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D2.1 HUMAN FACTORS AND METRICS ANALYSIS

Authors Neofytos Gerosavva (EIGHT BELLS), Gerasimos Arvanitis (UPAT), Nikos Stagakis (UPAT), Alessandro Zanella (CRF), Alessandro Cacciatore (CRF), Gianmarco Genchi (CRF), Petros Kapsalas (PASEU), Jordi Ferrer Riera (EIGHT BELLS), Michalis Tzifas(EIGHT BELLS), Ioannis Fytilis (EIGHT BELLS), Panos Markou (EIGHT BELLS)

Work Package WP2

Abstract

This document that is the deliverable D2.1 "Human factors and metrics analysis" represents the output of the Task 2.1 "Analysis of user skills/factors, virtual cognitive user/environment models and metrics modelling". Within the context of this deliverable, we moved into two directions: On the one hand we tried to collect and describe all the information coming from existing literature review and bibliography regarding related human factors concerning the automotive and manufacturing pillars respectively (and these findings are being presented in the first part of this document) whereas and on the other hand we designed and performed our own surveys (and at the second part of this deliverable we describe the results obtained).Some useful trends and conclusions regarding user behaviour and association between human factors and metrics were extracted and are also presented within this document.

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Project Coordinator	Industrial Systems Institute, ATHENA Research and Innovation Center 26504, Rio-Patras, Greece
Partners	1. ATHINA-EREVNITIKO KENTRO KAINOTOMIAS STIS TECHNOLOGIES TIS PLIROFORIAS, TON EPIKOINONION KAI TIS GNOSIS (ISI) the Coordinator 2. FUNDACIO PRIVADA I2CAT, INTERNET I INNOVACIO DIGITAL A CATALUNYA (I2CAT), 3. IBM ISRAEL - SCIENCE AND TECHNOLOGY LTD (IBM ISRAEL 4. ATOS SPAIN SA (ATOS), 5. PANASONIC AUTOMOTIVE SYSTEMS EUROPE GMBH (PASEU) 6. EIGHT BELLS LTD (8BELLS) 7. UNIVERSITA DELLA SVIZZERA ITALIANA (USI), 8. TAMPEREEN KORKEAKOULUSAATIO SR (TAU) 9. UNIVERSITY OF PELOPONNESE (UoP) 10. CATALINK LIMITED (CATALINK)

11. ROBOTEC.AI SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA (RTC)

12. CENTRO RICERCHE FIAT SCPA (CRF)

13. PANEPISTIMIO PATRON (UPAT)

Website www.cpsosaware.eu

Control Sheet

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	NAME
Prepared by	8BELLS
Reviewed by	ISI, RTC

Authorised by	ISI

Date	Recipient
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Table of contents

List of Figures

Executive Summary

This deliverable D2.1 "Human factors and metrics analysis" represents the output of the Task 2.1 "Analysis of user skills/factors, virtual cognitive user/environment models and metrics modelling". As such, this document will contain the description of the human factors that relate to the two CPSoSaware pillars (Automotive and Manufacturing). Our research for this deliverable was performed in two ways -literature review and data collection through online questionnaires. More specifically, an extensive literature review coming from available papers and other related resources will be presented at the first part of the deliverable -section 2 / subsection 2.1 for the related Human Factors (HF) for the automotive pillar and subsection 2.2 for the related HF for the manufacturing pillar- while for the second part of this document we designed and performed 2 surveys -one for each pillar-the results of which will be presented at section 3 along with all the related statistical results and conclusions. Furthermore, we tried to describe analytically the reasoning behind the creation of the questionnaires, the process and methodology followed for performing the related interviews for capturing the related human behaviour/ factors per pilot, and the way we correlated human factors to behavioural metrics in order to extract some useful conclusions.

1 Introduction

The current deliverable Human factors and metrics analysis represents the output of Task 2.1.

The Task T2.1. “Analysis of user skills/factors, virtual cognitive user/environment models and metrics modelling” involves organizing of interviews and user’s engagement activities towards collection and analysis of human factors and parameters, such as personality and behavioural traits promoting safety attention, risk taking, reliability, and task (work/driving) engagement, as well as experience and trust in using modern ICT tools. Human factor analysis is about understanding predisposing characteristics that may be associated with adverse events and accordingly designing the workplace and the equipment we use in order to allow for variability in humans and human performance. The methodology established for collecting and analysing the aforementioned end-users’ human factors will specify the number and type of users to be involved in this task and for each pillar (and more specifically their participation in the interviews), and issues like driver/ manufacturing operator skills, gender, expertise with ICTs, health condition, daily routines, driving behaviour etc. The user feedback was provided through online questionnaires. Towards this process, a series of questionnaires was prepared for analysing the way that the users interact within the respective environment either in autonomous driving (automotive pillar) or for human robot collaboration (manufacturing pillar). For this reason, and towards the preparation of the aforementioned interviews, the two project pilots PASEU and CRF provided useful preliminary information that helped the rest partners to define afterwards the respective surveys that were used eventually from the pilots in order collect the user feedback.

Another objective of this task is also to describe in detail the respective user models that will graphically represent the findings of the aforementioned interviews.

1.1 Document structure

<u>This document is structured into four major sections:</u>

- Section 1 introduces the scope of this deliverable and furthermore provides the structure and the methodology followed towards the human factors collection from the 2 pilots.
- Section2 presents all the related literature review on the human factors.
    - Sub Sections 2.1 and 2.2 present the human factors related to the automotive pillar/ autonomous driving and the manufacturing pillar and the human robot collaboration, respectively.
- Section 3 includes all the results extracted from the interviews that were performed by the 2 pilots along with the respective analysis.
- Section 4 concludes the document.

1.2 Approach - methodology

Within this deliverable we are going to describe and specify the number and type of users to be involved during the process of interviews along with the pilot users' characteristics such as, driver/operator skills, gender, ICT experience, health condition, daily routines, etc. All the experiments' user data after collected during the interviews stage will be analysed, and some conclusions will be presented. Furthermore, this document will describe the methodology for capturing the Human factors from both the project pilots PASEU and CRF. For accomplishing this, a series of questionnaires has been designed and tailored made on each pilot needs taking into account the environment that the pilot users interact within.

Having this in mind, we had to understand firstly the exact way that the users perform/accomplish a task either within an autonomous driving environment or during human robot joint collaborative activities.

Thus, in order to create the aforementioned questionnaires, we had firstly to collect information about the pilot use cases and the trials that are to be carried out within the WP6 context. More specifically, we held a preparatory round of questionnaires in order to collect data regarding the actual trial environment before designing the original questionnaires dedicated in collecting the human factors. These preparation questionnaires were prepared from the task leader and answered from the two pilots CRF and PASEU (and can be found at ANNEX I). This round helped to define afterwards the actual questionnaires that were used for the interviews stage. Again, the two pilots helped on the definition of these questionnaires as well.

This feedback will be provided <u>unfortunately only through online surveys- interviews</u> (taking into account the restrictions imposed by the current COVID-19 situation) in order to collect the human factors per pilot. We believe that this implication didn't affect the quality of the present document.

<u>The methodology steps we followed were the following:</u>

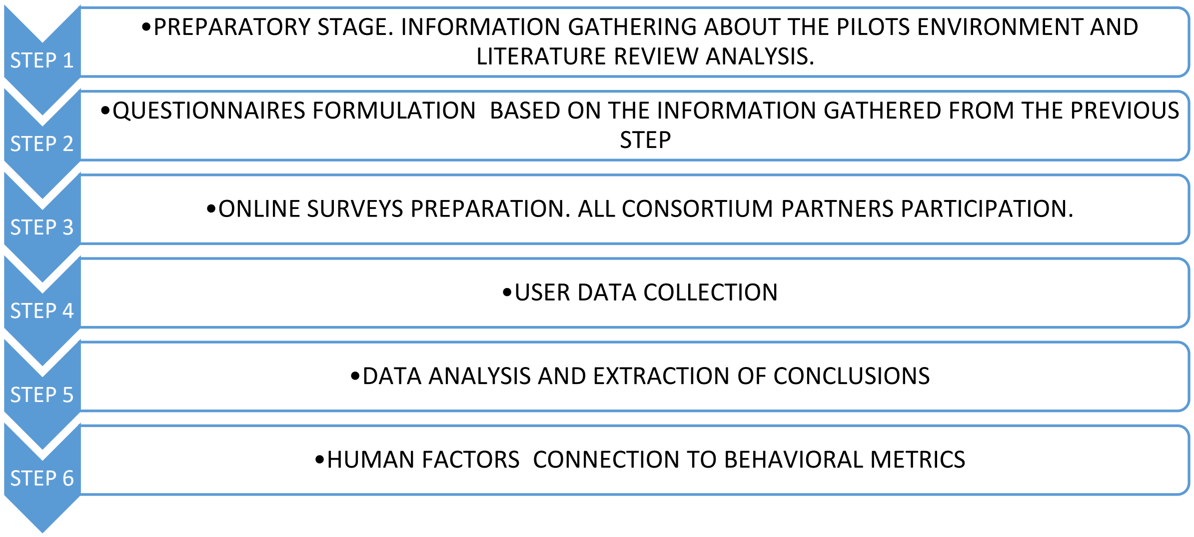


Figure 1: Methodology steps

2 Human Factors description

Human factors analysis [92] involves the study of the interrelationship between human beings, the tools and equipment they use in the workplace, or in the system with which they interact, aiming at improving efficiency, productivity, satisfaction, while also minimizing errors and increasing safety. The goal of good human factors design is to accommodate all the users in the system. This means thinking about design issues in respect to tasks being accomplished not only by experienced, qualified users in good physical or psychological state, but also for inexperienced operators/drivers who might be stressed, fatigued or in rush. Overall human factor principles incorporate the human–machine interactions (including equipment design) and human–human interactions, such as communication and organizational aspects. Human factors have been heavily studies during the last 5 decades in the Human Machine Interface (HMI) context [93]. In order to handle HMI at design time, commonly a human-centered design (HCD) [94] is followed. The ISO 9241-210 standard defines human-centered design as "an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques."

Within the CPSoSaware we have two pilots for testing the project use case scenarios:

- **The first pilot use case will be undertaken by Panasonic (PASEU).** The pilot will be focused on connected semiautonomous vehicles where we will perform trials focused on Human in the loop scenarios, like non predictable failures that may involve the human driver and how this affects the design operation continuum support of the CPSoSaware solution, as well as human situational awareness enhancement when using the CPSoSaware architecture. We will also use this use-case to access the cybersecurity mitigation strategies using the CPSoSaware architecture and its response to cyberattacks.

-**The second use case will be undertaken by CRF**. The pilot will be focused on human robot collaboration in the manufacturing environment and will involve trials that challenge the Model, Optimize, Design, deploy (MODD) CPSoSaware concept and will study accidents/failures as well as cybersecurity attacks that challenge the collaborative control mechanism and the autonomic decentralized operation of the CPSoSaware solution as well as the Design operation continuum support in the presence of cybersecurity attacks.

2.1 Human Factors (Automotive pillar)

Tasks that need to be performed by drivers in autonomous driving situations, depend on the level of vehicle automation. The most important tasks for drivers, for all the levers of automation are:

i) monitoring the proper performance of automated systems,

ii) intervening (resuming control) in order to control situations that cannot be handled by the automated system [95] [96], which may have been designed for being used only under certain driving conditions (e.g.,

on highways, in clear weather, etc.). According to existing literature, drivers fail to recognize early an automation problem and additionally delay to understand and act accordingly (e.g., take over control and resume manual driving) when the problem has occurred [1]. Vehicle feedback is not only essential but must also be provided to the drivers in an appropriate and timely manner. Human drivers may ignore minor warnings, whereas at the other hand major and continuous warnings can be perceived from the driver as annoying [2] . So, in this way, feedback received way ahead of its time or even wrongly (i.e., false alarms) can result in distraction, bypassing and ignoring the warning, or even shutting down the respective system entirely [3] [4]. Abe & Richardson [5] demonstrated that humans trust early collision alarms more than late alarms. Additionally, displays and automation settings may need to be configurable according to the drivers' preferences. Setting customization, however, can create confusion to other potential users. Time required for the driver to switch to manual driving depends also on the specific driving environment complexity (eg raining, accident, fog) during the event occurrence and furthermore on the specific time duration that is needed to gather/collect all the necessary information and take action accordingly [6].

A driver's capability to act quickly and avoid dangerous situations after vehicle automation fails is influenced by his/her **situation awareness and workload**, as well as the specific roadway conditions and the time available to avoid a collision. Vehicle automation can negatively affect phases in the take-over task (eg mental workload, situation awareness, and perception-reaction time). Recent research indicates that the braking reaction time for drivers using Level 1 and Level 2 automation is up to 1.5 seconds longer than drivers who operate the vehicle in manual mode [7]. Higher levels of automation enable drivers to engage in non-driving-related activities such as talking on the mobile phone or reading from a tablet [4]. These drivers can significantly delay to regain manual control -according to literature review a driver can take as long as 25 seconds to successfully take over [8]. Studies indicate that around 20% of all road accidents relate to **fatigue issues** [9]. Careful driving behaviour is essential for traffic safety and it is well known that humans are easily being distracted or drowsy. Each year motor vehicle accidents contribute to over 1.2 million fatalities globally [10]. While automation systems aim to lighten driver workload, this can also create multiple negative implications because if the driving tasks are little or near to zero during periods of high-level automation, the driver may experience **passive fatigue**, which according to sources can be created from situations in which cognitive load is low [11]. Additionally, literature states that passive fatigue can downgrade driving performance and reduced driver attention can be indicated by increased braking and steering reaction times in case of dangerous accidents and critical automation failures [12] [13]. Also ,studies conducted during driving simulations experiments indicate that drivers operating at higher levels of automation are more likely to involve in secondary tasks and spend more time on doing something else instead of driving carefully [14] [15]. These studies suggest that it may be easier to get distracted while driving during periods of automation, as the ability of the driver of switching to manual vehicle control when required to do so, is being compromised.

Drowsiness is one of the major causes of car accidents and can lead to severe physical injuries, deaths and significant economic losses. According to the National Highway Traffic Safety Administration (NHTSA)[16], drowsy driving resulted in 91,000 police-reported accidents, 50,000 people injured, and 800 deaths in the

United States only in 2017. Several recent studies suggest that around of 10-20 % of all accidents are possibly related with a tension for sleepiness, and furthermore distraction has been a contributing factor of up to 78-80% of all accidents and incidents [17]. Drowsiness mainly depends on the quality of the last sleep, the circadian rhythm, time of day and on the increase in the duration of the driving task [6-8]. The effects of insufficient sleep/ sleeplessness can include decreased level of alertness, lack of judgement and poor decision making, increased time reaction to a dangerous situation, limited attention, and increased probability of performing errors while driving. In around 99% of car accidents, human behavioural error that relates to driver drowsiness is a contributing factor [18].

Various **drowsiness** detection methodologies exist and can be categorized into vehicle-based measurements, physiological measurements, and computer vision techniques. Technological advancements have the potential to further reduce accidents among road users through the generation and provision of respective alerts when a drowsy state has been detected. Nabo [19], for example, found that drowsiness warnings enable driver to be in place to recognize dangers in the road earlier than driving without warnings. Additionally, [20] demonstrated that driver reaction times with respect to lane departure were faster when a warning was provided. Furthermore, according to the same source all kind of warnings (visual, haptic and sound) were all equally effective.

Metrics have been proposed to measure the state of the drivers drowsiness [21] : *Vehicle-based metrics* (steering wheel angle, pressure on acceleration pedal, and lane position (longitudinal and lateral control), *Physiological metrics* (electrocardiogram, electromyogram, electrooculogram, and electroencephalogram signals) [22] [23–26], *Behavioural metrics* (eye closure, eye blinking, head pose, and yawning, Gaze tracking, Blinking behaviour, Head tracking) [27 -29] .

Towards the mitigation of potentially dangerous incidents in vehicular transportation, car drivers should be in place to recognize hazardous situations and events (even before they are visible), create a safety corridor earlier, leading eventually to minimization of accident risks and saving critical time for the emergency response teams. **Situational awareness** (SA) is defined as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” [30]. In more simple words, situational awareness is the human operators’ perception of what is happening in the environment around them [31]. When drivers get distracted from the automated driving task or their attention is limited in the absence of a competing task [32] their level of situational awareness will most likely be decreased [33]. This can be dangerous, as incoming alerts will be most likely received unexpected and drivers can delay in adopting longer reaction times (creating an ‘automation surprise’) [34] [35]. For instance, a driver that performs some secondary tasks may fail to notice automated incoming alarms from its vehicle e.g during dangerous weather conditions. Kyriakidis et al (2015) [36] demonstrated this fact during a study where they investigated user acceptance, concerns, and willingness to buy partially, highly, and fully automated vehicles. By means of a 63-question Internet-based survey, (collected 5000 responses from 109 countries) they came into the conclusion that the research participants were more likely to be tempted on engaging in secondary tasks in case of high level of automation (Figure 3). More specifically the results show an important increase in the number of the people who would choose to do things such as resting/sleeping, watching movies, or reading, while driving in fully automated mode compared to the highly automated driving mode.

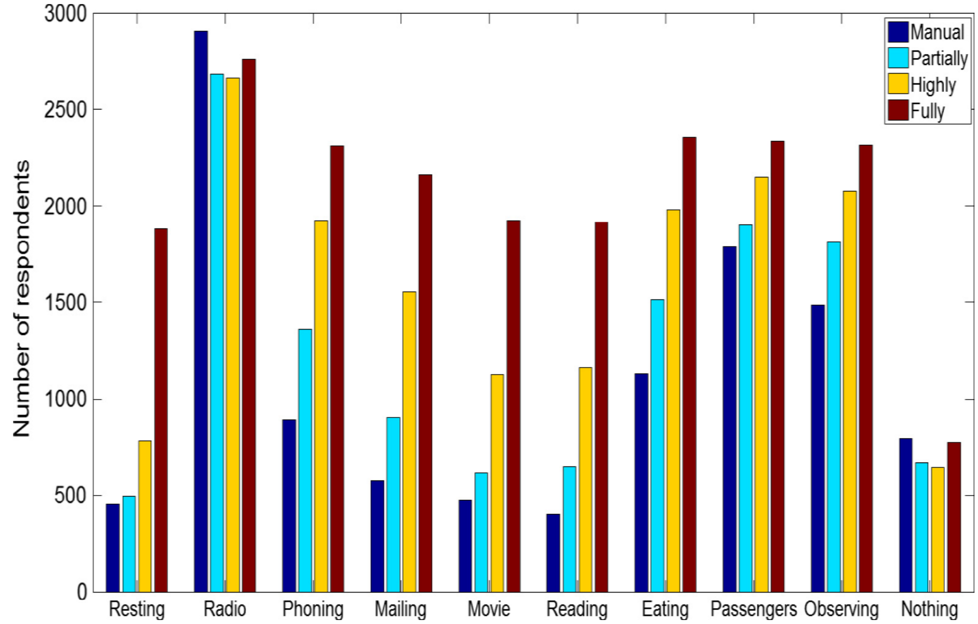


Figure 2: Number of respondents who indicated that they would engage in secondary tasks, for different driving modes [36]

Furthermore, a decreased level of driver situational awareness can also result to the "mode confusion" phenomenon. Mode confusion refers to a difference between the way that the driver *perceives* the vehicle to be operating and the way that actually the vehicle is *operating* [37]. In other words, it is a state of confusion that has to do with the vehicular functional aspects that are being controlled by the driver and the respective functional aspects being controlled by the vehicle automation at a specific time occurrence [38]. This can create situations where a driver takes decisions based on the wrong perception about the vehicle's control state. For example, a driver may choose to reverse the car without looking, having the wrong impression that the car's reverse collision sensors would provide alarms of a potential dangerous situation. Additionally, to this, research has revealed that lack of mode awareness can significantly increase the response time of the driver [39].

Users will generally **trust an automated system** if it functions in an expected way. Nonetheless, if they experience unexpected actions, there is a rapid drop in trust that often leads to disuse [40]. Therefore, manufacturers of Automated Vehicles need to consider the expectations and requirements of potential future users and take the appropriate measures in order their vehicles to be in place to fulfil these expectations. **Overreliance** occurs when drivers do not question the performance of vehicular automated systems and as a result, they neglect on performing the necessary counterchecks on the automation status [41]. **Distraction and poor judgment r**epresent two main causes of accidents [42]). The overreliance phenomenon means that the human operator's trust sense on the vehicle's automated systems, exceeds the normal level and its real capabilities [43]. The problem with overreliance and excessive trust is that drivers may believe that their car's automated systems will provide them with warnings when necessary [44]. Taking this into consideration, drivers may get into temptation to be involved in other tasks or activities, which increase the possibility of becoming distracted (an issue for driver re-engagement) [45]and adopt more dangerous driving behaviours. These consequences of over-reliance in the automation are known as negative behavioural adaptation effects and can seriously affect safe driving [46]. Furthermore, drivers that are highly dependent on automated driving systems neglect to use adequately their manual driving skills over long time periods [47]. This fact can eventually, downgrade their psychomotor ability and cognitive skills needed for manually completing a task successfully and safely [47]. Additionally, to the predicted long-term consequences (e.g., [45]), related studies such as a simulated driving study [48]) found that even short periods of highly-automated driving could cause driving performance impairment in a subsequent manual driving task, as evidenced by brief headway times and increased variability of lateral position. Also, we could refer to the motion sickness that is a condition that can be characterized by symptoms of nausea, dizziness, and other physical discomfort [49]. Motion sickness, according to Jaguar Land Rover can affect more than 70% of people, and is being experienced when the passenger 's eyes receive information different to that sensed by the inner ear, skin or body – for instance when reading during long car journeys or using a tablet etc. Furthermore, in [50] it is stated that approximately 10% of American adults are expected to experience motion sickness often in autonomous vehicles.

2.1.1 Relation between take-over sub-tasks and Human factors

Driver's capability to avoid errors and accidents on the take-over performance in autonomous driving situations (AD), is highly influenced by human factors [97]. According to related literature[98], **these factors (Table 1)** include gender, age, physical capabilities (vision, hearing, cardiovascular, pulmonary, coordination), health aspects (emotionally stable, amount of sleep, focus, multitasking), cognitive aspects (learning speed, education level), level of experience (license type, experience, ADAS exposure years, autonomous driving interactions), behaviour (driving style, car ownership), working shifts and trust to advanced driving assistance systems (ADAS).

Table 1: Potential HFs in control take-overs.[98]

HF Category	Autonomous driving (AD)	Human Factor	Level	Reference
1. Demography	*	1. Gender	Male Female	Kaur and Rampersad, 2018 [99] Loeb et al., 2019 [100]

		2. Age	Age < 20 20 _ Age < 40 40 _ Age < 60 Age _ 60	Kaur and Rampersad, 2018 [98] Loeb et al., 2019 [99] Sportillo et al., 2019[101] Lundqvist and Eriksson, 2019[102] Zhang et al., 2018[103]
		3. Height	Taller than average Average Shorter than average	
		4. Weight	Normal Overweight Obese L1, L2 Obese L3	
		5. Residency	Urban Suburban Rural	
2. Physical capabilities	*	6. Vision	Normal level Low level Chronic level	Aghaei et al., 2016[104] Arakawa, 2018 [105] Yoo et al., 2018[106]
	*	7. Hearing		Clark et al., 2019 [107]
	*	8. Cardiovascular		Aghaei et al., 2016 [104]
	*	9. Pulmonary		Aghaei et al., 2016 [104]
		10. Flexibility		
	*	11. Coordination		Salmon et al., 2010[108]
3. Health		12. Chronic /temporal diseases	Yes Chronic Yes Temporal No	
		13. Healthy lifestyle	Hydrated Regular Exercise	
	*	14. Emotionally stable	Stress Depression Anxiety	Aghaei et al., 2016[104]
	*	15. Amount of sleep	Between 6 and 10 h Less than 6 h More than 6 h	Aghaei et al., 2016[104] Arakawa, 2018[105]
		16. Diet	Fasting religious beliefs Fasting medical check Supervised Unsupervised Disorders	

			Eating time	
		17. Drugs	Depressant or Hallucinogen Performance enhancer Painkiller Stimulant	
4. Cognitive	*	18. Focus	Easy to divert Ease of boredom	Arakawa, 2018[105] Salmon et al., 2010[108] Li et al., 2020[109]
	*	19. Multitasking	Multitasker Not able to multitask	Aghaei et al., 2016[104] Li et al., 2020[109]
		20. Intelligence quotient (IQ)	Superior Average Lower	
	*	21. Learning speed	Superior Average Lower	Salmon et al., 2010[108] Dixit et al., 2016 [110] Virginia Tech Transportation Institute, 2017[111]
	*	22. Education level	University graduate level University pre-graduate level High school level Lower than High school	Kaur and Rampersad, 2018[99]
5. Experience	*	23. License type	Professional Not professional	Kaur and Rampersad, 2018[99]
	*	24. Driving experience	Beginner Experienced	Zhang et al., 2018[103]
	*	25. ADAS exposure years	No exposure Less than 1 year More than 1 year	Kaur and Rampersad, 2018[99] Cho et al., 2017[112]
	*	26. Autonomous driving interactions	No exposure Less than 1 year More than 1 year	Dixit et al., 2016[110]
6. Behavior		27. Personality	Neuroticism Extraversion Openness to experience Agreeableness	

			Conscientiousness	
	*	28. Driving style	Aggressive Defensive	Salmon et al., 2010[108] Li et al., 2018[113]
	*	29. Car ownership	Own car Rented car Company car	Kaur and Rampersad, 2018[99] Salmon et al., 2010[108]
7. Cultural influence		30. Family	Civil status Dependents	
		31. Collectivism	Individualism Groupism	
8. Work	*	32. Job position	Operative Administrative Supervision Management Strategic	
	*	33. Working shift	Day Night Rotative	Salmon et al., 2010[108]
9. Tech trust		34. Smartphone user	Average hours use Higher average hours use	
		35. Computer user	Average hours use Higher average hours use	
	*	36. Trust in ADAS	High confidence No confidence	Dixit et al., 2016[110] Cho et al., 2017[112]

The relationship between HFs and the sub- tasks required for a take-over, has been studied recently, in terms of information processing (Figure 3)[93]. The take-over scenario includes an alert from the system to the driver for being engaged in the driving mode, gain of driver's attention and delivery of information so that the driver understands (depending on the ongoing situation, his/her experience and the level of information quality provided by the interface) and proceeds to proper actions. In the next step, the driver is able to take control with a proper maneuver in order to avoid danger and/or continue with driving safely and comfortably.

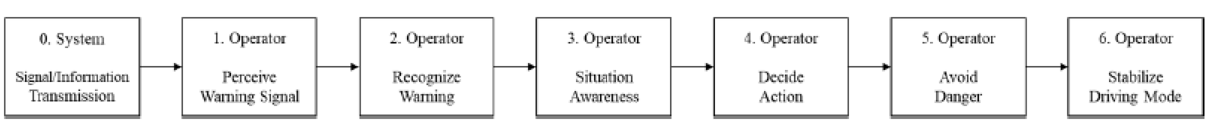


Figure 3: Sub-tasks of take-over scenario [93]

Four-point scale (strong: 9, medium:3, weak:1, no-relationship:0) describe resulted association between Human Factors categories and take-over subtasks (Table 2) and association between Human Factors and take-over subtasks (Table 3).

Table 2: Interrelationship matrix: Take-over subtasks and HF category (from [98])

Take-Over Subtasks	HF Category								
	Demography	Physical Capabilities	Health	Cognitive	Experience	Behavior	Cultural Influence	Work	Tech Trust
2. Recognize Warning	9	9	3	9	9	3	1	1	3
3. Situation Awareness 4. Decide Action	3	1	9	3	3	1	1	3	3
5. Avoid Danger 6. Stabilize Driving Mode	3	1	1	9	3	3	3	3	1
1. Perceive Warning Signal	9	1	3	9	3	1	1	1	1
Importance	5.64	4.2	4.52	6.3	5.22	1.96	1.14	1.18	2.4
Ratio (%)	17.32	12.90	13.88	19.35	16.03	6.02	3.50	3.62	7.37
Priority	2	5	4	1	3	7	9	8	6

Take-Over Subtasks	Weight	Critical Reason
2. Recognize Warning	0.41	Recognition Error
3. Situation Awareness 4. Decide Action	0.33	Decision Error
5. Avoid Danger 6. Stabilize Driving Mode	0.11	Performance Error
1. Perceive Warning Signal	0.07	Non-Performance Error

As we can conclude by observing the Table 1Table 2, the most **important HF categories influencing the take-over subtask appear to be the cognitive workload and the demography.** More specifically, these two categories have together a sum of 40% importance, approximately. The cognitive workload is highly related to cases 1 (Perceive Warning Signal), 2 (Recognize Warning), and 5–6 (Avoid Danger - Stabilize Driving Mode) and it has a higher weight than the other HF categories. Demography is more related to cases 1 and 2 with a relatively higher weight (9). On the other hand, the cultural influence and the work categories are the least important HF.

The importance value per each column is calculated by multiplying the scale values with the corresponding weights and then summarizing the results. An example of the estimation of the importance for the category of demography is presented below:

$$\mathbf{9 * 0.41 + 3 * 0.33 + 3 * 0.11 + 9 * 0.07 = 5.64}$$

The Table 3 presents the HFs that belong to the most critical categories, namely demography and cognitive workload, and they may be related to probable human errors in the take-over subtasks.

Table 3: Interrelation matrix: Take-over subtasks for **the most critical categories of** HFs (from [98])

Take-Over Subtasks	HFs in Demography and Cognitive Workload									
	Gender	Age	Height	Weight	Residency	Focus	Multitasking	IQ	Learning Speed	Education Level
2. Recognize Warning	1	9	0	0	1	9	9	3	3	3
3. Situation Awareness 4. Decide Action	1	9	1	1	3	9	3	9	9	3
5. Avoid Danger 6. Stabilize Driving Mode	1	9	0	0	3	9	9	9	3	1
1. Perceive Warning Signal	1	9	0	0	1	9	9	3	3	3
Importance	0.92	8.28	0.33	0.33	1.80	8.28	7.62	5.4	4.74	2.54
Ratio (%)	2.29	20.58	0.82	0.82	4.47	20.58	18.94	13.42	11.78	6.31
Priority	8	1	9	9	7	1	3	4	5	6

Take-Over Subtasks	Weight	Critical Reason
2. Recognize Warning	0.41	Recognition Error
3. Situation Awareness 4. Decide Action	0.33	Decision Error
5. Avoid Danger 6. Stabilize Driving Mode	0.11	Performance Error
1. Perceive Warning Signal	0.07	Non-Performance Error

The most important HFs, with decreasing order, seem to be: age, focus, multitasking ability, IQ, and learning speed while the rest HFs do not significantly affect the take-over subtasks, as also presented in Figure 4.

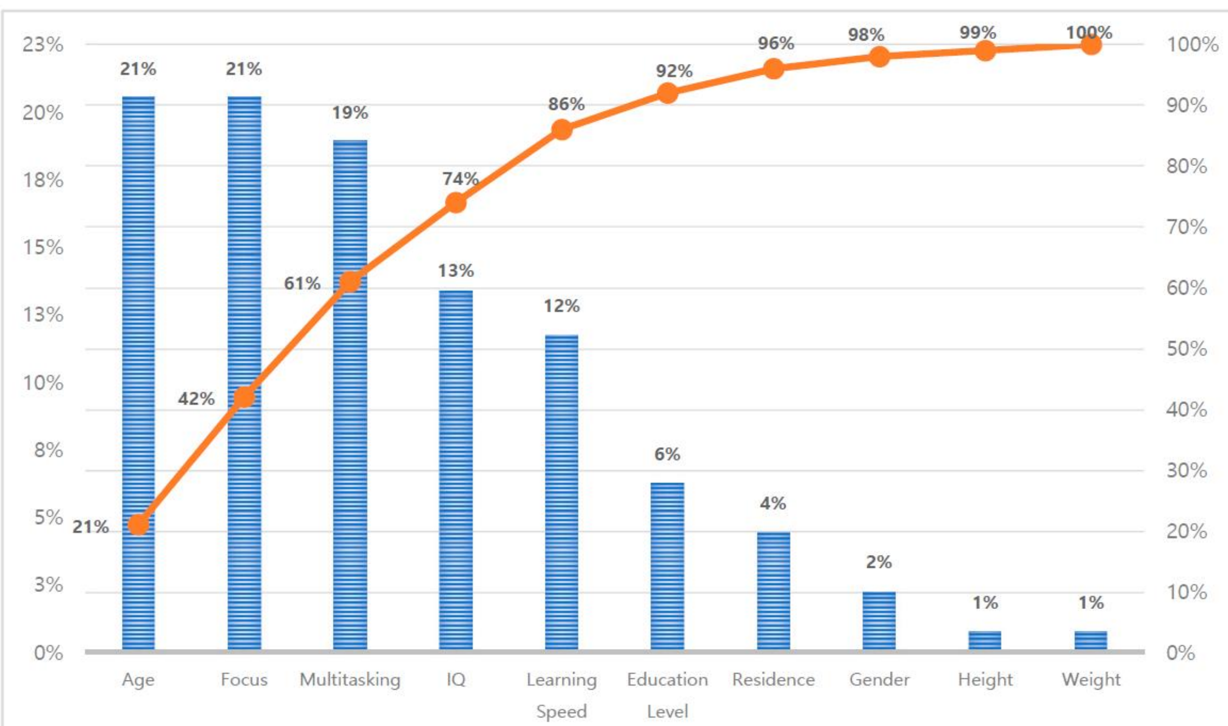


Figure 4 Take-over subtasks and HFs (from [98])

2.2 Human Factors (Manufacturing pillar)

2.2.1 Physical, psychosocial and behavioural human factors

Various studies have been conducted through the past years [114],[115] emphasizing the strong connection between occupational diseases and work conditions including physical factors, psychosocial factors, and organizational constraints. The musculoskeletal disorder represents one of the six most common occupational diseases in Europe with 52% share in illnesses related to work [116]. Recently with the Industry 4.0 (Industry 4.0 is the digital transformation of manufacturing/production and related industries and value creation processes) much attention has been dedicated to socio-technical systems [117] that integrate social human factors and technical factors to justify both economical and job satisfaction aspects. In such systems the aim is the study of interactions between production systems and workers [118],[119]. Human factors literature includes various models with different methods for enhancing human well-being. The step forward in this area is achieved through the work of Lanfranchi and Duveau [120] with their work demands, manoeuvre margins, and work recognition. In operational research, the most relevant human factor issues related to their performance in terms of time are seen through task duration, on one hand, and human error probability (HEP) in terms of quality, on the other. A very recent example is the work of Petronijevic et al.[121] who introduce **human factors under uncertainty into the design of manufacturing systems**. The goal was to control the level of the load by the introduction of specific manoeuvre margin – time margin. The effect of time margins was tracked through the evolution of fatigue while human error probability was used to represent quality of production.

The inclusion of human factors in operational research through *mathematical modelling* is relatively sparse. Three models have shown potential for the use in the addressed problem. Digiesi, et al.[122] have developed **"learning-tiredness" model** that computes task duration, but it doesn't take into account forgetting and recovery characteristics. Elkosantini and Gien [123] developed a complex model of workers' behaviours with their mathematically formulated evolution and with connections that can exist among them. Jaber, et al. [124] developed a learning-forgetting-fatigue-recovery model through parameters' variation that represents the worker's well-being as the evolution of fatigue, and task duration as learning dependent and influencing production.

Pereirai and Lima [125] paid attention to the human behavioural factors and the context, like machine or software that can impact on human performance to conduct a probabilistic risk analysis in jet engine manufacturing industry. They considered human physiological and psychological factors as the only performance shaping factors to conduct human reliability analysis and optimization of the manufacturing system. Wang et al. [126] on the other hand utilized Bayesian networks to describe the relationship between the human factors and human error qualitatively and also assessed the impact of human factors on system failures quantitatively. They focused on the human physiological and psychological factors consisting of personal abilities of flexibility, coordination, memory, and attention.

We could also refer to the decision-making style (DMS) that is a personality characteristic in psychology [127] which describes how individuals make decisions, and therefore, it can be considered as a human psychological factor. Various classifications are available for DMSs but one of the most acceptable is that proposed by Driver et al [127] , which classifies DMSs into five categories: decisive, hierarchic, flexible, integrative, and systemic. DMS plays an important role in manufacturing systems that rely heavily on human resources. It has already been shown that in the manufacturing systems where personnel interact with each other to perform their jobs, the consistency of DMSs **affects job satisfaction and productivity** [128]. For example, in cellular manufacturing systems, operators who work in the same manufacturing cells have large numbers of interactions for long periods of time, so considering the consistency of their personal characteristics (i.e., DMSs) could improve job satisfaction and the productivity of the manufacturing system[Error! Bookmark not defined.]. Azadeh et al. [129] determined a compatibility degree for DMSs, specifically in t he manufacturing areas based on Driver et al. [127].

2.2.2 Human Robot Collaboration in manufacturing

With more than 2 million companies employing 30 million workers, the European manufacturing industry faces two major raising issues:

(i) minimization of product life cycles, with a respective reduction in the amortization time for investments
(ii) an increase in business customization, which requires flexibility [51] and adaptability for manufacturing/ producing of smaller number of products with constant product changes [52].

Consequently, due to the high level of qualification and skills of its 17 million shop floor laborers, the EU manufacturing industry is very competitive within the global market by delivering high-quality goods. Sustaining it, includes retaining these highly trained workers as long as possible, extending their retirement age and ensuring a smooth transition by employing younger working staff.

However, the manufacturing industry's negative effect on health [53] as well as its the low working attractiveness, in a combination with ageing of the EU population, will create a necessity for more skilled shop floor staff in 2030 [54].

The main issue is that new automation methods in Europe have undervalued the importance of workers, and in an effect, they have promoted de-skilling and even discharging the respective workforces [55]. Japan, on the other hand that represents one of the main robotics manufacturers, has demonstrated that other manufacturing models are possible where robots and other technologies can efficiently support working staff and enhance their productivity rather than just replacing them [56].

Future workplaces are expected to be human-centric (in opposition to task-centered) as discussed in related literature and in previously accepted EC-funded projects (e.g., MAN-MADE [57]), with an increased role of human operators towards seeking improvement of production efficiency and personal welfare. In this new concept the task is appropriate and tailored made for the specific needs and capacities of the involved operators and existing research as well as pilots have proved that HR collaboration workcells, knowledge networks and support through AR technologies [58] can enhance productivity and operators welfare and at the same time decrease the first time assembly duration by 50% [59] and even enable inexperienced operators to be the same or very near efficient to the more experienced ones[60].

Furthermore, within the context of robotics, Zhang gives a definition for HMI: "A human–machine interface in a robotic system is a terminal that allows the human operator to control, monitor, and collect data, and can also be used to program the system". The main purpose of the interface is "communicating information from the machine to the user, and communicating information from the user to the machine" [61].

Human Robot Collaboration (HRC) gives the possibility to have both the operator and the robot to collaborate on the same application or in the same workspace in order to complete a task. This mixed operation is new work approach, and often standard procedures are not sufficient to design and describe collaborative workcells. During the last years, the market has experienced the introduction of the concept of collaborative robots (or "cobots")— a new category of robots capable to interact and co-exist with humans within common workspaces without having to follow the typical safety measures used in traditional robotics systems

HRC in manufacturing affects aspects related to **human performance (ergonomics), productivity and inherent quality and it is becoming popular worldwide**. Furthermore, due to the potential reduction of the spatial separation of human and robot in the collaborative workspace, physical contact between the human and the robot can occur during the operation. Protective measures are essential to ensure the operator's safety at all times.

The collaborative workspace is the space where the Operator(s) can interact directly with the robot, and shall be clearly defined (e.g., floor marking, signs, etc.). Persons/operators shall be protected through the use of various protective equipment and devices but also via the compliance with robot performance features allowed in ISO 10218-1 [62]. The collaborative workspace must be implemented in a way that will ensure that the operator can easily perform all tasks and the location of equipment and rest machinery shall not bring any additional hazards. Designing successful HR collaboration scenarios can improve manufacturing efficiency, productivity and quality and at the same time reduce operating costs since the weakness of the one collaborative part is being complemented by the strengths of the other. The Human robot collaboration is a combination of human flexibility and machine efficiency **and the HRC workspace design and task allocation are the combination of both human skills and robot capabilities. However, the interaction and collaboration of human operators and robots within the same workspace defines several challenges referring to human factors such as safety, stress levels etc.**

When designing a collaborative operation, the standard defines four possible collaborative modes, each characterized by its own specific functionality and safety requirements.

The allowed Collaborative modes are the following:

- **Safety-rated Monitored Stop (SMS):** If the robot is alone within the collaborative workspace it operates autonomously. If human walks into the collaborative workspace the robot must stop its previous movements and maintain a safety-rated monitored stop in order to eventually allow direct interaction of an operator and the robot (e.g loading a part to the gripper, thus the robot's operations can continue only after the person leaves the collaborative workspace.

- **Hand Guiding (HG):** Hand guiding operations is the way an operator manually operates a robot end effector

- **Speed and Separation Monitoring (SSM):** The Robot system is designed to ensure a safe distance between the operator and the robot in a dynamic manner (considering position and speed of both the Human operator and the Robot). Robot speed, minimum separation distance and other parameters shall be determined by risk assessment

- **Power and Force Limiting by design or control (PFL):** The Robot systems are designed to control potential dangers by power or force limiting to specific values depending on the type of possible contact and risks related to them. Parameters of power, force, and ergonomics shall be determined by risk assessment

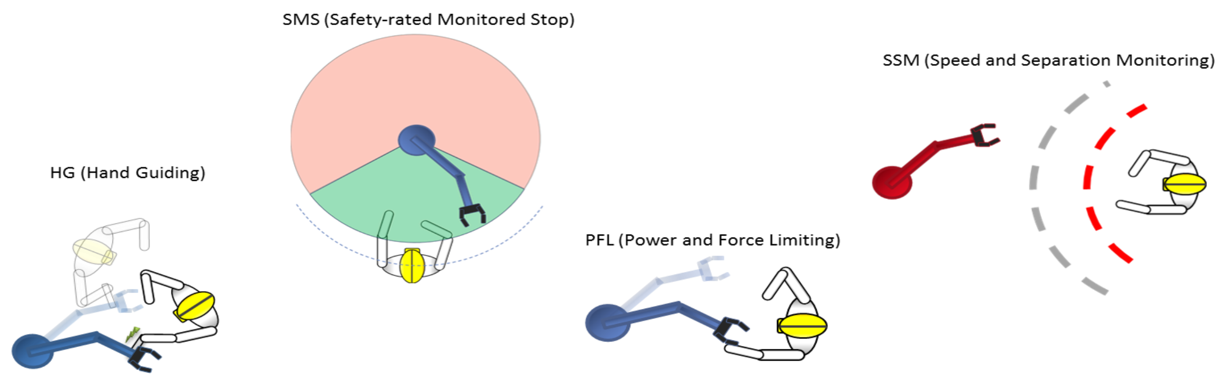


Figure 5: Collaborative Operating Methods

2.2.3 Ergonomics

As already mentioned, the Human operator and the robot are the main actors of the collaborative workspace; because of this the human factors are at the center of a proper design of Human Robot Collaboration (HRC) workcells.

The main characteristics affecting or describing the performances of the workcell are:

- the task analysis within the respective time duration
- the type of task to be completed
- the ergonomics - (short definition of the term is provided below)
- the distance walked by the operator within the work cell during the operation

It is easily understood that Human operators within the context of Human Machine Interaction and Human Robot Collaboration in the Manufacturing sector, rely on a finite set/unit of cognitive resources, in order to complete the specific tasks [63].

Additionally, a variety of factors are being considered to affect the way through which the aforementioned cognitive resources are being consumed and have impact on task performance, such as for instance: Fatigue [64-66]; Skill Level & Experience [67]; Stress Levels & Emotional State [68]; Environmental Conditions [69]; & Satiety [70]. Understanding these parameters is important as it can be utilized towards informative decision-making, and dynamically adjusting behaviour based on current and predicted performance, among the various operators; helping eventually on succeeding optimal control of the robotic elements of the system.

Ergonomics can be defined like the science that studies the way of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job [71]. Practically ergonomics is the scientific discipline involved with the understanding of the various interactions among humans and a specific system component, and incorporates this knowledge towards the application of theory, principles, data and methods to design in order to improve human welfare and the overall system performance.

The psychophysical and social well-being of the human operators relates directly with ergonomics (or human factors). COBOTS, from a physical point of view, can play a significant part towards biomechanical overload reduction of the operator via the provision of assistance during heavy and repetitive tasks. Nonetheless a close joint effort with the **robot, may cause to the operator additional psychological stress.** Furthermore, the well-being and efficiency of the human operators can negatively be affected from unknown and unpredictable activity of the robots [72].

During manufacturing operations human operators can often be exposed to many non-ergonomic movements/actions such as:

- Heavy loads manipulation
- Blind and awkward postures (Awkward postures is the situation where the worker performs his/her task with various parts of the body in bent, extended or flexed positions rather than working in a straight or neutral position. Working in such uncomfortable body posture increases the amount of effort and muscle force that a worker must put in order to complete a task
- Repetitive and cycling movements

It is a standard procedure to design the workplace in an aim to minimize the ergonomics workload on the human operators. The aim is to succeed the goals of occupational health and safety and productivity.

Ergonomics is nowadays faced by a preventive (and on the field) simulation and analysis of the positions, postures and actions performed by the operators. In case ergonomics issues are foreseen, workplaces can be redesigned to eliminate the issue or reduce the impacts to the operators. Proper job rotation planning is needed in order to keep the exposure to ergonomic risk below the acceptable level (defined by the law). Often technical equipment is used to support the human operator's actions, such as for instance adjustable seats, workstations and tables etc.

As for the flow of information towards the operator, it is important to highlight that the operator is already concentrated onto its own operations and for the detection of the robot's motion (in order to avoid collisions). This situation can be already generating cognitive stress; for this reason, the optimization of the HMI with the operator should take into account procedures in order to reduce the risks associated to cognitive ergonomics.

2.2.4 Human System Interactions

For understanding better the way cobots and operators collaborate we must, first identify (1) the intended interactions between a human and a robot and (2) the purpose of the information exchanged during this communication. As discussed previously the cobotic system is consisted by a robot and a human that join forces for completing a task within a defined collaborative workspace. Regarding cobotics, we must take seriously into consideration the human operator, the task performed, the potential human system interactions and the robot. For designing a cobotic system it is necessary to have a clear understanding of the potential human robot interactions, both requirements and constraints and the type of robot to be used towards the process [73].

Human – robot interaction in manufacturing environment

- **Synchronised** when the human operator and robot collaborate within the same workspace, but during different time intervals
- **Coexistence,** when the human operator and robot work within the same work environment but generally do not interact with each other.
- **Cooperation,** when the human operator and robot work within the same work environment and at the same time, but they undertake different tasks.
- **Collaboration,** when the human operator and the robot have to collaborate and complete a task jointly; as a result, any activity of the one part can affect the activities performed from the other thanks to special sensors and vision systems [74].

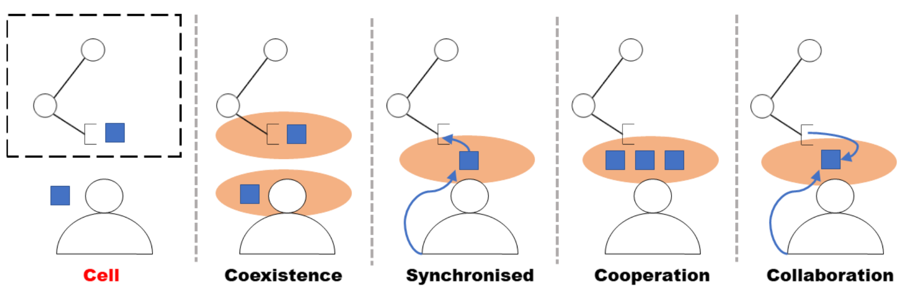


Figure 6: Types of use of a collaborative robot. [75]

2.2.5 Human Robot Collaboration and Trust

Regarding the human robot interaction (HRI), literature review lists a variety of factors that must be taken into account to be held responsible for establishing the operator's trust in the robot's capabilities, and some or all of these will eventually determine whether or not the robot/system is used and accepted.

We could refer also to the Three Factor Descriptive Model of Human Robot Trust ([76][77]), that demonstrates how environmental, human and robot related factors can all affect operators' trust in a system, and furthermore how the three elements can influence each other, as shown in Figure 7.

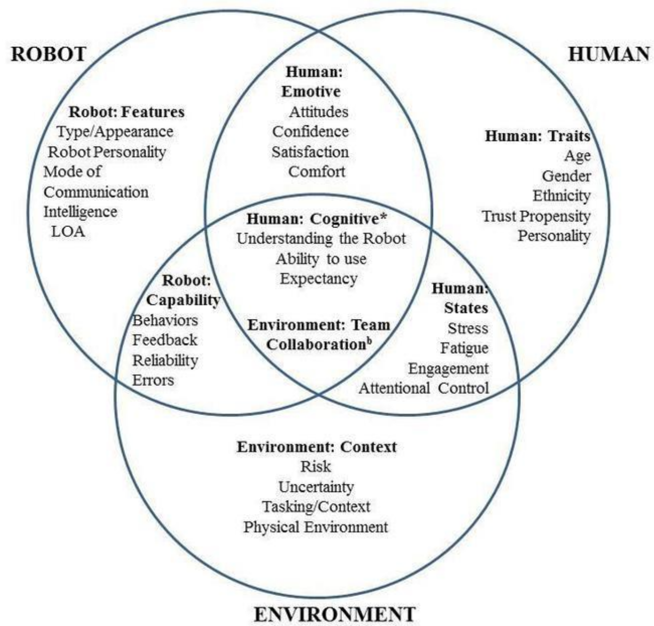


Figure 7: Venn diagram showing the interdependent nature of trust across the three factors of trust (from Schaefer et al., 2016) [130]

Hoff and Bashir [78], build on the **Three Factor Descriptive Model of Human Robot Trust** in order to suggest/ recommend of ways for maximising appropriate trust in automated systems. The authors stated that usability of a system affects the trust level of its potential users. Operators will generally trust an automated system if it demonstrates an expectable behaviour. Nonetheless, if they experience unanticipated actions, there is a rapid drop in trust that often leads to disuse [79].

Additionally, literature findings show that trust is an important factor towards a successful HRC. Lee and See [43] define trust as "*the attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability*" (p. 54). Indeed, within the context of human-automation

joint collaboration, trust can affect the willingness and decision of human operators to rely on the data information provided by an automated system, especially under high-risk situations [80][81].
As we have already mentioned any potential doubt and uncertainty will eventually lead the operator to undertake the manual control of the process [82]. Within human-robot collaboration environments literature states that trust development can be influenced by robot characteristics and attributes, such as appearance, movement, reliability and predictability. However, until recently, very little was known regarding trust development between humans and industrial robots.
Charalambous, Fletcher and Webb [83] developed a trust measurement scale appropriate for industrial HRC. The scale presents three key factors which influence human trust in industrial HRC.
A short description of each of the key factors is provided below:

- **Factor 1 – Safe co-operation**: This is the understanding or perception developed by the human operator of how safe it is to collaborate with the industrial robot.
- **Factor 2 – Robot's and end-effector's reliability**: This is the human operators' perception on the reliability of the robot and the end-effector (e.g gripper)
- **Factor 3 – Robot's motion and pick-up speed**: This is the human perception on the degree to which the robot's motion is fluent and non-disruptive as well as the robot speed at which it can collect and manage components.

Moreover, according to the International Organisation for Standardisation [84] HRC is a "special kind of operation between a person and a robot sharing a common workspace". A successful implementation of industrial HRC it can bring multiple benefits such as enhanced quality and resilience, increased production and reduced product cost [85]. Safety reasons have till recently prevented further expansion of HRC as companies put emphasis on mitigating the risks of possible accidents and hazardous situations that can cause injuries to the human operators. Recent developments in technology as well as in health and safety standards and regulations however, have significantly increased the potential of Human Robot collaboration. Robots nowadays are being designed having safety as top priority and being more lightweight, compact than before [86]. Thus, closer cooperation between the robots and the operators can be succeeded and HRC is expected to further increase in the future [84]. The level of trust is particularly important within high-risk situations as it directly influences human operators' willingness to digest data information coming from the robot, receive and take into account robots' suggestions, and eventually benefited from the potential advantages that robotic systems can provide [87]. So, trust can affect the decisions that human operators can take under risk circumstances [88]. For instance, if an operator doesn't trust the robot in will most certainly intervene at some point during the collaborative task, and this might potentially affect the task's successful completion [89].
Furthermore, a unique phenomenon known as "automation bias" takes place in these kinds of collaborative environments that causes humans to assign higher degree of authority, greater expectations on performance and higher initial level of trust to machine-like agents [90] rather than human agents [91]. Nevertheless, this initial trust being placed to machine-like agents can quickly collapse once a machine appears to operate at a lower level of consistency from the one that was initially expected.

3 Interviews for collecting the human factors

The purpose of this chapter is to present and analyse the results of surveys on autonomous driving and HR collaboration from a qualitative perspective. Results will be drawn from feedback covering a period of around 25 days within January 2021, from project partners regarding the autonomous driving and exclusively from CRF experts on the HR collaboration. The goal of T2.1 is to collect and assess the human factors and metrics both for autonomous driving and manufacturing pillars meaning to analyse issues related to human perception of the wider environment within which a human has to perform a related task. Previously in the document we provided a literature review collected from various sources in order to present factors that are responsible for influencing human task performance within autonomous driving or within human robot collaboration environment.

For the second part of this document, we created questionnaires in order to collect useful information on human factors. The questionnaires were created after collecting information from the pilot leading partners CRF and PASEU, and taking into account their suggestions regarding what will be useful to examine in relation to HR collaboration and autonomous driving respectively. We used Google Forms for converting these questionnaires to online surveys, that were distributed online to the pilot leading partners, CRF and PASEU. The pilot leading partners then, undertook the task to inform about its purpose and circulate it among their organizations and experts. Furthermore, the autonomous driving questionnaire was also circulated to all the consortium project partners from the task leader.

An overall number of 60 persons participated in these surveys, a sample not too big , Nonetheless our sample included professionals directly or indirectly involved in the project and that means that the respondents had a clear understanding of the issues referring on HR collaboration and autonomous driving respectively (thus their feedback was related to the conducted study).

For the T2.1 we needed 2 questionnaires assessing human factors that the participants consider as important towards the wider environment they are operating:

More specifically for the interview phase we designed:

1. A generic questionnaire on participants profiling/personal profile. This questionnaire assessed issues such as the participants age, gender height, experience, physical condition

2. A second questionnaire focusing on HR collaboration and on autonomous driving/driving behaviour

- Questionnaire on HR Collaboration. Our objective here was to collect participants’ feedback on HR collaboration issues and the way they perceive different things within the respective environment
- Questionnaire on autonomous driving. Our objective here was to collect participants’ feedback on autonomous driving issues/driving behaviour and the way they perceive different things within the respective environment

The feedback on these questionnaires will allow us to extract useful conclusions on the participants profiles, some potentially interesting personality traits and demographics and things that the participants consider important in relation to human factors and metrics.

EIGHT BELLS as the deliverable leader informed all the participants about the purpose of the study and provided all the relevant information about the project answering at the same time any potential questions were raised from participants. The respondents were explained that the participation was totally voluntary and furthermore they were informed that the questionnaire is completely anonymous and that the data will be treated with confidentiality by all the involved parties. **According to the data management policies all the participants before signing up for the study, participants received the respective consent form along with the research information sheet.**

All the related questionnaires can be found at the Annexes

3.1 PASEU interviews

3.1.1 Demographics

The autonomous driving questionnaire was completed from 42 participants. The questionnaire was circulated online within the consortium and was created taking into account PASEU's feedback.
The questionnaire consisted of 2 sub-questionnaires. In the first part, respondents answered demographic questions about their age, gender and frequency of driving, the number of years a full driving license has been held and annual mileage.
A significant percentage of the survey participants (45.2%) were between 35-50 years old while 35.7% of the respondents were between 51-65 years and the remaining 19% between 21-34 years old. The main part of the respondents was male (64.3%) in comparison with female participants (35.7%) while 50 % of the total number of the participants reported that are PhD holders and the other 50% answered that they are university degree holders. Moreover, all the survey participants answered that they own a car driving licence. A great majority of 69% of the respondents answered that they possess a driving experience of over 10 years while 23.8 % answered that their driving experience is between 5-10 years and the remaining 7.1% 0-5 years. So, we can state that the answers came mainly from experienced drivers. Additionally, to this and in relation to driving experience a percentage of 11.9% of the participants answered that they drive on average 30000 -40000 kilometers per year, while 33.3% drive on average 20000-30000 kms per year. A significant percentage of 33.3% of the respondents answered that they

drive between 10000 -20000 km per year. Regarding the same questions only 7.1% of the respondents answered that they drive for over 40000 km per year. Furthermore, regarding the familiarity / experience with the autonomous driving the majority of the survey participants (52.4%) answered that they are rather unfamiliar having under 2 years of experience with Autonomous Driving (AD) while a percentage of 35% are adequately familiar as they answered that they have an experience on autonomous driving from 2-5 years (40.5%)

Finally, only 7.1% of the respondents answered that they have an extensive experience on Autonomous driving from 5-10 years. Also, a vast majority of the survey participants (81%) answered that they use ICT applications in their daily living, while 9.5% use ICT technology once per week. On the other hand, 7.1% answered that they use it only a few times per month. Only a small percentage of 2.4% answered that they do not use ICT applications at all so they are totally unfamiliar with technology.

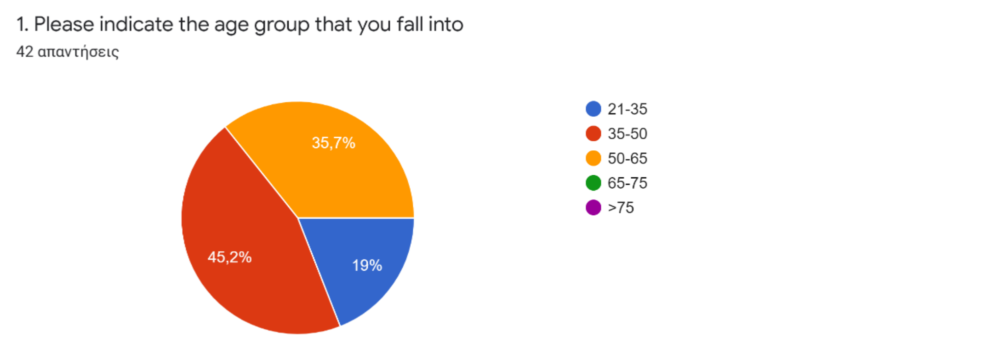
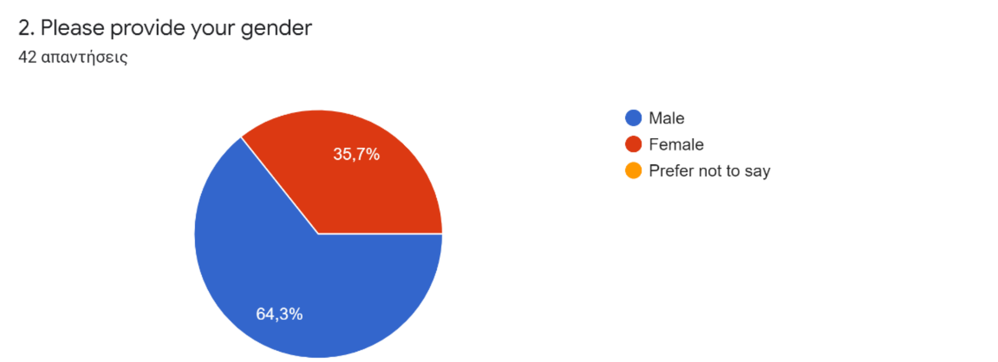
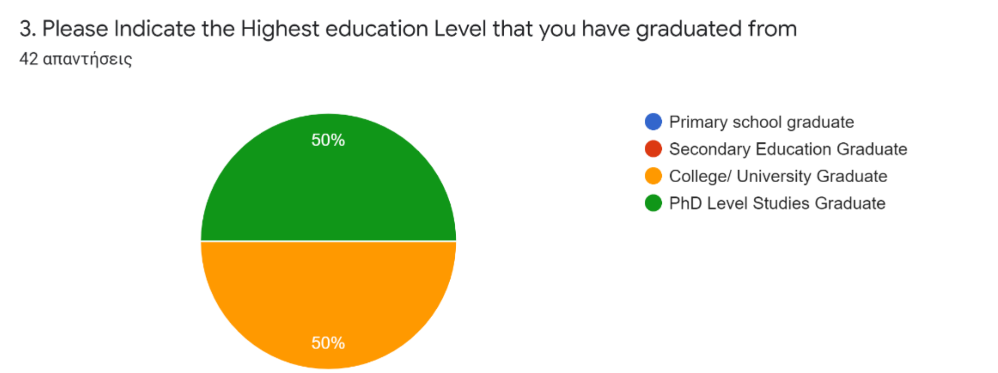
Now, regarding familiarity with VR/AR technology, a percentage of 40.5% of the survey participants considered their selves as familiar enough with such kind of technologies and at the same time 16.7% of the respondents consider their selves as very familiar with VR/AR technology.

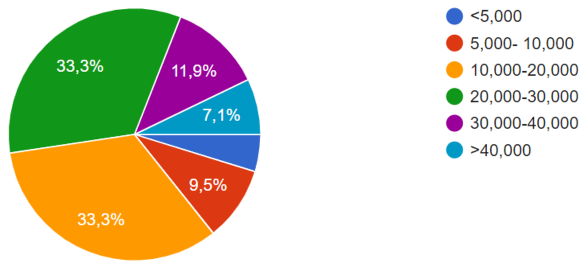
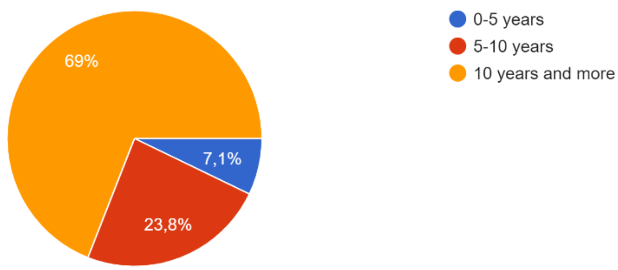
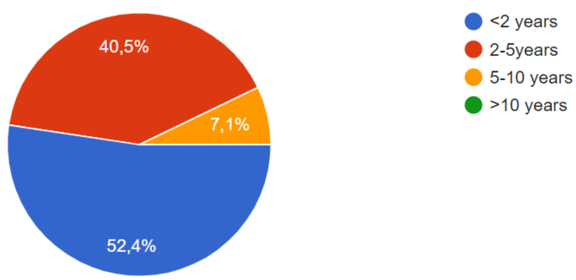
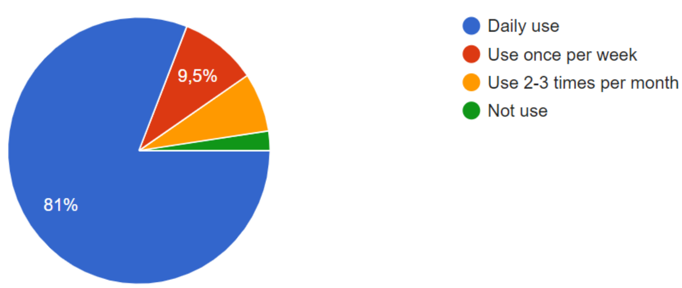
Also, regarding this question, 26.2% answered that they think that they are moderately familiar. So, in total the majority of respondents believe that they are familiar enough with the specific kind of technologies as only a percentage of 16.7% answered that they are not familiar at all. Moreover, concerning the issue of the tasks during their daily driving routine where they would prefer to receive assistance with the use of VR/AR, a percentage of 35.7% seem to prefer monitoring, while 31% answered "vehicle control" and another 9.4% selected the option of "decision making". Nonetheless the most popular answer on this question (having been selected from the 50.5% of the participants) was that that they would like to receive assistance on all the listed daily driving tasks.

Regarding health condition issues this specific question was answered by the 66% of the total number of participants meaning only 28 persons. A vast majority of the survey respondents that answered this question (67.9%) answered that they have vision impairment issues, while 50% said that they have some kind of chronic pain/ fatigue problems. Additionally, a percentage of 25% of the ones that answered this question replied that they have musculoskeletal problems while a percentage of 7.1% answered that they have cardiovascular diseases and 3.6% answered that they have some respiratory issues with their health and an equal percentage said that they have dizziness related problems. Regarding physical exercise 21.4%

of the respondents answered that they don't exercise at all. On the other hand, 14.3% answered that they exercise daily, 35.7% gave feedback that they exercise 3-4 times per month, 16.7% of respondents said that they do exercise 2-3 times per week and 11.9% selected the choice of exercising 1-2 times per month.

Table 4 : Autonomous driving questionnaire- Demographics

Age	
Gender	
Education level	

Annual mileage	5.2 Driving experience - Number of kilometers driven per year 42 απαντήσεις 
Driving experience	5.1. Driving experience-Years of driving since obtaining driving license 42 απαντήσεις 
Autonomous driving experience	6. Please indicate your experience with autonomous driving 42 απαντήσεις 
ICT familiarization	7. Please indicate your familiarization with ICT applications 42 απαντήσεις 

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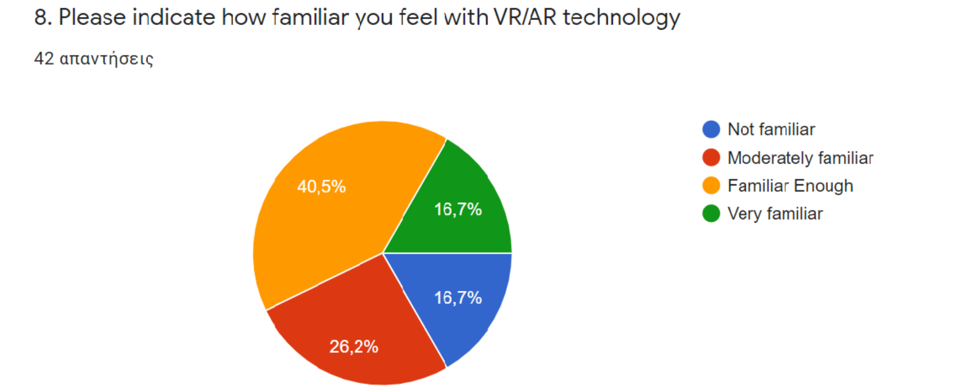
<tr><td>VR familiarization</td><td>
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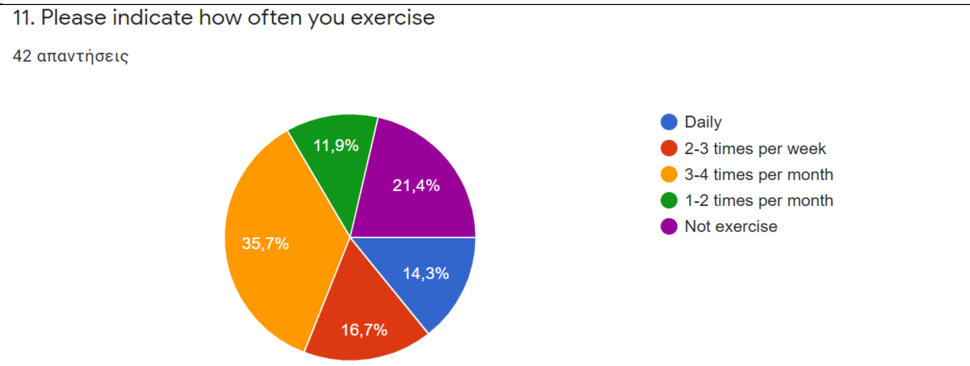
<tr><td>Exercise level</td><td>
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3.1.2 Driving behaviour questions

Below is a summary of the findings collected on the second part of the autonomous driving questionnaire, that tries to draw conclusions on driving behaviour.

When the question comes on driving over the legal limit in residential roads, 28.6% of the participants answered that they rarely drive over the legal limit, 31 % answered that they sometimes do so, while a l percentage of 40.5%, answered that they do it often (23.8%) or very often (16.7%).

If this happens to drive over the limit, the most common reasons for this are the following ones:

- 46.2% they drive over the limit because they are in a hurry
- 17.9% quoted other reasons
- 10.3% said that they do it because they like speed
- 25.6% said that they have to do it because they need to balance with time spend in other sub-tasks during their driving task (e.g. looking for parking place etc).

Regarding the question on how often they drive fast and without wearing a belt, a significant percentage of participants (40.5%) answered that they never do this, while 21.4% answered they sometimes do so, and an equal percentage of 21.4 % answered that they often do it while 11.9% said that they do it rarely. Regarding the question if there is a need to drive for any reason (e.g for work) between midnight -7 am and if yes in what frequency a great majority of the respondents in a percentage of 64.3% answered that they never drive within these night hours while 35.7% answered that they have to do this once per week.

On the next question the participants were asked to select reasons/occasions on when they tend to drive closer to the vehicle ahead. This question was answered by 38 persons out of the 42. The most popular answer was that this can happen due to hasty driving (answered by 60.5.% of the respondents that answered) while the two options "feel tired" and "feel sleepy" were selected by 50% and 39.5% respectively. Finally, a percentage of 10.5 % of the respondents answered that his may happen due to weather conditions.

When the question goes to the use of mobile phones / tablets while driving (engaging in secondary tasks) 21.4% of the participants answered that they never do this while driving, while 28.6% answered that this can happen to them rarely, while 16.7% stated that they sometimes do this and 28.6% said that this can happen often. The option "very often" was selected by only 4.8% of the participants.

About the question of ignoring car danger alarms when they are continuous, a percentage of 16.7%% of the respondents answered that they never ignore car alarms even if they are continuous while 14.3% answered that they rarely ignore such kind of alarms, and another 23.8% provided the answer that they sometimes do this. A percentage of 40.5% of the participants provided feedback that they often can ignore continuous alarms and similarly to the previous question the option answer "very often" was selected by only 4.8% of the participants.

Regarding the issue of alert signals and the minimum time to be raised before a possible collision a great percentage of 57.1% of the respondents answered they would like the alert signal to be provided from the vehicle over 4 seconds prior a possible collision while 35.7% stated that they would prefer to be provided this alert between 3-4 seconds before. A percentage of 7.1% of the participants selected the answer of receiving the alert less than 3 seconds before the collision. Regarding the way they would like to receive the incoming alerts a percentage of 21.4% of the respondents stated that they would like to receive them as generated alert sounds, while 19% selected the option of "displaying the alert on a vehicle screen". Nonetheless the majority of interviewees (59.5%) here answered that they would like to receive the alerts through all the possible available options: in-vehicle screens, out of vehicle alert components, and generated alert sounds. When the question goes on potential risk-taking actions during driving (for instance ignoring the red light when crossing junctions, switching lanes very fast) a percentage of 23.8% of the respondents answered that they never engage in such kind of activities during driving while 31% answered that this happens very rarely. This means that a percentage of 54.8% of the participants avoid risks when they undertake driving tasks. On the other hand, a percentage of 14.3% answered that sometimes have to take such risks and 26.2% selected the option of "often". A small percentage of the participants (4.8%) selected the option of "very often". Next survey questions dealt with rapid acceleration /deceleration while driving and the possible reasons for doing this. A percentage of 50% of the participants answered that they often (38.1%) or very often (11.9%) do this, 23.8% answered that they sometimes do it while 26.1% stated that they tend to accelerate/decelerate when driving rarely

(19%) or never (7.1%). Not every participant provided a reason for this kind of driving behaviour but those who did it provided as primary reasons for such driving behaviour firstly that this can represent a standard way of driving (46.2%) and secondly that this can happen if the driver is in a hurry (43.6%). Other reasons provided here were “to avoid collision” (2.6%), when driving during high traffic (2.6%), overtaking or emergency braking (2.6%), and “when drivers of nearby cars are insistent” (2.6%).

Regarding the issue of driving without adequate sleep before (drowsy driving) – something that can have as a result slow driver reaction times, reduced vigilance and impaired thinking and increase of the possibility of accidents-, 40.5% of the respondents answered that they never (9.5%) or rarely (31%) driver when being drowsy while 26.2% answered that sometimes had to drive without adequately sleeping before. A percentage of 33.4% of the survey participants selected the options often (31%) or very often (2.4%).

Regarding possible reasons for drowsy driving not everyone provided feedback, but the ones that did it, gave as main reasons for having to drive without adequate sleep before the following ones:

- anxiety
- necessity to go at work early
- Because it's needed due to a specific occasion (i.e., coming back to home after a weekend in the beach, when coming back from a trip/journey - when used the day to maximum and then had to drive home/another destination)
- Having a small child
- Spend a long night (either for work or for pleasure)

Regarding the question on the desired active area to be captured by sensing vehicle functions (a question that connects to situational awareness) a percentage of 42.9% of the participants answered that they will prefer this up to 20 meters from the vehicle, 45.2% selected the option “between 10-20 meters from the vehicle” and 11.9% selected the option of less than 10 meters from the vehicle.

Regarding the issue of keeping distances from other vehicles when raining, 45.2% of the survey participants answered that they do it very often while 54.8% that they do it often. No participant selected any other option.

Regarding the issue of the level of anxiety when driving within areas with much traffic a percentage of 61.9% of the participants answered that they feel a little anxiety when driving within areas with much traffic, pedestrians and bicycles around them while 9.5% answer that they feel very anxious during such occasions and finally 28.6% stated that they don’t feel any anxiety about this fact.

Regarding the issue of rushing on making decisions when driving (e.g for changing driving lane) 52.4% of the respondents answered that they often (47.6%) or very often 4.8% rush into hasty decisions while 19% said that they sometimes have to take such kind of decisions, and on the other hand 28.6% of the respondents answered that they never (2.4%) or rarely (26.2%) have to take this kind of decisions.

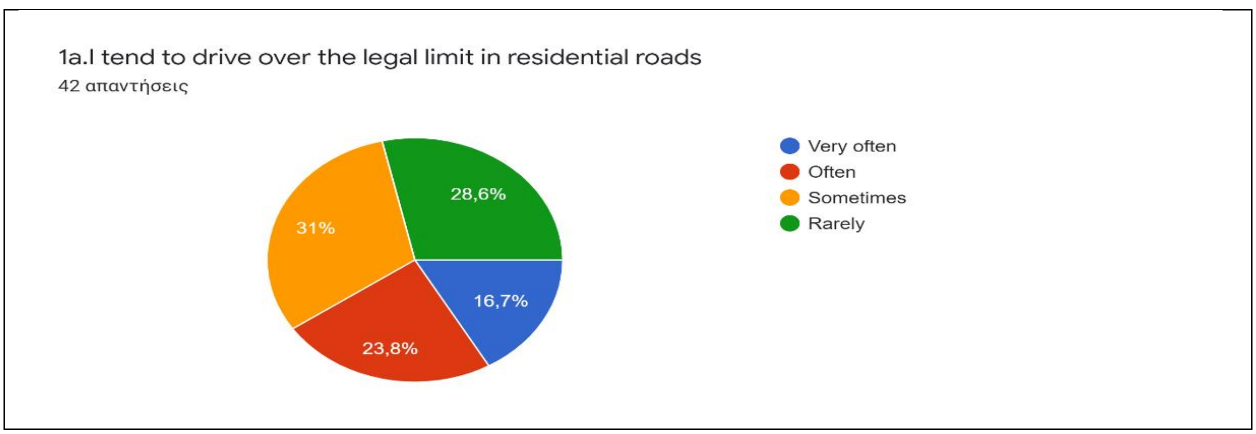
Regarding reasons of possible distraction when changing driving lane, the option “talking to the co-driver” was the most popular answer given from a percentage of 33.3% and the second most popular answer was using a smartphone or a tablet” (26.2%) and equally, another 26.2% said that this can happen due to a telephone call. Furthermore, a percentage of 9.5% of the respondents selected” the listening to the radio” option whereas a percentage of 4.8% said that this can happen due to other reasons from the ones listed as options.

Regarding the issue of getting impatient when slower drivers are in front of them while driving a percentage- majority of 66.6% of the respondents said that this can happen often (45.2%) or very often (21.4%), while 14.3% said that this can happen sometimes and finally 19.1% of the participants said that this can happen rarely (16.7%) or never (2.4%)

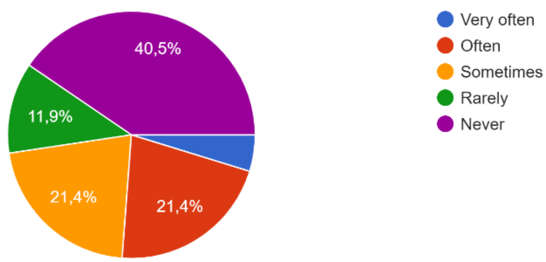
Regarding the issue of the level of importance of the image quality in the debug screens, a big percentage of 54.8% of the participants answered that they consider this as very important while 14.3% answered that they consider this issue as more important than sensing. A 11.9% of the respondents answered that they consider this as moderately important while 19% of the participants said that they consider it as less important than sensing.

Regarding the question on whether they participants would accept distortions on the (interior or exterior) vehicle’s design / appearance in order to favour sensors’ installation and improve safety, a big percentage of 52.4% of the respondents answered that they would most definitely accept this and an additional 38.1% answered that they would accept this. So, in effect 90.1% of the survey participants would accept these kinds of distortions towards safety improvement. A percentage of 7.1% appeared sceptical and said they maybe would accept such distortions while only 2.4% answered that they would be negative on such possibility.

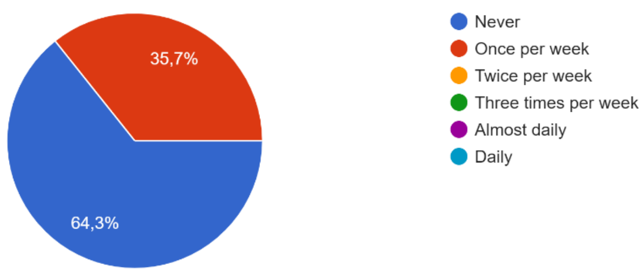
Table 5: Driving behaviour questionnaire statistics



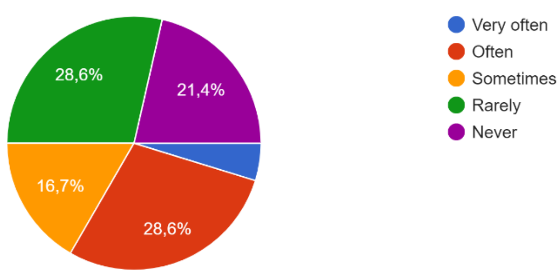
2a. How often you have to drive fast and without wearing a belt?
42 απαντήσεις



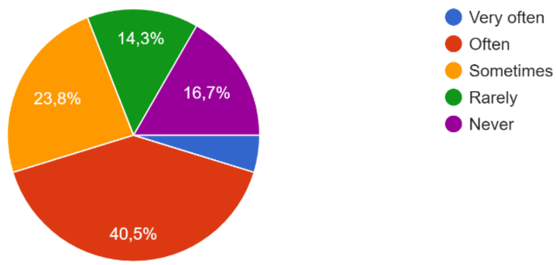
3. Do you need to drive for any reason (eg for work) between midnight and 7 am and if yes how often ?
42 απαντήσεις



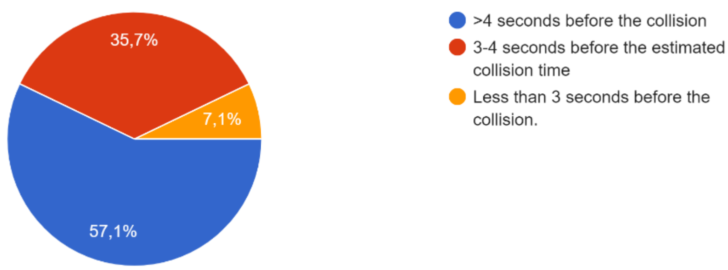
5.I tend to use mobile phone or tablet when driving
42 απαντήσεις



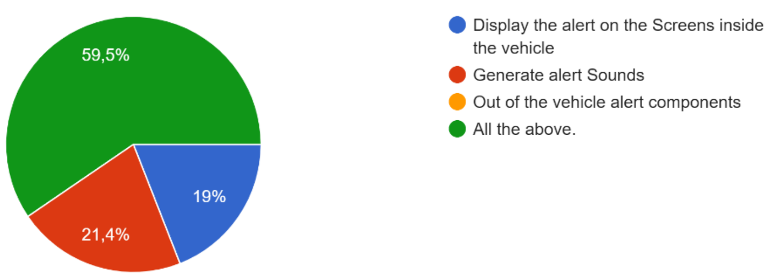
6.I tend to ignore car danger alarms when they are continuous
42 απαντήσεις



7. Which is the minimum time before collision that you want the alert signal to be raised:
42 απαντήσεις

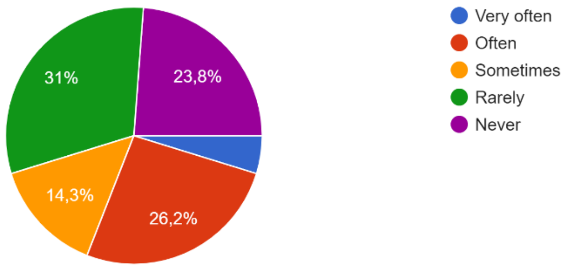


8.How do you prefer to receive the alerts?
42 απαντήσεις



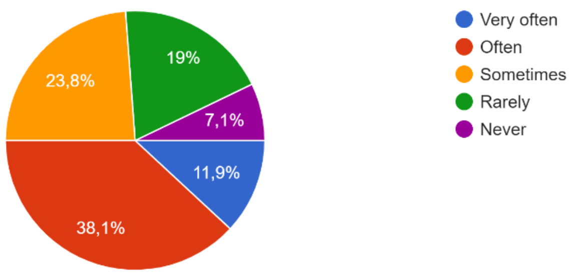
9. I take some risks when driving eg ignoring the red light when crossing junctions, switching lanes very fast

42 απαντήσεις



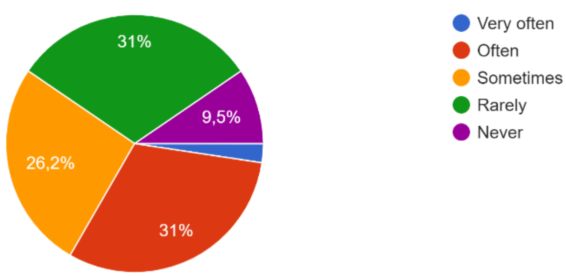
10a. I tend to accelerate and decelerate rapidly when driving

42 απαντήσεις

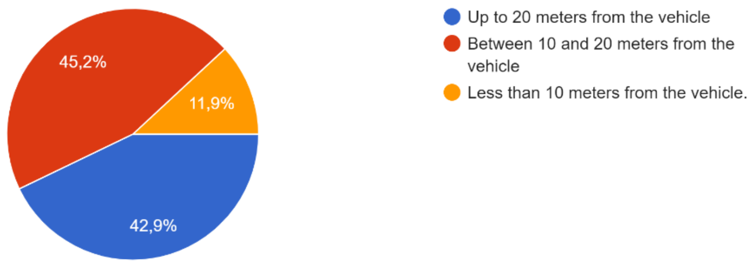


11a.How often till now you had to drive without adequately sleeping before, during the last year?

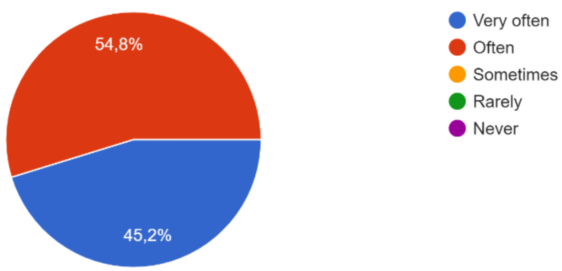
42 απαντήσεις



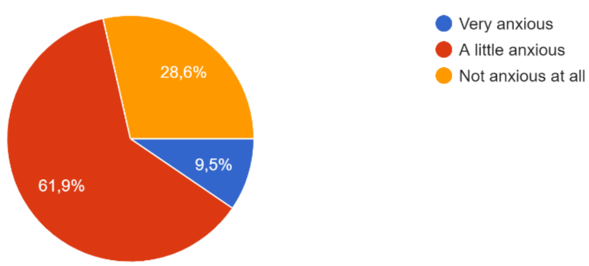
12. Which is the desired active area that you want to be captured by sensing?
42 απαντήσεις



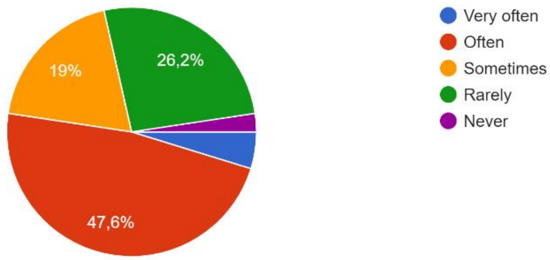
13.I keep distances from other vehicles when raining
42 απαντήσεις



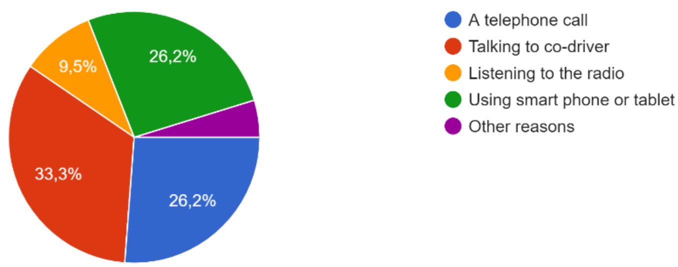
14. How much anxiety you feel when driving within areas with much traffic, pedestrians and bicycles around you?
42 απαντήσεις



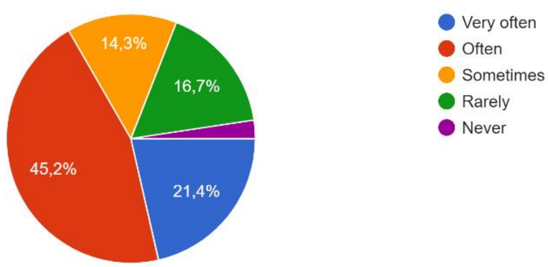
15.I rush on making decisions when driving eg for changing driving lane
42 απαντήσεις

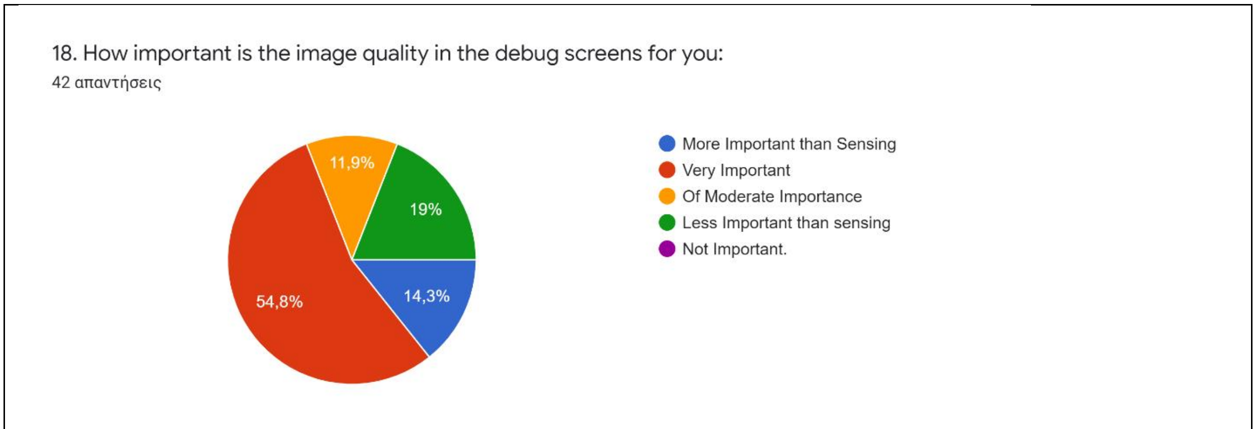


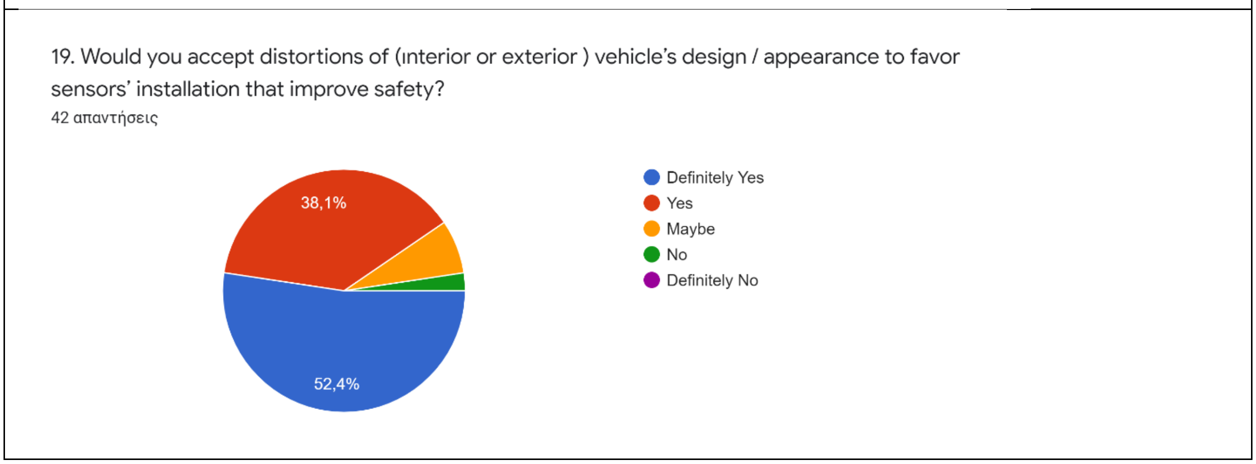
16.Please indicate what could distract your attention when changing driving lane
42 απαντήσεις



17. I get impatient when slower drivers are in front of me
42 απαντήσεις







3.1.3 Extraction of conclusions

Conclusions were extracted via the connection of the user characteristics with the participants answers on the driving behaviour. The first stage for doing so was to organize, group and categorize accordingly the responses. The methodology we followed at this point was to divide answers to human factors as inputs variables and metrics of interest as output variables, and then connect them in order to correlate the questionnaire inputs with questionnaire outputs. The categorization /division we did for the autonomous driving questionnaire was the following

AUTONOMOUS DRIVING QUESTIONNAIRE	Human Factors (Input Variables)	Metrics (Output) Variables
1. Please indicate the age group that you fall into	Age	
2. Please provide your gender	Gender	
3. Please Indicate the Highest education Level that you have graduated from	Education	
4. Please indicate the type of your driving license	Driver_Type	
5.1. Driving experience-Years of driving since obtaining driving license	Driving_Experience1	
5.2 Driving experience - Number of kilometers driven per year	Driving_Experience2	
6. Please indicate your experience with autonomous driving	Auto_Experience	
7. Please indicate your familiarization with ICT applications	ICT_Familiarity	
8. Please indicate how familiar you feel with VR/AR technology	XR_Familiarity	
9.Please indicate tasks in your daily driving routine, in which you would prefer to receive assistance with the use of VR/AR technology	Tools_Preference	
10.Please indicate type(s) of your health condition, if applicable	Health	
11. Please indicate how often you exercise	Fitness	
12. Please indicate medication you receive, if applicable	Medication	
1a.I tend to drive over the legal limit in residential roads		Risk1_Frequency
1b. In continuation to the previous question: If it happens to drive over the limit, the most common reason is that		Risk1_Etiology
2a. How often you have to drive fast and without wearing a belt?		Risk2_Frequency
2b. If it happens to drive fast and without wearing a belt can you indicate any reason(s) why this happens?		Risk2_Etiology
3. Do you need to drive for any reason (eg for work) between midnight and 7 am and if yes how often ?		Risk3_Frequency /Fatigue
4. Can you indicate occasions where you tend to drive closer to the vehicle ahead?		Risk4_Etiology
5.I tend to use mobile phone or tablet when driving		Attention/Risk5_Frequency
6.I tend to ignore car danger alarms when they are continuous		Alertness/Alert_Type_Effect
7. Which is the minimum time before collision that you want the alert signal to be raised:		Alertness/ Alert_Speed_Preference
8.How do you prefer to receive the alerts?		Alertness/ Alert_Preference
9. I take some risks when driving eg ignoring the red light when crossing junctions, switching lanes very fast		Risk6_Frequency
10a. I tend to accelerate and decelerate rapidly when driving		Driving_Style1
10b. If it happens to accelerate/decelate rapidly when driving why does this happen ? Is this is a constant way of driving or mainly you did it because you		Driving_Style1_Etiology
11a.How often till now you had to drive without adequately sleeping before, during the last year?		Fatigue / Fatigue_Frequency
11b. If you drive without adequate sleeping before why this happened ? Can you briefly indicate the reason		Fatigue/ Fatigue_Etiology
12. Which is the desired active area that you want to be captured by sensing?		Situational awareness/ Sensing_Preference
13.I keep distances from other vehicles when raining		Safety/ Weather_Effect
14. How much anxiety you feel when driving within areas with much traffic, pedestrians and bicycles around you?		Stress levels/ Environment_Effect
15.I rush on making decisions when driving eg for changing driving lane		Risk taking/ Driving_Style2_Frequency
16.Please indicate what could distract your attention when changing driving lane		Attention/ Driving_Style2_Etiology
17. I get impatient when slower drivers are in front of me		Risk8_Frequency
18. How important is the image quality in the debug screens for you:		HMI_Importance
19. Would you accept distortions of (interior or exterior) vehicle design / appearance to favor sensors installation that improve safety?		Safety/ HMI_Adaptation_Preference

Figure 8: Correlation analysis table – Autonomous driving

<u>**Below we present some trends identified from the questionnaire answers:**</u>

❖ The least experienced drivers (0-5 years) tend to driver over the legal limit (66%) more often than the other two driving experience groups. The second more experienced group (5-10 years' experience) driver over the limit on a percentage of 50%, while the most experienced drivers (10 years and more) are by far the group that do not drive over the legal limit (Only 31% answered that they often behave in this way).
❖ When it comes to performing secondary tasks while driving, the second more experienced group often tends to use mobile phones and tablets (at a percentage of 60%), while only 33% of the least experienced drivers demonstrate such behaviour. Again, the most experienced drivers seem to be the more careful ones, since only 24% answered positively on the specific question.
❖ The least experienced drivers tend to ignore continuous danger alarms at (66% percentage) while the second most experienced drivers behave like this at a 60% percentage. Only 37% of the most experienced drivers group demonstrate such driving behaviour.
❖ A 50% percentage of the second most experienced driving group consider themselves as risk-takers while from the least experienced drivers only 33% consider themselves as such. On the other hand, only 24% of the most experienced drivers consider themselves as such.
❖ Regarding the desired sensing area, the most popular answer from the least experienced drivers was "Between 10 and 20 meters from the vehicle" -being selected at a 66% percentage. The second most experienced group of drivers answered the same at a 50% percentage while the most experienced ones chose the same at a 41% while the answer "up to 20 meters for the vehicle "was very near on their preferences (being selected by a percentage of 37%).
❖ Regarding the autonomous driving users, we identified that the most experienced ones (5-10 years' experience in AD) all tend to ignore continuous alarms (100%) while the second most experienced group (2-5 years' experience in AD) behave like this at a 52% percentage. The least experienced autonomous driving participants ignore continuous alarms only at a 31% percentage.
❖ Also, the autonomous cars driving users behave differently regarding secondary tasks. More specifically, 66% of the most experienced group answered that they often use a mobile or a

tablet during driving while 47% of the second most experienced group behave similarly. Finally, only the 18% of the least experienced group demonstrate this driving behaviour.
❖ Regarding the minimum time before collision that the users wish the alert signal to be raised the most experienced group of autonomous cars drivers selected as the most popular answer the option “over 4 seconds before the collision” (66%) while the second most experienced users selected the same answer at a percentage of 64%. The least experienced autonomous cars drivers selected the same answer at a 50% percentage.
❖ A percentage of 33% of the most experienced group drive the last year without adequately sleeping before, while regarding the second most experienced group almost half of the users (47%) drive often under a drowsy state. Only 22% of the least experienced autonomous driving users drive having not slept adequately before.
❖ The most experienced autonomous driving users would like the desired active area to be captured by sensing to be between 10-20 meters from the vehicle (66%) while the second most experienced group voted equally (47%) for the respective options of “up to 20 meters” and “between 10-20 meters”. Similarly, the least experienced group selected the options “between 10-20 meters” and “up to 20 meters” at a percentage of 40%
❖ Regarding physical exercising, the participants that they have some kind of vision impairment answered that they exercise for over 2-3 times per week (66% percentage), while the ones with chronic pain, chronic fatigue do the same at an 80% percentage and the ones with some kind of musculoskeletal conditions exercise also in the same frequency at a 66% percentage. The ones that said that they have some cardiovascular diseases exercise 3-4 times per month at a percentage of 50%.
❖ People with vision impairment tend to drive over the legal limit sometimes, often or very often at a percentage of 78% and when they do it the main reason is that they are in a hurry (55%) ❖ People with chronic pain and fatigue tend to driver over the legal limit sometimes often or very often at a percentage of 80% as well and when they do it is because they are in a hurry (60%) ❖ People with musculoskeletal conditions tend to drive over the legal limit often or very often at a percentage of 66% and when they do it the main reason is that they need to balance with time spend in other sub-tasks during their driving task (e.g looking for parking place, following a route with a lot of traffic) -stated by 66%
❖ People with chronic pain and chronic fatigue often drive fast and without wearing a belt at a percentage of 80%

❖ People with musculoskeletal conditions never or rarely drive fast without wearing a belt (66%) ❖ People with vision impairment drive fast sometimes, often or very often without wearing a belt at a 60% percentage
❖ People with chronic pain and/or chronic fatigue engage often or very often in secondary tasks while driving at a percentage of 80% ❖ People with vision impairment engage often in secondary tasks only at 36% percentage ❖ People with some kind of musculoskeletal conditions engage often in secondary tasks only at 33% percentage
❖ People with chronic pain and/ or chronic fatigue tend often or very often to ignore car danger alarms when they are continuous at a percentage of 100% ❖ People with vision impairment problems tend often or very often to ignore car danger alarms at a 42% percentage ❖ People with some kind of musculoskeletal problems tend often to ignore car danger alarms at a 66% percentage
❖ People with chronic pain and/ or chronic fatigue would like to receive the alerts at minimum time of 3-4 seconds before the estimated collision time (60%) ❖ People with vision impairment would like to receive the alert o >4 seconds before the collision -selected by a percentage of 58% o 3-4 seconds before the estimated collision time- selected by a percentage of 36% ❖ Answers were split equally for the people with musculoskeletal problems o Less than 3 seconds before the collision -selected by a percentage of 33% o >4 seconds before the collision – selected by a percentage of 33% o 3-4 seconds before the estimated collision time -selected by a percentage of 33%
❖ Regarding stress levels (question: how much anxiety you feel when driving within areas with much traffic, pedestrians and bicycles around you) 100 % of the people with chronic pain and/or chronic fatigue feels a little anxious, while people with musculoskeletal problems feel no anxiety at all (66%). Regarding the ones with vision impairment 47% of them feel a little of anxiety while 31% feel no anxiety at all
❖ A 60% of the people with chronic pain and/or fatigue rush often on making decisions when driving while 100 % of the ones with musculoskeletal problems do this often. The ones with some kind of vision impairment do this often at a percentage of 57%

- A percentage of 80% of the people with chronic pain often get impatient when slower drivers are in front of them. All of the drivers with musculoskeletal problems get often impatient when being in such situation. A percentage of 73% of the drivers with vision impairment often or very often get impatient when there are slower drivers in front of team

We also considered useful to perform an analysis per age group. Three age groups were identified for this questionnaire:

FIRST GROUP

As regards to **user profiling** and according to the analysis from the **group of those autonomous driving questionnaire participants aged from** 21 to 34 (in effect the younger respondents of this survey), 75% were male and 25 % female. Additionally, the 50% of this group answered that they are PHD holders whereas the other 50% are college /University graduates. All the members of this category are quite experienced drivers having driving experience of 10 years (while additionally 62.5% of them travel yearly over 10000 miles). Furthermore, everyone from this group answered that their experience with autonomous driving is less than 2 years. Regarding ICT familiarization almost all of them (87.5%) are very familiar something natural as usually younger ages are much more familiar with ICT, while according to their feedback are less familiar with VR/ AR technology (37.5% said that they are familiar enough, 37.5% moderately familiar and 25 % not familiar). Regarding health status 50% have some kind of vision impairment while one participant said that he /she has also some respiratory disease. No participant of this group provided feedback on medication.
Regarding physical exercise, 33% of this group are well exercised having selected the choice "2-3 times per week", while an equal percentage of 33% answered that they answered daily and only 22% answered that they don't exercise at all. So, in total 66% of this group are well fit.
Regarding **driving behaviour** 62.5% of this group said that they tend to drive often or sometimes over the legal limit while 37.5% answered that they rarely do it. Furthermore, when the question goes on risky driving e.g ignoring the red light when crossing junctions, switching lanes very fast etc an overall percentage of 75 % of this group answered that they rarely do this (37.5%) or even never (37.5%). **Regarding stress levels and anxiety levels** the great majority of this group's members feel a little of anxiety while driving within areas of much traffic (87.5%) while most of them (62.5%) can become impatient when slower drivers are in front of them. Only 25% answered positively in this question. This connects also with risk frequency, in the sense that as much as drivers get impatient, it is most possible to take some more risks. Additionally, and similarly to the question that involves with driving patience/ impatience a percentage of 62.5% of this age group answered that they tend to accelerate and decelerate rapidly when driving (providing as main reasons hasty driving, or just way of driving) while the rest 37.5% rarely do this or even never. Nonetheless, regarding driving fast without a belt (a question that connects also with risk frequency along with safety) 75% answered that they never do it, so while this group of young drivers maybe they are at some point risk takers but they take into account safety as the majority of them always wears a **belt.**

Regarding questions that deal **with issues that connect to fatigue and drowsy driving**, none of this group's participants drives between night hours, so they avoid driving under a drowsiness state. Moreover, in relation to this point of drowsiness **and regarding driving without adequate sleeping before (being tired/ driving under fatigue)**, 62.5% of this group answered that they never or very rarely drive without adequate sleeping while 25% answered that this can happen sometimes and only 1 out 8 participants said that they do it often. Additionally, a percentage of 50% of the group quoted as a reason for driving close to vehicles ahead hasty driving, while 25% referred to drowsiness (feeling sleepy). This connects also with risk taking while driving.

Now in relation **to safety** and in connection also to the weather conditions while driving all the members of this group answered that **they keep distances from other vehicles during this type of conditions (75% answered often and 35% very often)".** When the question goes if the survey participants would accept any distortions on the car's interior and exterior design in order to improve their safety the great majority of this group (75%) answered positively while only one participant answered negatively on this question.

Regarding a set of questions that **connect to situational awareness** and more specifically if they engage in **secondary tasks while driving (something that connects also to risk taking) 75 % of this group of drivers said that never or rarely engage in secondary tasks (e.g., using a mobile or tablet).** Additionally, to this and regarding the desired active area to be captured by sensing (something that relates to the improvement of the drivers' situational awareness) the answers were distributed evenly on the answers "Between 10 and 20 meters from the vehicle" and "Up to 20 meters from the vehicle" on an equal percentage of 37.5% while 25% of this group selected the third option "Less than 10 meters from the vehicle."

Regarding questions that deal with alertness 50% of this group would like to receive alerts more than 4 seconds before the collision, while 25% would like to receive incoming alerts between 3-4 seconds before the collision and another 25% less than 3 seconds before the collision. Regarding danger alarms 50% ignore them rarely or never while the other 50% answered that this can happen sometimes.

When the question went to reasons that can cause driving **distraction (something that connects obviously with attention and driving style)** 37.5% quoted the reason "talking to co-driver" while an equal percentage selected the option of "using a smart phone or tablet". Regarding the way to receive these alerts, 50% of this group selected all the possible options (alert sounds, displaying the alert in internal screen,) while another 37.5% of them answered that they would like to receive generation alert sounds.

Finally, regarding HMI importance and the specific question "How important is the image quality in the debug screen for you" 37.5% of this group participants answered that they consider this as very Important while equally the same percentage selected as answer the option "less important than sensing". Only one out 8 participants answered that considers it more important than sensing while another one found it as "of moderate importance"

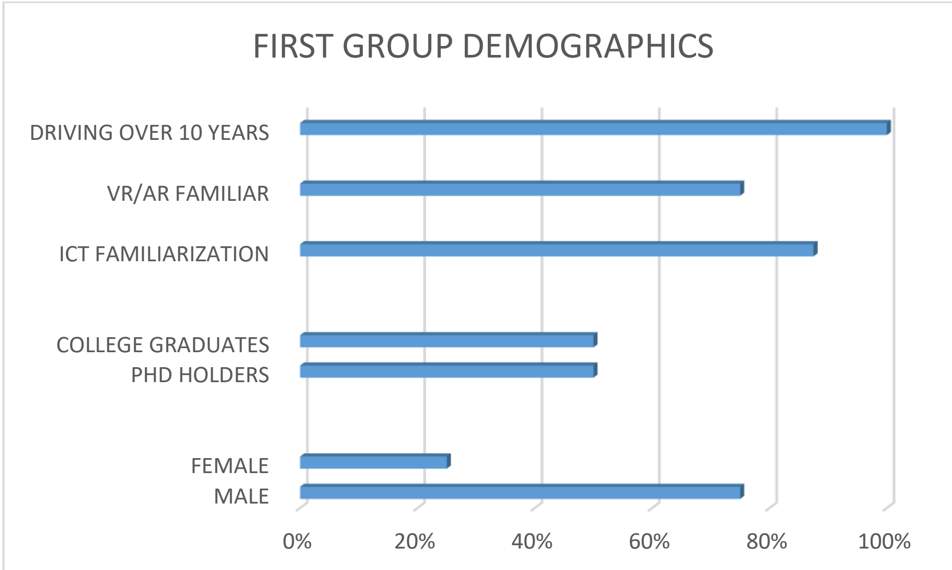


Figure 9: First Group (age 21-34) - Demographics

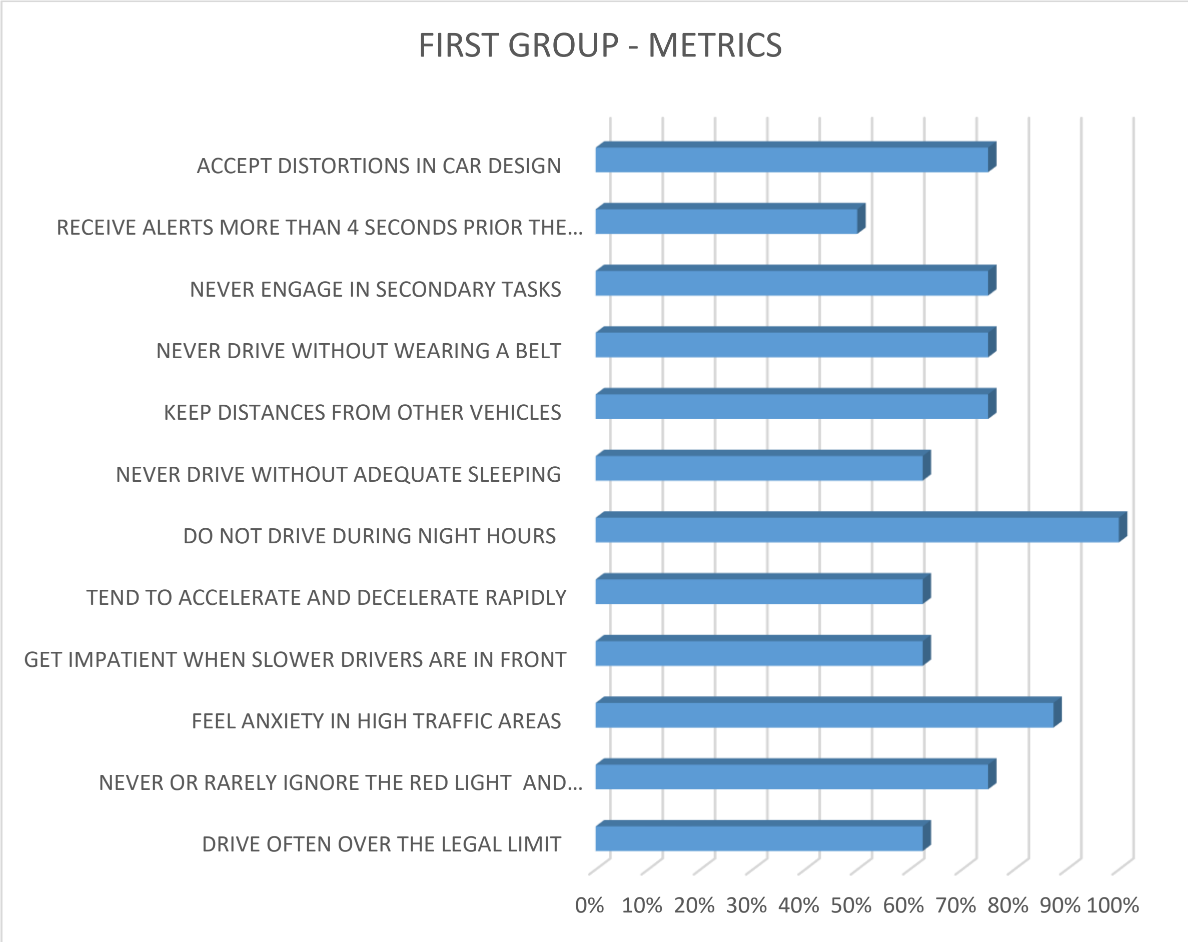


Figure 10 : First Group - Metrics' Results

Main conclusions drawn

" Most people in the age group of 21-34 that participated in the survey (8 persons), tend to drive often, or sometimes, over the legal limit while (62.5%). They feel a little of anxiety while driving within areas of much traffic (87.5%), but do not drive during night hours (100%). Most of these drivers, never or very rarely drive without adequate sleeping while (62.5%), while often keep distances from other vehicles (75%). Moreover, they never drive without wearing a belt (75%). They never or rarely engage in secondary tasks while driving (75 %) and would like to receive alerts more than 4 seconds before the collision (50 %). Half of them seem accept all the possible options for receiving alerts with some of them prefer sounds (37,5%), and only 37.5% consider the image quality in the debug screen very important. Finally, they would accept any distortions on the car's interior and exterior design in order to improve their safety (75%).

SECOND GROUP

According to the analysis of the group of those aged 35-50 that participated in the autonomous driving questionnaire, we had an overall of 19 responses. From this group of participants, 68% were male and 32 % female. The 57% of this group answered that they are PHD holders whereas the rest 43% are college / University graduates. Most members of this category are quite experienced drivers having a driving experience of 10 years (57%) while 26% have an experience between 5-10 years. Additionally, to this, a percentage of 84% of them answered that they travel yearly over 10000 miles (47% between 10000-20000 miles yearly, 21% between 20000-30000 yearly, and 10% over 40000 miles yearly). Furthermore, and referring specifically to the autonomous driving experience, this group of participants are more experienced from the previous group. Most of them (52%) answered that they have an experience on autonomous driving between 2-5 years while an additional 10 % have an experience bigger that 5 years. A percentage of 31% of this group answered that their experience with autonomous driving is less than 2 years. Regarding ICT familiarization, the great majority of this group of survey participants (89%) are very familiar while this group seem also to be adequately familiar with VR/ AR technology as well. More specifically 94% of this group answered that they are in some level familiar with this kind of technologies (42% familiar enough, 26 % moderately familiar, 26 % very familiar) while only 1 out 19 persons answered that is not familiar at all. **Regarding their health status**, 57% of the survey participants answered that they have some kind of vision impairment while additionally another 31% said they have problems that refer to musculoskeletal conditions, chronic pain, chronic fatigue, and slow reaction time. Additionally, one participant said that he /she has also some kind of respiratory disease. Not every participant of this group provided feedback on medication receiving, actually only 36% provided feedback on this question. From those that provided feedback 28% stated that they take antihistamines, while 57% receive some form of muscle relaxants and 42 % medication for anxiety. Multiple answer selection was possible for this question.

Regarding **physical exercising** that relates also with health condition and fitness, 42% answered that they exercise 3-4 times per month while another 21% stated that they exercise less and more specifically for only 1-2 times per month. Furthermore, a percentage of 26% answered that they don't exercise at all while only 10 % exercise often (2-3 times per week).

Regarding **driving behaviour and risk taking while driving,** a percentage **of** 52% said that they tend to drive often or very often over the driving limit while 21% selected the option of "sometimes". A percentage of 21% answered that they rarely drive over the speed level (a percentage representing 4 out of 19 people of this group). Main reasons for driving over the legal limit were provided as follows:

-31 % provided the reason that they need to balance with time spend in other sub-tasks during their driving task (e.g looking for parking place, following a route with a lot of traffic)

-36% said that they are in a hurry

-31 % selected the option of “other reasons”

Regarding driving fast without a belt (a question that connects both with risk taking and safety) in comparison with the previous group, only 47% answered that they never do it, while another 10% answered that this can happen rarely. A percentage of 26% answered that they drive fast without wearing a belt often or even very often whereas another 15% answered that they sometimes do this. Furthermore, when the question goes on driving dangerously/ risky e.g ignoring the red light when crossing junctions, or switching lanes very fast a percentage of 31 % answered that they never do this, while an additional 36% said that they display this driving behaviour rarely. Only 4 out of 19 participants (19%) answered that they often behave in this way while driving. Furthermore, regarding tension for acceleration and deceleration rapidly when driving, 31 % answered that they do it rarely or never, while 42% answered that they do it often. Lastly, 3 participants stated that they drive in this way sometimes. “Way of driving” was selected from this group as the main reason for doing so, having been provided by the 57% of the participants. Regarding driving close to vehicles ahead, a percentage of 23% quoted as a reason to do so hasty driving while the majority of this group (57%) referred both to drowsiness (feeling sleepy) and fatigue (feeling tired).

Regarding stress levels and anxiety, almost half from this group (47%) feel a little of anxiety while driving within areas of much traffic while 28% answered that they don’t feel any anxiety at all during this kind of situation. Furthermore, most people of this group (52%) can become often or very often impatient when slower drivers are in front of them. Only 21 % of this group answered that they rarely feel any impatience during this kind of driving occasions.

Regarding questions that will **deal with fatigue (and drowsy driving)**, 57 % of the group answered that they never drive between night hours, so they are avoid driving under a drowsiness state. Nonetheless and in comparison, with the previous group of participants a significant percentage of 33% of this group answered that they have to drive during night hours once per week. Moreover, and in relation to the issue of driving without adequate sleeping before(fatigue) ,42% of this group answered that they never or very rarely drive without adequate sleeping before while 23% answered that they have to do it sometimes. An important percentage of 23% answered that they often or very often have to drive without adequate sleep before.

In relation to **weather conditions** while driving all the members of this group answered that they keep distances from other vehicles during raining conditions (more specifically 36% answered often while the great majority of 63% answered very often). Regarding the question that deals with the issue whether the participants would accept any distortions on the car’s interior and exterior design in order to improve safety the great majority of this group (94%) answered that they would accept it in favour of safety improvement while only one participant appeared sceptical on this question answering maybe.

Regarding the set of questions that **connect to situational awareness/attention**, 52 % of this group of drivers said that never or rarely engage in secondary tasks such as using a mobile/ tablet etc when driving while 26% answered that they do it often or very often and an additional 21% selected the option of sometimes.

Regarding the desired active area to be captured by sensing (something that connects also to situational awareness) 47 % of this group selected the option “Between 10 and 20 meters from the vehicle” while 42% chose to answer “Up to 20 meters from the vehicle”. A small percentage of 10% (2 out of 19) selected the third option of “less than 10 meters from the vehicle”.

Regarding **alertness** related questions, the great majority of this group participants (at a percentage of 73%) would like to receive alerts more than 4 seconds before the collision, while 21% would like to receive incoming alerts between 3-4 seconds before the collision and only one participant selected the option of “less than 3 seconds before the collision”. Regarding danger alarms, 36% of this group stated that they tend to ignore them rarely or never while the other 31% answered that this can happen sometimes. An equal percentage of 31% answered that they often or very often tend to ignore continuous danger alarms. Regarding the way to receive these alerts, 63% of this group selected all the possible options (alert sounds, displaying the alert on vehicle screens etc) while another 21 % of them answered that they would like to receive generation alert sounds. When the question went to reasons that can cause distraction when changing driving lane 31% quoted the reason “talking to co-driver” while 26% selected the option of “using a smart phone or tablet”.

Finally, regarding HMI importance and the specific question “How important is the image quality in the debug screen for you” 31% of this group participants answered that they consider this as very important while 15% selected as answer “less important than sensing”. Only one out 19 participants considered it more important than sensing while 15% consider this as “of moderate importance”.

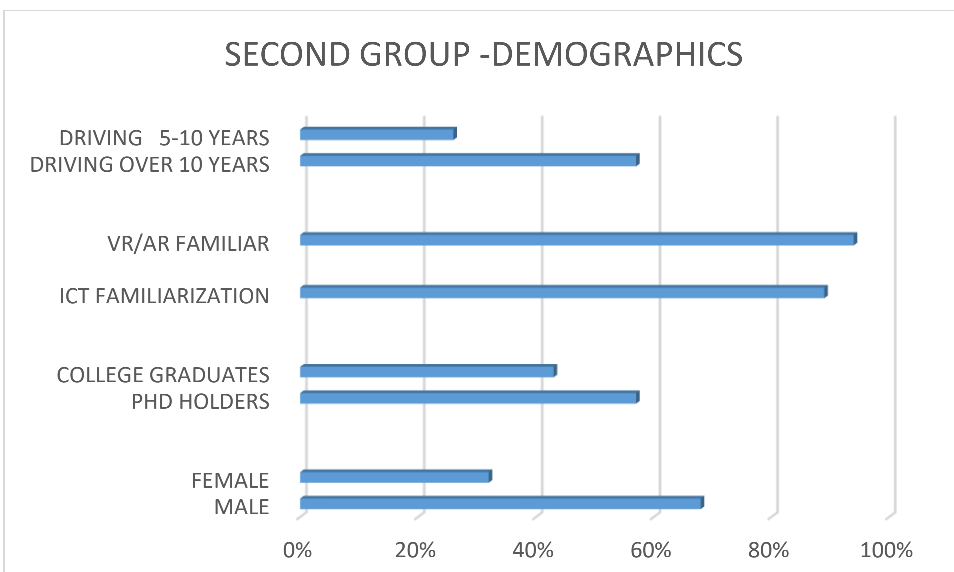


Figure 11: Second Group (age 35-50) - Demographics

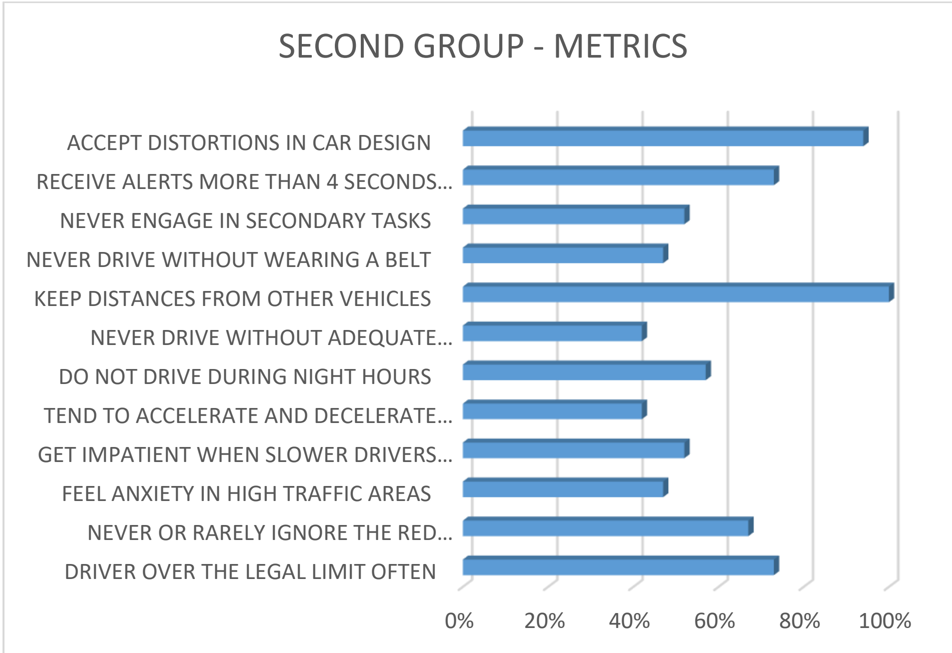


Figure 12: Second Group – Metrics' Results

Main conclusions

" Most people in the age group of 35-50 that participated in the survey (19 persons), tend to drive often, or sometimes, over the legal limit while (73%). All the members of this group answered that they keep distances from other vehicles during raining conditions. A 52 % of this group of drivers said that never or rarely engage in secondary tasks such as using a mobile/ tablet etc when driving. The great majority of this group (94%) answered that they would accept distortions in the car's interior and exterior design in favour of safety improvement and they would like to receive alerts more than 4 seconds before the collision (at a percentage of 73%).

THIRD GROUP

According to the analysis of the older group of this survey and more specifically those aged 51-65, we had overall 15 responses on the autonomous driving questionnaire. From those participants 54% were male and 46 % female. The 40% of this group answered that they are PHD holders whereas the 60% of this group are college /University graduates. As it was expected members of this category are quite experienced drivers having driving experience of 10 years (66%) while 26% have an experience between 5-10 years. All of this group's members answered that they travel yearly over 10000 miles (20% drive between 10000-20000 miles yearly, 60% drive between 20000-30000 yearly, and 20% over 30000 miles yearly).

Regarding autonomous driving experience, 53% of this group participants answered that they have less than 2 years' experience, 40% answered that they have an experience between 2-5 years while only one participant answered that has experience bigger that 5 years.

Regarding ICT familiarization, a big percentage of 66% of this group answered that they make daily use of such kind of technologies while 13% stated that they make use of them 2-3 times per month and the remaining 20% said that they use them once per week.

Regarding VR/AR technology familiarization, only a small percentage of the survey participants (13%) answered that they are very familiar with these technologies while most of them (60%) answered that they are familiar enough (40%) or moderately familiar (20%).

Regarding survey participants' **health status** multiple answers selection were possible for this question**.** A percentage of 53% of this group answered that they have some kind of vision impairment while additionally, while 53% said they have problems that relate to chronic pain, chronic fatigue, and slow reaction time. An additional percentage of 33% reported that they have also some musculoskeletal condition problems. Not every participant of this group provided feedback on medication receiving, actually only 66% provided feedback on this question. From those that provided feedback 80% stated that they take muscle relaxants and 40 % receive some medication for anxiety. One participant also said that is taking antihistamines.

Regarding physical exercising, 46% answered that they exercise 3-4 times per month while the answers "2-3 times per week" and "daily" were selected from equally small percentages of 13% respectively. Regarding driving behaviour and risk taking**, a** percentage **of** 33% of this group said that they tend to drive often or very often over the driving limit while an important percentage of 40% selected the option of "sometimes". A percentage of 26% answered that they rarely drive over the speed level. Main reasons for driving over the legal limit were provided as follows:

-53% said that they can speed up when they are in a hurry

-26% provided the reason that they need Ito balance with time spend in other sub-tasks during their driving task (e.g looking for parking place, following a route with a lot of traffic

-6% said that they just like speed

Regarding driving fast without a belt (a question that connects with risk taking while driving and safety as well) a percentage of 26% of this group answered that they do it rarely or never. A percentage of 33% answered that they drive fast without wearing a belt often or even very often whereas a percentage of 40 % of this group answered that they sometimes behave in this way while driving.

Furthermore, when the question goes on the issue of ignoring the red light when crossing junctions, or switching lanes very fast, similarly to the previous question a percentage of 26% answered that they never or rarely display such dangerous driving behaviour. A significant percentage of 46% answered that they take such kind of risks when driving often or very often.

Moreover, and moving to the next question that assess the participants' tension for rapid acceleration and deceleration when driving, 13% answered that they do it rarely, while the majority of the participants and more specifically a percentage of 60% answered that they do it often or very often. Lastly, 4 out of 15 participants (26%) stated that they drive in this way sometimes. The answer "When in a hurry" was selected from this group as the main reason for doing so, having been provided by the 66% of the participants while the 33% of the participants selected the option of "way of driving".

Regarding the question of driving close to vehicles ahead (multiple answers were possible on this point), a significant percentage of 80% quoted as a reason for this "hasty way of driving" while 60% referred also both to drowsiness (feeling sleepy) and fatigue (feel tired) reasons.

Regarding stress levels and anxiety, 60% of this group feel a little of anxiety while driving within areas of much traffic while 33% answered that they don't feel any anxiety at all during this kind of situations. Only one participant selected the option of "very anxious".

Additionally, the great majority of this age group (80%) can become often or very often impatient when slower drivers are in front of them. As discussed above this specific question relates with risk taking during driving so it is important to note that the percentage at this question indicates that this age group can demonstrate a riskier type of driving behaviour even in relation to the younger drivers group.

Regarding questions that deal with fatigue and drowsy driving, a percentage of 53% of this group answered that they never drive during night hours. Nonetheless, a significant percentage of 45% of this group answered that they have to drive during night hours once per week. Also, a percentage of 20% of this group answered that they never or very rarely drive without adequate sleeping before while 26% answered that they have to do it sometimes. An important percentage of 53% answered that they often or very often have to drive without adequately sleeping before, thus they often drive tired and under drowsiness.

Regarding driving during bad weather conditions, all the members of this group answered that they keep distances from other vehicles during this type of conditions (66% answered often while the remaining 33% answered very often). Regarding the question that assess if they would accept any distortions on the car's interior and exterior design in order to improve safety, similarly to the age group of those being 35-50, the great majority of this group (93%) answered that they would accept it in favour of safety improvement while only one participant appeared sceptical on this question answering maybe.

Regarding a set of questions that connect to situational awareness, 20 % of this group of drivers said that never or rarely engage in secondary tasks (eg using a mobile or tablet) while 53% answered that they do it often or very often and an additional 13% selected the option of sometimes. Regarding the desired active area to be captured by sensing, 46 % of this group selected the option "Between 10 and 20 meters from the vehicle" while an equal percentage of 46% chose to answer "Up to 20 meters from the vehicle". A small percentage of 6% (1 out of 15) selected the third option of "less than 10 meters from the vehicle".

Regarding alertness related questions, a percentage of 40% of this age group would like to receive alerts more than 4 seconds before a possible collision, while 56% would like to receive incoming alerts between 3-4 seconds before the collision while no participant selected the option of "less than 3 seconds before the collision". Regarding danger alarms, 13% of this group ignore them rarely while a big percentage of 86% answered that they often or very often ignore continuous danger alarms. We observe that this group of participants is more possible to ignore continuous danger alarms comparing with the other two groups. Regarding the way to receive these alerts, 60% of this group selected all the possible options (alert sounds, displaying the alert in internal screen,) while 26% selected the option "display the alert on the screens inside the vehicle" and another 13 % of them answered that they would like to receive generation alert sounds. When the question went to reasons that can cause distraction when changing driving lane, 33% quoted the reason "talking to co-driver", an equal percentage (33%) said "a telephone call, while 20% selected the option of "using a smart phone or tablet". Finally, a small percentage of 13% selected the option of "listening to the radio".

Regarding HMI importance and the specific question "How important is the image quality in the debug screen for you", 80% of this group participants answered that they consider this as very Important while 13% selected as preferable answer the option "less important than sensing". Only one out 15 participants answered that considers it more important than sensing.

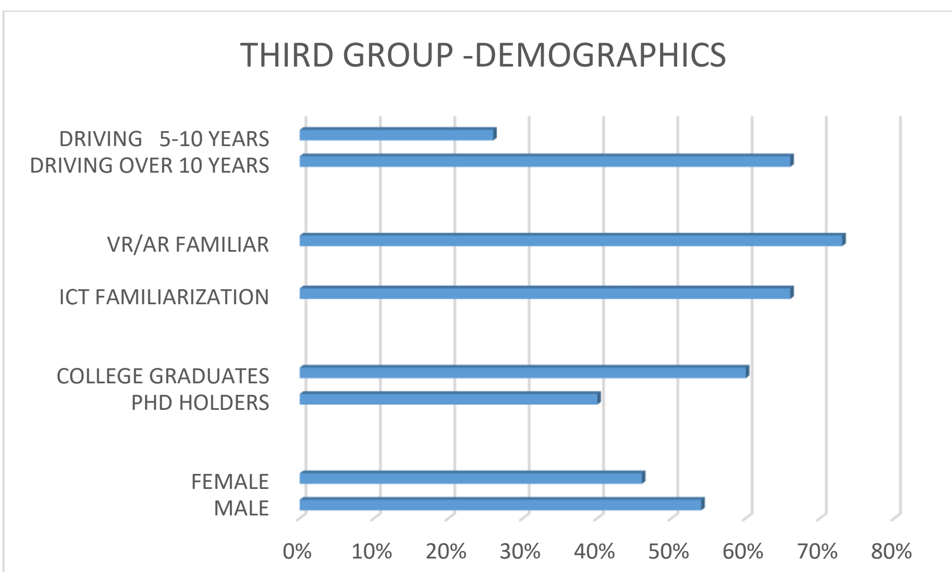


Figure 13: Third Group (age 51-65) -Demographics

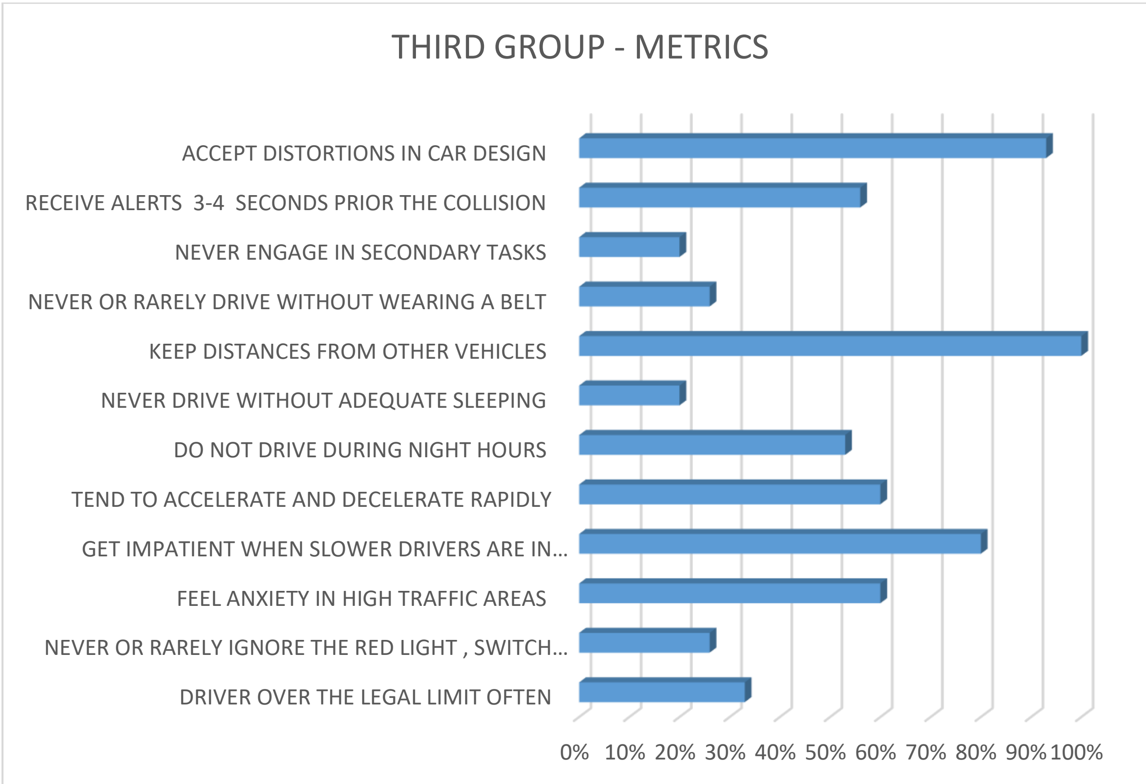


Figure 14: Third Group - Metrics' Results

Main conclusions

" Most people in the age group of 51-65 that participated in the survey (15 persons), have a tension for *rapid acceleration and deceleration when driving (60%) and 80% of them believe that a reason for driving closely to vehicles ahead of them is being hasty while 60% believe also that drowsiness can be an important reason for displaying such driving behaviour. The great majority of this group's -participants (80%) can become often or very often impatient when slower drivers are in front of them. When they have to drive under bad weather conditions all the survey participants of this group said that they keep distances from other vehicles during this type of conditions and they would accept any distortions on the car's interior and exterior design in order to improve safety (93%). Nonetheless when the question comes to danger alarms a big percentage of 86% of this age group answered that they ignore continuous danger alarms. We observe that this group of participants is more possible to ignore continuous danger alarms*

comparing with the other two groups. Finally, a significant percentage (80%) consider very important the image quality at the debug screen of their vehicles

3.1.4 Statistical significance tests

A statistical significance test measures the strength of evidence that the data sample supplies for or against some proposition of interest. For this reason, we performed Chi-squared tests between each of the human factors and each of the examined nominal metrics in order to determine whether an association (or relationship) between them is likely to reflect a real association in the study population. The sample data was used to calculate the test statistic, the value of which reflects the probability (p-value) that the observed association between the two variables has occurred by chance (due to sampling error). Our null hypothesis was that each selected metric (or a preference variable) is not associated with the examined human factor. **The null hypothesis is rejected if $p < 0.05$, in which case a conclusion is drawn that the examined metric is associated with the respective human factor.**

The obtained Chi-squared values and the corresponding p-values for the autonomous driving questionnaire are being presented in the Table 6 below.

As being demonstrated, for several statistical tests the null hypothesis could be rejected: For instance, Human factors such as the age were found to be associated with metrics such as risk frequency and driving style while the same could be stated for human factors such as education (that similarly could be associated with risk frequency and driving style), autonomous driving experience (that could be associated with metrics such as risk frequency and risk etiology), ICT familiarity (that could be associated with risk frequency, fatigue frequency, driving style) etc. In comparison with the respective tests performed for the HR collaboration questionnaires (that you can find in the respective section below) more tests were found to have a significant value for the autonomous driving questionnaire. The main reasons for this, was that in the automotive case more variables considered as Human Factors or the variables had fewer classification levels, or (most probably) some factors were really related because the users were professionals. For practical reasons we have listed below only the values (human factors and metrics) that showed significant association between them. No significant associations were identified between human factors and preferences.

Table 6: Autonomous driving questionnaire Chi-squared values and p-values

Human Factor	Metric	chi2	p-value
Age	Risk1_Frequency	12.96	**0.044**
Age	Driving_Style1	19.15	**0.014**
Education	Risk3_Frequency	5.08	**0.024**
Education	Driving_Style1	9.60	**0.048**
Driving_Experience1	Risk1_Etiology	12.59	**0.050**
Driving_Experience1	Fatigue_Frequency	16.19	**0.040**
Driving_Experience2	Risk4_Etiology	69.09	**0.012**
Driving_Experience2	Driving_Style1	46.37	**0.001**
Driving_Experience2	Risk8_Frequency	33.08	**0.033**
Auto_Experience	Risk1_Etiology	13.24	**0.039**
Auto_Experience	Risk2_Frequency	16.38	**0.037**
Auto_Experience	Risk3_Frequency	7.24	**0.027**
ICT_Familiarity	Risk6_Frequency	36.83	**0.000**
ICT_Familiarity	Fatigue_Frequency	21.54	**0.043**
ICT_Familiarity	Driving_Style2_Frequen	27.09	**0.008**
Health	Risk2_Frequency	65.23	**0.007**
Medication	Risk1_Etiology	30.71	**0.031**

3.2 CRF interviews

3.2.1 Demographics

This questionnaire was answered by 18 CRF experts who provided feedback on HR collaboration. Overall, 88.9% of the participants were male and 11.1% female. Regarding the age range of the survey participants

33.3% of the respondents were between 55-64 years old, 27.8% between 35-44 years old, and 22.2% between 45-54 years old. Also, a percentage of 16.8% of the participants answered that they are between 25-34 years old. Regarding working experience in the specific field of manufacturing where the CRF use case will take place 61.1% answered that they have over 2 years of such experience. A percentage of 11.1% of the respondents answered that their experience is between 1-2 years, a percentage of 11.2% of them claimed having an experience of 1-12 months whereas 16,7% of the respondents answered that they have experience of less than a month on the specific field.

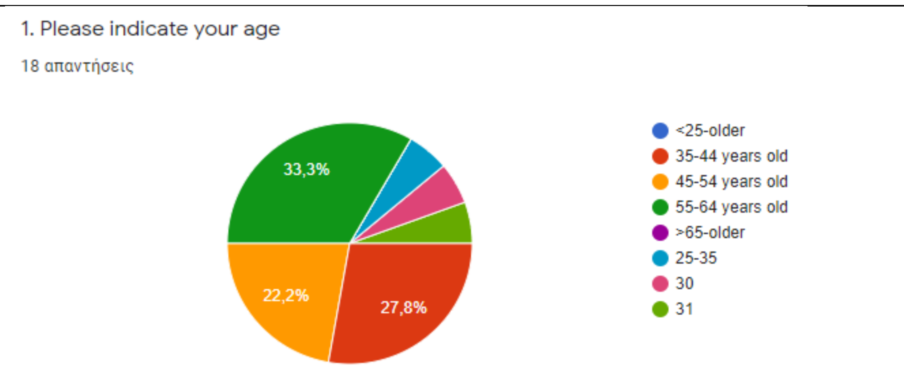
Relating to the previous question the next question examined the participants involvement/experience in the field of manufacturing with collaborative robot(s).

So, in this question a percentage of 33% of the participants answered that they don't have experience in this field while 11.1% answered that they have less than one month experience working with cobots.

A percentage of 33.3% answered that their experience on the area of manufacturing using cobots is between 1-3 years, a small percentage of 5.6% said that their experience is between 4-5 years while 16.7% answered that they have over 5 years' experience so we could state that percentage of 22,3 % of the respondents have an experience of over 4 years in the field. In the next question which examined the importance of the participants' relationship with technology applied both at work and in their private life, a percentage of 50% answered that they consider it important while 39% answered that they consider it very important. A percentage of 11.1% answered that they think that this issue is moderately important for them while no participant answered that they consider this as a non-important issue.

When the question went to the level of familiarity with VR/ AR technologies a percentage of 44.4% answered that they feel familiar (22.2%)/ or very familiar (22.2%) with VR/AR whereas 27.8% of the respondents answered that they moderately familiar and 16.7% provided the answer that they feel slightly familiar. Only 11.1% answered that they do not feel familiar with VR/AR.

Table 7: HR collaboration questionnaire- demographics

Age	

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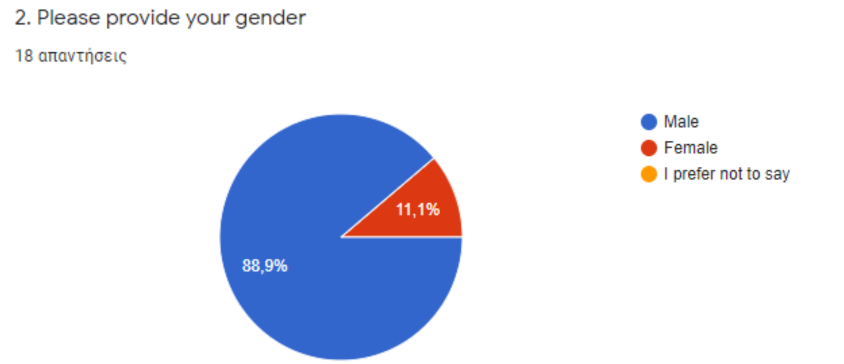
<tr><td>Gender</td><td>
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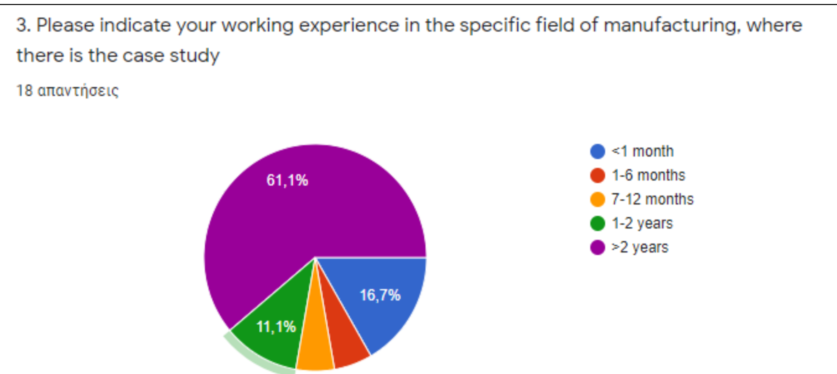
<tr><td>Working experience in manufacturing</td><td>
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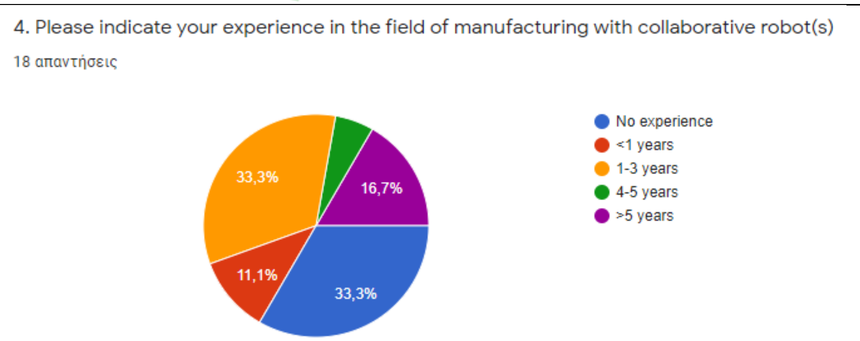
<tr><td>Working experience in the field of manufacturing with collaborative robots</td><td>
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3.2.2 HR Collaboration questions

The next question was related with VR/AR and more specifically it dealt with the time that the participants feel comfortable to use VR/AR during their daily working routine. A percentage of 27.8% answered that they feel comfortable on using VR/AR more than 60 minutes daily during their working routine while 22.2% answered that they feel comfortable to use daily such kind of technologies for a time duration of 31-60 minutes. A smaller percentage of 11.1% selected the choice of 21-30 minutes, while an equal percentage answered that they could use VR/AR for 11-20 minutes daily. A percentage of 27.8% answered that they will feel comfortable to use such technologies for just under 10 minutes per day.

Regarding the question on the importance of being aware if there are new robotic devices on the market (called collaborative robots or cobots) suitable for working together safely close to operators, a big percentage of 50% of the respondents answered that they consider this as very important while 38.9% consider it as important and another 11.1% answered that they consider this fact as moderately important. No participant selected the choices of not important/ slightly important.

Furthermore, a percentage of 61.1% of the respondents consider it easy (38.9%) or very easy (22.2%) to use cobot (collaborative robot) during normal activities while 33.3% of the responses were neutral on this statement. Furthermore, a small percentage of 5.6% said that they consider it not easy. Regarding the question if the participants think that the functions of the cobot system are well integrated and consistent with their daily work a big percentage of 44.4% of the participants preferred to remain neutral on this question. A percentage of 44.5% either agreed (38.9%) or totally agreed (5.6%) with the statement while a percentage of 11.2% either disagreed (5.6%) or strongly disagreed (5.6 %) with this argument.

Regarding the participants' perception and if they think that the use of cobots help to improve the quality of their daily work a great majority of the participants (more specifically a percentage of 72.2%) either totally agree (22.2%) or agree (50%) with this statement. Moreover, a percentage of 22.2% of the respondents preferred to remain neutral on this question while a small percentage of 5.6% expressed their strong disagreement on this statement.

When going to the question whether the survey participants think that the checklist for the activities carried out jointly from an operator and the robot can be a valid support for not forgetting anything a significant percentage of 77.8% either agrees (50%), or strongly agrees (27.8%) with this statement, whereas 16.7% of the responses were neutral. Again, only a small percentage of 5.6% strongly disagreed with this statement.

Regarding the question if the participants would like the devices, they use during normal work to be adjusted according to their physical characteristics (for instance height weight, arm length) all the respondents agreed.

Regarding the question if the participants would like to be able to communicate with the robot (be warned of what the robot does; give it commands; stop it if necessary) all the participants similarly to the previous question agreed with the statement :61.1% answered that they strongly agree with this while 38.9% simply agree with this.

The next question deals with the way the participants would like to communicate with the robot during their shift. On this question the participants were given with some possible options towards communicating with the robot. These options were:

- I don't think there can be the same interaction that happens with a human
- With standard interfaces, such as tablets, buttons, etc…
- With natural interfaces, such as voice commands, physical contact, gestures and signs
- With both possibilities

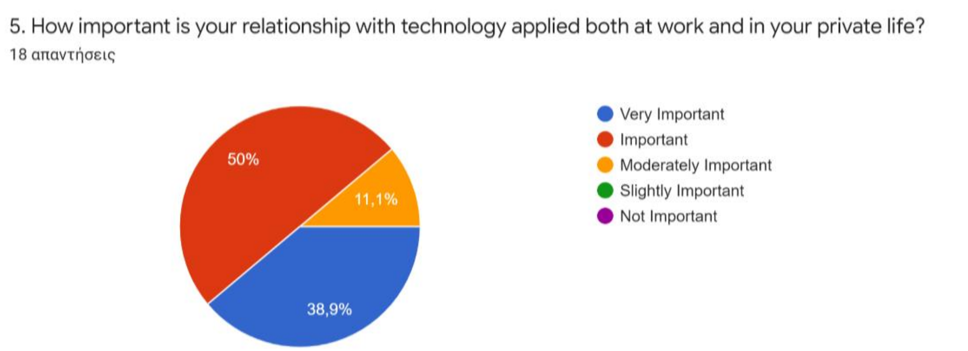
Here 16.7 % of the participants selected the option of communicating with the robot through standard interfaces (such as tablets buttons etc) while a small percentage of 5.6% stated that they will prefer to do so with natural interfaces. The great majority of participants (77.8%) stated that they will prefer both possibilities whereas nobody selected the first option "I don't think there can be the same interaction that happens with a human".

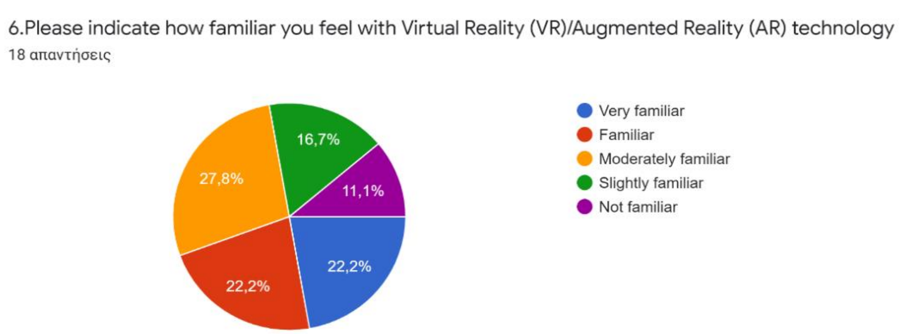
Regarding the question if the participants consider useful to have the current state of the robot always available and visible in front of them (For example, what the robot it doing, what will be the next task it will do, whether or not it understood your gestures) 94.4% consider it either useful (50%) or find it very useful (44.4%) while only 5.6% of the participants remained neutral on this question. No participant selected the other options.

Regarding the question on how the respondents would prefer to receive information about the robot status, 33.3% expressed ignorance on this subject while 38.9% answered that they would prefer it through a traditional fixed screen and 27.8% through wearable devices.

Regarding the question on how much important the participants consider receiving warnings (for example, surface flashing, alarm sound on) when entering the robot's workspace 94.4% consider it either important (33.3%) or very important (61.1%) while 5.6% consider it as moderately important. The rest options were not selected from any participant.

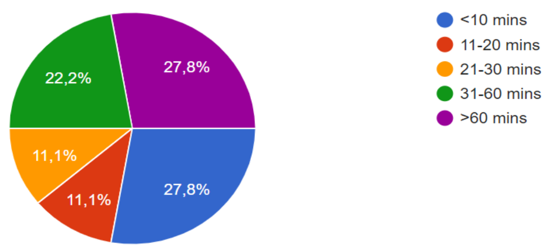
Table 8: HR collaboration questionnaire -statistics





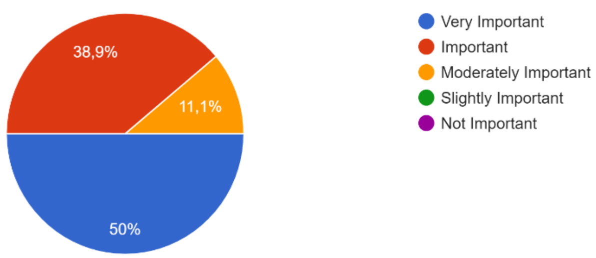
7. Please indicate how much time in your daily working routine, you would feel comfortable to work with the use of VR/AR technology

18 απαντήσεις



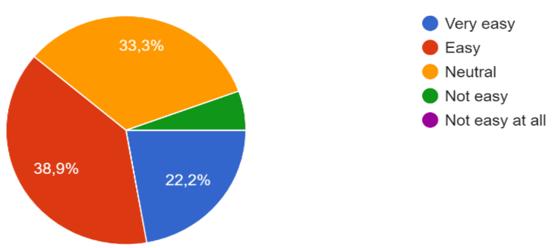
8. How important is it to know that there are new very safe robotic devices on the market (called collaborative robots or cobots), suitable for working together safely close to operators?

18 απαντήσεις

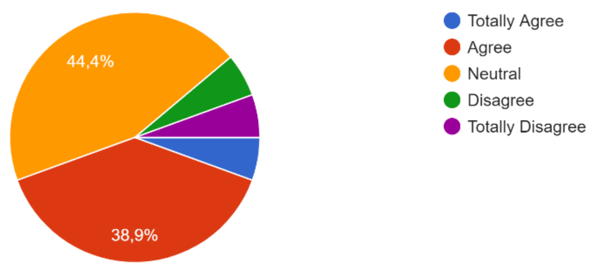


9. Do you think it can be easy to use cobot (collaborative robot) during normal activities?

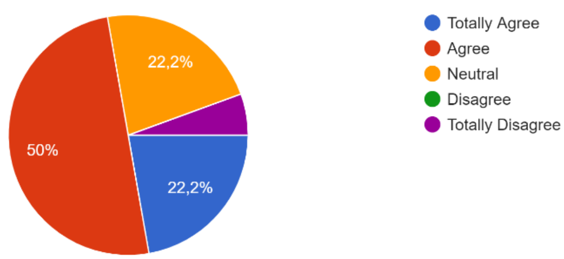
18 απαντήσεις



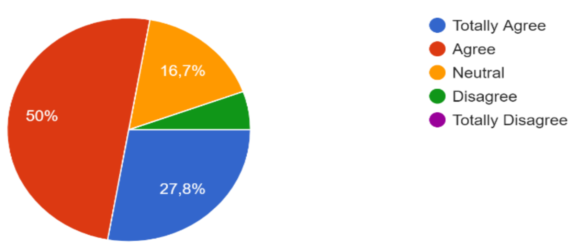
10. Do you think the functions of the cobot system are well integrated and consistent with the work you do?
18 απαντήσεις



11. Do you think that the use of these cobots helps to improve the quality of your work?
18 απαντήσεις

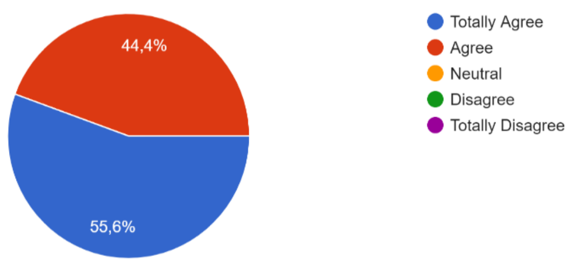


12. Do you think that the checklist for the activities carried out jointly from you and the robot can be a valid support for not forgetting anything?
18 απαντήσεις



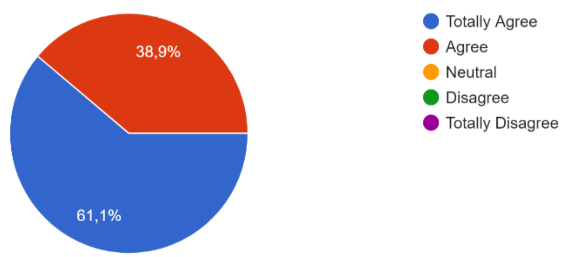
13. Would you like the devices you use during normal work to be adjusted according to your physical characteristics? For example: height, we... allowed by the movement of the human body, etc...

18 απαντήσεις



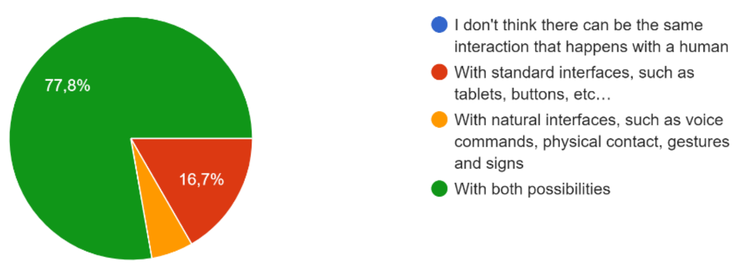
14. Among the features provided for the robot there is also that of being able to interact with the operator; would you like to be able to communicate ... it does; give it commands; stop it if necessary)?

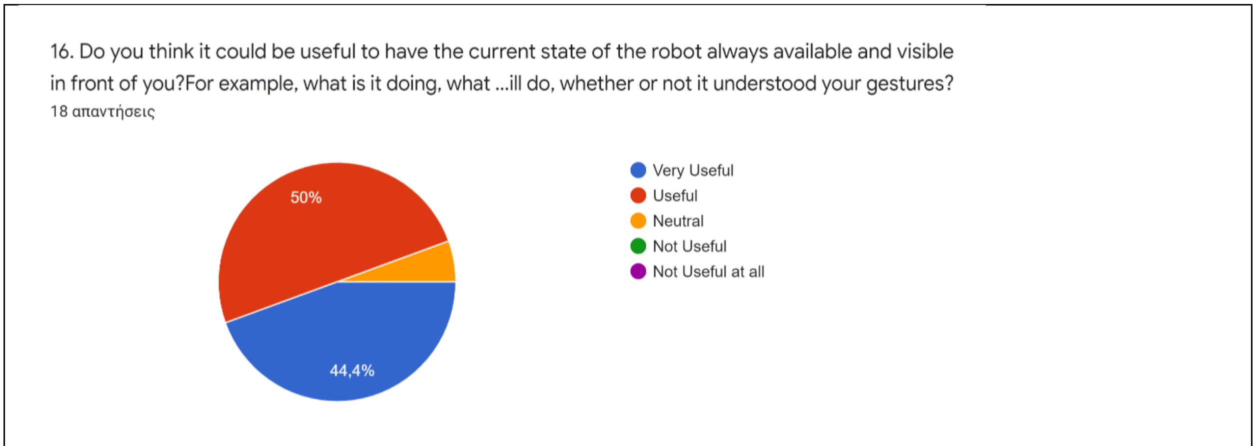
18 απαντήσεις

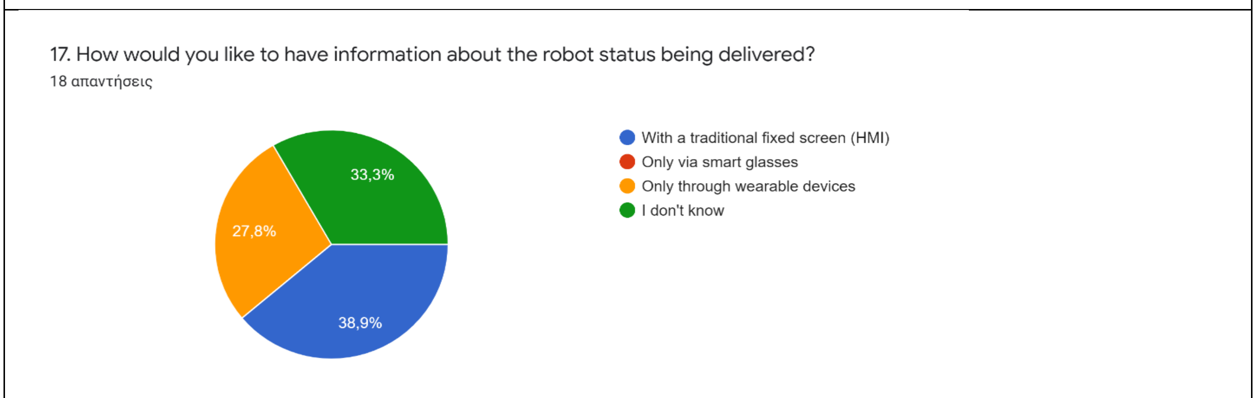


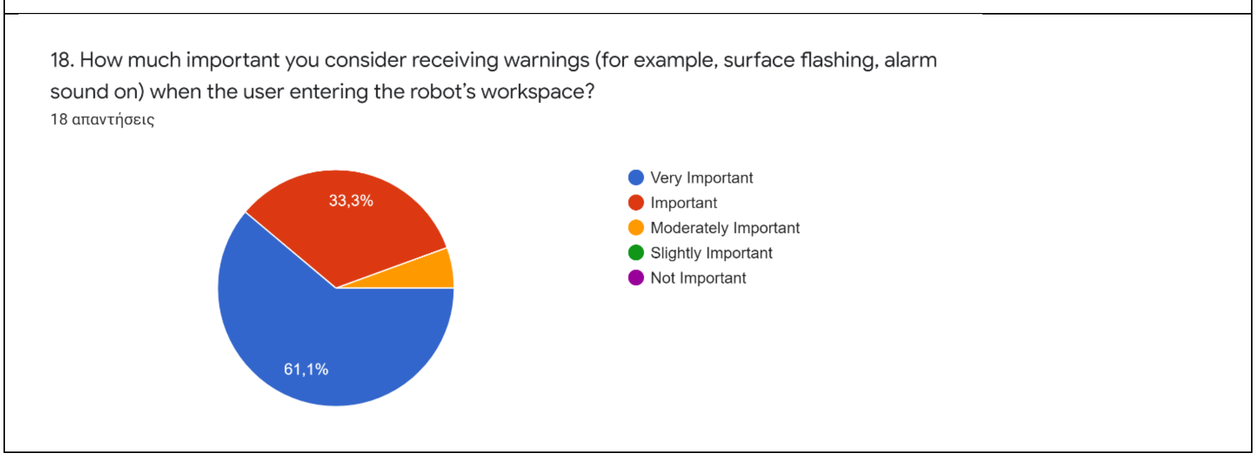
15. During your shift, how would you like to communicate with the robot?

18 απαντήσεις









3.2.3 Extraction of conclusions

Similarly, to the autonomous driving questionnaire, some conclusions were extracted via the connection of the user characteristics with the metrics on the HR collaboration. The first stage for doing so was to organize, sort and group accordingly the responses. The methodology we followed at this point was to classify answers to inputs variables (human factors) and output metrics and then connect them. The categorization /division we did for the questionnaire was the following:

QUESTIONNAIRE	Human Factors (Input Variables)	Metrics (Output) Variables
1. Please indicate your age	Age	
2. Please provide your gender	Gender	
3. Please indicate your working experience in the specific field of manufacturing, where there is the case study	Work_Experience	
4. Please indicate your experience in the field of manufacturing with collaborative robot(s)	Cobot_Experience	
5. How important is your relationship with technology applied both at work and in your private life?		Technol_Importance
6.Please indicate how familiar you feel with Virtual Reality (VR)/Augmented Reality (AR) technology	XR_Familiarity	
7. Please indicate how much time in your daily working routine, you would feel comfortable to work with the use of VR/AR technology		XR_Comfort
8. How important is it to know that there are new very safe robotic devices on the market (called collaborative robots or cobots), suitable for working together safely close to operators?		Cobot_Dissemination
9. Do you think it can be easy to use cobot (collaborative robot) during normal activities?		Cobot_Facility
10. Do you think the functions of the cobot system are well integrated and consistent with the work you do?		Cobot_Relevance
11. Do you think that the use of these cobots helps to improve the quality of your work?		Cobot_WorkBenefit / Work quality
12. Do you think that the checklist for the activities carried out jointly from you and the robot can be a valid support for not forgetting anything?		Cobot_CollabBenefit
13. Would you like the devices you use during normal work to be adjusted according to your physical characteristics? For example: height, weight, arm length, accessibility areas allowed by the movement of the human body, etcâ€¦		UCD_Preference
14. Among the features provided for the robot there is also that of being able to interact with the operator; would you like to be able to communicate with it (be warned of what it does; give it commands; stop it if necessary)?		Interaction_Preference
15. During your shift, how would you like to communicate with the robot?		Communication_Preference
16. Do you think it could be useful to have the current state of the robot always available and visible in front of you?For example, what is it doing, what will be the next task it will do, whether or not it understood your gestures?		Awareness_Preference /situational awareness
17. How would you like to have information about the robot status being delivered?		Info_Preference /situational awareness
18. How much important you consider receiving warnings (for example, surface flashing, alarm sound on) when the user entering the robotâ€™s workspace?		Warnings_Preference /attention

Figure 15: Correlation analysis table -HR collaboration

Here below we present some trends identified from the HR collaboration questionnaire answers:

- From the group having very small working experience in the specific field of manufacturing (less than a month) nobody has any experience with cobots. Also, they are all of them slightly or moderately familiar with AR/VR.
- From the group having an experience over 2 years 36% stated that they have experience with cobots from 1 to 3 years while equally 36% of this group have over 4 years' experience. A 27 % of this group has no experience with cobots. A percentage of 72% of this group are familiar or very familiar with VR/AR while 18% are slightly or moderately familiar with AR/VR. Only 9% are not AR/VR familiar.

❖ From the group having a working experience in the manufacturing field 1 month -2 years 50% have 1 to 3 years' experience with cobots and the rest 50% less than 1 year. Furthermore 75% of them answered that they are slightly or moderately familiar with AR/VR while 25% are not familiar.
❖ From the group having an experience over 2 years, 81 % consider easy/very easy to use cobot (collaborative robot) during normal activities. ❖ The group having working experience in the manufacturing field from 1 month to 2 years 75% consider easy /very easy to use cobot (collaborative robot) during normal activities while from the third group that have less than a month experience everybody remained neutral on this point, having a sceptical perspective on the issue.
❖ From the group having an experience over 2 years a great majority of 90% think that the use of these cobots helps to improve the quality of their work while from the second more experienced group (1 month – 2 years) 75% think the same. The least experienced group agree at this point only at a 33% percentage while the rest 66% of them remain neutral.
❖ From the most experienced group (over 2 years) 54% would like to have information about the robot's status being delivered with traditional fixed screen (HMI) while 27% of this group answered that they would like to do it only through wearable devices. ❖ From the second most experienced group (1 month -2 years) 25% would like to have information about the robot status being delivered with traditional fixed screen (HMI) while 25% of this group answered that they would like to receive it only through wearable devices. A 50% of this group expressed ignorance on the issue. ❖ The most people from the least experienced group expressed ignorance (66%) on this issue while 33% of them selected the only wearable devices answer.
❖ All the groups regardless of their age and experience find very useful to have the current state of the robot always available and visible in front of them (what is it doing, what will be the next task it will do, whether or not it understood their gestures).
❖ All the groups regardless of their age and experience consider very important receiving warnings (eg surface flashing, alarm sound on) when the user entering the robots workspace.
❖ All the groups regardless of their age and experience consider would like to communicate with the robot with both possibilities (natural and standard interfaces). ❖ The group having very small working experience in the specific field of manufacturing (less than a month) choose both possibilities (66%). ❖ The group having an experience over 2 years in the manufacturing sector select both possibilities for communication (81%). ❖ The group having a working experience in the manufacturing field from 1 month -up to 2 years select both communication options (75%).

❖ All the groups regardless of their age and experience totally agree that the devices using during normal work should be adjusted according to their physical characteristics.
❖ All the groups regardless of their age and experience agree that they would like to be able to communicate with the robot (be warned of what it does; give it commands; stop it if necessary).
❖ The group having very small working experience in the specific field of manufacturing think that the checklist for the activities carried out jointly from the robot and the robot can be a valid support for not forgetting anything (66%). ❖ The group having an experience over 2 years in the manufacturing sector think that the checklist for the activities carried out jointly from the robot and the robot can be a valid support for not forgetting anything (72 %). ❖ The group having a working experience in the manufacturing field from 1 month -up to 2 years think that the checklist for the activities carried out jointly from the robot and the robot can be a valid support for not forgetting anything (100 %).

As in the autonomous driving questionnaire, we considered useful to perform an analysis per age group for this questionnaire as well. Four age groups were identified for the HR collaboration questionnaire:

FIRST GROUP

This group consisted from 3 CRF experts that are being categorized under the age range 25-34 so they are the younger group of the HR collaboration survey. All the members of this group are males (100%). Regarding their working experience in the specific field of manufacturing, where the respective case study will take place one participant answered that is over 2 years, while another said that his experience is between 1-2 years. The third member of this group stated that his experience is less than one month. The next question assessed the participants' experience in the field of manufacturing as regards to collaborative robot(s). The majority of this group -at a percentage of 66 %- answered that their working experience with cobots is between 1-3 years, while the rest 33% stated that they have not any experience with this type of collaborative robots. Regarding the participants perception of the importance of their relationship with technology applied both at work and in their private life, all the group members answered that they considered it important (33%) or very important (66%). Regarding the next question that deals with the participants' familiarity with Virtual Reality (VR)/Augmented Reality (AR) technology one participant stated that he is slightly familiar with this kind of technologies, another one selected the option of "moderately familiar" and the third one said he is familiar.

Regarding the Extended Reality (XR) comfort of the participants, meaning the time during their daily working routine, that the participants would feel comfortable to work with the use of VR/AR technology one participant answered that he would make a use of such technologies for a duration between 21-30 minutes while the second one of this group said that he would use such kind of technologies for a little shorter and more specifically for a duration between of less than 10 minutes. Finally, the third one said that they would use VR/AR technologies for a duration between 31-60 minutes. Regarding the question on the importance of having knowledge on the cobots existence on the market all the participants consider it either as important (66%) or even very important (33%). Regarding the level of easiness of using cobots during normal activities, an overall percentage of 66% answered that they consider it easy or very easy while 33% of this group chose to remain neutral. Going to the question (that is related to ergonomics) if the functions of the cobot system are well integrated and consistent with the work (tasks to complete) of the survey participants, the majority of this group participants (66%) agreed with the statement while the rest 33% disagreed with the statement. Regarding the participants' perception whether the use of these cobots helps to improve the quality of their work 66% agrees with the statement, while the rest 33 % chose to remain neutral and not to express any opinion.

The next question tried to assessed a collaborative benefit from the joint collaboration of the operator with the cobot and more specifically if the checklist of the collaborative activities towards the completion of a task can be a valid support for not forgetting anything. On this point only one participant agreed, while the other two ones (66%) chose to remain neutral.

The next question was also related with ergonomics and more specifically of the issue whether the survey participants will like to see the devices they use during their normal work activities to be adjusted according to their physical characteristics. Here, all the participants either agreed with the statement (100%). Regarding the operators' interaction preference with the robot and whether they would like to be able to communicate with it (eg be warned of what it does; give it commands; stop it if necessary), similarly to the previous question all the participants agreed with the statement.

The next question in continuation of the previous one assesses the participants preference on the way to communicate with the robot during their shift. The following options were possible here:

- I don't think there can be the same interaction that happens with a human
- With standard interfaces, such as tablets, buttons, etc…
- With natural interfaces, such as voice commands, physical contact, gestures and signs
- With both possibilities

This group selected at a percentage of 66% the answer of both possibilities for communication with the robot while the rest 33% expressed the desire to communicate with the robot through standard interfaces, such as tablets, buttons etc

Going to the next question and regarding the users' awareness preference and more specifically it they believe that it would be useful to have the current state of the robot always available and visible in front of them all of this group members stated that they consider this fact as very useful.

The next question examined the user preference on the way to receive information about the robot status. The possible options at this point were:

- With a traditional fixed screen (HMI)
- Only through wearable devices

- Only via smart glasses
- I don't know

Two out of three selected the option "with a traditional fixed screen (HMI)" while the third participant selected the option "I don't know".

Finally, at the last question of the questionnaire, regarding to the participants warnings preferences and more specifically on how much important they consider receiving warnings (when the user entering the robot's workspace) all the participants consider this as important.

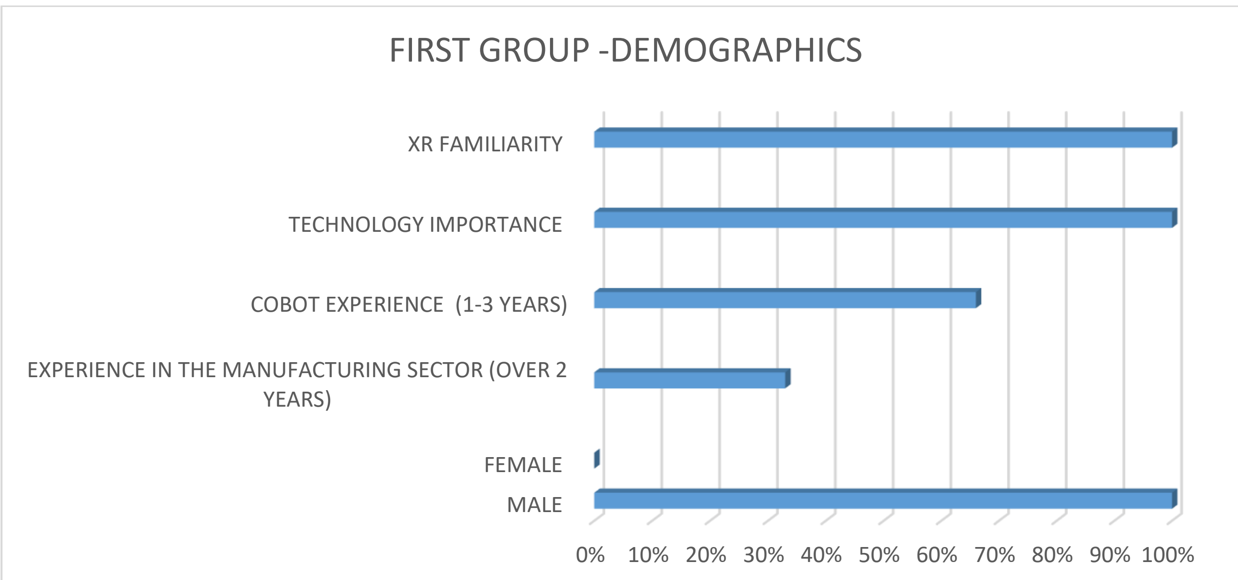


Figure 16: First Group (age 25-34)-Demographics

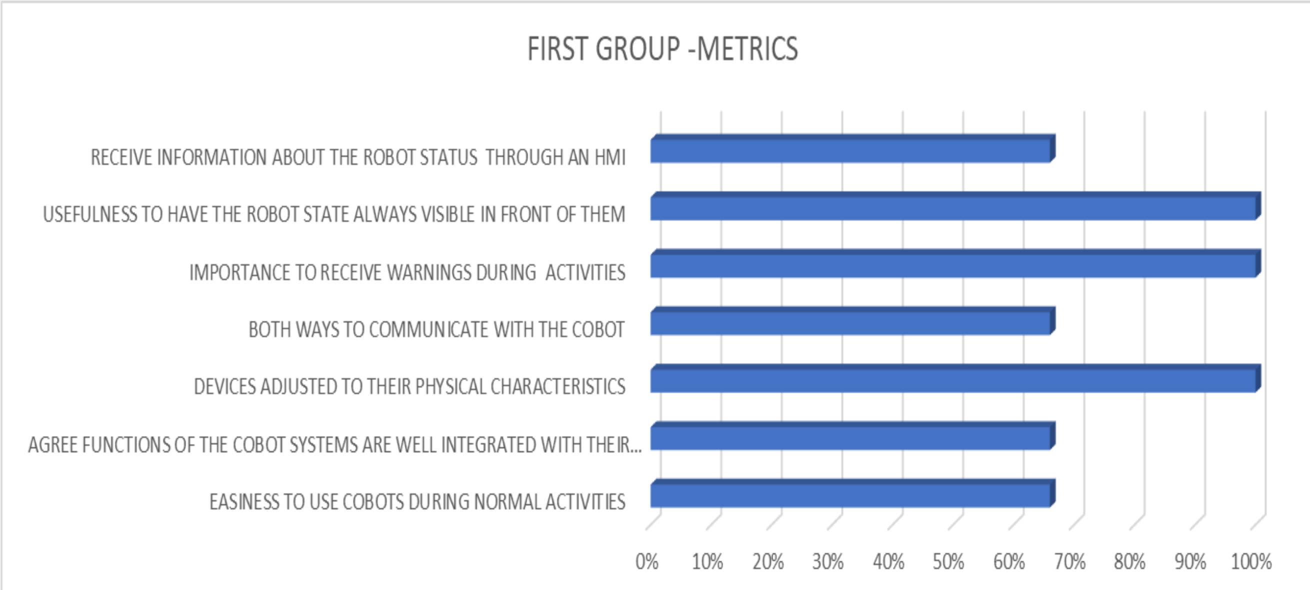


Figure 17: First Group – Metrics' Results

__Main conclusions drawn__

All people that belong in the age group of 25-34 that participated in the survey (3 persons), consider their relationship with technology applied at work and private life along with having adequate knowledge on cobots market existence as important. They consider it easy to use cobots during normal activities (66%) while they agree (66%) also that the functions of the cobot systems are well integrated and consistent with their work (tasks to complete) and furthermore help them to improve their work quality. Additionally to this they would like to see devices that use daily during their normal work activities to be adjusted according to their physical characteristics (100%) and additionally they would like to be able to communicate with the robot both with standard and natural interfaces (66%).Finally they would like to receive warnings during HR collaboration activities (66%) and they believe that it would be useful to have the current state of the robot always available and visible in front of them (100%).

SECOND GROUP

This group consisted from 5 CRF experts that fall under the age range 35-44 so they are the second youngest group of this survey. Four out of 5 members of this group are males (80%). Regarding their working experience in the specific field of manufacturing, where the specific CRF use case study will take place, a percentage of 80% answered that it is over 2 years, while the rest 20% stated that their experience is between 1-2 years. The next question assessed the participants' experience in the field of manufacturing with collaborative robot(s). The majority of this group at a percentage of 60 % answered that their experience with cobots is between 1-3 years, another percentage of 20 % said that their experience is over 5 years, while the rest 20% stated that they do not have experience with this type of robots. Regarding the participants' perception of the importance of their relationship with technology applied both at work and in their private lives all the group members answered that they considered it either moderately important (20%), important (60%) or even very important (20%). Regarding the next question that deals with the participants' familiarity with Virtual Reality (VR)/Augmented Reality (AR) technology 60% of this group members answered that they are familiar or even very familiar, while the rest 40% answered that they are moderately familiar.

Regarding the XR comfort of the participants, meaning the time during their daily working routine, that the participants would feel comfortable to work with the use of VR/AR technology, a percentage of 20% answered that they would make a use of them for a duration between 21-30 minutes while 40% would use such kind of technologies for a little shorter and more specifically for a duration between 11 to 20 minutes. Finally, the rest 40% said that they would use VR/AR technologies for a duration between 31-60 minutes. Regarding the importance of having knowledge on the cobots' existence on the market all the participants consider it either as moderately important (40%), important (40%) or even very important (20%). Regarding the level of easiness of using cobots during normal activities, an overall percentage of 40% answered that they consider it easy or very easy while 40% of this group chose to remain neutral. Only 20% selected the "not easy" option. Going to the ergonomics issues and regarding the question if the functions of the cobot system are well integrated and consistent with the work (tasks to complete) of the survey participants, the majority of this group's participants (80%) chose to remain neutral while only the 20% agreed with the statement. Regarding the participants' perception whether the use of these cobots helps to improve the quality of their work only 40% agrees with the statement, while 40% chose to remain neutral and not express any opinion and furthermore a percentage of 20% said that they totally disagree with the argument. The next question tried to assess a collaborative benefit from the joint collaboration of the operator with the cobot and more specifically if the checklist of the joint activities towards the completion of a task can be a valid support for not forgetting anything. On this point 80% of this group either agreed or strongly agreed, while 20% chose to remain neutral.

The next question again was related with ergonomics and more specifically of the issue whether the survey participant would like to see the devices that they use during normal work to be adjusted according to their physical characteristics. Here, all the participants either agreed with the statement (40%) or totally agreed (60%). Regarding the operators' interaction preference with the robot and whether they would like to be able to communicate with it (be warned of what it does; give it commands; stop it if necessary), similarly to the previous question, all the participants either agreed (40%) or totally agreed (60%) with the statement. The next question in continuation of the previous one assesses the participants preference on the way to communicate with the robot during their shift.

This group selected at a percentage of 80% the answer of both possibilities for communication (standard and natural interfaces) with the robot while the rest 20% expressed the desire to communicate with the robot through standard interfaces.

Going to the next question and regarding the users' awareness preference and more specifically it they believe that it would be useful to have the current state of the robot always available and visible in front **of** them all the group members stated that they consider this fact as useful or very useful. The next question examined the user preference on the way to receive information about the robot status.

The participants of this group at this question selected at a percentage of 20% the answer "only through wearable devices" while 40% expressed ignorance (selected the option don't know) and the rest 40% selected the choice "with a traditional fixed screen (HMI)". No participant of this group selected the choice of the smart glasses.

Finally, at the last question of the questionnaire, regarding to the participants warnings preferences and more specifically on how much important they would consider receiving warnings (when the user entering the robot's workspace) all the group participants consider this fact important / very important.

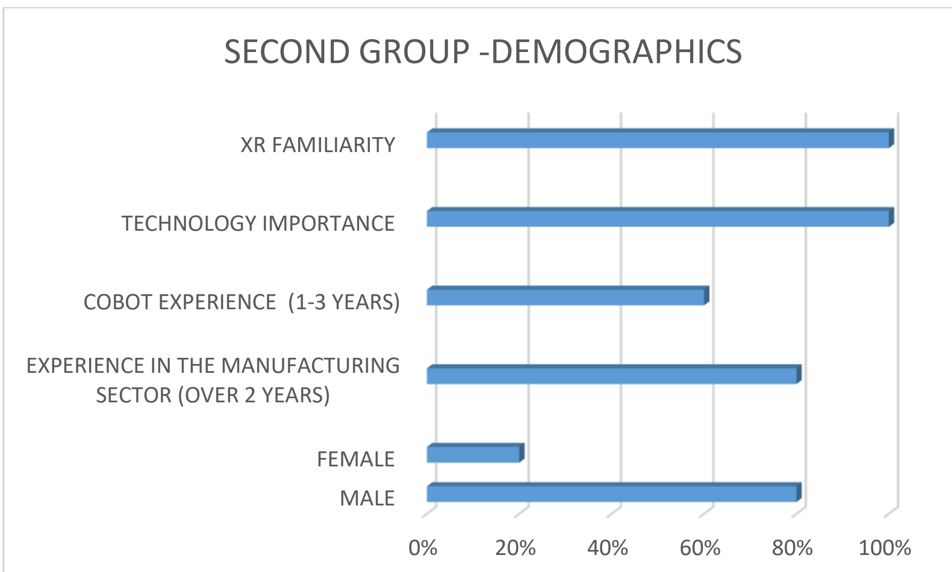


Figure 18: Second Group **(age 35-44)** -Demographics

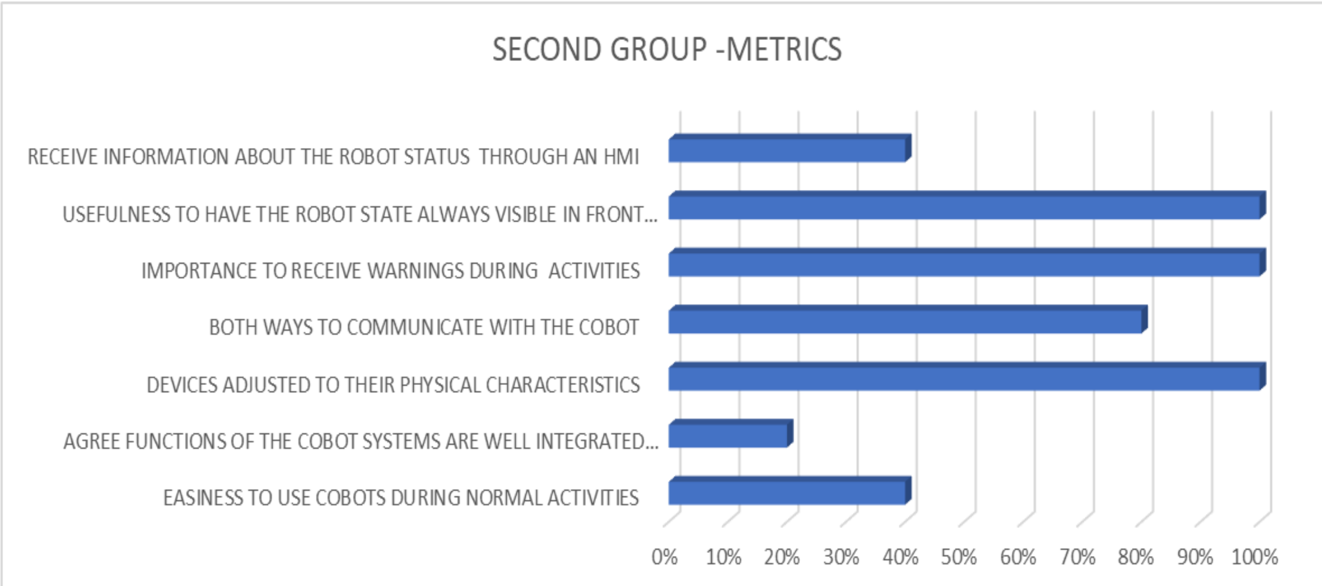


Figure 19: Second Group - Metrics' Results

Main conclusions drawn

> ***All people in the age group of 35-44 that participated in the survey (5 persons), consider their relationship with technology applied at work and private life along with having adequate knowledge on cobots market existence as important (100%). They agree that the checklist of joint activities towards the completion of a task can be a valid support (80%) and would like to see devices that use daily during normal work activities to be adjusted according to their physical characteristics (100%). They all think that is a good idea to be able to communicate with the cobot (be warned of what it does; give it commands; stop it if necessary), and they would like to be able to communicate with the robot both with standard and natural interfaces (80%). They think that it would be useful to have the current state of the robot always available and visible in front of them (100%) and finally they think it is important to receive warnings during joint collaboration activities (100%).***

THIRD GROUP

This group is being consisted from 4 CRF experts that fall under the age range 45-54 so they are the second oldest group of this survey. Three out of 4 members of this group are males (75%). Regarding their working experience in the specific field of manufacturing, where the specific use case study will take place, a percentage of 75% answered that it is over 2 years, while the rest 25% stated that their experience is between 1-6 months. The next question assessed the participants' experience in the field of manufacturing with collaborative robot(s). Various answers were received at this question from the specific group and were equally distributed:

- A percentage of 25% answered that their experience with cobots is between 1-3 years
- A percentage of 25 % said that their experience is over 5 years
- A percentage of 25 % said that their experience is under one year
- A percentage of 25% stated that they do not experience with this type of robots.

Regarding the participants’ perception of the importance of their relationship with technology applied both at work and in their private life, all the group members answered that they considered it either moderately important (25%), important (25%) or even very important (50%). Regarding the next question that deals with the participants familiarity with Virtual Reality (VR)/Augmented Reality (AR) technologies 50% of this group participants answered that they are familiar or even very familiar, while an equal percentage of 50% answered that they are slightly familiar.

Regarding the XR comfort of the participants, meaning the time during their daily working routine, that the participants would feel comfortable to work with the use of VR/AR technologies a percentage of 75% answered that they would make use of them for over one hour while the rest 25% said that they would use it for a duration for a time duration from 30 to 60 minutes. Regarding the importance of having knowledge on the cobots’ existence on the market all the participants consider it either as very important (50%) or important (50%). Regarding the level of easiness of using cobots during normal activities, an overall percentage of 75% answered that they consider (25%) it easy or very easy (50%) while the rest 25% of this group chose to remain neutral. Going to the ergonomics issues and regarding the question if the functions of the cobot system are well integrated and consistent with the work (tasks to complete) of the survey participants ,50% of this group agree or totally with this statement while the rest 50% remained neutral. Regarding the participants’ perception whether the use of these cobots help to improve the quality of their work all the group members agree or totally agree with this argument.

The next question tried to assessed a collaborative benefit from the joint collaboration of the operator with the cobot and more specifically if the checklist of the joint activities towards the completion of a task can be a valid support for not forgetting any of the tasks. Again, all the survey participants of this group agree or totally agree with this argument and nobody selected the disagree option.

The next question again was related with ergonomics and more specifically of the issue whether the survey participants would like to see the devices they use during normal work to be adjusted according to their physical characteristics. Here all the participants agreed/ totally agreed with the statement. Regarding the operators’ interaction preference with the robot and whether they would like to be able to communicate with it (be warned of what it does; give it commands; stop it if necessary), again all the participants either agreed (50%) or totally agreed (50%) with the statement. The next question in continuation of the previous one assesses the participants preference on the way to communicate with the robot during their shift.

This group selected at a percentage of 75% the answer of both possibilities of communication (natural interfaces, standard interfaces) with the robot while the rest 25% expressed the desire to communicate with the robot through natural interfaces, such as voice commands, physical contact, gestures and signs.

Going to the next question and regarding the users' awareness preferences and more specifically it they believe that it would be useful to have the current state of the robot always available and visible in front of them all of this group members stated that they consider this fact as useful/very useful.

The next question examined the user preference on the way to receive information about the robot status. Here, a percentage of 25% of this group selected the answer "only through wearable devices" while a percentage of 25% expressed ignorance (selected the option don't know) and the rest 50% selected the choice "with a traditional fixed screen (HMI)". No participant of this group selected the choice of the smart glasses.

Finally, at the last question of the questionnaire regarding to the participants' warnings preferences and more specifically on how much important they consider receiving warnings all the group participants consider this fact either as very important or simply as important.

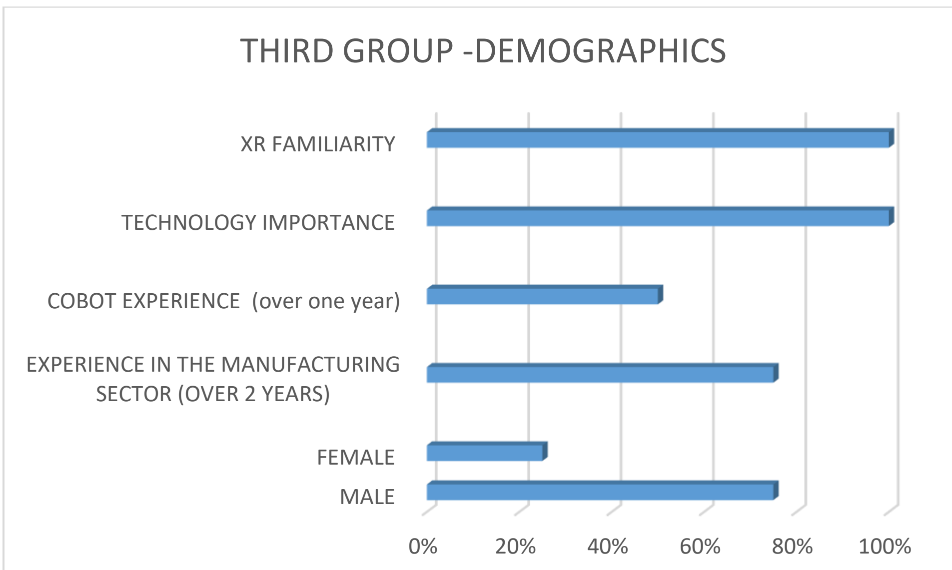


Figure 20: Third Group **(age 45-54)** -Demographics

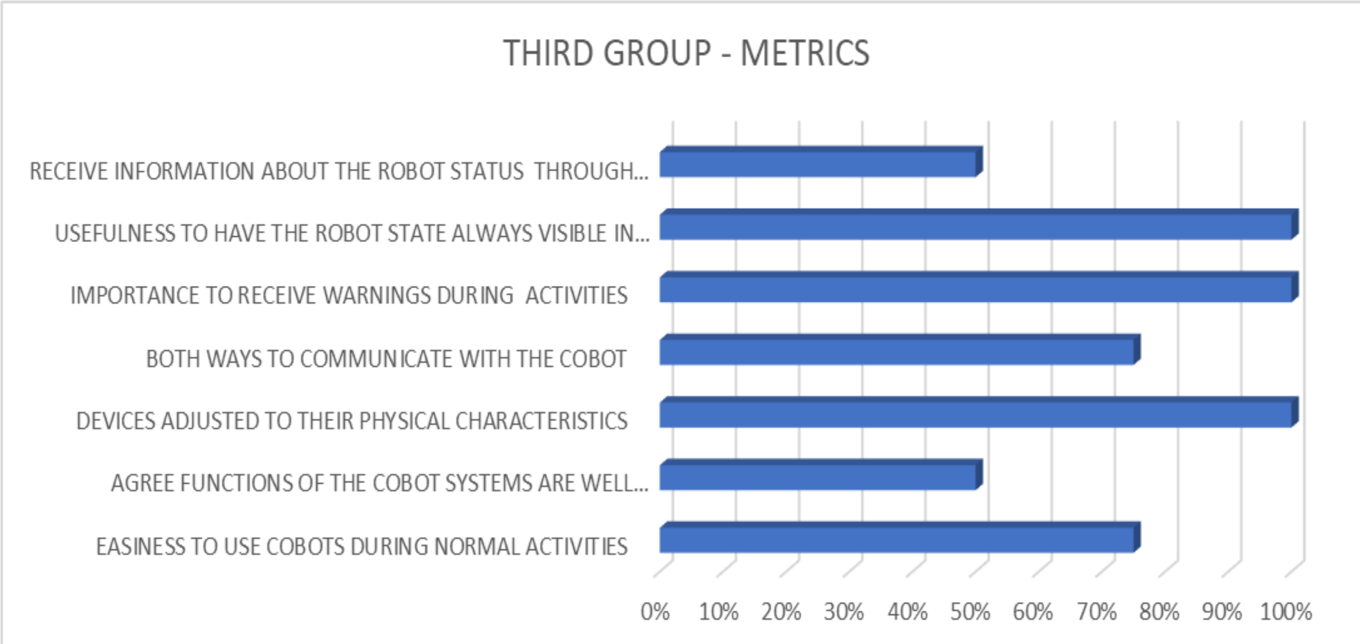


Figure 21: Third Group -Metrics' Results

Main conclusions

All people in the age group of 45-54 that participated in the survey (4 persons), consider their relationship with technology applied at work and private life along with having adequate knowledge on cobots market existence as important (100%). Moreover, they would feel comfortable to work with the use of VR/AR technologies for over one hour (75%) and additionally they consider it easy to use cobots for performing normal activities (75%).

They would like to see devices that use daily during normal work activities to be adjusted according to their physical characteristics (100%) and they also agree (100%) that they would like to communicate with the cobot and monitor its activities. They would like to communicate with the robot both with natural and standard interfaces (75%), they consider useful to have the current state of the robot always available and visible in front of them (75%) and they all consider important (100%) to receive warnings during the HR joint collaboration activities.

FOURTH GROUP

This group consisted from 6 CRF experts that fall under the age range 55-64 so they are the older group of this survey. All the members of this group are males. Regarding their working experience in the specific field of manufacturing, where the CRF use case will take place a percentage of 50% answered that it is over 2 years, 16% stated that their experience is between 7-12 months while the rest 33% said that their relevant experience is less than a month. The next question assessed the participants' experience in the field of manufacturing with collaborative robot(s). One third of them (33%) answered that their experience with cobots is over 4 years, 16% said that they have less than one year experience while 50% stated that they have no experience. Regarding the participants' perception of the importance of their relationship with technology applied both at work and in their private life all the group members answered that they considered it important (66%) or even very important (33%). Regarding the next question that deals with the participants familiarity with Virtual Reality (VR)/Augmented Reality (AR) technology 33% of this group participants answered that they are familiar or even very familiar, while an equal percentage of 33% answered that they are moderately familiar and the rest 33% answered that they are not familiar with these technologies.

Regarding the XR comfort of the participants, meaning the time during their daily working routine that the participants would feel comfortable to work with the use of VR/AR technology, a percentage of 66% answered that they would use these kind of technologies for less than 10 minutes while the rest 33% stated that they would make a use for over one hour's duration. Regarding the importance of having knowledge on the cobots existence on the market all the participants consider it either as very important (83%) or important (17%). Regarding the level of easiness of using cobots during normal activities, 66% answered that they consider it easy while the rest 33% of this group chose to remain neutral. Going to ergonomics issues and regarding the question if the functions of the cobot system are well integrated and consistent with the work (tasks to complete) of the survey participants, a percentage of 50% agree or totally agree with this statement while 33% remain neutral and only 17% disagree. Regarding the participants' perception whether the use of these cobots helps them to improve the quality of their work the great majority of this group on a percentage of 83% agrees with this argument while the rest 17% chose to remain neutral on this statement.

The next question tried to assess a collaborative benefit from the joint collaboration of the operator with the cobot and more specifically if the checklist of the joint activities towards the completion of a task can be a valid support for not forgetting anything. Again, at this point a percentage of 83% agrees with this argument while the rest 17% said that disagrees on this statement.

The next question again was related with ergonomics and more specifically of the issue whether the survey participant will like to see the devices that they use during normal work to be adjusted according to their physical characteristics. Here all the participants either agreed with the statement (50%) or strongly agreed (50%). Regarding the operators' interaction preference with the robot and whether they would like to be able to communicate with it (be warned of what it does; give it commands; stop it if necessary), again all the participants agreed with the statement. The next question in continuation of the previous one assesses the participants' preference on the way to communicate with the robot during their shift. This group selected at a percentage of 83% the answer of both possibilities (natural interfaces, standard interfaces) for communicating with the robot while the rest 17% expressed the desire to communicate with the robot only through standard interfaces.

Going to the next question and regarding the users' awareness preference and more specifically if they believe that it would be useful to have the current state of the robot always available and visible in front of them, again similarly to the previous questions 83% stated that they consider this fact as useful or very useful whereas 17% chose to remain neutral. The next question examined the user preference on the way to receive information about the robot status.

The participants of this group at this question selected at a percentage of 50% the answer "only through wearable devices" while 33% expressed ignorance and only 17% selected the choice of the traditional fixed screen (HMI). No participant selected the choice of the smart glasses.

Finally, at the last question of the questionnaire regarding to the participants warnings preferences and more specifically on how much important they consider receiving warnings (when the user entering the robot's workspace) a percentage of 83% of the participants consider this fact as important/ very important while only 17% consider this as moderately important.

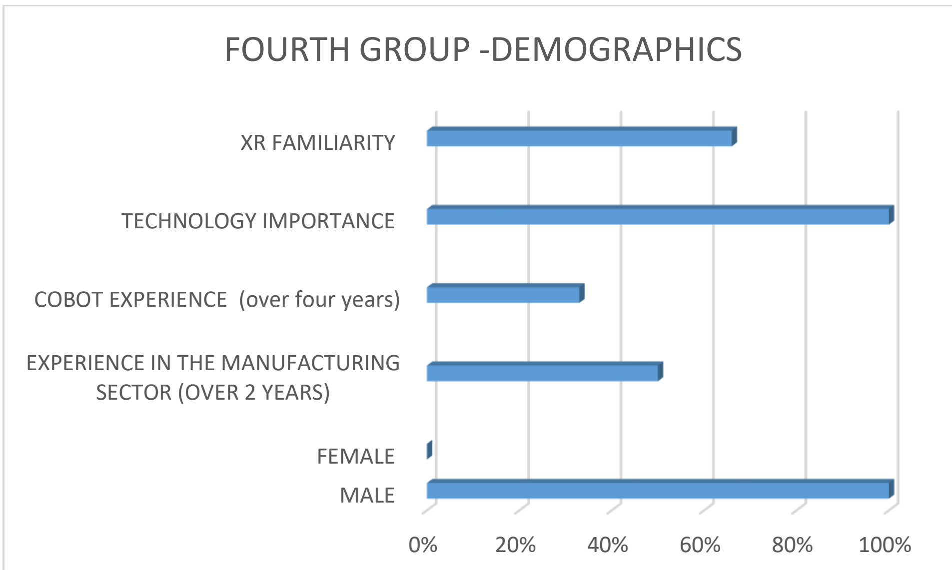


Figure 22: Fourth group (age 55-64)- Demographics

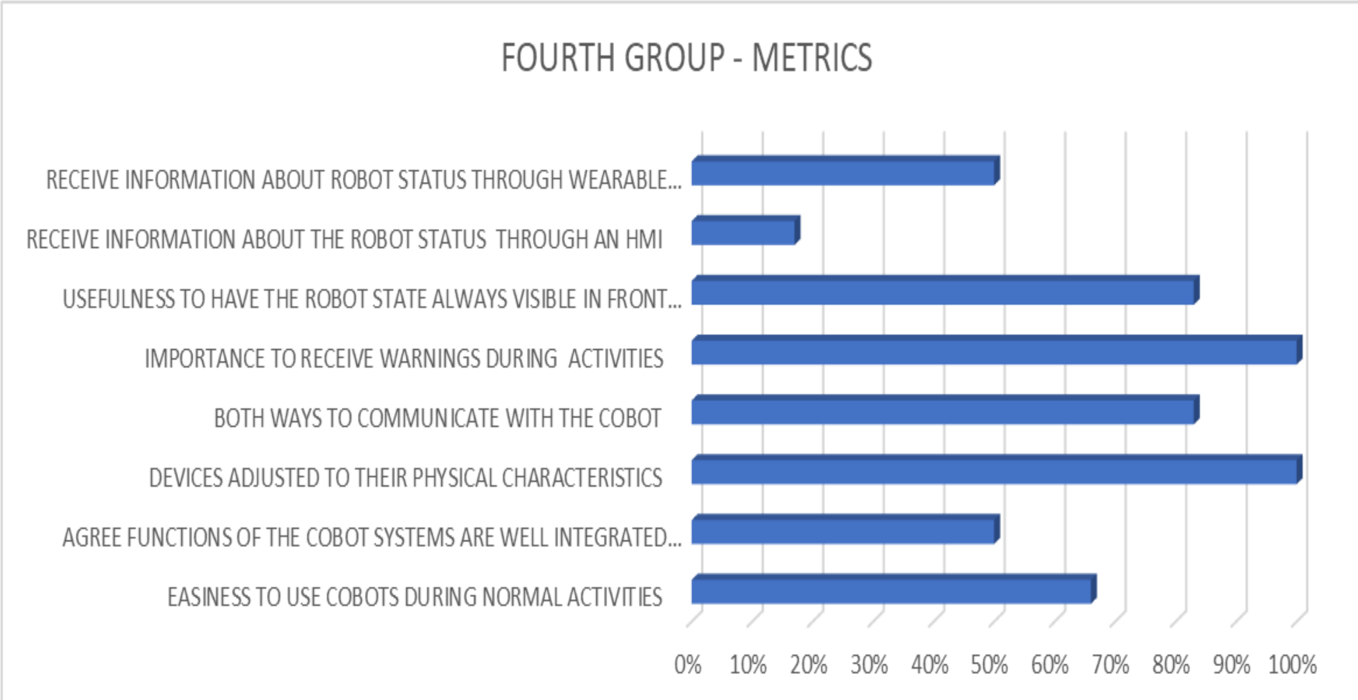


Figure 23: Fourth group - Metrics' Results

Main conclusions

All people that belong in the age group of 55-64 that participated in the survey (6 persons), consider their relationship with technology applied at work and private life as important (93%) and furthermore they consider also as important(100%) to have adequate knowledge on the cobots market existence Moreover they would feel comfortable to work with the use of VR/AR technologies for less than 10 minutes daily (66%) and they would like to see the devices they use during normal work to be adjusted according to their physical characteristics (100%). They prefer both ways of communication with the robot -standard and natural interfaces-(83%) and they agree (83%) that a checklist of the joint activities towards the completion of a task can be a valid support for not forgetting anything. They believe that it would be useful to have the current state of the robot always available and visible in front of them (83%) and finally they consider important (83%) to receive warnings during HR joint collaboration activities.

3.2.4 Statistical significance tests

Similarly, to the autonomous driving questionnaires, we performed Chi-squared tests between each of the human factors and each of the examined nominal metrics to determine whether an association (or relationship) between them is likely to reflect a real association in the study population. The sample data was used to calculate the test statistic, the value of which reflects the probability (p-value) that the observed association between the two variables has occurred by chance (due to sampling error). Our null hypothesis was that each selected metric (or a preference variable) is not associated with the examined human factor. The null hypothesis is rejected if $p < 0.05$, in which case a conclusion is drawn that the examined metric is associated with the respective human factor.

The obtained Chi-squared values and the corresponding p-values are shown in the two Tables below.

Table 9: HR collaboration questionnaires- Chi-squared values

Chi-sq	Technol_Importance	XR_Comfort	Cobot_Facility	Cobot_Relevance	Cobot_WorkBenefit	Cobot_CollabBenefit
Age	4.38	**21.53**	7.52	13.18	6.84	10.52
Gender	3.94	4.84	1.97	0.46	1.41	2.25
Work_Experience	8.28	14.47	12.15	14.83	10.59	7.27
Cobot_Experience	2.71	15.45	14.71	13.23	13.50	11.20

Table 10: HR collaboration questionnaire p-values

p-value	Technol_Importance	XR_Comfort	Cobot_Facility	Cobot_Relevance	Cobot_WorkBenefit	Cobot_CollabBenefit
Age	0.626	**0.043**	0.583	0.356	0.654	0.310
Gender	0.140	0.304	0.579	0.977	0.704	0.522
Work_Experience	0.406	0.564	0.434	0.537	0.564	0.839
Cobot_Experience	0.951	0.492	0.257	0.656	0.334	0.512

Table 11: HR collaboration questionnaires- Chi-squared values

Chi-sq	Cobot_Dissemination	UCD_Preference	Interaction_Preference	Communication_Preference	Awareness_Preference	Info_Preference	Warnings_Preference
Age	9.0857	0.315	2.4312	4.7786	6.7125	3.6557	2.4136
Gender	4.2589	1.8	1.4318	8.5982	2.8125	0.8839	1.4318
Work_Experience	6.803	4.2545	3.719	7.2208	7.4508	9.0377	10.2645
Cobot_Experience	9.3333	3.825	1.1688	4.5714	6.4583	5.9	3.9545

Table 12: HR collaboration questionnaire p-values

p-value	Cobot_Dissemination	UCD_Preference	Interaction_Preference	Communication_Preference	Awareness_Preference	Info_Preference	Warnings_Preference
Age	0.1688	0.9572	0.4879	0.5725	0.3483	0.7232	0.878
Gender	0.1189	0.1797	0.2315	0.0136	0.2451	0.6428	0.4887
Work_Experience	0.558	0.3727	0.4454	0.513	0.4889	0.3391	0.247
Cobot_Experience	0.315	0.4302	0.8832	0.8022	0.596	0.6584	0.8612

Only for one statistical test the null hypothesis could be rejected: The age was found to be associated with the time feeling comfortable to work in the daily working routine with the use of VR/AR technology,

We also performed Chi-squared tests between each of the human factors and each of the preference variables with the same significance level for rejection of the null hypothesis. None of the tests showed a p-value less than 0.05, thus no significant association was observed.

We mainly attribute the difficulty to identify associations in both experiments to the small sample size and large number of categories in the examined variables.

3.3 User model diagrams

Two user models were being designed one for the autonomous driving and one for the HR collaboration.

We tried to represent on these schemes the human factors we assessed in this document along with the metrics capturing behavioural aspects we collected through the questionnaires in relation to the specific tasks for the respective two pilot use cases.

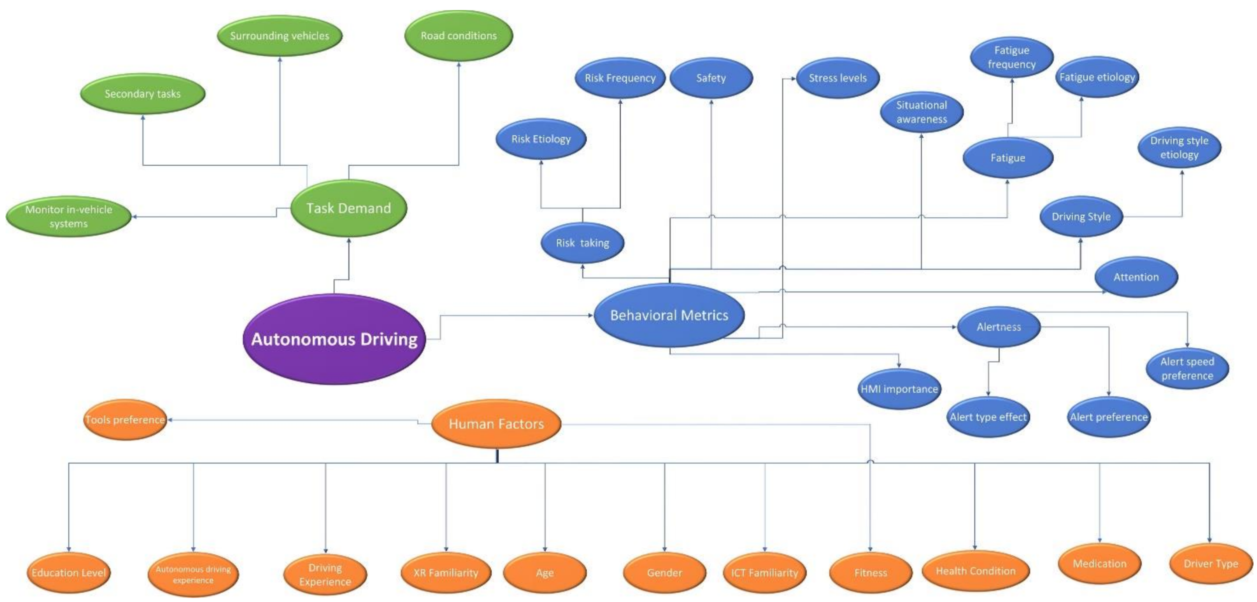


Figure 24: Autonomous driving user model

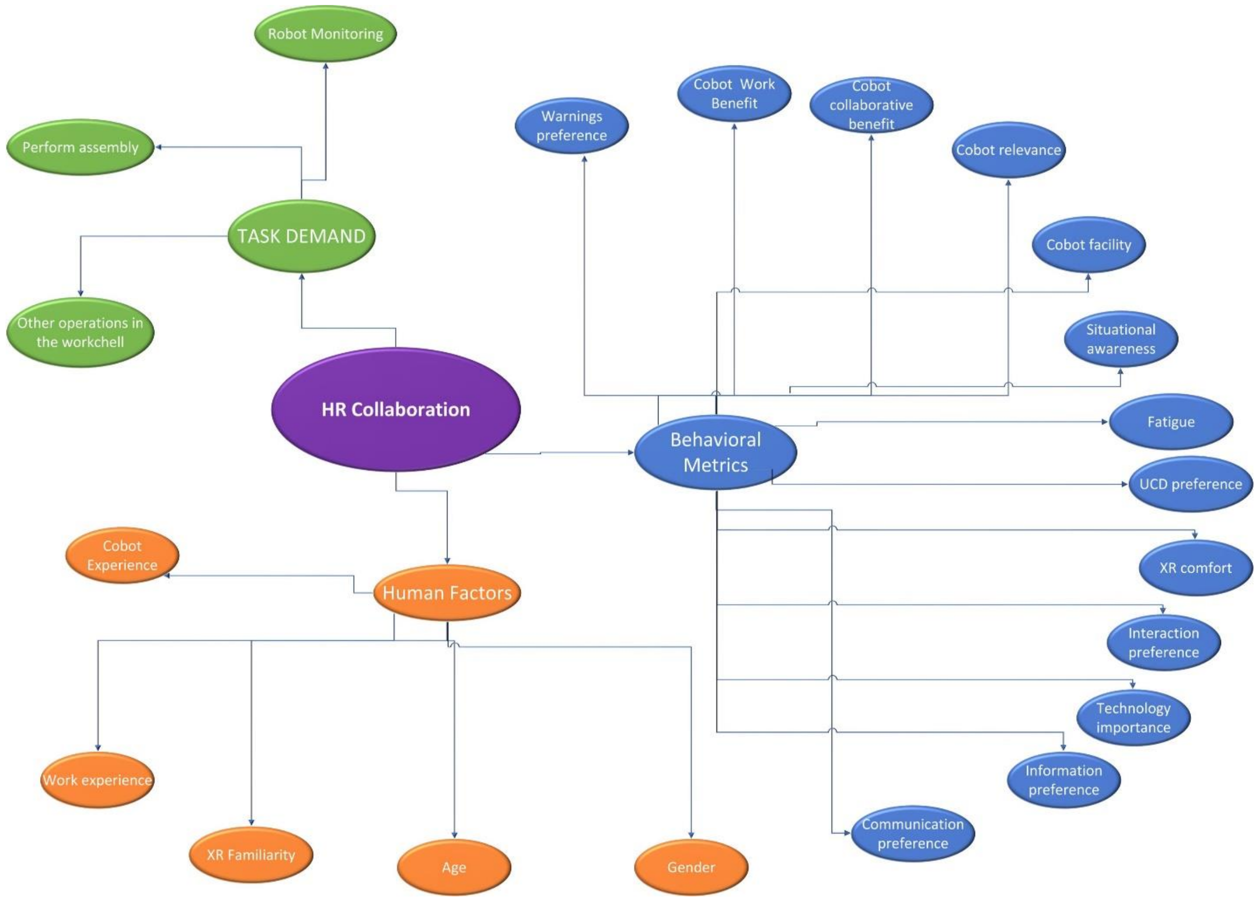


Figure 25: HR Collaboration user model

4 Conclusion

This deliverable involved with the examination and description of human factors related to the automotive and manufacturing use cases. For this reason, in the first part of the deliverable we have reviewed and presented information collected from available bibliography and existing literature, while in the second part of the deliverable we performed online surveys for receiving feedback from actual users and experts. The design of the online questionnaires was done through the collaboration of the two pilots PASEU and CRF. The questionnaires were circulated internally within the two pilots' organizations as well as to the CPSoSaware consortium. A total number of 60 experts answered these questionnaires. This expert feedback was analysed at the second part of the deliverable and some conclusions were extracted and presented along some statistical significance tests. This document will be useful to be combined along the D1.2 "Requirements and Use Cases" findings in order to draw safer conclusions on potential user preferences and trends towards the autonomous driving/ HR collaboration and provide appropriate input to the preparation of the WP6 "Industry Driven Trial and Evaluation" pilot use cases.

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ANNEXES

ANNEX I: QUESTIONNAIRE TOWARDS PREPARING THE METHODOLOGY

Project Acronym	QUESTIONNAIRE
CPSoSaware	

Description: ***The intention of this questionnaire is to be used towards the T2.1 objectives***
Analysis of user skills/factors, virtual cognitive user/environment models and metrics modeling [M1-M12] This task involves collection and analysis of reliability, security, trust and safety issues. The methodology established for collecting and analyzing the aforementioned end-users requirements and preferences will specify the number and type of users to be involved in this task, and issues like driver/operator skills, gender, expertise with ICTs, health condition, daily routines, etc.
INSTRUCTIONS: THIS QUESTIONNAIRE WAS PREPARED FOR UNDERSTANDING HOW THE TWO PILOTS PASEU AND CRF CAN REALISTICALLY CAPTURE THE HUMAN FACTOR IN THEIR ALREADY DEFINED SCENARIOS

	PASEU / HUMAN IN THE LOOP CONTROL IN SINGLE VEHICLE SCENARIOS	**CRF/ HUMAN ROBOT COLLABORATION –IN MANUFACTURING ENVIRONMENT**

	Panasonic AUTOMOTIVE	FCA FIAT CHRYSLER AUTOMOBILES CRF
FACTORS	**DROWSINESS** **How you plan to capture Drowsiness? Which of the following are possible to use?** **-Physiological measures** (Pulse rate, Brain signals, Heart activity) (e.g Wearable Bracelet, ECG-electrocardiagram)? **-Behavioral measures** (Camera, eye tracking, eye closure, blink analysis, yawning, head movement)? -**Vehicle based measures** (movement of steering wheel, standard deviation of lane position, magnitude and frequency of steering activity, pressure of the acceleration pedal, number of lane crossings, mean lateral position, mean yaw rate)?	**HUMAN ROBOT COLLABORATION FACTORS** **How you plan to capture to capture operator's fatigue?** **How you plan to capture the operator's Heart Rate?** **How you plan to capture Action/Motion recognition for the human operator?**
DEPENDING ON THE SCENARIO YOU HAVE ALREADY PROVIDED	▪ Driver Monitoring– Human performance evaluation ▪ Cyber Attacks on Autonomous Driving ▪ Co-operative Situational Awareness	▪ Legend ▪ Standard ▪ Gravity shelf ▪ Windshield container ▪ Safety zone violation

WILL THESE HUMAN FACTORS CHANGE?		
ETHICAL PROCEDURES	**How you plan to set up ethical and data protection procedures?**	**How you plan to set up ethical and data protection procedures?**
PRE-CONDITIONS	What pre-conditions must be in place in order to be ready to start the experiments?	What pre-conditions must be in place in order to be ready to start the experiments?
SAMPLE	How big can be the Pilot size? For instance, 20-25 participants could be enough?	How big can be the Pilot size? For instance, 20-25 participants could be enough?
READINESS	When you will be ready to contact the experiments for capturing the human factor? Based on indicative roadmap that was circulated in T2.1 is September feasible?	When you will be ready to contact the experiments for capturing the human factor? Based on indicative roadmap that was circulated in t2.1 is September feasible?
DURATION	How much time will you be needing for contacting the experiments?	How much time will you be needing for contacting the experiments?

	For instance, one month can be adequate? How many measurements can be performed within this period? (daily? day by day?)	For instance, one month can be adequate? How many measurements can be performed within this period? (daily?, day by day ?)
RECRUITMENT PROCESS	What will be the process for selecting/ recruiting the participants /target group?	What will be the process for selecting/ recruiting the participants/target group?
INCLUSION CRITERIA & EXCLUSION CRITERIA	**What can be the inclusion criteria for participants selection?** **What can be the exclusion criteria for non-selection?**	**What can be the inclusion criteria for the participants selection?** **What can be the exclusion criteria for non-selection?**
KEY ACTORS	Who are the key actors of the process for your case?	Who are the key actors of the process for your case?
PREPARATION	The staff that will be involved in the pilots must be briefed on the purpose and aims of the process. How you plan to do this?	The staff that will be involved in the pilots must be briefed on the purpose and aims of the process. How you plan to do this?
FOCUS GROUPS	Do you think that prior to the experiments focus groups are needed for assessing for instance user ICT knowledge etc?	Do you think that prior to the experiments focus groups are needed for assessing for instance user ICT knowledge etc?

USER PROFILE	What we will have to collect regarding users' profile? For instance • Age • Gender • ICT knowledge • driver/operator skills, • gender, • expertise with ICTs, • health condition etc	What we will have to collect regarding users' profile? For instance • Age • Gender • ICT knowledge • driver/operator skills, • gender, • expertise with ICTs, • health condition etc
DATA COLLECTION	**How we could collect the data coming from the experiments?** Please describe the data collection procedure	**How we could collect the data coming from the experiments?** Please describe the data collection procedure
DATA MANAGEMENT AND PRESERVATION	How you plan to manage and preserve the collected data?	How you plan to manage and preserve the collected data?
There are many different ways of extracting user needs, ranging from highly qualitative	How we could combine questionnaires and focus groups with your efforts?	How we could combine questionnaires and focus groups with your efforts?

methods to quantitative ones		
COVID-19	Is the COVID 19 hindering in any way the efforts towards capturing the factor?	Is the COVID 19 hindering in any way the efforts towards capturing the factor?
CONSTRAINTS	What other external factors- constraints can impact the experimental period and must be taken seriously into account?	What other external factors- constraints can impact the experimental period and must be taken seriously into account?
CONNECTION WITH KPIs	How the aforementioned human factors can be connected with KPIs such as productivity, safety, quality within the specific cases ?	How the aforementioned human factors can be connected with KPIs such as productivity, safety quality within the specific cases?

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

ANNEX II HUMAN FACTORS QUESTIONNAIRES

ANNEX IIA: CRF QUESTIONNAIRE

CRF QUESTIONS

The aim of this questionnaire is to assess the participants' interaction within the human robot collaboration environment and to collect the various human factors such as attention, fatigue, stress levels and situational awareness. This questionnaire collects information about the participant profile and investigates issues that are relevant to the CPSoS approach and on this basis, aims to extract useful conclusions on Human Factors related with the specific pillar (manufacturing)

CRF QUESTIONNAIRE

CONSENT

THIS SURVEY WILL BE USED IN ORDER TO COLLECT THE HUMAN FACTORS WITHIN THE CONTEXT OF THE CPSOSAWARE PROJECT

THE SURVEY DOES NOT COLLECT PERSONAL DATA AND THE RESEARCHERS CONDUCTING IT CANNOT KNOW WHICH INDIVIDUAL RESPONDED IN THE QUESTIONNAIRE OR THE INDIVIDUAL'S RESPONSES.

YOU AGREE TO PARTICIPATE VOLUNTARILY.

IF YOU PROCEED, YOU CONFIRM THAT:

- YOU ARE AN ADULT,

- YOU GRANT PERMISSION FOR THE DATA GENERATED FROM THIS SURVEY TO BE USED IN THE CPSOSAWARE RESEARCHER'S PUBLICATIONS AND INTERNAL REPORTS ON THIS TOPIC, AND

- YOU'VE READ THE DISCLAIMER.

- I consent
- I do not consent

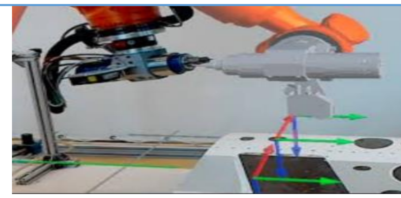
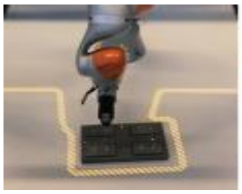
SIGNATURE

CRF questionnaire

1	Please indicate your age	☐ <25-older ☐ 35-44 years old ☐ 45-54 years old ☐ 55-64 years old ☐ >65-older
2	Please provide your gender	☐ Male ☐ Female
3	Please indicate your working experience in the specific field of manufacturing, where there is the case study	☐ <1 month ☐ 1-6 months ☐ 7-12 months ☐ 1-2 years ☐ >2 years
4	Please indicate your experience in the field of manufacturing with collaborative robot(s)	☐ No experience ☐ <1 years ☐ 1-3 years ☐ 4-5 years ☐ >5 years
5	How important is your relationship with technology applied both at work and in your private life?	☐ Very Important ☐ Important ☐ Moderately Important ☐ Slightly Important ☐ Not Important

6	How important is it to know that there are new very safe robotic devices on the market (called collaborative robots or cobots), suitable for working together safely close to operators?	☐ Very Important ☐ Important ☐ Moderately Important ☐ Slightly Important ☐ Not Important
7	Do you think it can be easy to use cobot during normal activities?	☐ Very easy ☐ Easy ☐ Neutral ☐ Not easy ☐ Not easy at all
8	Do you think the functions of the cobot system are well integrated and consistent with the work you do?	☐ Totally Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Totally Disagree
9	Do you think that the use of these cobots helps to improve the quality of your work?	☐ Totally Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Totally Disagree
10	Do you think that the checklist for the activities carried out from you and the robot can be a valid support for not forgetting anything?	☐ Totally Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Totally Disagree
11	Would you like it, if the devices you use during normal work can be adjusted according to your physical characteristics? For example: height, weight, arm length, accessibility areas allowed by the movement of the human body, etc...	☐ Excellent ☐ Good ☐ Neutral ☐ Poor ☐ Very poor

12	Among the features provided for the robot there is also that of being able to interact with the operator; would you like to be able to communicate with it (be warned of what it does; give it commands; stop it if necessary)?	☐ Totally Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Totally Disagree
13	During your shift, how would you like to communicate with the robot?	☐ I don't think there can be the same interaction that happens with a human ☐ With standard interfaces, such as tablets, buttons, etc… ☐ With natural interfaces, such as voice commands, physical contact, gestures and signs ☐ With both possibilities


14	Do you think it could be useful to have the current state of the robot always available and visible in front of you? For example, *what is it doing, what will be the next task it will do, whether or not it understood your gestures?*	☐ Very Useful ☐ Useful ☐ Neutral ☐ Not Useful ☐ Not Useful at all
15	How much important you consider receiving warnings (for example, surface flashing, alarm sound on) when the user entering the robot's workspace?	☐ Very Important ☐ Important ☐ Moderately Important ☐ Slightly Important ☐ Not Important
16	Please indicate how familiar you feel with Virtual Reality (VR)/Augmented Reality (AR) technology	☐ Very familiar ☐ Familiar ☐ Moderately familiar ☐ Slightly familiar ☐ Not familiar

17	How would you like to have information about the robot status available?	☐ With a traditional fixed screen (HMI) ☐ Only via smart glasses ☐ Only through wearable devices ☐ I don't know
18	Please indicate how much time in your daily working routine, you would feel comfortable to work with the use of VR/AR technology	☐ <10 mins ☐ 11-20 mins ☐ 21-30 mins ☐ 31-60 mins ☐ >60 mins

ANNEX IIB: PASEU QUESTIONNAIRE

QUESTIONS

	The aim of this questionnaire is to assess the participants' interaction within connected cars environment and to collect the various human factors such as attention, fatigue, drowsiness, situational awareness etc. This questionnaire collects information about the participant profile and investigates issues that are relevant to the CPSoS approach and on this basis, aims to extract useful conclusions on Human Factors related with the specific pillar (automotive)
	PASEU QUESTIONNAIRE Panasonic AUTOMOTIVE
	CONSENT THIS SURVEY WILL BE USED IN ORDER TO COLLECT THE HUMAN FACTORS WITHIN THE CONTEXT OF THE CPSoSaware PROJECT. THE SURVEY DOES NOT COLLECT PERSONAL DATA AND THE RESEARCHERS CONDUCTING IT CANNOT KNOW WHICH INDIVIDUAL RESPONDED IN THE QUESTIONNAIRE OR THE INDIVIDUAL'S RESPONSES. YOU AGREE TO PARTICIPATE VOLUNTARILY. IF YOU PROCEED, YOU CONFIRM THAT: - YOU ARE AN ADULT,

	- YOU GRANT PERMISSION FOR THE DATA GENERATED FROM THIS SURVEY TO BE USED IN THE CPSoSaware RESEARCHER'S PUBLICATIONS AND INTERNAL REPORTS ON THIS TOPIC, AND - YOU'VE READ THE DISCLAIMER. • I consent • I do not consent	
1	Please indicate the age group that you fall into	☐ 21-35 ☐ 35-50 ☐ 50-65 ☐ 65-75 ☐ >75
2	Please provide your gender	....
3	Please Indicate the Highest education Level that you have graduated from	☐ Primary school graduate ☐ Secondary Education Graduate ☐ College/ University Graduate ☐ PhD Level Studies Graduate
4	Please indicate the type of your driving license	☐ Car ☐ Bus ☐ truck
5	Please indicate your driving experience	Years of driving since obtaining driving license ☐ 0-5 years ☐ 5-10 years ☐ 10 years and more Number of kilometers driven per year ☐ <5,000 million ☐ 5,000- 10,000 million

		☐ 10,000-20,000million ☐ 20,000-30,000 million ☐ 30,000-40,000 million ☐ >40,000 million
6	Please indicate your experience with autonomous driving	☐ <2 years ☐ 2-5years ☐ 5-10 years ☐ >10 years
7	Please indicate your familiarization with ICT applications	☐ Daily use ☐ Use once per week ☐ Use 2-3 times per month ☐ Not use
8	Please indicate how familiar you feel with VR/AR technology	☐ Not familiar ☐ Moderately familiar ☐ Familiar Enough ☐ Very familiar
9	Please indicate tasks in your daily driving routine, in which you would prefer to receive assistance with the use of VR/AR technology	☐ Monitoring ☐ Vehicle control ☐ Decision making ☐ All the above
10	Please indicate type(s) of your health condition, if applicable	☐ vision impairment ☐ hearing impairment ☐ dizziness ☐ respiratory disease ☐ cardiovascular diseases ☐ chronic renal disease ☐ neurological disorders ☐ cognitive impairment ☐ peripheral vascular disease ☐ musculoskeletal conditions ☐ chronic pain, chronic fatigue, slow reaction time ☐ diabetes
11	Please indicate how often you exercise	☐ Daily ☐ 2-3 times per week

		☐ 3-4 times per month ☐ 1-2 times per month ☐ Not exercise
12	Please indicate medication you receive, if applicable	☐ for anxiety ☐ for cough ☐ sleeping pills ☐ antihistamines ☐ muscle relaxants

PASEU QUESTIONNAIRE Panasonic AUTOMOTIVE QUESTIONS FOCUSED ON DRIVING BEHAVIOUR	
1a	I tend to drive over the legal limit in residential roads • Very often • Often • Sometimes • Rarely
1b	In continuation to the previous question If you tend to drive often over the limit why you do so ? • I like speed • I am in a harry

	• I need to balance with time spend in other sub-tasks during their driving task (e.g looking for parking place, following a route with a lot of traffic) • For other reasons
2	Do you need to drive for any reason (eg for work) between midnight and 7 am and if yes how often ? • Once per week • Twice per week • Three times per week • Almost daily • Daily
3	Can you indicate occasions where you tend to drive closer to the vehicle ahead? • Weather conditions • Feel tired • Feel sleepy • Hasty driving
4	How often you have to drive fast and without wearing a belt? • Very often • Often • Sometimes • Rarely • Never If yes can you briefly describe the occasion/reason for this?

	--
5	I tend to ignore car danger alarms when they are continuous • Very often • Often • Sometimes • Rarely • Never
6	I tend to use mobile phone or tablet when driving • Very often • Often • Sometimes • Rarely • Never
7	I take some risks when driving eg ignoring red when crossing junctions, switching lanes very fast • Very often • Often • Sometimes • Rarely • Never

8	I tend to accelerate and decelerate rapidly when driving: • Very often • Often • Sometimes • Rarely • Never If yes this is a constant way of driving or mainly you did it because you were stressed and in a harry? • Way of driving • When in a harry • Other reason (please describe)
9	How often till now you had to drive without adequately sleeping before, during the last year? • Very often • Often • Sometimes • Rarely • Never If yes why this happened?

10	Which is the minimum time before collision that you want the alert signal to be raised: • >4 seconds before the collision • 3-4 seconds before the estimated collision time • Less than 3 seconds before the collision.
11	Which is the desired active area that you want Sensing to capture: • Up to 20 meters from the vehicle • Between 10 and 20 meters from the vehicle • Less than 10meters from the vehicle.
12	I keep distances from other vehicles when raining • Very often • Often • Sometimes • Rarely • Never
13	How much anxiety you feel when driving within areas with much traffic, pedestrians and bicycles around you?

	• Very anxious • A little anxious • Not anxious at all
14	I rush on making decisions when driving eg for changing driving lane • Very often • Often • Sometimes • Rarely • Never
15	Please indicate what could distract your attention when changing driving lane • A telephone call • Talking to co-driver • Listening to the radio • Using smart phone or tablet • Other (please describe)
16	I get impatient when slower drivers are in front of me • Very often • Often • Sometimes • Rarely • Never
17	How important is the image quality in the debug screens for you:

	• More Important than Sensing • Very Important • Of Moderate Importance • Less Important than sensing • Not Important.
18	How do you prefer to receive the alerts? • Display the alert on the Screens inside the vehicle • Generate alert Sounds • Out of the vehicle alert components • All the above.
19	Would you accept distortions of vehicle's appearance to favour sensors' installation that refine safety? • Definitely Yes • Yes • Maybe • No • Definitely No

ANNEX III: INFORMATION SHEET

INFORMATION SHEET

CRF INFORMATION SHEET

Project: CPSoSaware http://cpsosaware.eu/

Aim of the study

The aim of this questionnaire is to assess the participants' perception and understanding of the human robot collaboration environment and to collect feedback on the various related human factors such as for example attention, fatigue, safety, trust, stress levels and situational awareness. Additionally, this questionnaire collects generic information about the participants' profiles and investigates issues that are relevant to the CPSoSaware approach and on this basis, aims to extract useful conclusions related to the specific pillar (manufacturing use case scenario).

Description of the study and incentive

Privacy and anonymity

- All data gathered in our project **will be processed anonymously and only be used within this project.** All participants personal info will be coded (for example using pseudonyms) in the analysis and reporting of the data. This means that your name will not be linked to the gathered information.

INFORMATION SHEET

PASEU INFORMATION SHEET

Project: CPSoSaware http://cpsosaware.eu/

Aim of the study

The aim of this questionnaire is to assess the participants' perception and understanding of the autonomous car driving environment and to collect feedback on the various related human factors such as for example attention, fatigue, drowsiness, situational awareness etc. Additionally, this questionnaire collects generic information about the participants' profiles and investigates issues that are relevant to the CPSoSaware approach and on this basis, aims to extract useful conclusions related with the specific pillar (automotive use case scenario).

Description of the study and incentive

Privacy and anonymity

- All data gathered in our project **will be processed anonymously and only be used within this project.** All participants personal info will be coded (for example using pseudonyms) in the analysis and reporting of the data. This means that your name will not be linked to the gathered information.

ANNEX IV CONSENT FORM

CONSENT FORM

INFORMED CONSENT FORM

Project: CPSoSaware http://cpsosaware.eu/

Aim of the study

THIS SURVEY WILL BE USED IN ORDER TO COLLECT USER FEEDBACK ON THE VARIOUS HUMAN FACTORS WITHIN THE CONTEXT OF T2.1 "ANALYSIS OF USER SKILLS/FACTORS, VIRTUAL COGNITIVE USER/ENVIRONMENT MODELS AND METRICS MODELING" OF THE EU FUNDED CPSoSaware PROJECT.

THE SURVEY DOES NOT COLLECT SPECIFIC PERSONAL DATA AND THE RESEARCHERS CONDUCTING IT CANNOT KNOW WHICH INDIVIDUAL RESPONDED IN THE QUESTIONNAIRE OR THE INDIVIDUAL'S RESPONSES.

Permission

I, ____, agree with the content of this document and agree to participate in the CPSoSaware project.

Date:

Signature: