OLI. The participation of these workers has several contributions, the most important being the insights about their values, needs and goals that elicited the requirements needed to develop these Preliminary Guidelines. So, it is determined that the collaboration of this group of participants is of great value since it assures a methodological robustness of the process.

In section 2.3.4, there was a summary of HCI and Visualization principles that draw parameters mentioned as desired. These parameters include: good design practices, screen organization, typography, color, clear labels and descriptions, good mapping, charts and simple and clear interactions. The preliminary guidelines suggested in this dissertation respect and reflect the mentioned concerns and provide to future developers useful information to make judicious choices, developing the Worker Companion. Thus, even though the current year demanded multiple adaptations and changes, the main objectives of this dissertation are considered to be accomplished.

6.1 Discussion

Given the pandemic situation, there were stages of development that did not occur as planned. However, there were stages of development that became even more interesting and challenging. The Observation phase was challenging since the author did not have any previous context on factories and did not know what information to expect from indirect observation, through pictures and recording. However, after receiving the first pictures of shop floors and, especially, after visiting Bosch and OLI's shop floors it was easier to understand the first focus points of this stage. Besides this, the Co-Design Sessions were also challenging since the research team did not know if there would be a possibility to perform those sessions in situ or remotely. So, both sets of activities were planned to adapt to both the scenarios, making it a challenging task to adapt the work to both scenarios.

It was not possible to visit shop floors as many times as desired and as it was initially planned nor to interact with people the way it would happen if there was no pandemic situation. However, it is important to mention the fact that, more than visualization solutions, one of the main goals of the project was successfully accomplished. This goal was the development of research resorting to a participative and user-centred process with real workers, their participation, and engagement in multiple stages of development. The preliminary guidelines to visualize information arise as an outcome of that process that enriched the work developed in the context of this dissertation.

6.2 Future Work

Even though the objectives of this dissertation were accomplished, this project will not be finished until the Worker Companion application is completed. So this work will continue in the future.
Since the Worker Companion needs to be understood by every worker, no matter their levels of education or background, it is necessary to continue the process of development with the workers to validate these preliminary guidelines with more participants.

For this to happen, it might be useful to validate the guidelines presented in this dissertation with workers and check if those guidelines make a difference in their interaction with the platform. This validation can happen through more Co-Design Sessions, A/B Testing or Usability Testing. This validation will clarify if these preliminary guidelines are adequate to users' needs, values, fears and goals and if they are adequate to integrate in a future Worker Companion that will accompany their daily routine.

6.3 Personal Remarks

Personally, it was with great enthusiasm that I chose this dissertation. Besides the challenge of trying to understand a reality that is not mine, this dissertation allowed me to develop and apply a solid methodology in a practical context. Allowing me to work in an evolving reality that joins two major areas in which I am very interested in — Health and Design —, I consider that this research enriches my experience and knowledge on multiple levels. Besides this, the dissertation allowed me not only to learn and apply multiple methods with different roles but to perform different tasks and roles applying those methods. Summarily, it is adequate to state that this dissertation teached me a lot more than I could ever imagine, through a correct and structured process that enriched my personal and professional experience.

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Annexs

Annex A

Nome do Estudo: Augmanity **Investigador Principal**: Ricardo Melo, PhD

Olá, o meu nome é Mafalda Silva. Sou estudante do mestrado em Design e Multimédia na Universidade de Coimbra e estou a desenvolver a minha dissertação na Fraunhofer AICOS. Para poder avançar, gostaria que me confirmasse se aceita que grave esta video-chamada?

Obrigado. Gostaria de o/a convidar para participar no estudo Augmanity, que pretende desenvolver tecnologia para a indústria, assim como melhorar processos, condições, e bem-estar dos trabalhadores envolvidos nos processos industriais. Este projeto tem uma duração prevista de 36 meses. Na sessão de hoje, ser-lhe-á pedido que responda a algumas questões relativamente ao seu trabalho, com uma duração total prevista de 1 hora. Esta sessão será registada em vídeo para posterior análise.

A participação não envolve qualquer prejuízo ou dano e não haverá lugar a qualquer pagamento nem terá custos para o si (o/a participante) nem para a instituição em que se encontra. Os seus dados pessoais serão analisados pelos investigadores da associação *Associação Fraunhofer Portugal Research,* não serão partilhados com ninguém fora do projeto e serão destruídos no final do estudo.

Tem alguma questão sobre a sua participação ou sobre o estudo?

Se tiver perguntas pode contactar o Gestor de Projeto via email (ricardo.melo@fraunhofer.pt, telefone ([redacted], ou através da instituição. Deseja anotar os contactos?

Aceita participar neste estudo?

Assinatura do Investigador Principal

____

Annex B

Intervie[redacted]
Primary[redacted]
Second[redacted]
Observe[redacted]
Date of [redacted]
Locatior[redacted]
List of A[redacted]
MG = M[redacted]
RM = R[redacted]
EO = El[redacted]
Pedro M[redacted]

____

PT 1

[Begin Transcript 00:00:10]

RM: Ok, então neste caso, gostaria de vos perguntar se não se importam que gravemos esta conversa.

(MG sorri e acena com a cabeça)

JL: Sim, não nos importamos.

MG: Não nos importamos.

RM: Ok, obrigado. Já não nos podem processar. (risos) Ok, então… vamos começar… eu vou começar esta entrevista mas os meus colegas estão livres de intervir, de comentar… se vocês não se importarem… vocês também… Vou fazendo umas perguntas mas se vocês acharem necessidade de explicar um bocadinho melhor ou de desenvolver ou de pedir alguma clarificação, por favor, estejam à vontade.

(JL e MG acenam afirmativamente com a cabeça. MG responde "hm-mm")

RM: apenas só para termos aqui uma introdução registada, eu apenas pedia-vos para rapidamente explicarem qual é que é exatamente o vosso papel, funções na Bosch, quais são as vossas tarefas do dia-a-dia, de que é que são responsáveis.

JL: Ahm… posso começar eu, se calhar…

MG: Sim.

JL: Ahm… então, eu sou responsável pelo departamento de recursos humanos. Muito recente, desde janeiro deste ano. ahm… Portanto as minhas funções não são tão operacionais portanto não estou tão diretamente relacionada com a gestão dos processos e com as pessoas no dia-a-dia, não é? É mais a nível estratégico, desenvolvimento da equipa e, obviamente, também desenvolvimento de políticas que façam sentido dentro da organização a nível de recursos humanos mas já tenho bastante experiência, já passei por essas funções, mais operacionais e, neste caso, até bastante responsável ou muito responsável pelas áreas mais diretas, as pessoas que estão diretamente associadas à transformação e produção dos nossos produtos… e pronto, basicamente acho que é isto…. Não sei se precisam de mais detalhe… mas… será suficiente, ok.

MG: Ok, do meu lado, então, dentro da equipa, então, de recursos humanos nós temos várias funções. A minha função é de HR Business Partner, no fundo, somos 3 e o que fazemos, então, é dividir os vários

Consult Documents in submitted in the platform.

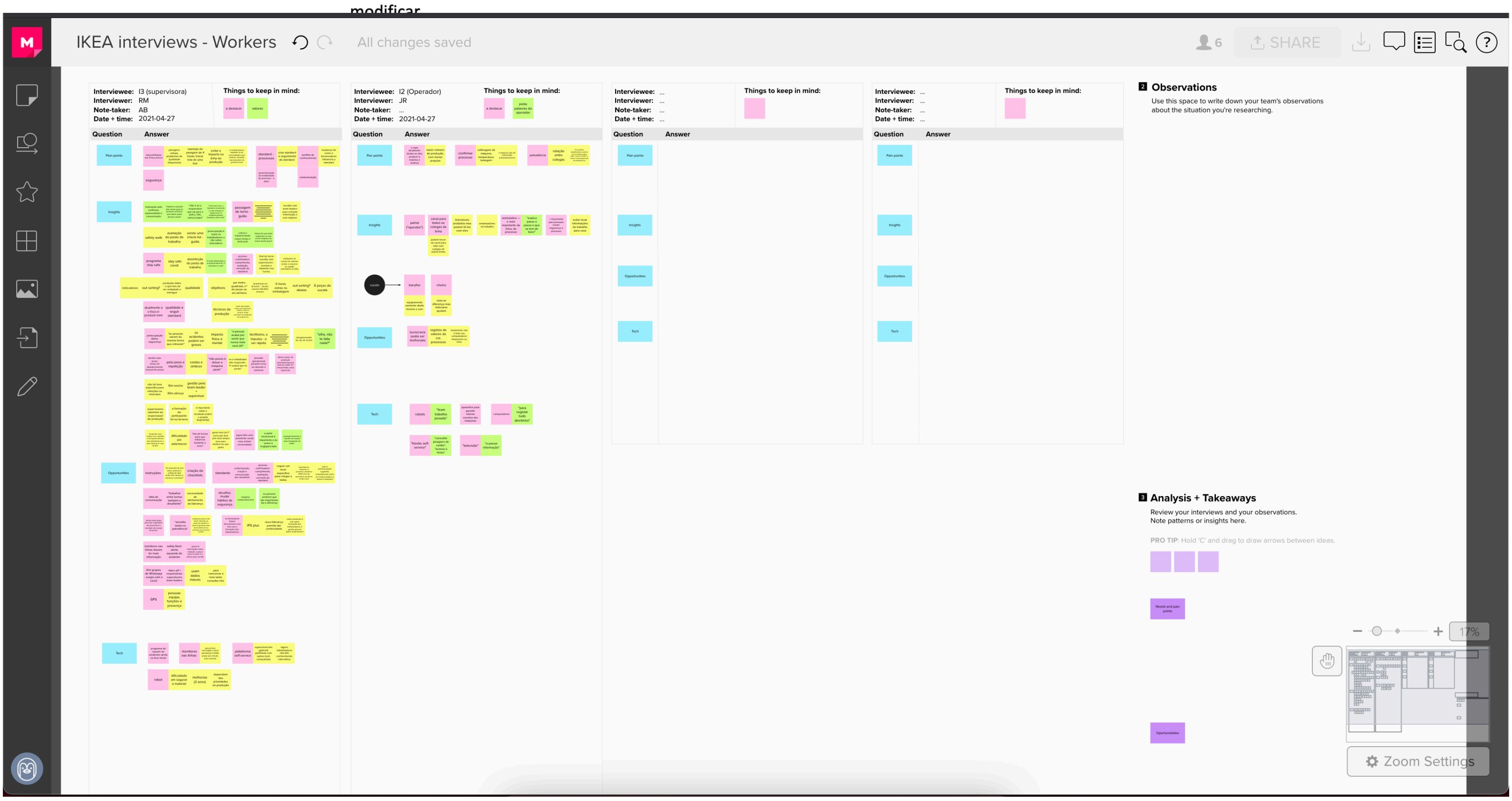
Annex C

00:03 **Como é um dia da na vida deles, na Bosch?**

- [NA] Teletrabalho, regime misto em casa/trabalho. Pouco contacto com pessoas
- Sempre uma pessoa HSE na fabrica
- Tema principal em HSE é acidentes de trabalho. Todas as ocorrências na empresa são comunicadas e registadas pela HSE, tratadas no posto médico da Bosch. HSE faz uma análise do que foi feito—falando com as pessoas e perceber o que pode ser melhorado.
- Lidam com doenças profissionais. Problemas músculo-esqueléticos não são tão fortes como em outras industrias, mas existem. Os "directos" são pessoas mais velhas (vs os CE). Pessoas que ainda trabalham desde criação da empresa em 77. Pessoas com 40 anos de casa, que trabalham na área directa. É algo bastante tipico.
- [Interrupção Joana Filipe]: Fez levantamente da idade das pessoas, **média de idades colaboradores Bosch está nos 47 anos.**
- + de 10/15 anos que trabalham ergonomia e ergocheck, mas pessoas há 25, 40 anos na empresa viveram muitos anos com práticas que não eram "tão extraordinárias".
- Pessoas que têm segundo emprego, part-time, trabalho na agricultura. Idade + postos de trabalho problemáticos "no passado" + doenças profissionais + doenças naturais = limitar a capacidade das pessoas mais antigas.
- Desafio saber o fazer com estas pessoas, querem "tirar o mesmo rendimento de toda a gente". Não há maneiras de medir que considerem incapacidade, limitação de capacidade das pessoas. Querem que todos dêem 100%.
- Fizeram recentemente benchmark com outras empresas para perceber como estes assuntos foram tratados—prática é igual ao que a Bosch faz: secções de trabalho que não são tão exigentes, em que não há grandes dependências / trabalho em linha / postos mais isolados [Maria Gaspar interrompe para mencionar "855"].

00:10 **RM pediu para elaborar sobre este assunto**

- [NA] Tecnologia trazem desafios, muitos destes colegas tem escolaridade baixa, acomodados a tipo de trabalho mais simples, estão pouco disponiveis para assumir um novo papel e posto de trabalho com tecnologia mais exigente
- Há secções em que as pessoas estão mais isoladas, a fazer as coisas a seu ritmo. Postos mais simples, acabam por fazer o mesmo que uma pessoa sem limitações lá faria. Estas pessoas estão "presas a estes postos" e não dá para fazer rotação. Não há flexibilidade para modificar



Annex D

What is your role at [company]?

Can you tell us what would be a typical day at work?

Work

What are the most challenging moments of your jobs and why?
What were the strategies developed to deal with these challenges?
What are the most difficult tasks?
How much control do you have over the work that is being done?
How easy is to ask to do different task if you are feeling physical or mentally fatigued?
How is your work dependent on the machine? Do you control the machine, or do you have to do what the machine asks you to do?
How useful to you are the performance metrics from machine? Does it make it you to work faster or slower?
What would help you to work better?
What would you do you help [company] work better?
And to improve workers' conditions?

Work motivation and well-being

What do you enjoy in your work the most?
What are the main complains of workers?
What could [company] do took keep workers motivated?
What do you think it could help you to be more satisfied in your job?
What kind of things here that you think are a just a burocracy and not really necessary?
What do you think are the effects of this work in your health? (physical and mental)
What do you do cope with that?
In what ways do you think the company tries to help workers cope with physical and mental health problems?

Privacy concerns

How do you feel about having [company] collecting data about your performance at your job?

With whom would you be comfortable to share performance data?

HR, Responsável de equipa, Responsável de área, Outros operadores

How do you feel about having [company] keeping track of your mental health at the job?

Which kind of personal information do feel comfortable sharing with [company]?

And which one do you NOT feel comfortable sharing?

Tech on the job

How has your job evolved over the years in terms of technology and tools? (older workers)

For the best? And for the worst?

Why workers did not like to use the watch that warn them when the machine stopped? (if the worker knows this project)

Why workers did not like to use the exoskeleton? (if the worker knows this project)

What kind of tech or wearables (smartphones, watches) are you allowed to keep while working?

Kiosk na entrada (smiles)

Annex E

Consult Documents in submitted in the platform.

Annex F

Consult Documents in submitted in the platform.