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Ergonomics and Nudging for Health, Safety and Happiness

Results of SIE 2022

Springer

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Tommaso Bellandi · Sara Albolino ·
Ennio Bilancini
Editors

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Editors
Tommaso Bellandi
Azienda USL Toscana Nord Ovest
Lucca, Italy

Ennio Bilancini
IMT School for Advanced Studies
Lucca, Italy

Sara Albolino
Organizzazione Sviluppo e Qualità
Policlinico Umberto I
Rome, Italy

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Contents

Ergonomics and Nudging

Tommaso Bellandi[1(✉)], Sara Albolino[2], and Ennio Bilancini[3]

[1] Tuscany Northwest Trust, Lucca, Italy
tommasobellandi@gmail.com
[2] Umberto I Academic Hospital, Roma, Italy
[3] IMT School for Advanced Studies, Lucca, Italy

1 Ergonomics, human factors and behavioural economics

Ergonomics is the science of interactions, systems' wise and design oriented. In the past three decades there has been a continuous and systematic move of researchers and professionals to affirm and clarify why human factors are the fundamental elements of every system (Dul et al. 2012; Wilson 2014; Xie and Carayon 2015). This has pushed the International Ergonomics Association and national societies to systematically pair these terms in the definition of the discipline, as well as in the name of national societies. For the purpose of the contributions in this book, we use the term Ergonomics and Human Factors (EHF). Nowadays, it is widely accepted that humans, with their limitations and potentials, are the crucial factors for the success of a system and that their individual factors, physical-cognitive-emotional-social, have to be addressed and seriously considered in the design and management of technologies, organizations, and institutions (Thaler and Sunstein 2009; Vicente. 2015). In fact, even highly automated systems require human intervention for maintenance and especially to manage the unexpected or critical incidents (Weick and Sutcliffe 2001; Reason 2017).

Basic sciences such as biology, psychology and neuro-psysiology have seen a dramatic improvement in the understanding of the nature of human beings and the impact of their environment on their behavior, providing also some evidence for the explanation of complex behavioral patterns in social interactions and effectively clarifying an increasing set of connections between body and mind (Rizzolati 2005; Maturana and Varela 2012; Cryan and Dinan 2012; Damasio and Carvalho 2013; Alòs-Ferrer, 2018a). Also, traditional western philosophy based on humanism and individualism has been questioned, thanks to the recognition of scientific evidence behind the different conceptions of human and individual life laid down in eastern philosophy and religions (Braidotti 2016), as well as in the proven benefits of simple practices such as meditation (Goleman and Davison 2017) and fasting (Brandhorst and Longo 2019).

On the other side of the curve, leading from micro to macro systems, political, social and economic sciences are considering the new evidence from basic sciences and the extraordinary potential of computing to systematically collect and automatically elaborate data on human behaviors with the aim of designing and integrating policies or marketing strategies into physical and virtual interfaces (Carlsson and Johansson-Stenman 2012; Rice 2013; Chetty 2015; Thaler and Ganser 2015; Thaler 2018; Gigerenzer 2018; Bicchieri and Dimant 2019; Bilancini et al. 2020). In this regard, Behavioral economics

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(BE) has recently been extremely successful in promoting awareness regarding the role of human factors in political, economical, and social phenomena and, at the same time, in generating influential think tanks and research-based policy agencies that have demonstrated to be capable of influencing actual policy-making (Team B.I. 2010; Cassidy 2011) in a wide spectrum of sectors (health care, environmental protection, traffic management, tax compliance, pensions, school choice, lifestyle, addictions, technological standards) and at different governance levels (hospital, municipality, utility firm, local government, ministry, central government, army).

The success of BE in this regard has been obtained in two steps: first, by providing compelling experimental evidence that many relevant economic and social phenomena could not be explained relying only on the basis of the assumption of "homo oeconomicus" (i.e., the simplification that economic agents are only interested in their own material benefits; Henrich et al. 2001; Gintis, 2005; Fher and Gintis. 2007; Bowles and Polanya-Reyes. 2012; Bowles 2016) and the assumption of "unbounded rationality" (i.e., costless and exact computation, costless attention, infinite memory, bayesian elaboration of information; Simon 1990; Jones 1999; Gingerenzer and Todd. 1999; De Martino et al. 2006; Evans 2017; Bilancini and Boncinelli 2018), and, second, by providing alternative assumptions on human behaviour and decision-making, inspired by experimental evidence, which encompass other-regarding preferences (e.g., envy for social status, Bilancini and Boncinelli 2014; 2019; social norms, Bicchieri 2016; altruism, Choi and Bowles, 2007; reciprocity, Bowles and Gintis 2004; Bilancini et al. 2022; fairness, Fehr and Gächter 2000; inequity aversion, Fehr and Schmidt 1999; spite, West and Gardner 2010; in-group favoritism, Bilancini et al. 2020) and bounded rationality (e.g., limited memory, Mullainathan 2002; reliance on heuristics, Alòs-Ferrer, 2018b; Belloc et al. 2019; inattention, Gabaix 2019; cognitive biases, Enke et al. 2021; multiple selves, Alòs-Ferrer and Strack 2014; costly cognition, Bilancini and Boncinelli 2021; non-bayesian elaboration of information, Bilancini and Boncinelli 2018). It is not necessary to go back to Kanheman and Tversky's Prospect Theory (Barberis 2013) or, more recently, to Thaler and Sunstein's Nudge Theory (Hertwig & Grüne-Yanoff, 2017), to realise that BE has deeply impacted the study of human behaviour and its interaction with the social and technological environments. How to promote cooperation in the workplace? How to minimize the likelihood of mistakes by professionals? How is human behavior affected when the actual interaction is with an AI rather than another human decision-maker? All these questions have been answered - or are being answered – also thanks to the tools, methods and theoretical framework provided by BE.

We believe in the encounter between EHF and BE provides a threefold opportunity: (i) to improve the understanding of safe and effective interactions between humans and the other elements of a system; (ii) to extend and aggregate methods and tools for the design of usable and attractive physical and virtual artifacts; (iii) to contribute to the establishment of a new ethics for public and private institutions based on joy, happiness, satisfaction and well-being.

In this introductory chapter of the Proceedings of the SIE 2022 national congress, we briefly outline the current and potential value of the encounter between EHF and BE in the 3 above-mentioned areas, trying to connect the following chapters with existing literature as well as our individual, and diverse, scientific perspectives.

2 Safe and Effective Interactions in Dynamic Complex Systems

The development of a human being throughout her lifetime is deeply rooted and dependent on the interactions with other humans and the environment. Our knowledge of the world, skills and competences unfold from basic potentials given at birth through continuous interactions with parents, families and communities permeated by one or more referent cultures (Cole 1998; Vygotsky. 2014). Interactions occur since the very early days of life with the mediation of an uncountable number of artifacts, that are the results of adaptation and creativity of current and previous generations, facing problems, creating solutions and opportunities for interactions in the natural and human-made environment (Wenger 1999). The pervasivity and ubiquity of technologies during the past two decades have created unprecedented scenarios, on one side through the physical implant of devices, on the other side due to the neverending connection to humans and non-humans via portable or wearable digital interfaces (Harari 2016).

Today, and even more in the foreseeable future, EHF and BE share the opportunity to provide new visions, to inform research directions and contribute to the development of new products and services, bringing together the accumulated knowledge for an updated understanding of dynamic interactions between humans and non-humans in complex systems, blended within physical and virtual environments.

Traditional questions such as cooperation vs competition between individuals and groups, autonomy vs centralization of planning and control in organizations, substitution vs integration of workers and robots in industries and services are already under review as we can read through the chapters of this book.

From transportations to manufacturing, from health services to health protection and promotion, we can see how the combination of a bio-psycho-social model enhances comprehension and inclusion of the multiplicity of dimensions and factors that shape human condition and potentials. When the focus is on the system and the interactions of its parts, rather than on single components, then the challenge for researchers and practitioners moves from the classic distinction between three types of interactions classified in physical, cognitive and social ergonomics to an integrated and updated version of holistic ergonomics. Human beings are constantly embedded in exchange of: strength through physical interaction with the hardware surrounding their environment; information retrieval through the five senses by means of concrete and virtual interfaces; relations through emotions, rules and values. As we cannot separate body and mind for health and wellbeing, a worker from her tools in safe and effective activity, a nurse from her identity and position within a hospital or a community, we have to apply an holistic approach to face even the apparently simple tasks, such as hand washing to prevent the spread of hospital acquired infections (Hollnagel et al. 2015).

Moreover, the focus on micro, meso or macro system levels can somehow be merged thanks to the evidence from BE, that demonstrates the connections between behaviors, management of daily lives at home or in the workplaces, with policies and values. An inaccurate understanding of individual attitudes, preferences and determinants of behaviors may contribute to the failure of entire systems, while a comprehensive approach may provide options to the individuals that are actionable and easy to understand at the micro-level, respectful and flexible to different rules and practices at the meso-level, transparent and coherent to the reference values at the macro-level (Bellandi and Albolino 2019).

This second movement of integration can create the conditions for informed decision making as well as for social engagement, as we have seen for example, with lights and shadows, during the vaccination campaign for Covid-19.

The convergence of the two movements to integrate physical-cognitive-social interactions on the one side and micro-meso-macro systems dynamics on the other side is a theoretical perspective that we suppot and that the reader may appreciate by reading the chapters of this book and playing to connect the dots which support this vision.

3 Mixed Methods to Study and Design Convergent Systems

If we accept a new vision of human conditions and systems of interactions, then we need to update methods and tools to study the present and shape the future.

First of all, the traditional separation between subjective and objective data, as well as between qualitative and quantitative methods do not fit with the complexity of a holistic approach to interactions and a merge of system's levels either in the controlled laboratory situation or in real life scenarios (Poth 2018). The definition, collection and elaboration of objective data through quantitative methods is fundamental to understand questions, generalize eventual patterns of observed relations and make some predictions for the future which can be extended to the same problems under uncertain conditions. Anyway, how people make sense of a problem in a real context and make decisions to enact a behavioral response is something that cannot be understood just by objective data (Weick 1995).

The meaning of a problem for an individual in the real world can be different from those observed in experiments, depending on many variables that vary according to individual's and system's conditions. Therefore, a combination of subjective and objective methods, that is typical of EHF and BE can widen the view of researchers and the toolbox of practitioners.

A good example comes from the use of wearable sensors and portable devices to track physical conditions, actions and interactions in the environment, where recognized metrics are systematically combined with subjective data to understand human efforts in physical and cognitive tasks. Devices that originated in the military industry for performance measurement and enhancement, such as exoskeletons, are today top priorities for research in manufacturing and in healthcare. Implantable, wearable and portable devices create the condition to collect and use an enormous amount and variety of data, along with the power of calculation available at an accessible price.

Actually, the potential of wearable sensors and portable devices to routinely collect and elaborate big data is already a reality, even though the production and use of this data for research or marketing purposes represent a challenge for privacy, industrial and political relations. On the one hand, collective events such as trends and effects of a pandemics can be automatically tracked through routine collection of population data, on the other hand a rehabilitation treatment can be hyper-personalized by creating solutions on the basis of individual data.

According to our view, a strong public engagement in big data collection and analysis is the condition to provide a perspective to scientists and professionals where sensitive data can be used under the control of the individual who is the producer and should be the owner of her data.

EHF has a tradition of participatory approach and user engagement in evaluation of problems and design of solutions. It is a strong basis to be applied in the new landscape where artificial intelligence is substituting humans in decision making in work systems and daily lives. Evidence from BE may then help to understand and design decision making processes related to the purchase or the use of new technologies. The disseminated computing, taking more and more the characteristic of robots which replace, cooperate or lead interactions with humans within convergent systems, can be addressed with a combination of methods and tools from EHF and BE.

4 A New Ethics for Research and Practice in Behavioral Sciences

A new vision on human systems and a multi-disciplinary methodology to investigate and shape interactions require a new ethics, capable of encompassing the challenges for humanity in the young but extreme era of anthropocene (Lewis and Maslin 2015).

The current official definition of ergonomics dates back to 2000 and seems out of date especially when it refers to "the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance." The optimization of human well-being and system performance should be based on a balance between individual and population health and well-being, opportunities provided by today's and future technologies and the limited natural resources of our planet. It is maybe the time for considering an update of the definition that encompasses the overlaps with BE and, more in general, with the science of human behavior, interaction and decision-making (Gintis 2014).

Finally, let us stress that, on the ethics side, we also believe that any ambitious research agenda should be informed with frugality to: avoid waste, protect common resources and public goods, promote prosociality towards present and future generations, taking into account the different cultural values and welcoming pluralism. These are fundamental premises for peace (Shiva 2005), as well as to prevent the loss of lives due to missed access to care and cure. The authors' contributions in this book aim at embracing the challenge to improve health, wellbeing and happiness in different areas of working and daily lives.

5 Presentation of the Book

The Congress took place on the 2nd, 3rd and 4th of May 2022 in Lucca, hosted at the IMT School for Advanced Studies Lucca, that is a public university for higher education and research with a special statute that focuses on the analysis of economic, societal, technological and cultural systems.

The editors invited authors to submit the long papers that have been peer reviewed with recommendation to publish.

The majority of selected contributions were on the track of ergonomics and nudging in health-care systems (9), followed by ergonomics and technological innovation (4), design for all (3), health and safety in industry 4.0 (2), neuroergonomics (1), ergonomics and nudging to face the pandemic (1).

The invited speaker Valerio Capraro presented a state of the art review on cooperation and pro-social behavior and some perspectives on the strategies to facilitate cooperative interactions between individuals and groups.

Augusto and colleagues reported the original research project, started in 2021, on the occasion of the World Usability Day, to innovate EHF methods by integrating user experience and strategic foresight to design scenarios for home care in 2041.

In the work of Menicagli et al. and in Frangioni et al. some good examples of ergonomic and nudging techniques have been used to promote vaccination among pregnant women and to improve hand hygiene in a pediatric hospital, while in the paper dedicated to "ErgoMeyer" Frangioni and its colleagues present a selection of EHF intervention in the context of an academic pediatric hospital.

In the papers of Lefosse, Del Gaudio, Dagliana and Terranova different qualitative studies and interventions are reported with the common denominator of complexity of systems and dynamic interactions in place among healthcare workers, patients, organizational procedures and technologies.

Coraci and colleagues presented an interesting analysis of risk communication strategies during Covid-19 pandemic and their potential effects on people's understanding about reliability of lab tests, by using up to date evidence from EHF and BE.

Barresi and his group illustrated the ongoing research at the Italian Institute of Technology on EHF applications to enhance surgeon performance by improving physical and cognitive interactions with tools and the patient's body.

Carnazzo and colleagues presented an innovative approach to evaluate risks of musculoskeletal disorders in manufacturing, through a combination of motion capture techniques and virtual reality with existing risk assessment tools.

Orfei reported an original research, including a new tool to evaluate occupational stress related to the intensive use of new technology among bank workers and a training intervention to mitigate stress based on behavioral techniques.

Duca and Sangermano described two different packages of a European research program to model human behaviors in air traffic control, tackle a dynamic system with updated rules and increasing volume of work and providing reliable tools to train and evaluate performance with simulations.

Frisiello and colleagues is one of the most original contributions at the congress, as they showed the potential of gamification to support decision making of commuters in busy urban centers.

Attaianese and Rossi proposed a research agenda to integrate concepts from sustainable development within human centered design, with an original classification of innovative approaches for the design of systems and artifacts.

Capodaglio and her colleagues presented a EHF perspective on domotics solutions for people with disabilities, by using a complex case study to illustrate potential and limits of current technologies and approach to provide assistive tools and an enabling home environment.

Tosi and her research team described the guidelines they prepared for the design of people centered urban parks, in order to create an urban environment that facilitates physical activity and healthy social life in a residential area.

Oberti et al. also proposed an evidence-based approach to support institutions in the design of urban environments, integrating EHF and BE methods with design for all principles to sustain healthy life in the aging population.

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How to Promote Cooperation for the Well-Being of Individuals and Societies

Valerio Capraro(✉)

Middlesex University, London NW44BT, UK
caprarovalerio@gmail.com

Abstract. The most successful human societies are those that have found better ways to promote cooperative behaviour. Yet, cooperation is individually costly and, therefore, it often breaks down, leading to enormous social costs. In this article, I review the literature on the mechanisms and interventions that are known to promote cooperative behaviour in social dilemmas. In iterated or non-anonymous interactions, I focus on the five rules of cooperation, as well as on structural changes, involving the cost or the benefit of cooperation, or the size of the interacting group. In one-shot and anonymous interactions, I focus on the role of internalised social heuristics as well as moral preferences for doing the right thing. For each account, I summarize the available experimental evidence. I hope that this review can be helpful for social scientists working on cooperation and for leaders and policy makers who aim at promoting social cooperation or teamwork.

Keywords: Cooperation · Prisoner's Dilemma · Public goods game · Social heuristics · Moral suasion

1 Introduction

Cooperative behaviour is defined as paying a cost to give a greater benefit to one or more other people. Since the benefit is greater than the cost, cooperation increases the total payoff of the group made of all people involved in the interaction. For this reason, cooperative behaviour is considered by social scientists to be one of the key ingredients for a successful society (Boyd et al. 2003; Fehr and Gächter 2002; Fehr and Fischbacher 2003; Tomasello et al. 2005; Nowak, 2006; Rand and Nowak 2013; Perc et al. 2017). Moreover, while individual cooperation increases social well-being, collective cooperation not only increases social well-being, but also increases personal well-being: each individual within a society made of cooperators is better off than each individual within a society made of defectors.

Yet, since cooperation is individually costly, it often breaks down. So, one of the most important research programs across social sciences seeks to find ways to promote and sustain cooperative behaviour. In this article, I will review the literature on this topic.

Obviously, this field of research is enormous, and, in the limited space of these pages, I can only scratch its surface. To try to counterbalance this, I will include several references, where the interested reader can find more detailed information. I hope that this review can be a useful starting point for social scientists, policy makers and leaders who are interested in how to promote cooperative behaviour.

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2 Models of Cooperation

Cooperation is formally studied through social dilemmas. These are strategic interactions in which $N > 1$ individuals get to decide between two or more actions. Among these actions, there is one that benefits the group and one that benefits the individual. This tension between self-interest and collective interest is what defines a *social dilemma*. Moving down from general to particular, social scientists have defined different social dilemmas meant to conceptualise cooperative behaviour in different prototypical circumstances. In this article, I will focus on the two most-studied social dilemmas: the prisoner's dilemma and the public goods game.

2.1 Cooperation Between Two Agents: The Prisoner's Dilemma

In the prisoner's dilemma there are two players, each of whom has two available strategies, cooperate or defect. Cooperators pay a cost c to give a greater benefit b to the other player. Defectors pay no cost and generate no benefit.

The conflict between individual and collective interest descends from the assumption $b > c$. Indeed, if both individuals cooperate, they each pay the cost of cooperation but also enjoy its benefit; therefore, they each get $b - c$. However, each individual has an incentive to deviate from cooperation to get the full payoff b, obtained by saving their own cost of cooperation, while keeping the benefit of the other's cooperative act. However, if both individuals reason this way, they both end up with 0, which is smaller than $b - c$, the payoff that they would have gotten if they had both resisted the temptation to defect.

There are also other ways to formalise cooperative behaviour between two agents, including the traveller's dilemma (Basu 1994), the Bertrand competition (Bertrand 1883), and the centipede game (Binmore 1987). While I acknowledge the importance of these models, in this article I will focus on the prisoner's dilemma (for two individuals), because the theoretical mechanisms and the experimental regularities discussed below have been developed and tested mainly using the prisoner's dilemma, but they are expected to work, in a similar fashion, in the other 2-player social dilemmas.

2.2 Cooperation Among N Agents: The Public Goods Game

The most popular N-player social dilemma is the public goods game, which is meant to conceptualise situations in which a group of individuals get to decide how much to contribute to a common project.

Formally, in the public goods game, each of N individuals gets to decide how much, if any, of their initial endowment e they want to contribute to the public good. Let c_i be the contribution of individual i, the total amount contributed by all individuals is then $c_1 + \ldots + c_N$. Let a be the "marginal return of cooperation", the payoff of individual i is defined as $e - c_i + a^*(c_1 + \ldots + c_N)$, that is, i receives the portion of the endowment that she decided to keep plus a proportion a of the common good. The marginal return of cooperation a is assumed to be greater than $1/N$ and smaller than 1. This assumption guarantees that the public goods game is a social dilemma: the collective interest would be maximised if all individuals contribute the whole endowment, but each individual has an incentive to deviate and keep the whole endowment.

There are also other ways to conceptualise cooperation among N individuals, as the N-player prisoner's dilemma and the piecewise linear-then-constant public goods game, among others (threshold public goods game, resource dilemma, volunteer's dilemma, etc.). Although in this article I will not focus on these games, I think it is worth defining them because this allows to shed light on the different effects that group size can have on cooperative behaviour depending on the social dilemma.

In the public goods game as defined above, there is the underlying assumption that the individual return for full cooperation increases linearly with the number of individuals, that is, if all individuals cooperate, then each of them gets $e*a*N$, which increases linearly with N. In some practical contexts, however, this assumption is unrealistic. For studying these situations, one can consider social dilemmas where the assumption of linearity of the relationship between group size and individual return for full cooperation is replaced with other assumptions. Here, I discuss two prototypical cases. One is the N-player prisoner's dilemma. Over the years, several definitions of this game have been proposed at various levels of generality (e.g., Hamburger 1973; Carroll 1988). Here, I define an N-player prisoner's dilemma to be any N-player social dilemma where the individual return for full cooperation is constant with the number of players. This game is useful to formalise situations in which the individual benefit of cooperation does not depend on the number of players, but, still, one needs all players to cooperate (Yao and Darwen 1994; Grujić et al. 2012; Barcelo and Capraro 2015). Another practically relevant N-player social dilemma is the piecewise linear-then-constant public goods game, where the return of cooperation increases linearly until a certain group size N_0, and then becomes constant. This conceptualises situations in which the production of the public good reaches a *plateau* due to natural limits in the production (Yang et al. 2013; Capraro and Barcelo 2015).

3 Iterated or Non-anonymous Interactions

Most of our everyday interactions are repeated or with people who are not completely anonymous. For example, we may interact with a friend of a friend, or with a company that has been recommended to us. In these cases, cooperation can evolve even among self-interested agents, according to five fundamental rules that have been summarised by Nowak (2006) in the case of the prisoner's dilemma. I review these rules below. For each rule, I will also review the experimental evidence. Most of the experimental work is taken from Rand and Nowak (2013)'s review, which I recommend for further details.

3.1 Kin Selection

Kin selection allows to explain cooperation between relatives. The general assumption of the theory is that, if r is the probability of sharing a gene, then an individual does not only receive its payoff, but also a proportion r of the others' payoff. Applying this to the prisoner's dilemma, it follows that, if $r*b > c$, then it becomes individually optimal to cooperate. This rule takes the name of Hamilton's rule, from the pioneering work of biologist William D. Hamilton (e.g., Hamilton 1964). The experimental evidence in support of this rule is, however, scarce, mainly because it is difficult to isolate the effect

of genetic relatedness from other components that are usually associated with genetic relatedness, such as long-term relationships and the possibility of future interactions. Despite these technical difficulties, Madsen et al. (2007) were able to analyse data from two different cultures while controlling for three potential sources of confound, generational effects, sexual attraction, and reciprocity. In doing so, they found that people behaved in accordance with Hamilton's rule.

3.2 Direct Reciprocity

Direct reciprocity permits to explain the evolution of cooperation in the context of repeated interactions between the same individuals. In this case, I can cooperate with you today, to receive the benefit of your future cooperation tomorrow. However, this leads to a cooperative equilibrium only when the probability of another encounter is large enough, so that the future benefit of cooperation, discounted by the probability of another encounter, is greater than the present cost of cooperation. Formally, let w be this probability of another encounter, one needs $w*b > c$. Experimental studies have shown that, indeed, the rate of cooperation in indefinitely iterated social dilemmas increases when the probability of future encounters increases (Roth and Murnighan 1978; Murnighan and Roth 1983; Duffy and Ochs 2009; Dal Bó and Fréchette 2011; Fudenberg et al. 2012).

3.3 Indirect Reciprocity

In case of repeated interactions with rematching after each round, people may become more likely to cooperate when they have information about the others' reputation. In its simplest form, reputation simply coincides with the behaviour in the past interaction. In this case, people can selectively cooperate with those who have cooperated in the previous round. Anticipating this, people may become more inclined to cooperate from the first round. Several experiments have indeed shown that people tend to cooperate with people who have cooperated in the past and that the presence of a reputational mechanism can promote and sustain cooperation (Bolton et al. 2005; Milinski et al. 2006; Rockenbach and Milinski 2006; Seinen and Schram 2006; Rand et al. 2009; Pfeiffer et al. 2012). The fact that people assign value to knowing others' behaviour is shown also by the fact that people invest a lot of time in acquiring information about the behaviour of others (Dunbar et al. 1997; Sommerfeld et al. 2007). Indeed, it can be shown that cooperation can be supported by indirect reciprocity only if the probability of knowing someone's reputation is greater than c/b (Nowak and Sigmund 1998).

3.4 Network Reciprocity

Most human interactions are not random, but structured. Network reciprocity allows to explain the evolution of cooperation on graphs, where nodes represent actors and edges represent interactions between actors. The idea is that, if interactions are structured, then clusters of cooperators can protect themselves from the invasion of defectors. This however requires that the ratio b/c is large enough. A simple rule that works on many

graphs and with several strategy updating mechanisms is $b/c > k$, where k is the average degree of the graph (Ohtsuki et al. 2006). Rand et al. (2014a) showed experimentally that cooperation indeed can evolve in graphs satisfying this rule. Instead, if this rule is not satisfied, the rate of cooperation in structured populations is typically the same as in well-mixed populations (Grujić et al. 2010; Traulsen et al. 2010; Suri and Watts 2011; Gracia-Lázaro et al. 2012; Grujić et al. 2012a). Some work also explored the evolution of cooperation on dynamic networks, where people can break old links and create new ones after each interaction. It has been found that people tend to break links with defectors and create links with cooperators, and this leads to an additional increase in the rate of cooperation, compared to static networks, both in mathematical models (Bilancini & Boncinelli, 2009; Bilancini et al. 2018) and in economic experiments (Fehl et al. 2011; Rand et al. 2011; Wang et al. 2012).

3.5 Group Selection

When there is group selection, that is, competition between groups, groups of cooperators might outperform groups of defectors, leading to the evolution of cooperation (Richerson et al. 2016). A mathematically simple necessary condition for the evolution of cooperation can be found assuming rare group splitting and weak selection: let n be the maximum group size and m the number of groups, cooperation may evolve only if $b/c > 1 + n/m$ (Traulsen and Nowak 2006). To the best of my knowledge, this specific formula has not been tested experimentally. However, there is abundant evidence that the presence of intergroup competition can lead to the evolution of intragroup cooperation (Erev et al. 1993; Gunnthorsdottir and Rapoport 2006; Puurtinen and Mappes 2009), even when there is no monetary prize associated with winning the competition (Tan and Bolle 2007; Böhm and Rockenbach 2013).

3.6 Cost, Benefit, and Group Size

Beyond the five mechanisms above, there are also structural changes in the social dilemmas that might promote the evolution of cooperation, by facilitating the application of one of the five rules of cooperation. Two of these structural changes are straightforward. In fact, the five mathematical conditions described above imply that, when b increases or c decreases, the evolution of cooperation becomes easier, in the sense that the set of the values of the other parameters for which cooperation can evolve grows larger. Experimentally, the fact that cooperative behaviour in iterated prisoner's dilemmas depends positively on b and negatively on c was already observed in the early book of Rapoport and Chammah (1965). Similar findings have been reported also in the iterated public goods game, where an increase in the marginal return of cooperation a is typically associated with an increase in cooperative behaviour, both with partner- and with random-rematching (Gunnthorsdottir et al. 2007).

For social dilemmas with $N > 2$ players there is another parameter that may affect cooperative behaviour, group size. However, the effect of group size on cooperation depends on the type of social dilemma: in the iterated public good game, larger groups tend to cooperate more (Isaac et al. 1994), whereas, in the iterated prisoner's dilemma, larger groups tend to cooperate less (Grujić et al. 2012b). The intuition behind this result

is that, in the prisoner's dilemma, the individual return for full cooperation is constant as the group size increases, so it becomes more and more difficult to get the same payoff, and this may work as an incentive to defect; on the other hand, in the public goods game, the individual return for full cooperation increases linearly with the group size, and this might incentivise people to cooperate, despite a potentially larger absolute number of defectors.[1]

3.7 Punishment and Reward

Numerous studies using iterated social dilemmas have shown that the presence of punishment or reward tend to increase cooperative behaviour (Yamagishi et al. 1986; Ostrom et al. 1992; Fehr & Gächter, 2000; Rand et al. 2009), despite the presence of occasional anti-social punishers, people who punish cooperative behaviour (Herrmann et al. 2008). In other words, if people interact knowing that they might be punished or rewarded for their behaviour, they tend to cooperate more. This happens because, on average, people tend to punish defectors and reward cooperators. This finding can be interpreted as a form of reciprocity (direct or indirect, depending on whether the punisher/rewarder is affected by the choice of the defector/cooperator) and therefore it could be seen as a way in which one can apply two of the five rules of cooperation in reality; indeed, institutional punishment of defectors is perhaps the oldest-known way to promote cooperative behaviour within a society.

4 One-Shot and Anonymous Interactions

In one-shot and anonymous games, the standard theory of rational, payoff-maximising behaviour predicts that people never cooperate. However, behavioural experiments have repeatedly shown that some people do cooperate even in these contexts (Rapoport and Chammah 1965). Usually, the structural changes in the strategic interaction that promote cooperation in iterated games (while maintaining the anonymity of the interactions) promote cooperation also in one-shot games. Specifically, decreasing the cost of cooperation (Engel and Zhurakhovska 2016) or increasing its benefit (Capraro et al. 2014) do promote cooperative behaviour; increasing the size of the group promotes cooperative behaviour in the public goods games, but reduces it in the N-player prisoner's dilemma (Barcelo and Capraro 2015). In one-shot anonymous games and in iterated games with random-rematching, there is also some research on the effect of group size on cooperation in the piecewise linear-then-constant public goods game, but the results are mixed: one study found an inverted-U relationship, such that intermediate size groups were the most cooperative (Capraro & Barcelo 2015), but a subsequent study failed to replicate this finding and found a positive effect of group size on cooperation (Pereda et al. 2019).

The presence of punishment or reward increases cooperation also in one-shot games (Capraro et al. 2016; Capraro and Barcelo 2021a). Moreover, cues that suggest that the

[1] This suggests that there might be intermediate cases in which the individual return of full cooperation increases too slowly with the group size, leading to a null or even a negative effect of group size on cooperation. For example, it could be interesting to study the relationship between group size and cooperation in a logarithmic public goods game.

interaction may not be anonymous or one-shot can increase cooperative behaviour. For example, information about the other participants' behaviour can increase cooperation, via conditional cooperation (Fischbacher et al. 2001; Kocher et al. 2008).

However, this does not explain why people cooperate in one-shot and anonymous social dilemmas. In this section, I review the main frameworks that have been proposed in the last decade.

4.1 Social Heuristics

One prominent account contends that people internalise strategies that are useful in their everyday life and use them as heuristics when they happen to interact in novel situations. Specifically, most real-life interactions are not one-shot and anonymous, but they are repeated or non-anonymous, they happen with friends or colleagues, or with individuals about whom we have information regarding their past behaviour. In these contexts, people may learn that cooperative behaviour pays off in the long run, especially when its cost is low, or its benefit is high (or in groups of special size). People might then learn and internalise these heuristics and apply them in one-shot and anonymous games. This framework takes the name of Social Heuristics Hypothesis (Rand et al. 2014b).

Over the last decade, scholars have sought to experimentally test this framework. The idea behind the experimental approach is the following: if cooperation in one-shot and anonymous games is driven by heuristics, then experimental manipulations aimed at increasing reliance on heuristics should promote cooperative behaviour. The non-trivial experimental challenge is how to promote the use of heuristics in the laboratory. Scholars have developed four different techniques: time pressure, ego depletion, cognitive load, and conceptual primes of intuition[2]. I review them below:

- When people have little time to think about the details of a decision problem, they might be more likely to rely on general heuristics. Therefore, putting people under *time pressure* might increase their reliance on heuristics.
- When people are depleted of their self-control, they might lose their ability to calculate the details of the decision problem at hand and, therefore, become more likely to use general heuristics. Self-control can be depleted through an *ego depletion* task, such as the Stroop task or the *e*-hunting task, or, in general, through any task that requires the use of self-control.
- When people's working memory is reduced by a concurrent task, their ability to make the complex reasoning needed to evaluate the situation they are facing might be reduced as well, making them more likely to follow simple heuristics. Working

[2] To be precise, there is also a fifth technique: neurostimulation. Neurostimulation methods come from the idea that high-level, reflective reasoning comes primarily from a specific brain area, the right dorsolateral prefrontal cortex (rDLPFC). Therefore, deactivating this area, using transcranial magnetic stimulation or transcranial direct current stimulation, might make people more likely to follow their heuristics. However, in this article, I decided not to focus on this method because, to the best of my knowledge, there are no studies testing the effect of neurostimulation of the rDLPFC on cooperative behaviour using prisoner's dilemmas or public goods games. There is only one study, but it uses an asymmetric public goods game (Li et al. 2018). I hope that future work can fill this gap.

memory can be depleted using *cognitive load* tasks, such as keeping in mind a long sequence of numbers (typically seven).

- *Conceptual primes of intuition* refer to a class of nudges that promote reliance on intuitive thinking. These nudges can be implicit or explicit. An instance of an implicit nudge could be that people, before playing a social dilemma, are given a set of letters that they can use to form words, and these words are related to intuitive decision making, (e.g., "intuition", "emotion", or "quick"). An explicit nudge could be to ask people to follow their intuition or their emotion, or to write about a time of their life in which following their intuitions worked out well.

It is important to note that none of these methods is perfect. Time pressure has been criticised because it is usually too long to eliminate reflective reasoning and access quick heuristics (Libet 2009; Soon et al. 2008). Ego depletion may even do something fundamentally different from deactivating reflective reasoning and activating reflexive reactions; moreover, the very basic assumption that self-control draws on a limited resource also came under scrutiny (Inzlicht et al. 2014). Cognitive load tasks might interact with the primary task, while conceptual primes, especially the explicit ones, may generate experimenter demand effect (Rand 2016).[3]

Being aware of the limitations of these experimental manipulations, scholars have turned to meta-analytic techniques to find out whether, overall (i.e., putting all the studies together, regardless of the cognitive manipulation being used), intuition favours cooperative behaviour. An earlier meta-analysis found a positive effect of promoting intuition on cooperation (Rand 2016). However, this result was later criticised by another meta-analysis, which found a null effect (Kvarven et al. 2019), which in turn was criticised by a third meta-analysis, which replicated the original positive effect (Rand 2019). The debate about whether promoting intuition increases cooperative behaviour is still ongoing (see Capraro (2019) for a review). However, there is a result that has been consistently found in all meta-analyses: explicit primes of emotions increase cooperative behaviour. To make an example, an explicit message (shown to participants before making their decision) used to prime reliance on emotions is the following:

Sometimes people make decisions by using feeling and relying on their emotion. Other times, people make decisions by using logic and relying on their reason.

Many people believe that emotion leads to good decision-making. When we use feelings, rather than logic, we make emotionally satisfying decisions.

Please make your transfer decision by relying on emotion, rather than reason.

This prime was initially introduced by Levine et al. (2018) and shown to increase cooperative behaviour in the prisoner's dilemma. More recently, it has been applied also to other contexts. For example, it has been shown to reduce speciesism, that one can interpret as a form of cooperation between humans and non-human animals (Caviola and Capraro 2020). However, this very same prime has also been shown to *reduce* intentions

[3] For completeness, I mention that also neurostimulation tools have been criticised, as they are usually applied over the brain area of interest. This implicitly assumes that the stimulus spreads uniformly towards the target area. However, this is generally not true, but depends on the topography of the cortical surface, which, in some cases, can even reverse the polarity of the stimulus (Berker et al., 2013; Rahman et al., 2013).

to wear a face mask during the COVID-19 pandemic (Barcelo & Capraro, 2021). This raises an issue that I think it deserves attention. While previous research has focused on "general cooperation" using stylised games, it is possible that particular forms of cooperation, especially those we are unfamiliar with, may require reflective reasoning.

Another important point to reflect upon is that the aforementioned work regards the effect of "general emotions" on cooperation. Specific emotions may affect cooperation in different ways, depending on the emotions themselves. For example, Polman and Kim (2013) found that inducing anger decreases cooperation in the public goods game, while inducing disgust increases cooperation. Motro et al. (2017) found that inducing anger decreases cooperation in a prisoner's dilemma, but only when the other participant was angry as well. Chierchia et al. (2021) found that inducing fear increased cooperation compared to inducing anger, but none of them was different from the control condition.

4.2 Moral Preferences

Another account that has been proposed is the morality preferences hypothesis, according to which cooperative behaviour in one-shot and anonymous interactions is primarily driven by moral preferences for doing the right thing (Capraro and Perc 2021). This account is not mutually exclusive with the social heuristics hypothesis because personal norms – internal standards about what is right or wrong – may come from the internalisation of behaviours that have been learned in everyday interactions.

The experimental evidence on the morality preferences hypothesis began with a paper by Biziou van Pol et al. (2015), which found that cooperative behaviour in the one-shot prisoner's dilemma correlates positively with honest behaviour in a sender-receiver game where a sender can send a dishonest message and increase both his payoff and that of the receiver. Therefore, the honest choice in this game is considered as a measure of moral preferences beyond monetary outcomes. The fact that this choice correlates with cooperative behaviour suggests that cooperative behaviour is partly driven by moral preferences beyond monetary outcomes. A subsequent article by Kimbrough and Vostroknutov (2016) showed that cooperative behaviour in the public goods game correlates with norm-following in a task where subjects, moving a virtual person on a computer screen using a keyboard, get to decide how long to stand at a virtual traffic-light which displays the red colour, losing time and money, in a context where they receive no negative payoff if they just cross the road disregarding the traffic-light. The decision in this norm-following task is anonymous, has nothing to do with social interactions, and does not have any material consequences. Therefore, although Kimbrough and Vostroknutov (2016) do not mention personal norms in their paper, I think it is fair to consider their task as a measure of people's propensity to follow their personal norms. In this light, their results may be interpreted as providing further support for the assumption that cooperative behaviour in one-shot and anonymous social dilemmas is partly driven by moral preferences. Then, Capraro and Rand (2018) demonstrated that cooperative behaviour in the prisoner's dilemma correlates with the moral choice in the trade-off game, regardless of the trade-off game frame, thus providing additional evidence that

cooperative behaviour is partly driven by moral preferences beyond monetary outcomes.[4] Recently, Bašić and Verrina (2021) provided evidence that personal norms are complementary to social norms in predictive cooperative behaviour, and Catola et al. (2021) showed that both social and personal norms are correlated with cooperative behaviour in the public goods game, but the predictive power of personal norms is higher.

This line of research suggests that nudges that make the personal norm salient might be effective at increasing cooperative behaviour. However, to the best of my knowledge, only two papers explored this question.[5]

Capraro et al. (2019) explored the effect of two norm-nudges, one based on the injunctive norm, and one based on the personal norm. Specifically, before playing a prisoner's dilemma, participants answered one of the following questions:

Personal norm question: "*What do you personally think is the morally right thing to do in this situation?*".

Injunctive norm question: "*What do you think your society considers to be the morally right thing to do in this situation?*".

After answering this question, participants played a one-shot prisoner's dilemma. The results showed that both messages increased cooperative behaviour compared to a baseline, where participants made their decision without being asked any question. Moreover, the effect of the two nudges was similar.

Mieth et al. (2021) tested the effect of moral labels on cooperative behaviour in the prisoner's dilemma. They found that labelling the available options with morally loaded words, such as "I cooperate" vs. "I cheat", increases cooperation, compared to using neutral labels "Option A" vs. "Option B".

Thus, these two studies provide evidence that making the personal norm salient tend to increase cooperative behaviour. However, it seems that also making the injunctive norm salient increases cooperative behaviour to a similar extent, suggesting that also injunctive norms may play an important role in determining one-shot and anonymous cooperation. It might be possible that different people are nudged by different norms; for example, it could be that people high in internalised moral identity tend to react to personal norm-nudges, while people high in symbolised moral identity tend to react to injunctive norm-nudges.[6] In general, studying the role of potential moderators could be a promising route for future research. Moreover, perhaps surprisingly, I could not find any work testing the effective of making the descriptive norm salient.[7] One can imagine that this would also increase cooperative behaviour via conditional cooperation, but it is

[4] I refer to Capraro, Halpern and Perc (in press) for a review article providing many examples of situations in which people's behaviour cannot be explained using outcome-based utility functions but require language-based utility functions; moral preferences can be seen as particular language-based utility functions, where morally loaded language carries the moral utility of an action.

[5] There is also one work exploring the effect of moral messages in the iterated prisoner's dilemma. Dal Bó and Dal Bó (2014) found that making participants read the Golden Rule increases cooperation in the iterated prisoner's dilemma, although the effect vanishes after a few rounds.

[6] Internalised moral identity measures the extent to which being moral is important to one's self-concept, while symbolised moral identity measures the extent to which people care about looking moral (Aquino and Reed 2002).

[7] The descriptive norm represents what other people actually do (Cialdini et al. 1990).

an open question if this is actually the case and, if so, how the magnitude of this effect compares with the magnitude of the effects of the other norm-nudges.

5 Conclusion

In this article, I reviewed the main mechanisms and interventions that are known to promote cooperative behaviour in social dilemma games. I summarise them in Table 1. I also highlighted some open questions that I hope can be answered in future work. I summarise them in Table 2.

Table 1. Summary of the mechanisms and interventions that are known to increase cooperative behaviour in social dilemmas.

Iterated or non-anonymous games
• *Genetic relatedness* increases cooperative behaviour
• *Future interactions* increase cooperative behaviour
• Public *reputation* increases cooperative behaviour
• *Networked interactions* increase cooperative behaviour, especially if one can break old links and create new ones
• *Group competition* increases cooperative behaviour withing groups
• *Reducing the cost* of cooperation or *increasing its benefit* increases cooperative behaviour
• *Larger groups* are *more cooperative* in the *public goods game*, but *less cooperative* in the *prisoner's dilemma*
• *Punishment* or *reward* increases cooperative behaviour
One-shot and anonymous games
• *Reducing the cost* of cooperation or *increasing its benefit* increases cooperative behaviour
• *Larger groups* are *more cooperative* in the *public goods game*, but *less cooperative* in the *prisoner's dilemma*
• *Cues* suggesting *that interactions might be repeated or non-anonymous* increase cooperative behaviour
• Inducing *general emotions* increases cooperative behaviour
• *Personal norm-nudges* increase cooperative behaviour
• *Injunctive norm-nudges* increase cooperative behaviour

Table 2. Open questions.

Open questions
• What is the effect of group size on cooperation in the piecewise linear-then-constant public goods game? If inverted-U, is it possible to estimate the size of the group that produces the largest public good?
• Does intuition promote cooperation?
• Do specific forms of cooperation – arguably those we are not familiar with – require deliberative thinking?
• Which specific emotions promote cooperation? Which undermine it?
• What is the effect of neurostimulation of the dorsolateral prefrontal cortex on cooperative behaviour?
• Do descriptive norm nudges increase cooperative behaviour? How does their effect compare with the effect of personal and injunctive norm-nudges?
• Are people who respond to personal norm nudges somehow different from people who respond to injunctive norm nudges?

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Home Care 2041: Signals from the Future

M. del Gaudio[1], E. Fabbri[2], F. Fraboni[3], G. Frangioni[4], F. Masci[5,6], F. Millo[3], G. Miranda[7], M. Pistolesi[8], R. Randazzo[9], A. Rondi[10], A. Rosa[11], and A. Augusto[10](✉)

[1] Inail UOT CVR, Avellino, Italy
[2] Regional Agency for Health and Social Care, Emilia-Romagna Region, Bologna, Italy
[3] Department of Psychology, University of Bologna, Bologna, Italy
[4] NOS ERGOMeyer, Meyer Children's Hospital, Florence, Italy
[5] Department of Health Sciences, University of Milan, Milan, Italy
[6] Colorado State University Radiological Health Department, Fort Collins, CO, USA
[7] KION Group, Antwerpen, Belgium
[8] Laboratory of Ergonomics and Design (LED), Department of Architecture, University of Florence, Florence, Italy
[9] Clinical Psychologist, Catania, Italy
[10] Sky Runner Srl, Bergamo, Italy
augusto@augustostudio.it
[11] Proges Soc Coop, Parma, Italy

Abstract. Technological evolution has made available tools capable of connecting the patient to treating doctors and health facilities for ordinary activities and carrying out medical investigations directly at the patient's home, thanks to increasingly sophisticated devices.

The restrictions on the movement of people due to the COVID-19 pandemic have encouraged the use of tools already available to doctors and patients but have also accelerated the development of ongoing projects. The Italian Society of Ergonomics and Human Factors SIE has created a multidisciplinary working group that has tried to imagine the shape of home care in the next twenty years. The study is based on integrating the "Human-Centered Design" and "Strategic Foresight" processes. According to their skills, the eight researchers have tried to identify the trends that will most influence the future, designing the possible scenarios in which home care will take place.

Keywords: Ergonomics · Human factors · Human-Centered Design · Strategic Foresight · Home care

1 Introduction

1.1 International Background

Traditionally, when we talk about "care" within the welfare system, we mainly refer to the pursuit of reducing and/or eliminating the state of the malaise of a population through the implementation of a complex system of services and interventions toward

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the people themselves. In recent decades, however, we witnessed a shift in focus towards promoting healthy conditions rather than focusing exclusively on eradicating the causes of illness.

This change of focus takes place in a global context in which we are witnessing the development of various factors such as the change in demographic dynamics [1, 2] and in the health care needs of the population with an increasing number of older adults and/or people with chronic pathologies [3].

The experience of the restrictions resulting from the pandemic situation that society has had to face makes it clear that the network of personal services needs to be reorganized in order to strengthen the possibilities of territorial care. In this sense, technological innovations (both in the health and non-health sectors) are fundamental for developing a personal support and care network.

Therefore, we are dealing with "emerging technologies that cause disruptions to the current operating models of governments and enable innovative solutions, both for public policies and for the provision of goods and services, as well as for the socio-economic context in general" [4].

Technological development has a substantial impact on both the social and economic spheres, especially on health organization policies. The recent pandemic has favoured the proliferation of new digital tools, implementing both the knowledge and the use of them by health service operators and users in the various stages of treatment. We refer to the development and diffusion of Telemedicine practices [5–7], defined according to the guidelines of the World Health Organization as "the provision of care and assistance services, in situations where distance is a critical factor, by any health worker through the use of information and communication technologies for the exchange of information useful for the diagnosis, treatment and prevention of disease and trauma, for research and evaluation and for the continuous training of health personnel, in the interest of the health of the individual and the community" [8].

This method of access to care, therefore, offers, as far as the users of the service are concerned, the possibility of keeping their medical parameters under control by accessing their online health records, thus allowing the constant monitoring of their state of health and encouraging active participation in prevention and health implementation. On the other hand, as far as the provision of health care by doctors and health care personnel is concerned, this method offers the possibility of accessing more advanced equipment that favours a multidisciplinary approach tailored to the individual characteristics of the patient/user, from diagnosis to treatment and subsequent follow-up. However, it should be specified that these services should not be regarded as a replacement for the doctor-patient relationship but as an improvement and streamlining of that process. The risk, in this sense, is a shift of focus from the person's centrality to digital and technological development.

It follows that it is necessary to bear in mind that when we talk about "care", we are mainly referring to a "care relationship" in which the main actors are the doctor and the patient, who actively collaborate in the development of the psycho-physical wellbeing of the subject in the totality of the elements that constitute and promote it. From this point of view, it is essential to analyze the social, environmental, technological, political and economic elements that determine the evolution of healthcare organizations. This

process aims to hypothesize the possible and future scenarios of the care services and initiate beneficial choices and actions to implement and apply in the care process.

Therefore, the main objective of the research project is to create a transdisciplinary synergy, from healthcare professionals to researchers and developers of new technologies, to anticipate the risks, possibilities, and impact of technological development in the field of care. The overarching goal is to favour the cultural development towards innovation, keeping the people at the center, and promote the development of technologies capable of positively impacting the future of care.

In this paper, we describe the methodology used and the objectives achieved during the research programme promoted by the Italian Society of Ergonomics and Human Factors (SIE) and the World Usability Day (WUD), whose objective was the definition of a preferred scenario for home care in the next 20 years, through the integration of Human Centered Design and Strategic Foresight.

2 Material and Methods

2.1 Human-Centered Foresight Project

The Human Centered Foresight Project (HCFP) started between July and September 2021, with the establishment of the research team (8 experts on different drivers and two experts in Human Factors and Ergonomics).

The researchers were selected among the Italian Society of Ergonomics and Human Factors (SIE) members and external professionals in the field of home care. The requisites for participating in the project were two: i) having work experience in the social, economic, technological, environmental and political sectors as driving forces behind all change; ii) having work experience in health and personal care.

The project aims to answer the question: How will technology change people's home care in the next twenty years?

With the aid of the researchers involved, the project aspires to question and lay the foundations for a people-centered culture of innovation capable of driving the design of technologies that will positively impact the future of home care.

The researchers developed a new methodological process, hybridizing "Human-Centered Design" and "Strategic Foresight", to codify it in an effective and efficient methodological specification.

The project was developed through 7 workshops, each with the duration of eight hours:

1. *Future Literacy and Past Analysis*: presentation of the Strategic Foresight methodology, key concepts, historical drivers and new forces for change;
2. *Trend Analysis*: Horizon Scanning phase, identification of current relevant trends, counter-trends, weak signals and stability factors;
3. *Cross-Impact Analysis & Scenarios Development:* weighting the cross-impact of the identified trends, counter-trends, weak signals and stability factors and development of future scenarios considering the cross-impacts of trends, counter-trends, weak-signals and stability factors;

4. *Objectives and Critical Factors*: identification of 4 possible scenarios, identification of the preferred scenario and the objectives to be achieved, development of a road map using the "three horizons" method;
- WudSIE2022: involvement of experts;
5. *Follow Up and Validation*: revision of the scenario and road map based on the experts' findings, identification of a defined scenario and road map as the output of the table;
6. *Conclusion*: examination of the concepts, comparison of possible new "inspirations", final validation of the results, fixing the modalities of production and communication of the results (report).

The process included an intermediate step for checking the results elaborated in the first half of the project. This was done during the WudSIE2021 event, presenting the future scenario to 2041. In this phase, a team of 8 experts on the different drivers (society, economics, technology, environment and politics) plus two experts in Human Centered Design were added to support the project, who provided feedback regarding the desirability and feasibility of the identified future scenario.

The experts' feedback was used in the last two workshops for developing the final scenarios as the conclusive output of the project.

3 Results

This section outlines the results of the HCFP process.

The first workshop focused on introducing the methodology to the project researchers. A practical retrospective activity was carried out to analyze the historical drivers and forces of change over the past twenty years. The researchers were able to familiarise themselves with the Strategic Foresight methodology, analyzing the events that have shaped the world as we know it, namely the historical events that occurred in the last twenty years and how they have changed the way we live. In this phase, the focus was on society at large and not only the domain of home care.

The second workshop focused on the Horizon Scanning phase. The researchers carried out individual investigations and analyses between the first and second workshops. Elements that could impact the world of home care over the next twenty years were identified. Results of individual investigations were then shared during the workshop itself. The identified elements were systematized into a diagram to identify rising and downwards trends (Table 1). The researchers identified potential counterforces for each trend. In addition, researchers also identified "weak signals" (i.e. new ideas, issues, or technologies that are currently "under the radar" but could develop into relevant drivers of change) and "stability factors" (i.e. elements of the current society that will slow or prevent changes).

The third workshop started with the so-called cross-impact analysis phase. Firstly, the researchers reached an agreement on which elements collected in the Horizon Scanning phase had to be included to build the preferred future scenarios. The researchers then analyzed if and with what magnitude these factors could impact each other. The identified trends, counter-trends, weak signals and stability factors were then entered into a matrix table, and each crossing was assigned an impact value ranging between -3 and + 3. This

Table 1. Trends analysis: horizon scanning

	Drivers of change	Counter-trends
Rising trends	BlockChain Robotics and Exoskeletons AI New migratory flows Energy: photovoltaic - wind - electricity Smart home - Smart cities -5G Health policies New foods Search for solutions to climate change Request for self-determination at the end of life Ageing Gamification	Bitcoin rejection (El Salvador, China) Rejection (fear) of workers / trade unions Taxation of robots Closing the borders Environmental movements - land availability Absence of public incentives - deductions Vegans - vegetarians - slow food Denial of the climate problem Legal limits EU push for regulations and bans
Downward trends	"Physical" Iteration - Appointments in presence." Energies: methane / LPG Traditional family Use of cash Physical stores Landline phones Quality/accessibility to water Paper books	Physical iteration requests increase Electricity cost increase Limits to "rainbow" families Limits to access to means of payment Game stop

Table 2. Clusters resulting from the cross-impact analysis

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Factors included in the cluster	Gamification Circular Economy Smart Homes Alternative energies Environmental policies	Religious/cultural extremism Poverty Transport drones New pandemic viruses New economics concepts	Transhumanism Circular Economy Intelligent Robotics Alternative energies New economics concepts	Religious/cultural extremism Circular Economy Intelligent Robotics Alternative energies New economics concepts

analysis resulted in four clusters of factors. Each cluster composes a possible scenario to be developed. Figure 1 illustrates the selected factors and the cross-impact weightings assigned by the researchers, while Fig. 2 shows the resulting clusters.

	A. SOCIETY						B. ECONOMICS						C. TECHNOLOGY						D. ENVIRONMENT				E. POLITICS				
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	E1	E2	E3	E4	E5
A. SOCIETY																											
- A1 Population decline							0	2	2	-1	0	1	0	1	0	0	1	0	-2	-2	-2	0	0	2	0	0	1
- A2 Transhumanism							1	0	2	0	3	0	1	2	2	2	1	3	-1	0	0	1	1	1	0	1	2
- A3 Body positivity							0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2
- A4 Gamification							0	0	1	0	2	0	0	1	1	1	0	1	0	0	0	0	3	0	2	0	0
- A5 Religious/cultural extremisms							0	-2	-2	-2	-2	3	-3	-3	-3	-3	-3	-2	0	0	0	-2	-3	-3	-2	2	-3
- A6 social differences							-2	3	3	0	3	3	0	0	0	0	0	0	2	0	0	0	-2	2	-2	2	2
B. ECONOMICS																											
- B1 Microenterprise System	0	0	0	1	0	-2							1	1	1	1	1	1	0	0	0	1	1	2	0	0	-1
- B2 Universal Basic Income	0	0	0	0	-2	-2							0	0	0	0	0	0	0	0	0	0	0	-2	0	2	-2
- B3 Circular Economy	0	0	0	0	0	-1							1	1	1	0	1	0	0	-2	-1	3	0	0	2	2	0
- B4 New natural resources	0	0	0	0	0	0							1	1	1	0	1	0	3	0	2	-1	0	0	-1	0	0
- B5 Power of corporations	0	2	1	2	2	3							2	3	2	2	3	1	0	2	2	3	-2	1	-2	-3	1
- B6 Poverty	2	0	2	0	3	3							0	0	-2	0	0	0	3	0	0	0	-2	3	-2	1	2
C. TECHNOLOGY																											
- C1 Quantum computing	0	2	0	1	0	0	0	0	0	0	2	0							0	0	0	0	0	0	0	0	0
- C2 Smart Robotics	0	2	0	2	2	2	2	2	2	0	3	2							0	0	0	2	0	0	1	2	0
- C3 Smart Home	0	1	0	2	0	0	2	0	2	0	1	0							0	0	0	0	0	1	0	0	0
- C4 Domotics Blockchain	0	1	0	0	0	0	0	0	0	0	2	0							0	0	0	0	0	0	0	0	0
- C5 Unmanned Transport	0	0	0	0	0	0	2	0	0	0	0	0							0	0	0	0	0	2	1	0	0
- C6 Deepfake	0	0	0	1	0	0	1	0	0	0	0	0							0	0	0	0	1	0	0	0	0
D. ENVIRONMENT																											
- D1 New pandemic viruses	2	0	0	0	3	3	-1	3	0	0	2	3	0	1	2	1	3	0					1	1	1	2	2
- D2 Water shortage	3	0	0	0	3	2	-1	0	3	0	1	3	-2	-2	-2	-2	-2	-2					0	0	3	3	1
- D3 Increase in negative natural phenomena	3	1	0	0	3	3	-1	1	2	1	1	3	0	2	0	0	2	0					0	1	3	2	1
- D4 Alternative energy resources	0	0	0	0	1	0	2	0	3	0	1	0	2	2	2	2	2	0					0	0	2	1	1
E. POLITICS																											
- E1 Health literacy	-1	0	1	0	0	0	1	0	0	0	-1	0	0	0	1	0	0	0	-1	0	1	0					
- E2 Increased services to families	-1	0	0	0	-2	-2	1	-1	0	0	0	-2	0	0	0	0	0	0	0	0	0	0					
- E3 Environmental policies	-1	0	0	0	1	0	0	0	2	0	-1	1	1	2	2	1	2	0	-1	-1	-2	3					
- E4 New models of economics/ownerships	-1	0	0	0	-1	-2	1	2	2	0	-2	-3	0	1	0	0	0	0	0	0	0	1					
- E5 Health related associations	-1	0	1	0	0	-1	1	0	1	0	-1	-1	0	0	0	0	0	0	0	0	0	0					

Fig. 1. Weightings of the Cross-impact Analysis

After the cross-impact analysis, the third workshop saw the development of possible future scenarios. Each researcher was asked to choose one of the four clusters identified in the third workshop. Then, based on the selected cluster, each researcher had to develop a preferred scenario using a storytelling methodology. The developed scenario had to show and clarify the interactions between the various cluster elements for each identified driver. Simultaneously, a survey for experts was developed. The survey aimed to check the result of the second and third workshops against the judgments of a pool of experts belonging to the WUD group. The results of the qualitative questionnaire were later used to complement the researchers' work.

In the fourth workshop, the researchers selected one scenario according to two criteria: highest preferability and presence of the highest number of trends analyzed in the previous workshops. The selected scenario was labelled as the "Preferred Scenario". Then, on the basis of the "Preferable Scenario", a set of requirements was identified for the five drivers. On the basis of the requirements, the steps for the realization of the scenario were identified, i.e., the objectives linked to the requirements and critical factors for the achievement of each objective.

The WudSIE2021 event was the last step of the first phase of the research. As mentioned in the method section, it helped gather feedback on the results and encouraged a discussion about the identified objectives.

In the fifth workshop, a follow-up and validation of the researchers' output were conducted. In particular, the Preferable Scenario, its requirements, and critical factors were adjusted according to the experts' comments and feedback gathered through the survey and during the WudSIE2022 event. This allowed progressing to another crucial step of the project, the development of a road map for reaching the Preferable Scenario. The roadmap consisted of a series of steps, distributed across the five drivers, that should

be achieved within the next 20 years to reach the Preferable Scenario. The roadmap was considered the basis for the definition of the system architecture.

Finally, the last step involved the definition of the system architecture, which, during the SIE Conference "Ergonomics and Nudging for Health, Safety and Happiness", was helpful in the working group of designers to graph the preferred scenario proposed by the group of researchers.

Six system architectures were provided to the designers (see Fig. 3), divided in time: Scenario 2024, Scenario 2026, Scenario 2029, Scenario 203, Scenario 2036 and Scenario 2041.

The realization of the objectives, identified with the letters T (technology), S (society), A (environment), E (economics) and P (politics), allowed the researchers to define

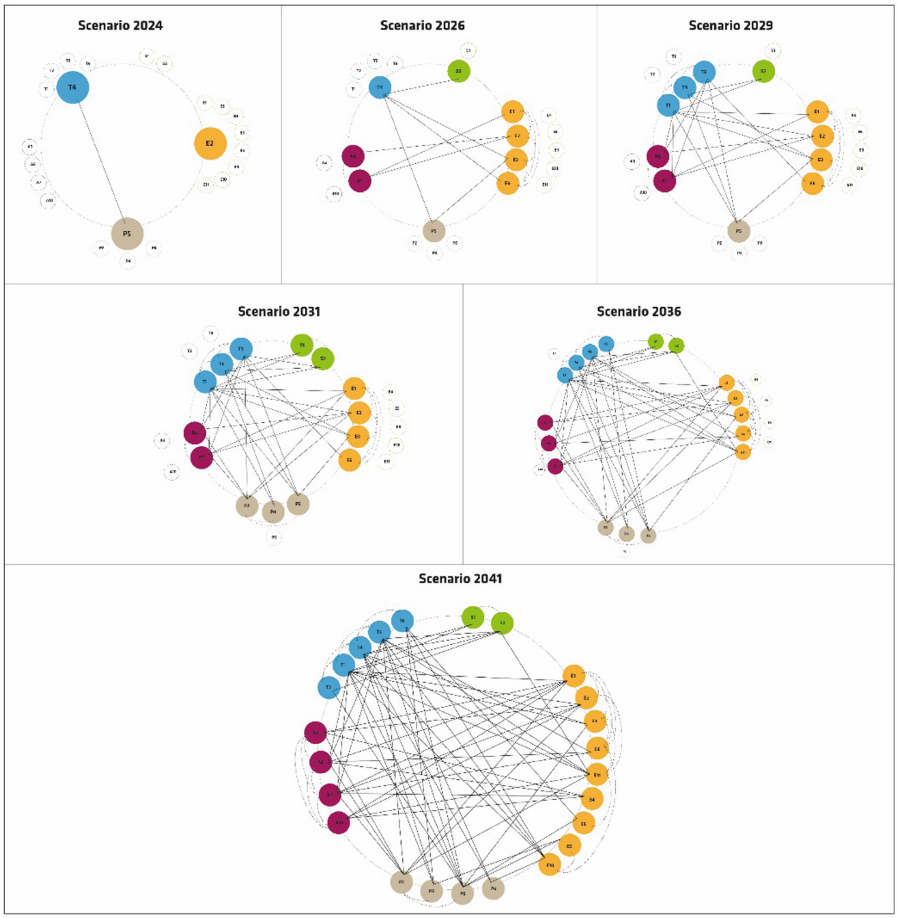

Fig. 2. System architecture, scenario 2041

time divisions. During the workshop phase, the researchers asked themselves two questions: i) How long does it take to realize each objective? ii) How do the objectives relate to each other?

As shown in Fig. 2, the various time steps, and the various relationships between objectives, allow for the definition of a complete and accurate short- and long-term preferred scenario.

4 Discussion

Starting from the "Strategic Foresight" methodology, the global changes of the last 20 years were analyzed concerning the topic of investigation: technological progress, innovative ideas and values, behaviours and expectations, previously unpredictable changes, identifying the "historical" drivers that led to the current situation and identifying the "historical" drivers that are still current. Then we identified the new "forces" of change (e.g., new technologies, new potential policies, new ideas or concepts, etc.), considering the social, technological, economic, environmental, political context. In the so-called "Horizon Scanning", we analyzed trends and counter-trends, hypothesizing their present and future impact and outlining the basis of the Preferable Scenario.

The process has allowed us to assume that, in order for the technological implementation to maintain people at the centre of the care system, understood as a bio-psycho-social system [9], it is necessary that, as of now, inter-professionalism, both health and technological, initiate solid and constant collaborations. In order for this to happen, it is necessary to initiate changes in organizational paradigms of social and economic policies. This implies a greater awareness of the influence that the areas analyzed can develop reciprocally. If, on the one hand, the political and economic class needs to initiate concrete organizational choices of wide-ranging development and actions to consolidate what already exists, on the other hand, it is necessary to implement new health and social culture among users and operators in the sector by developing training and information activities on all the aspects inherent to the implementation of the research project.

At the same time, it is necessary to develop innovative technologies that are easy, both economically and technically, accessible to the target group and specialists. Fostering greater awareness of the circularity of events, the so-called One Health, is based on recognizing that human health, animal health, and the ecosystem's health are inextricably linked.

The holistic One Health vision [10], i.e., a health model integrating different disciplines, is ancient and current. It is an ideal approach to achieving global health because it addresses the needs of the most vulnerable populations based on the intimate relationship between their health, the health of their animals and the environment in which they live, considering the broad spectrum of determinants that emerges from this relationship. The Italian Ministry of Health officially recognizes it, the European Commission, and all international organizations as a relevant strategy in all areas that benefit from collaboration between disciplines (doctors, environmentalists, economists, sociologists, etc.).

5 Conclusions

The construction of future scenarios on the theme of home care is of broad interest also outside the health sector. It is linked to various aspects and categories of products and services, from the furnishing of the home, where data collection and monitoring technologies will have to be integrated, to the professionalism of health workers to be developed to bring the most appropriate skills into the home.

At the same time, transport and communication systems will also have to be aligned with the new modes of interaction. This requires the construction of comprehensive, accurate, feasible and desirable future scenarios using Strategic Foresight and Human Centered Design methodologies, which can be the basis for political and economic decision-making processes. As a result, companies can implement strategies in the short term and be ready for the envisaged future by providing services and products adapted to society's future needs and requirements.

The boundaries drawn by humans on maps lose their meaning in the face of modern global challenges posed by climate, health, and an increasingly interconnected world. Considering ourselves as extraneous elements of the ecosystem has meant that we significantly alter 75% of the earth's surface and 66% of the seas and oceans, often without respecting their balance [11]. We are elements of a single system, in which the health of each human, animal or environmental element is closely interdependent with that of the others: this is the heart of the One Health approach, which promotes integrated management in the field of public health, and which must become the overall vision to be developed at all levels of decision-making.

It is also necessary to renew education and training courses, which primarily operate in watertight compartments and have little dialogue, limiting the development of a circular culture where the "contamination" of skills becomes increasingly important.

Understanding how much the health of living beings on the planet increasingly requires an integrated approach is enough to observe the decrease in emissions in China and Italy, a direct consequence of the restriction on the free movement made in the two countries for the Coronavirus. Integration, the sharing of programmes, organizations, training and technologies, may be the only way forward so that there are no winners or losers, but only a more balanced ecosystem, capable of conserving valuable resources, with a greater capacity for social, political, health and economic inclusion, and able to provide adequate responses to the present and future needs of the population.

Finally, the added value of this research project is the involvement of companies and professionals already working in specific fields and who are developing innovative systems and solutions not yet available to the public or limited to small contexts but which is a desirable and not so distant future will become easily accessible and widespread.

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Use of Digital Devices to Assess Vaccine Hesitancy and Promote Pertussis Vaccination Among Pregnant Women

Dario Menicagli[1(✉)], Guglielmo Arzilli[2], Elena Lucaccini[3], Giuditta Scardina[2], Daniele Sironi[2], Lara Tavoschi[2], and Pierluigi Lopalco[4]

[1] IMT School for Advanced Studies Lucca, 55100 Lucca, Italy
dario.menicagli@imtlucca.it
[2] Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy
[3] University Hospital of Pisa, Pisa, Italy
[4] Department of Biological and Environmental Sciences and Technology, University of Salento, Lecce, Italy

Abstract. The pertussis vaccination in pregnancy represents the main preventive strategy against this disease in the first trimester of life. The purpose of the study is to develop an e-health tool for assessing vaccination attitudes and to evaluate three types of communication for pregnant women, providing efficient information for their vaccination choice. One-hundred-and-five participants were assessed using a psychometric questionnaire implemented on a tablet and subsequently, they were exposed to different communication formats based on the Elaboration Likelihood Model (ELM). The participants in each group receive the same information contents on vaccination and pertussis in a different format (two provided by digital devices and one by leaflet). The difference between the post-intervention scores on vaccination intention showed that a video containing an expert-patient conversation was equivalent to the information provided by a collaborator delivering the leaflet and these two formats were significantly more efficient compared to the information provided through interactive infographics. These results demonstrate the importance of interpersonal exchange as a key factor also in the e-health tool to provide persuasive health information.

Keywords: Pregnancy · Pertussis · Vaccine · E-health · Communication

1 Introduction

Pertussis is a highly contagious infectious disease of bacterial origin caused by Bordetella pertussis. The disease affects all ages, in particular, children: in 2018, there were 35627 cases of pertussis reported from 30 EU/EEA countries. Individuals under fifteen years of age accounted for 62% of all reported cases. Children under one year of age were the most affected age group, with the highest rate of 44.4 cases per 100,000 inhabitants [1]. The disease is widespread worldwide with an endemic pattern and epidemic outbreaks

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occur every three to five years with summer-autumn seasonality. Clinically, the course of the disease is either paucisymptomatic or requires hospitalization with respiratory complications. Pertussis typically occurs as a primary infection in unvaccinated children, more rarely in vaccinated children and adults.

Vaccination offers an effective opportunity to prevent the disease, particularly in children. In 1974, the anti-pertussis vaccination was included in the Expanded Program on Immunization (EPI) established by the World Health Organization (WHO) [2]. The available scientific evidence indicates that vaccination of this category of young subjects is safe and effective in achieving protection, despite this decrease in effectiveness in subsequent months [3]. Although this approach is successful, vaccination of newborns cannot induce complete protection in the very early stages of life, when children are very vulnerable. To address this problem, the prevention of the disease in the first few months of life was made with two approaches: cocoon strategy and maternal immunization. The former concerns the protection of the infant by vaccinating the mother in the post-partum period and family contacts as potential sources of infection, while the latter regards the vaccination from the 3rd trimester of gestation regardless of the woman's previous vaccination status and to be repeated at each subsequent pregnancy.

The most easily pursued strategy is vaccination during pregnancy, which is the most effective in protecting infants during the first weeks of life [4, 5]. Vaccination acceptance is the result of a complex decision-making process that is influenced by a wide range of factors. It is therefore essential to provide pregnant women with specific education and information on the need for vaccination coverage. Interventions in this area thus make it possible to clarify what are the possible confounding factors that influence individual choice, distorting the beliefs that the individual holds about the risks and benefits of a given disease condition and health interventions [6].

In line with such a vision, we pioneered an innovative communication path to increase adherence to pertussis vaccination during pregnancy. The proposed approach included the e-health methodology, combining the intervention and the assessment phase of individual attitudinal variables related to vaccination. The study of communication and decision-making processes in psychology and behavioral economics clarified the possible frameworks provided to individuals to guide their choice, especially in a particular context such as vaccination during pregnancy [7]. The use of electronic devices within the outpatient setting allowed both to assess of a specific population on their attitude towards the prevention strategies and to create specific communication features to raise awareness and facilitate decision-making on health issues.

The theory we adopted to guide interventions in vaccination education and effective communication is the Elaboration Likelihood Model (ELM) [8]. This model describes two different ways of processing information, denominated peripheral and central routes. These two paths differ in the way they convey the message and distinguish individuals based on the effort they used to employ to process the information provided to them. Individuals highly motivated to process the message follow the central route of persuasion, while those who have a low level of motivation tend to process the message by the peripheral route. Mirroring the difference between these two paths, the strength of the arguments and contents characterize the central route requires a receiver that actively analyzes, and deeply reflects on the information presented, leading to a strong and lasting

persuasion. The peripheral route, on the other hand, is characterized by a low level of re-elaboration by the receiver, and a greater focus on the superficial and formal aspects of the message, without critical analysis and cognitive engagement, resulting in a low level of information. The persuasion achieved by the peripheral route is unstable and not lasting. The choice of whether to use one or the other channel depends on the receiver's basal cognitive capacity, need for cognition, and how long the sender wants the message to last.

Despite the ELM, being a theory of persuasion, the central route could be exploited to boost individual behavior by appealing to their rational analysis of the problem, while the peripheral route could be influenced by an approximation of the information or by emotional and social components implied in the decision, resembling other classical dual-model explaining decision-making processes [9].

These dual representations of the decision coincide when they are applied in the design of web or digital tools to foster individual behavior with a persuasive or nudging effect [10, 11].

Our study aims to design an experimental model for evaluating the effectiveness of innovative communication approaches to increase adherence to pertussis vaccination in pregnancy. The use of e-health methodology combines the intervention phase and the evaluation phase of individual attitudinal variables related to vaccination.

2 Methods

2.1 Setting and Study Design

This study was conducted in a single-blinded, parallel-group, quasi-experimental form involving a sample of pregnant women recruited in the waiting room of four different gynecological clinics in Tuscany, Italy. The study was conducted from March 2019 to February 2020. Participants enrolled were over 18 years old and had a sufficient level of literacy to self-complete a questionnaire in Italian. We obtained informed consent from all respondents and ethical approval of the study from the Ethics Committee of the North-West Regional Health Department of Tuscany.

2.2 Measures and Interventions

Each of the three interventions was divided into three different phases: participants were initially assessed with a tablet using a battery of 5-point Likert scales (from 1 - strongly disagree to 5 - strongly agree) evaluating individual levels of Vaccine Hesitancy, Risk Perception, Subjective Norms and Self-Efficacy. We used the questionnaire proposed by Shapiro et al. for this assessment [12]. After the initial evaluation, participants of each clinic were assigned into three groups based on different communication formats based on the Elaboration Likelihood Model (ELM) theory[8]. Each of the three communicative ways was equivalent in terms of the content provided (information about pertussis vaccination during pregnancy) but differed in the presented modalities, resulting in a different elaboration of the topic and a different decision-making process adopted by the participants. We considered three groups: "Peripheral-route" intervention (P), which

consists of displaying a single video representing a conversation between physician and patient; "Central-route" intervention (C), in which participants actively selected a series of short videos according to the information they found most interesting. These videos reported question-answer infographics on vaccination topics. The tablet previously used to administer the initial assessment provided both these communication formats. The last group represents the “Control group” (V), in which a standard paper leaflet about vaccination was given to the participant by the investigating physician or health care provider as a collaborator. In the post-intervention phase, the respondents were asked via the same digital tool about their intention to vaccinate. Figures 1, 2, and 3 give an example of each of the proposed interventions.

Fig. 1. Display a frame of the video that represents the peripheral intervention.

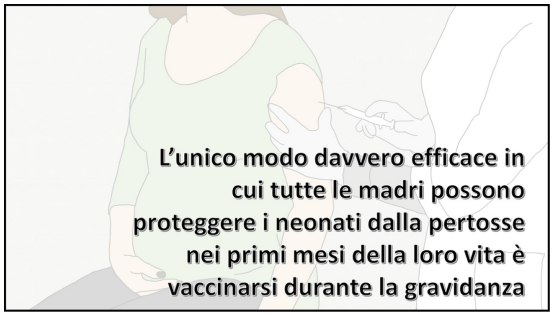

Fig. 2. Reported an example of the short video representing the central intervention.

2.3 Data Collection

The pre-and post-intervention responses were stored offline and then transferred to a password-protected cloud system. The personal data identifying the enrolled subjects were collected and stored on paper forms together with the documentation of informed consent and authorization to process the data. Each questionnaire was marked with an identification code, which made it possible to check the participant’s vaccination status from the regional vaccination register at the end of the study.

Fig. 3. Shows the Vaccine Leaflet used in the control group intervention.

2.4 Statistical Analysis

Statistical analysis was performed with SPSS 20 software. Descriptive analysis was carried out in the global sample and separated different treatment groups. An equality test for each self-reported scale was performed to analyze possible group discrepancies in the initial individual evaluation.

To analyze the effect of treatment on mothers' attitudes toward vaccinating, we carried out a linear multiple regression setting the mean score of Vaccination Intention measured after interventions as a dependent variable and treatment type as a categorical fixed factor. Self-Efficacy, Vaccination Hesitancy, Risk Perception, and Subjective Norms scale mean scores were included as independent variables.

Finally, we analyze the vaccination rate after one year with a two-way contingency table with the Vaccination Rate and Treatment types as variables. A chi-square test was performed to investigate the significant difference between treatments.

3 Results

3.1 Descriptive Analysis

We included in the study a sample of 105 pregnant women. The participants were equally assigned to each type of intervention. The mean age of all participants was 33 (IQR 29–36 years; SD = 5.573). Vaccine Hesitancy, Risk Perception, Subjective Norms, and Self Efficacy scales showed good reliability with alpha di Cronbach > 0.70. We observed that participants had a low vaccine hesitancy (mean VA = 4.374; SD = 0.588). The Risk Perception scale, as well as the Self-Efficacy and Subjective Norms assessment indexes, were evaluated in the whole sample (mean RP = 2.786; SD = 1.09; mean SN = 2.7; SD = 1.44, mean SE = 3.471; SD = 1.030).

The equality test between treatment groups showed a significant difference in Self-Efficacy and Vaccination Hesitancy between groups. Peripheral-route group was significantly lower in Vaccine Hesitancy, while the Central-route group was significantly different compared to the other two groups (Table 1).

Table 1. Shows assessment scales mean and standard deviation in treatment groups

	Treatment					
	C		P		V	
	Mean	Standard Deviation	Mean	Standard Deviazion	Mean	Standard Deviation
Self-Efficacy	$3,4_{a,b}$	1,0	$3,3_{a}$	1,1	$3,8_{b}$	1,0
Subjective Norms	$2,8_{a}$	1,5	$2,8_{a}$	1,3	$2,5_{a}$	1,5
Risk Perception	$2,7_{a}$	1,0	$2,8_{a}$	1,2	$2,9_{a}$	1,1
Vaccine Hesitancy	$4,4735_{a}$	,5410	$4,1959_{b}$	,6032	$4,4531_{a,b}$	,5936

Note: Values in the same row and subtable that do not share the same index are significantly different at p <.05 in the two-way equality test for column means. Unsubscribed cells are not included in the test. The tests assume equal variances.

3.2 Intervention Effect on Intention to Vaccinate and Vaccination Behavior

Linear regression on intention to vaccinate was significant across groups $F_{(6, 98)=}6.407$, $p < 0.001$) (Table 2). Vaccine Hesitancy score showed a significant impact on intention ($\beta = 0.4$, $t = 2.02$, $p < 0.046$), showing as expected that a higher measure corresponds to a positive attitude to vaccination, while the significant role of Risk Perception ($\beta =$ -0.29, $t =$ -2.74, $p < 0.007$) indicated the negative effect of perceived harmfulness of the vaccines. Subjective Norms did not have any role in the mothers' intention ($p =$ ns), while Self-Efficacy could be of marginal importance ($p = 0.05$). The treatment effect measured by the Intervention to Vaccinate scale was significant in the peripheral ($t =$ 3.290, $p < 0.001$) and vaccine leaflet ($t = 2.932$, $p < 0.004$) conditions compared to the central route of communication.

The Contingency Table does not show any difference between communication conditions in the following vaccination rate reported by regional administrative data, $\chi^2_{(2,105)} = 2.143$, $p = 0.343$ (Table 3).

Table 2. Reported model summary - Post-intervention intention and Linear Regression treatment effects on Post-intervention Intention. Predictors refer to the mean score for scales and treatment difference compared to central-route intervention (C) that represents the reference level, Vaccination Leaflet (V), and peripheral-route (P).

Model Coefficients - Post-Treatment intention

			95% Confidence Interval			
Predictor	**Estimate**	**SE**	**Lower**	**Upper**	**t**	**p**
Intercept [a]	1.1708	1.0515	-0.91579	3.2574	1.113	0.268
Trattamento:						
P – C	0.8967	0.2725	0.35591	1.4375	3.290	0.001
V – C	0.8064	0.2750	0.26067	1.3521	2.932	0.004
Self-Efficacy	0.2259	0.1140	-3.27e−4	0.4521	1.982	0.050
Subjective Norms	0.0700	0.0794	-0.08762	0.2276	0.881	0.380
Risk Perception	-0.2947	0.1072	-0.50754	-0.0819	-2.748	0.007
Vaccine Hesitancy	0.4213	0.2085	0.00756	0.8350	2.021	0.046

[a] Represents reference level

Table 3. Shows Contingency Tables related to vaccination rate after one year from the intervention.

	Intervention			
Vaccination	**C**	**P**	**V**	**Total**
No	16	18	22	56
Yes	19	17	13	49
Total	35	35	35	105

4 Discussion

The use of digital methodologies and tools consent simultaneous assessment and intervention in the promotion of healthy behavior. E-health approaches need an accurate design that defines the experience of the health professional and the patient in their use, facilitating evaluation and communication procedures for health purposes [13]. This study aimed to develop innovative communication approaches to increase adherence to pertussis vaccination in pregnancy. The results showed that there was good heterogeneity in the sample regarding the variables analyzed. Vaccination hesitancy, self-efficacy, risk perception, and the impact of subjective norms on mothers' decisions showed a good distribution through the interventions performed. We showed how these factors influenced post-intervention vaccination intention and related vaccination. If self-efficacy did not

bring any change in intention, risk perception of vaccination was inversely proportional to vaccination intention during pregnancy. Vaccination hesitation as expected leads to a greater to a corresponding lower vaccination intention.

Describing the impact of our interventions, the peripheral and control interventions were found to be more effective in modifying post-intervention intention than the central route. This result is in contrast to the existing literature which emphasizes that an intervention linked to the central pathway is more effective than the peripheral [14]. The reason that could explain this discrepancy could be the specific design of the content proposed with the central intervention, which was not easy to understand and required too much effort for the participants. Despite the effect of the central route being described as more long-lasting, the cognitive effort required by this category of processes could be ineffective if the subjects do not pay attention or are not interested in scrutiny the information regarding the topic. On the contrary, the impact of the peripheral route and vaccination leaflet interventions rely on the same mechanism linked to the interpersonal dialogue with a medical or health professional. The importance of authority is one of the key persuasive strategies linked to the peripheral route and our study demonstrated efficacy in a digital version proposed through the tablet. The leaflet intervention was initially intended to represent a control condition, but it increased the chance of contact and possible questions from the participant to the collaborator. The face-to-face relationship established with the study collaborator during the delivery, even in the minimum time available, could result in a more incisive effect for the mothers, with an emotional and social impact similar to the fictional conversion filmed in the peripheral video [15].

The lack of difference between the proposed interventions compared to the final vaccination behavior could be explained by external factors. The limitations of this data were various, but surely, the role played by the COVID-19 pandemic on access to the prevention service may have been crucial. The last part of the sample was collected in February 2020, just before the first lockdown experienced in Italy. Although the service did not cease, some of these women ended their pregnancies during the period when most of the public health efforts were devoted to COVID-19 case contact tracking.

The possibility of accurately designing an e-health intervention that investigates different persuasive approaches to vaccination information demonstrated how the reproduction of emotional and interpersonal communication could be more effective to modify individual reported intention compared to the effortful and reflective commitment of the subject. The digital features of the intervention showed how an electronic simulation of interpersonal conversion has a persuasive power linked to cognitive and social representation more incisive in particular during a rapid intervention [16]. This simulated dialogue could be compared to the real personal exchange with a health operator performed in the same medical environment.

5 Conclusion

We implemented and assessed the impact of different communication strategies to promote vaccine uptake among pregnant women. Our results suggest that comparable effects may be obtained using simulated or live patient-physician communication, in particular adopting an emotional and socially meaningful format related to the peripheral route of

persuasion. This kind of content could be designed in a digital tool with a comparable effect to a real-life interpersonal exchange.

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Nudging for Hand Hygiene

G. Frangioni(✉), K. P. Biermann, M. de Luca, C. Furiesi, D. E. Papini, E. Parente, M. Pirinu, L. Tacchini, L. Vagnoli, V. Vizzarro, and M. Guasti

Meyer Children's Hospital IRCCS, Florence, Italy
gabriele.frangioni@meyer.it

Abstract. Prevention of healthcare related infections requires appropriate hand hygiene before and after procedures. Hand hygiene is one of the main Patient Safety Practices. Compliance and upholding have to be supported by a correct behavioral, organizational and structural approach. A Team expert in Human Factors and Ergonomics (ERGOMeyer) has developed an implementation and support service that collects the contributions of cognitive psychology and the theory of nudging, through point of care and thoughtful communication. An increase in adherence to hand hygiene up to 92.2% in 2021, an increased use of alcoholic gel, both certainly also related to the precautions implemented to cope with the SARCoV-2 pandemic, and infection rates close to the standard values were observed. It also ensured an appropriate management of critical issues due to the pandemic. By planning a good architecture of choices, it is possible to act on the behavior of operators and users, encouraging the correct actions and increasing patient safety.

Keywords: Infection control · Patient safety · Human-centered design · Communication · Human factors · Ergonomics

1 Introduction

1.1 International Background

Hand hygiene is central to the prevention and control of healthcare associated infections. The Region of Tuscany has adopted the Patient Safety Practice (PSP) "Clean Hands" by Resolution of the Regional Council no. 267/2007. The regional "Centre for Clinical Risk Management and Patient Safety" revised and published the data sheet in 2017 [1].

Since 2006, Meyer Children's Hospital has been adopting and implementing the World Health Organization (WHO) guidelines [8] and PSPs for Hand Hygiene [1] based on scientific evidence. It ensures the use of the practice by distributing posters, cartoons and reminders, as well as training operators, informing patients, their parents and visitors and monitoring adherence to the PSP. It also provides Healthcare Workers (HCW) and users with prevention tools such as detergents, disinfectants and hand hygiene wipes [2, 3].

Behavioural sciences introduce the concept of Nudging that, through a "gentle push", directs us towards a good architecture of both individual and social choices. The way in which environments are designed influences our choices and determines our actions [7].

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Human Centered Design (HCD) aims to manage complexity, transforming what seems complicated into a tool that is suited to the task, comprehensible, usable and enjoyable. The use of defaults, automatic actions, is an effective way to simplify interactions with the complex world we live in. Defaults are one of the most effective tools for acting on behaviour. [5].

The Nudge theory can helpful in the application of PSPs, can increase the adherence of operators and optimise the use of control, communication and monitoring tools.

The project started when the PSP adherence rate at AOU Meyer in 2017 was 38%, requiring a major improvement programme.

2 Material and Methods

2.1 Hand Hygiene Programme

The Hand Hygiene programme was launched in 2017 under a mandate from the Chief Executive Officer to the Clinical Risk Manager. Following the request of the Clinical Risk Manager, the programme was implemented by the ERGOMeyer Strategic Operational Unit (NOS), a multidisciplinary team for the continuous improvement of safety and quality of care in the field of Human Factors and Ergonomics (HFE).

The ERGOMeyer team, formed by professionals from the medical, nursing, psychological, rehabilitation, engineering, physiotherapy, architectural and communication disciplines, carried out a design and development centred on patients and HCWs.

The programme was conducted in the following steps:

- Mapping of alcoholic-based hand gel dispenser: Sep - Oct 2018
- Planning of the Hand Hygiene service: Nov - Mar 2019
- Installing alcoholic-based hand gel dispenser: Mar - Dec 2019
- Planning and implementation “Communication Plan”: Mar - Dec 2019
- Implementation of delivery points: Jan 2020 - current (new areas)
- Communication plan: continuous
- Monitoring: continuous

The programme was preceded in March 2018 by a training of nursing contact persons in the operational units for the application of the “Framework Hand Hygiene WHO” [8].

The programme includes the managing of more than 400 wall-mounted dispensing points (Fig. 1) according to the Point of Care methodology, as well as an installation, maintenance and monitoring service for the dispensers (manual or automatic). There are also more than 200 desktop dispensers for outpatient areas, reception, workstations, etc.

The service is supported by a Communication Plan (Figs. 1, 2) which includes the application of posters, the highlighting of dispensers, the display of cartoons on monitors (Figs. 3, 4), and information for operators and users. A standardised image was identified through a Communication Plan and disseminated by means of posters, point-of-delivery displays, flyers, articles on Meyer Children’s Hospital intranet and internet pages and cartoons “In Terms of Safety we are a Great Team, Clean your Hands” (Figs. 3, 4) [2–4].

Fig. 1. Wall-dispensing points

Fig. 2. Meyer Children's Hospital Hand Hygiene Poster

Observers from inside and outside the units using the "WHO Observation form" [8] carry out monitoring. The results are sent first monthly, then quarterly to the operational units.

The introduction of the Points of Care and communication were developed by applying the Nudge theory. Permanent and mobile Points of Care are located at the points of highest accessibility and passage during the care processes, in order to encourage spontaneous use of the alcoholic-based hand gel dispenser. A repeated communication on posters, screens, dispensers and internal information media constantly addresses the message of Hand Hygiene.

An integrated microbiological surveillance system, with instant feedback of critical values, is being developed on the electronic medical record. This system will allow daily monitoring of critical values and provide proper patient care.

Fig. 3. Frame Cartoon n 2 "Hand Clean" of the Cartoon series "In Terms of Safety we are a Great Team, Clean your Hands" [4]

Fig. 4. Screen wall, Cartoon n 2 "Hand Clean"

The programme is constantly updated with the development and adaptation of spaces and in relation to needs and criticalities (e.g. COVID adaptations, new areas…).

3 Results

The programme has shown significant results in terms of PSP adherence. The observation collected pre (2017) and post (2021) project delivered the following facts:

- A decrease in the incidence rates of nosocomial Rotavirus Gastroenteritis from 1.15 to 0.26 per 1000 hospital days in seasonality (November - December, January - May); (Fig. 5)
- A decrease in the point prevalence rates of Healthcare associated Infections from 7.3% to 2.6%;
- An increase in the overall adherence rate to hand hygiene from 38% to 92.2% (Fig. 6).

Due to the application of continuous observation, based on the WHO Frameworks, the average adherence in 2019 was 78.4%, which comes close to the WHO standard for hand hygiene PSP (80%). In fact, the WHO Standard was met / surpassed in 5 out of 12 months. In 2020 and 2021, the standard was always met / surpassed in 12 months.

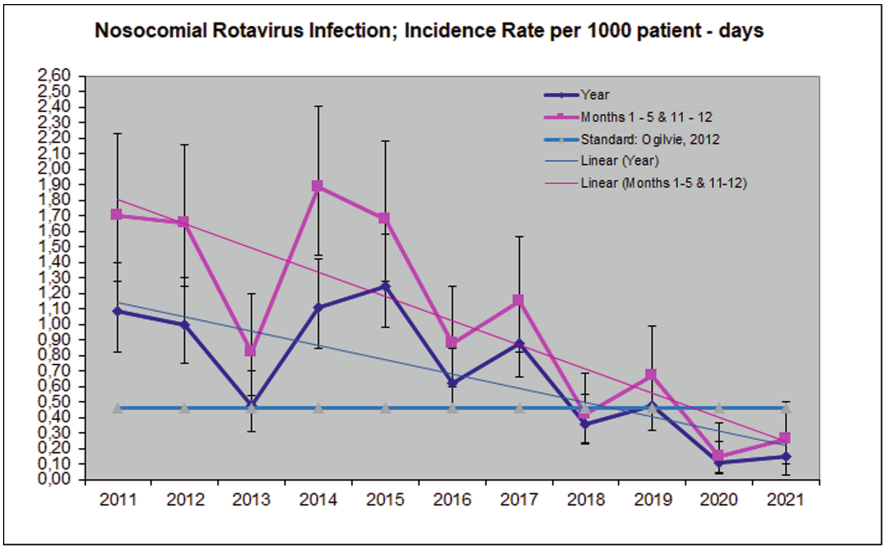

Fig. 5. Incidence rates of nosocomial Rotavirus gastroenteritis at Meyer Children's Hospital. Standard: 0.46 (0.00–1.87, Ref. Ogilvie I, 2012)

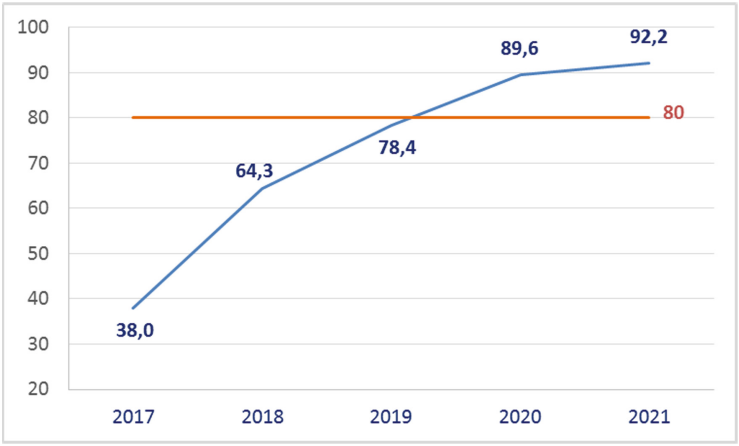

Fig. 6. Hand Hygiene PSP adherence rate 2017–2021, Meyer Children's Hospital vs Standard WHO (≥80%)

4 Discussion

The results provide us with important data and support us in keeping a high level of attention to safety indicators.

The pandemic year 2020 and 2021 presented a significant "stress test" for the Hand Hygiene programme. The infrastructure created made it possible from the early months of 2020 to guarantee stock management even when supplies were very low. It has also

ensured the availability of a punctual widespread system of alcoholic-based hand gel dispenser.

During the pandemic year, the lack of this prevention programme could have created important criticalities in Risk Management.

The implementation of new spaces and paths necessary for user management followed the methodology applied in the implementation phases of the Hand Hygiene Programme. This guarantees that the safety levels of the PSP are maintained.

The programme will be progressively extended to the new areas of the Family Center, Meyer Health Campus and the new outpatients' facility.

5 Conclusions

Hand Hygiene as a central element of infection prevention is essential for achieving Patient Safety.

The work of analysis and development carried out by the ERGOMeyer Team has made it possible to optimise processes and reduce implementation times, ensuring a unified and systemic vision of the interventions.

The application of the tools and methods of Human Factors and Ergonomics enabled the correct identification of needs and the implementation of a Human Centered service.

The contribution of the Nudge theory, allowed through the processes of choice architecture to include solutions within the reach of Healthcare Workers, patients and relatives. This theory can present a new opportunity in planning processes and give additional input into the design and development of working environments.

Acknowledgments. To all the Healthcare Workers that contribute to the continuous improvement of the programme and that in these years are managing the critical issues related to the pandemic.

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ERGOMeyer for Patient Safety and Quality of Care: Ergonomics in a Children's Hospital

G. Frangioni(✉), M. de Luca, C. Furiesi, D. E. Papini, E. Parente, M. Pirinu, L. Tacchini, V. Vizzarro, and L. Vagnoli

Meyer Children's Hospital IRCCS, Florence, Italy
gabriele.frangioni@meyer.it

Abstract. Increased complexity in healthcare environments, together with scientific and technological advances, require advanced research and resource support, and need an approach based on human factors and ergonomics. Meyer Children's Hospital has instituted a Strategic Operational Unit called "ERGOMeyer", to support Risk Management for the safety and wellbeing of healthcare workers and patients, to improve the performance of the organization and to achieve international standards of safety and quality of care. The ERGOMeyer Team operates in the areas of Human Factors and Ergonomics, Clinical Risk Management, Simulation in paediatrics, Health, Safety and Environment. In the four years of activity, important projects have been carried out regarding prevention of infections, patient identification, safety in surgery, and the re-organization of healthcare environments.

Keywords: Human factors · Human-centered design · Healthcare design · Simulation · Risk Management

1 Introduction

1.1 International Background

Improving patient safety in Healthcare has been a slow process, despite the commitment and efforts of individual healthcare professionals. Patient Safety confronts us with complex problems that are rarely caused by a single factor or component of the system [7].

The steadily growing technological advancement of products and services is increasing cognitive stress on operators and the complexity of healthcare environments, requiring advanced support in terms of research and resources, and introducing new risk factors that require preventive actions in terms of implementation.

Human factors analysis, defined as "the study of interactions between human beings, the tools they use and the environment in which they live and work", is very important for the development of healthcare facilities [12]. This analysis is conducted by learning

M. de Luca, C. Furiesi, D.E. Papini, E. Parente, M. Pirinu, L. Tacchini, V. Vizzarro, L. Vagnoli—Alphabetic order.

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about the interactions between people and the physical fixed, mobile and technological interfaces available [9].

Dul, in the paper "A strategy for human factors/ergonomics: developing the discipline and profession" states that "Human Factors and Ergonomics (HFE) focuses on systems in which humans interact with their environment". The environment is complex and consists of "physical environment ('things'), organisational environment (how activities are organised and controlled), and social environment (other people, culture)" [2].

Colman affirms, "Healthcare is a complex adaptive system, and the interplay of its components contributes to medical errors, adverse events, employee, and organizational outcomes. The Institute of Medicine (IOM) and the Agency for Healthcare Research and Quality (AHRQ) promote the application of systems engineering and human factors to understand how complex interactions between people and their environment contribute to patient safety and quality" [1].

The Meyer Children's Hospital in Florence, in collaboration with the "Centre for Clinical Risk Management and Patient Safety of the Tuscany Region" (GRC Centre), has adopted these elements with the awareness that HFE can have an important role in Paediatric Healthcare [11].

The requirement to act proactively on critical issues and complexities in the paediatric context has led Meyer Children's Hospital to establish an Advanced System of Risk Management (Fig. 1). This system integrates the areas of "Clinical Risk Management", "Health, Safety & Environment Service" (HSE), "Paediatric Simulation" (SIMMeyer, Paediatric Simulation Centre), "Human Factors and Ergonomics" (NOS ERGOMeyer) [4–6].

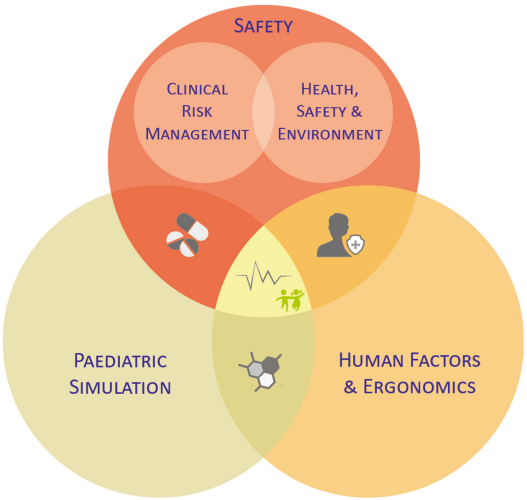

Fig. 1. Advanced system of risk management, Meyer Children's Hospital

2 Material and Methods

2.1 ERGOMeyer for HFE in Paediatric Hospital

From the interaction between Clinical Risk Management and Paediatric Simulation, the "ERGOMeyer" programme was established in May 2018.

The programme is a new approach to risk management for safety and wellbeing of Healthcare Workers (HCW) and patients, to improve system performance and to achieve international standards of safety and quality of care.

In February 2019, the programme evolves as the "Strategic Operational Unit" (NOS), in order to:

- Develop tools and methods of HFE, in the physical, cognitive and organisational components of systems;
- Enhance human wellbeing and performance in living and working environments;
- Identify all those elements that prevent errors.

It is implemented with a systemic and multidisciplinary approach by the ERGOMeyer Team (EMT), composed of specialists from different disciplines (medicine, nursing, psychology, architecture, engineering, design, communication) and coordinated by an Ergonomist. It ensures educational support for healthcare and non-healthcare workers and students in understanding HFE.

The EMT is joined by a Support Team consisting of the Technical Office Manager, an Organizational Psychologist, and a Head Nurse of the Health Professions Department.

Since February 2020, the EMT has been integrated with a member of the technical office, and a physiotherapist (Fig. 2), previously in the Support Team.

Fig. 2. ERGOMeyer team

Since 2021, a roadmap has been started with HSE, in order to integrate all safety aspects (patient, operators, environment and facilities).

The NOS ERGOMeyer operates through services called ERGOSIM, ERGO on Demand, ERGOSafe [3].

ERGOSIM. The term refers to HFE and Paediatric Simulation for the proper design, implementation, organisation and setting up of spaces.

Using different project scales, the aim is to develop environments through Full-scale and Desktop Mock-ups, including Digital Mock-ups, in order to eliminate all those latent risk factors that could be generated in the various phases of the project or service, from ideation to implementation. It also aims to act on the active factors to facilitate the work of the HCWs.

In existing environments, the aim is also to optimise spaces through "In Situ Simulations" carried out together with the operators working in the settings subject to the simulation. Environments and HCWs are "stressed" through emergency scenarios.

ERGO on Demand. HFE to support HCWs and services that require an ergonomic assessment and/or intervention regarding environments, equipment, workstations, devices, documents, procedures, operating instructions, forms, work-related stress, etc.

Specific forms are available for intervention requests.

ERGOSafe. HFE and Clinical Risk Management, activated by the Clinical Risk Manager following events with patient injury and/or Sentinel Events for the analysis of the causes that led to the event.

Proactive analysis and intervention on critical issues identified in the system.

2.2 HFE Studio

The renovation of the Meyer Health Campus will lead to the creation of the "Bottega di Ergonomia" (HFE Studio) that will be a laboratory for the development and application of methods and tools for ergonomic assessment and intervention, imagined as a transposition of the Florentine Renaissance "Bottega" (craftworks). It will be a point of research, simulation, experimentation and development of new elements and a place of dissemination and training for HCWs, users, professionals, students and companies.

3 Results

The development of ERGOMeyer has been conducted through progressive phases of EMT training and project implementation, enabling important operational growth of the whole organization.

EMT training is planned with the support of an ergonomist.

In October 2019, a company-wide Workshop on Ergonomics in the Hospital for Nursing Coordinators and Physicians with the role of facilitators in the clinical risk management was held. From May 2022, the workshop activity continues with several editions.

Ongoing training of the team is a basic element and is planned annually, with the aim of gathering contributions also from non-healthcare sectors. (e.g. Aeronautics, Economics, etc.).

The system introduced has allowed the development of complex projects that have produced important results in terms of safety and improvement of products and healthcare environments, like in the following examples.

3.1 Hand Hygiene

Combining WHO guidelines and tools, Patient Safety Practice (PSP), and Thaler's principles of Nudging [10], a widespread infection prevention plan was developed by updating and implementing the experience conducted in the Meyer Children's Hospital since 2006.

After an initial phase of mapping the existing supply points for alcohol-based hand sanitizers, more than 400 wall-mounted points, including Points of Care at patient's bedside, and more than 200 desktop dispensers for outpatient areas and workstations were implemented.

A standardised image was identified through a Communication Plan and disseminated by means of posters, point-of-delivery displays, flyers, articles on Meyer Children's Hospital intranet and internet pages and cartoons "In Terms of Safety we are a Great Team, Clean your Hands" [8].

Hand Hygiene results are reported quarterly to the Operating Units. A microbiological surveillance system linked to the Electronic Medical Record (EMR) is being developed.

This plan has led to an average hand hygiene compliance rate from 38% (2017) to 92,2% (2021), an increase in the use of alcoholic-based hand gel and to infection rates close to standard values.

3.2 SAFE (Situational Awareness For Everyone): Safety of Care in Paediatric Surgery Teams

The project has started in March 2019 with the support of the GRC Centre, to improve adherence to clinical risk management tools in the Surgical Area, through a general review of pathways and direct involvement of teams, in order to increase collective awareness.

The process involved operators from the Operating Rooms (OR) and the Clinical Risk Management staff, through observations, meetings and interviews. The analysis allowed optimisation of the surgical pathway through the review and testing of existing risk prevention and management tools (Surgical Patient Safety Checklist, Handover, Anaesthesiological Assessment Consent, and Informed Consent) and a reorganisation of activities of the various OR teams.

In addition, the project showed an increased utilisation of surgical check list which includes items of patient identification process and infection prevention practices.

3.3 ID Wristband for Patients in Neonatal Intensive Care Unit

The study started from the need to identify neonatal or premature patients in the absence of parents and to achieve International Standards of Patient Safety. The lack of solutions at international level required careful market research to identify wristbands suitable for the baby's delicate skin and compatible with hospital technology (printers and EMR).

The study involved nurses from the Neonatal Intensive Care Unit (NICU) and two Master's students in Paediatric Nursing in testing the solutions identified and their successive optimisation. A key factor was the comparison with the companies to identify the best solution in terms of management, flexibility and integration with existing infrastructure.

The study resulted in a skin-friendly product, suitable for the skin of Newborn babies in the NICU, consisting of a soft component in contact with the skin and a section to apply the label with the patient identification data. The wristband can be integrated with existing hospital technology (e.g. printers, EMR, etc.) and enables secure patient identification.

3.4 Emergency Room

In the context of ERGOSIM, a study was carried out on the reorganisation of the Emergency Room of the Emergency Department, through the analysis of the Video Recordings made during In Situ Simulations, in order to optimise the work of the HCWs during the emergency phases.

The new organisation was tested through several simulations with different teams in order to identify the remaining risk factors. Two days of simulation testing of solutions were carried out. The second day included the modifications identified in the first day.

Pre- and post-simulation video recordings showed a significant reduction in the movements of HCWs in handling materials, devices and drugs during emergency procedures.

3.5 Tackling the Pandemic with HFE

Since March 2020, the EMT has been working on several fronts to respond to the present pandemic emergency, supporting HCWs in dealing with the critical issues. The ergonomic approach was fundamental to the reorganisation of spaces (Intensive Care Unit, Emergency Department, Drug Preparation Areas, etc.), the evaluation of COVID paths, HCWs workstations, optimisation of EMR, etc.

This process has led to the formation of a "Working group for improvement of healthcare environments" in which ERGOMeyer is an integral part together with managers or referents of HSE, the Technical Office, the Healthcare Management, and the Purchasing Office. ERGOMeyer is the contact point for the assessment and development phases of each modification proposed.

4 Discussion

The NOS ERGOMeyer acts as an interdisciplinary support for the operators and a link between the management and the operational units.

The wellbeing of operators is essential to promote safe working environments. Our aim is to take the "stories" of HCWs and users and make them together into designs, products and environments that are safe and developed for their needs and those of the patients.

Applied Research and Innovation are the elements that will guide us in future implementations. Proactive analysis allows us to develop our systems by working on the present. Early, anticipatory analysis will allow us to contribute to tomorrow's healthcare by developing a network of skills and partnerships with professionals, researchers and universities. We need to anticipate risks, eliminate latent factors from design to implementation stages, so that we can focus on active factors that occur in our healthcare settings.

Innovation for paediatric age will necessarily have to pass through the development of products, environments, organisations and services, affecting all places where children live. In the awareness that people's wellbeing is built from birth, together with their families, professionals and institutions.

5 Conclusions

The data was collected using a qualitative analysis method. The future aim should be to use methodologies that allow proper quantitative analysis.

Training, information and support activities will also have to be implemented to increase awareness among HCW in the use of HCF analysis and intervention tools.

In a past interview, Captain Chesley Sullenberger, the senior crew member of the Hudson River aircraft incident, is reported as stating [9]:

> *"Safety should be part and parcel of everything we do… In healthcare are islands – visible islands of excellence in a sea of invisible failures, with risk lurking just below the waterline. We need to widen those islands of excellence. We need to connect these islands with more dry land. We need to address these areas of risk…"*

Ergonomics has the challenge of connecting those *"islands of excellence"*, making them interact and communicate. Gathering the stories of HCWs, from the front line to management, can help us bring to light active and latent errors and transform them into opportunities for improvement and change. In other words, building bridges over a visible sea of resources in a future of safe interaction.

We have the technologies and tools to create safe and humane environments. We must communicate and structure our organisations dynamically, learn to manage complexity, work on human factors and ergonomics.

Acknowledgments. To all the operators who provide us with "stories" every day to improve our organisation.

To the members of the ERGOMeyer Team who constantly contribute with passion to the safety and wellbeing of patients and workers and to the innovation of healthcare environments.

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An Action Research for System Change in Nursing Homes (NHs)

Giulia Lefosse[1(✉)], Laura Rasero[2], and Tommaso Bellandi[3]

[1] Phd Clinical Science and Risk Management, University of Florence, Italy DMSC Largo Brambilla 3-50134, Firenze, Italy
giulia.lefosse@unifi.it
[2] Phd Clinical Science and Risk Management, University of Florence, Largo Brambilla 3-50134, Firenze, Italy
[3] ASL North West Tuscany, Azienda USL Toscana Nord Ovest, edificio B IV Piano Corridoio B, Cittadella Della Salute, Via Ospedale, 1, 55100 Lucca, Italy

1 Introduction

1.1 Context

Long term care (LTC) reality, in particular Nursing Homes (NHs) represent a very diversified and complex environment. The intrinsic heterogeneity, the demographic change of the population and of the national health system in recent years (increase chronicity, territorial absorption of patients, ageing population, etc…) affects the quality and safety levels of long-term care support services. The quality and safety of care in NH and LTC are less studied by scientific research and health policies compared to health services [1]. To undertake pathways of systemic change it is necessary to know the reality of these contexts. Also taking that what we are going through is a period of inevitable and desired transformation and reorganization of LTC in Tuscany and Italy. First of all, it is necessary to reflect and analyze the needs of these realty and their staff, organizational level, resources and skills [2]. The aim is to imple-ment most appropriate choices to respond to needs of people and families who live experience of life in NH. The emergency situation made it necessary to fight many problems and face managerial and structural changes, that at another time would have seemed insurmountable. The NHs, in particular, have seriously blamed the waves of Covid-19, remaining uncovered in terms of resources, staff and support of health services [4]. LTC context is characterized by intrinsic fragility and the pandemic has highlighted it; NHs population is made up of frail patients, consequently exposed to greater risks and adverse events [5]. The most common concern infections but also behavioral disorders, immobilization syndrome, emergencies management, therapy and drugs management, nutritional risk, polypharmaceuticals, escapes and the use of contain [5]. We can find as many difficulties in quality assistance dimentions: development of desires, need for communication, relationship with family members, relations with community etc. … [6]. Until a few yers ago this fragility was contained because the series of events was reduced and low traceable. In recent years, however, the LTC's patients' complexity has grown and risks proportionately. The safety of care is recognized as a fundamental right of human being and 24/2017 Italian law lays

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foundations for a redefinition of care paths and fields of application in the field of social and health services, making health professionals the guarantors of this right. Law 24 is aimed at all LTC organizations, requiring them to systematically define, analyze and prevent risks [7]. The same is required by new Tuscany Regional accreditation system [8], underlining the need to implement skills of professional healthcare. The epidemiological curve's change has seen NHs destined to redefine the health system, moving care from the hospital to local area. In line with this inevitable change, staff of the NHs will be called to take roles with require greater professional judgment, organization and adequate resources. The question we should ask ourselves is: are the NHs ready?

1.2 Background

According to conducted research, the factors that influence safety incidents in NHs are both intrinsic to patient (age, sex, co-morbidities, depression, cognitive deficits, functional status, compliance) and extrinsic (team experience, staff training and education drug management, patient monitoring, patient assessment and reporting, documentation, communication between multiple levels of functioning, staff workload [9]. There is often shortage of material and structural resources, inadequate contracts for staff, heavy workloads, high tour over rate [10–12] and lack of adequate training [13, 14]. Lack of resources, staff frustation and turnover, negatively affect safety and quality of care. The same is true for the lack of training, since there is a direct link between training and a culture of safety, between competence and measurable adverse events. [15, 16]. According to the WHO (World Health Organization) [17] strategies are needed to ensure the adequacy of staff with appropriate skills mix and awareness for most vulnerable population. During 2016, WHO calls on healthcare professionals and policy boss to look beyond disease states and move towards a holistic methodology, in which disease prevention and maintenance of function, become the main aims [18]. Skills should therefore be improved by educating health professionals, creating conditions for continuous learning [19]. During Covid-19 pandemic, to respond to NHs needs and fill the pre-existing gaps, it was necessary to have resources from hospital services (for example moving, professionals and tools to patient's bed) [20].

This "replacement" solution was fundamental during emergency, but should invite us to reflect and look beyond. It is certainly necessary to transfer these skills and resources, not in a substitute way, but in an educational and integrative way. Health care system advanced goals cannot be separated from quality of education and integration of LTC services, but, despite this, they do not always represent a priority for policy makers and professionals. Improving quality and goals should be seen as a way of addressing change in care, focusing on self-reflection, honestly assessing needs and gaps, and addressing them in a multifactorial way [21]. This is why it is important to reflect on how and what are the most effective methods to improve the quality and safety of care, especially in such a difficult context. From the literature reviews it emerges that qualitative research is an optimal tool for the study of this kind of reality, given the need to adopt an interpretative and ethnographic approach [22–24]. It is necessary to adopt a systemic approach method, preserving the peculiarities and diversifications of the observed setting, while maintaining a standard rigor guaranteed by methods and tools used, as well as by the skills of researchers [7].

This study aims to investigate and understand the levels of quality and safety within NHs, their weaknesses and strengths, and to define an "ad hoc" intervention that can improve performance, including good practices, developing culture of safety and reduce preventable errors.

2 Methods

This study follows action research method. It analyzes practices relating to field of experience with the aim of introducing substan improvements [25–27]. It is qualitative research with a systemic approach, based on analysis of interactions in real practice between human factors, technologies and organizational structures and processes [28]. It is an innovative approach based on ergonomic models, that analyze system as a whole and the correlations between the elements that populate it. It has a complex development, based on site observations of daily practices, inter-views with workers and patients, participatory interactive sessions for redesigning care processes. With 2 resolutions [29, 30], Tuscany Region allocated funds to conduct research and observe levels of quality and safety of care in 10 NHs in the Region (of which 7 were observed). The study was conducted in agreement with management of NHs and keeps privacy of patients and workers. Inclusion criteria were defined by study group to select a sample that was representative of the average Region Nhs. Inclusion criteria are: public proprerty, rural or urban site, location in different areas of Tuscany Region, performance levels found in accreditation assessments (some high-performance, some low-performance) [31] number of beds (from 20 to 100) and presence of dementia's core [32].

2.1 Field Observations Methodology and Data Analysis

Field observations and training interventions were conducted by two trainers-researchers (one nurse specializing in risk management and LTC and a research psychologist specializing in geriatric age psychology). For data colection and field observations, an original framework was created and used, with the definition and dimensions of quality indicated by WHO, considering how quality assistance can be measured [33–35]. Data were collected through field observations carried out with least possible interaction through an explicit, non-participating modality, with the shadowing technique [36], guaranteeing as much as possible the neutrality. Sampling of the people observed was "snowball", following the natural unfolding of the activities guided by the observation units [37]. Time units are the peak care hours of a day in NH, in particular time of awakening, breakfast, educational-animative and physiotherapy activities (7.00–10.30) and during evening from the animative activities, to dinner until night rest (17–20.30). In some cases, brief ethnographic interviews were conducted with operators and assisted persons, to better understand meaning of activities carried out and of life in NH [38]. Observational notes collected are reworked and analyzed, supported by reference literature, international protocols, recommendations and finally reviewed by two expert reviewers (a nursing

manager and a patient safety manager with experience in ergonomics and human factors). Results were approached according to grounded theory methodology, in which the theoretical constructs to which observations refer are constantly compared, in order to adapt and redefine them starting from the collected material [39–41]. Data are thus interpreted transversely, applying clinical and ergonomic interpretations, identifying critical skills and strengths detectable from the observed behavior and situation. The collection and processing of data is then used to conduct the training intervention.

2.2 Training Intervention Methodology

Training intervention is inspired by elements that emerged from the review of the literature, regarding elements and training methodology to affect risk prevention impact [42, 43]. Training program is spread over 16 h, 8 for each working group. Follows bottom-up technique on small multidisciplinary groups, including all professional NHs figures (including top management). It is structured in interactive meetings divided in two thematic days: the first with focus on critical issues, called "The NO Day", the second with a focus on strengths called "The YES Day".

The purpose of interactive meetings is to bring out criticalities and strengths of structure, through thematic analysis without predefining the "hot" issues of care. This method borns from different reflections of working group and trainers, consideration the need to listen professional healthcare experiences, both from an emotional and professional point of view, deconstructing rigid constructs generated by a hierarchical and frontal training [44, 45]. This methodology based on the need to trace learning back to professional experience, expecially if concerns event with a high emotional impact (how it could be an adverse event) [46, 47]. Furthermore, we believe that sharing of cases or events brings the working group closer, creating a sharing climate, both as regards critical events and positive events, focusing attention to used resources to prevent an unfortunate event. At the end of sharing of events, the emerging themes are summarized in real time through a concept map on witheboard.

This method supports emotional learning with cognitive constructs, helping to relate emerged elements in a network that recalls system concept. [48]. When salient thematic areas have been identified, trainers proceed based on literature, guidelines and best practices, constantly tracing the contents back to examples of daily practice. These examples may derive by the suggested themes, to what emerged during field observations or by clinical cases external that particular context. The weaknesses analysis that emerged (for example falls, healthcare-related infections, drug therapy errors, escapes, nutritional and dehydration risk, emergency management …), is structured both from theoretical point and by providing suggestions for real good care practices.

At the end of first step of trainign days, staff is divided into small groups (maximum 5 participants) to work on most relevant themes. Therefore, using focus group methodology, each group is entrusted with a theme and to analyze it. This aims to strengthen teamwork, through sharing of critical points and strength and a possible improvement action that could be undertaken. This could provide participants with the identification of common aims and clarify a collective vision, for once, not imposed in a top-down way, but by the group itself according to own points of view and methods [49]. The works comes then exposed to everyone through a spokesperson.

At the end of the two days the trainers structure some scenarios and management data sheets, to be developed for next meeting (up to 1–3 months). Scenarios are real clinical cases that invite working groups to reflect critically and systemically, starting from a story which reports adverse or critical events of daily work practice and invites them to abstract, to define a plan for risk prevention.

Management data sheets are a model of procedure or protocol, with some indication to draw up or revise it. It's providing a solid and formal structure, with the aim of standardizing the action, normally carried out in routine way, in a logical and systematic scheme. For the development of management data sheets, it may be necessary to read the literature, protocol and internal procedure, to provide a starting point for learning. The goal is to feel an active part in a process of standardized definition and management, to embrace the accountability process, both as individuals and professionals and as a group [50–52]. Follow-up (up to few months) is based on a second phase of field observations and on 4-h meeting with the participants. During follow-up observations, process indicators are observed to detect the presence of changes. On same day, others meeting is held with groups to brainstorming on improvement actions, across the work done of remote (scenarios and management data sheets). Trainers stimulate this type of work with the aim of strengthening processes of self-determination, empowerment and intrinsic motivation on the part of all production lines (healthcare staff, management…) [53–56] (Table 1).

Table 1. Descriptors of training intervention methodology

Activity	Specific training aim	Contents	Methodology
Interactive meetings. "The day NO" and "The day YES"	Analyze and understand weaknesses and strengths in working practices in NH	Adverse events, case studies, strategies	Thematic analysis from the perspective of the participants
Interactive meetings Real-time themed analysis with concept map	Know the principles of risk management and the systemic approach. Know good practices to prevent errors	Safety in NH, regulatory evolution, systems theory, incindent'sapproach, good practices	Front lesson Interactive front lesson
Working in a small group	Develop skills to reduce preventable adverse events. Skills for analysis and management of Clinical Risk with an inductive process conducted in team	Analysis of clinical cases and adverse events occurred in NH. Planning for improvement actions. Error detection systems	Focus group on themes

(*continued*)

Table 1. (*continued*)

Activity	Specific training aim	Contents	Methodology
Scenarios	Develop self -awareness and teamwork in daily actions and active participation in the success of the system	Resolution of scenarios for application of systemic thinking. Techniques and methods of self-analysis and awareness	Focus group Brainstorming
Management data sheets	Approaching health documentation, knowing how to read and interpret it, how to improve it and implement it according to changes	Define or review a check-list or an operational protocol Planning	Focus group Brainstorming Reviw of literature and protocols

3 Results

The data was collected between June 2018 and February 2020, just before the start of the Covid-19 pandemic. The data reported are only a few, both for reasons of brevity and because a further analysis of the impact of the method is required. For this reason and to measure the impact of the intervention through qualitative and quantitative outcome indicators, in the near future the impact of the training intervention will be measured more specifically on a sample of 2 NHs with a non-randomized pre-post study. Field observation was received fairly well by the staff, despite some phrases of embarrassment and discomfort and the feeling of being "under scrutiny". At the end of the observations, it was easy to exchange news and employees replied to short ethnographic interviews. The interviews made it possible to clarify emotional component of observers and some "obscure" data during the observations (for example work plans, forms, procedures, roles…). The most emerging criticalities in the observed structures are: infections, drug therapy errors and management of behavioral disorders. For the quality theme we can define weaknesses about: management of pain, respect for spirituality and the overload of staff work. The strengths of safety topic are management of falls and pressure ulcers and for quality are personal care, food, care for relationships with the surrounding community and the intrinsic motivations of professional healthcare and staff. The majority of staff have followed training with a good degree, but above all intention to change and improve. Already during follow-ups, we were able to observe changes in good practices but also elements of faiulure to change organizational stasis and care practices. Overall, however, what emerged most was the desire to do better, the motivational drive that came from the meetings.

4 Discussion

Emerged results confirm and expand what is already detectable in literature. Infections and medication errors are two major emergencies in the healthcare world in recent years [32–57]. Awareness campaigns on hand washing, use of antibiotics and correct patient hygiene care, should be monitored and incorporated into good daily practice actions. The lack of a general doctor in the structures makes the management of infections inadequate, delegating everything to the nurses and general practitioners, who should be appropriately trained, prepared, recognized and guaranteed the adequate tools for proper management [32]. Excessive drug use has a large impact on each individual patient's time to cure and increases the risk of errors, side effects and side effects [58]. Most therapies are crushed or split, with all the risks associated with inhalation by staff, incorrect administration, absorption and bioavailability of the drug [59]. Sometimes therapies are not given according to the 8G rule (right drug, right patient, right dose, right way, right time, right registration, right approach, right monitoring) and recorded on handwritten or transcribed STU (single therapy paper), increasing the risk of misinterpretation. In some NHs an electronic patient dossier is already adopted, with the possibility of online prescription, accompanied by patient photos and warnings for interactions, allergies, etc. Adopting technological tools facilitate management, patient's identification and risk of errors related to drugs [60]. Behavioral disorders are a peculiar event of these realities, given the intrinsic characteristics of the context and patients [61]. Therefore, importance of adopting non-pharmacological and holistic strategies emerges, to reduce impact that these disorders, for increase patient's life quality and to prevent other adverse events related to it (escapes, aggressions, falls, self-harm, reduction in the use of drugs, dehydration, nutritional risk, alteration of the sleep wake cycle etc. …). Pressure ulcers they are long working themes in the NHs, therefore in all structures management strategies are adopted and the impact is minimal or close to 0 [62]. The same is true for falls, although with a different finding than for pressure ulcers, since restraints are sometimes used to reduce the risk of falling [63]. Therefore, the indicator should be analyzed more carefully and the real impact on the patient's well-being and the benefit-risk ratio of restraints. In the area of quality, the most redundant critical issues are pain management. There is little or no use of ad hoc pathways for the detection, monitoring and residential management of pain therapy [64]. Spirituality, soul care and desires are often absent or standardized [65]. These aspects are framed by the frequent overload of work of health workers, with little valorisationpeople and professional skills [66]. The strengths in the area of quality are the attention to food (from distribution to seasonality), the care of clothing, relationships with family members and the surrounding community. However, the intention to change and the great motivation of the staff always emerge strongly, often the guarantor of all the improvement actions carried out within NHs [67, 68].

5 Conclusions

Results show the need to improve the NH's assets, both in terms of training and technology to improve health outcomes. One method could be the creation of territorial network and to define risk managers and facilitators figure for quality and safety within

NHs, so can implement, monitor and manage systems. To respond to the health needs of the population it will be necessary to strengthen local services, guarantee high levels of assistance as close as possible to the individual needs and comfort of chronic and elderly patients. The goal is to develop a patient-centric and a person-centric system. Furthermore, the methodology of training courses for health professionals should be rethought. This paper described a program based on evidence literature showing the most effective method for andragogic learning. When we talk about risk prevention we are talking about human factors and the mechanisms underlying errors, risk management and ergonomic studies of the barriers that can guarantee the reduction of preventable errors. So how to act in terms of safety through training if we do not think about the human condition, emotions and psychic dynamics? The word "human factors" suggests that it is not possible to think about tools without thinking about the interiority of health professionals. We often do it as if we wanted to fill an empty structure or, in any case, a free space without barriers and obstacles. The expectation of the results is immediate and direct, as if it had a natural conclusion and translation of what was learned during the trainings or of the indications that were given by the managers. But let's not talk about technologies, let's talk about human beings. When we think of the management and training methodology, we could instead begin to try to insinuate ourselves into the spaces left free, and to impregnate people's knowledge, not only cognitive, but also emotional. Training staff using the gentle nudge, which consider emotions, experience and take care of the person himself, can be a motivational boost, an attraction, as well as developing the potential and the empowerment of our staff and means. Andragogy shows that an adult will only learn if he deems what he is learning useful for his life and work. This connection with real job and life practice, stimulates self-confidence, the desire to be better and to go further, traveling from the bottom up the top, the top of Maslow's pyramid. An organization that offers transversal and holistic professional tools is the business model that a care setting should aim for. The staff could limit the levels of stress, could be proud to working in the NH and job could acquire a value connotation. Education, therefore, as a practice for freedom [69].

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Comfort for the Health of Premature Patients

M. del Gaudio[1(✉)], A. Lama[2], C. Vedetta[3], and S. Moschella[3]

[1] National Institute for Insurance Against Accidents at Work, Avellino, Italy
m.delgaudio@inail.it
[2] Health Work Observatory, Department of Public Health, Federico II University of Naples, Naples, Italy
[3] UOC of Neonatology and Neonatal Intensive Care. S. Giuseppe Moscati Hospital, Avellino, Italy

Abstract. The newborn hospitalized in a health facility, to receive the best care, must also be able to count on a global comfort of the rooms. As it is now the case in the workplace, the assessment of the causes of discomfort must simultaneously consider the various aspects. The control of noise, brightness and microclimatic and air quality parameters all contribute to the achievement of the well-being of the subject as well as health treatments. The environment contributes to strengthening the body's response to treatments and improves the endurance of pain. This condition is even more evident in premature subjects or subjects affected by pathologies in the first months of life. The health care worker must therefore take care of the environmental aspects or be assisted by the technical services of the health facility to achieve the best patient comfort. The quality of the environment will also affect the psychophysical state of health workers who are called to guarantee high standards of care and to whom it is necessary to guarantee safety conditions in the workplace.

The managers of the UOC of Neonatology and Neonatal Intensive Care. S. Giuseppe Moscati Hospital Avellino have decided to improve the care and work environment to avoid the negative effects on the health of newborns, and to improve the psychophysical conditions of workers, preventing them from suffering injuries or making mistakes during assistance.

Keywords: Newborn · Comfort · NICU

1 Introduction

After delivery, a newborn finds himself exposed to a series of stimuli that were absent or perceived in a reduced way in the mother's womb. The sounds reached him at much lower levels and were covered by those of the mother's body, primarily the heartbeat sound, the temperature was constant and the light stimuli filtered.

After separation from the umbilical cord, all body systems must acquire perfect functioning to compensate for stimuli that are never constant in the external environment.

In the preterm infant, the body systems are even less developed and therefore greater precautions must be activated.

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Preterm infants spend their first days (sometimes months) of life in the NICU which is also a particular workplace.

It is therefore necessary to mediate between the primary needs of the small clients and those of the staff to whom it is necessary to guarantee psycho-physical well-being.

Healthcare professionals are often too focused on medical activities and are not always aware that some characteristics of the environment and some bad habits can negatively affect the course of young patients and can affect the health and safety of the operators themselves.

This work aims to highlight the criticalities present in intensive care, also thanks to similar investigations carried out in other hospitals, for the benefit of the technicians who have to adapt the environments and the same operators to whom the results of this analysis will be transferred during periodic training.

2 Comfort

2.1 Patient Comfort

Follow-up studies and increasingly sophisticated instrumental investigations have highlighted sequelae in the population most at risk linked to the degree of immaturity at birth. Brain development follows a path in the interval, 22nd –35th week, genetically programmed to take place in the "protective" conditions of the maternal uterus. In intensive care, also due to the curative needs, it is not possible to reproduce these conditions but it is necessary to be aware of the factors involved to minimize the discomfort.

The studies by Brazelton [1] have shown how the immature infant relates to the environment in ways related to its development. The effects of the treatments, the conditions of the TIN environment and nursing nursing, therefore, will leave traces in the brain of the little patient and may affect his development in the short term and his quality of life in the long term.

The goal is to reproduce an environment, if not the same, very similar to the maternal uterus, where the fetus listened to the muffled sounds of the mother's voice, the heartbeat and the rustle of the bowels.

Furthermore, the fetus was gently cradled in an environment where the brightness was reduced and above all it was never alone.

The sensory channels of hearing and sight mature later and early stimulations have negative effects. Noisy stimulations modify heart and respiratory rate and the sleep-wake rhythm by increasing energy expenditure by subtracting resources necessary for growth.

Until the 26th week of pregnancy, newborns are not even able to open their eyes, only after that, the type and intensity of visual stimuli affect the development of visual acuity, color vision, eyeball growth and retinal development [2].

Studies conducted by Richard Lang have confirmed that already in the uterus the fetus perceives whether it is "day" outside.

Some studies reported that, compared to dim light conditions, cyclic exposure to light favors longer periods of nocturnal sleep in premature babies [2].

Furthermore, cyclic exposure to light significantly reduces crying and agitation in very young premature infants (30.6 ± 0.95 weeks) and simultaneously promotes faster

weight gain and a greater degree of activity during the day. (compared to infants exposed to dim light conditions) [2].

One of the most important elements for a newborn's survival is the temperature. Like all human beings, the baby is able to control the temperature of the body but, in situations of excessive cold or heat, the thermoregulation system can be ineffective. In particular, the reduced mass does not allow to dissipate large quantities of heat, vice versa the thin skin provides a low thermal insulation. Furthermore, the newborn is unable to assume postures that allow him to conserve heat or to change clothing in response to thermal stress. Physiological reactions can be further conditioned by diseases or by particular conditions such as hypoxia. In case of too high ambient temperatures, the newborn reacts with sweating but this function can be limited by immaturity.

The energy spent on temperature control is subtracted from that necessary for weight gain which is an important goal for the preterm infant [3] (Fig. 1).

Fig. 1. Neonatal Intensive Care. S. Giuseppe Moscati Hospital Avellino Italy

3 Workers Comfort

In Italy, health facilities must comply with the environmental characteristics provided for by the D.P.R. 37/97 and regional regulations for accreditation, but equally, as a workplace, they must try to comply with the requirements for workplaces dictated mainly by Legislative Decree 81/08.

The work of healthcare workers in intensive care is characterized by periods in which patients must be carefully monitored and by the succession of emergency situations [1].

These workers must be protected from all risks present in the workplace, but they must be guaranteed a state of well-being that allows them to maintain a psychophysical balance in order to react promptly to various needs and maintain a good level of concentration.

The risk assessment carried out on the entire health facility will certainly have identified the critical issues related to the use of electromedical equipment and the manual handling of loads, but an additional effort must be devoted to achieving a condition of well-being.

These workers work in shifts on different time slots, making up for the shortage of staff by reducing rest and therefore are often tired and less able to withstand discomfort.

Risk prevention for workers can only be collective because in an open space the discomforts affect everyone even if they are not directly involved in a specific activity.

The parameters to be kept under control are the thermo-hygrometric conditions, the illuminance values and the noise levels.

The Legislative Decree 81/08 makes a generic reference to the need to ensure the best conditions of thermo-hygrometric comfort, air quality and lighting in all workplaces. It will therefore be necessary to refer to technical standards such as UNI EN 7730 for thermal comfort, EN 16798 for air quality and UNI EN 12464-1 for lighting. For noise, it will not be possible to follow the provisions of art. 190 of Legislative Decree 81/08 as it is necessary to evaluate an extra auditory risk by referring to good practices.

In addition to these regulatory references, it will be necessary to take into account the DPR. 37/97 and the regional accreditation criteria for healthcare facilities, which establish the minimum environmental requirements to be guaranteed in order to provide healthcare services.

The Presidential Decree 37/97 provides for a minimum air exchange of 6 vol/h for intensive care, an air temperature between 20 and 24 °C with a relative humidity between 40 and 60%.

The illuminance values should be between 300 and 500 lx throughout the room and above 1000 lx (possibly obtained with localized lamps) on the neonatal islands or in all places where maximum precision was required.

The noise level should not exceed the level of 60 dB but various bodies, including the WHO (World Health Organization) suggest values below 45 dB to avoid damage to the health of newborns.

The UOC of neonatology and NICU of the Moscati Hospital in Avellino has decided to evaluate the conditions of the ward to limit negative stimuli and improve the conditions of hospitalization and the well-being of health workers.

4 Materials and Methods

The U.O.C. AO Moscati di Avellino consists of an intensive care environment and a subintensive one dedicated to the care of premature babies, in a further separate room the newborns who have arrived in the emergency room of the neonatology department are housed in an intensive care regime to which an environment is attached for the isolation of cases carrying the most contagious pathologies.

The neonatal intensive care unit was assessed by highlighting the trend of the parameters that most influence the well-being of the young patients and also of the healthcare staff.

The analysis underlying this study concerned all environments to highlight the sources of noise, the effectiveness or disturbance of the lighting equipment, the evaluation of thermal conditions and air quality. All the assistance procedures adopted in the department were also analyzed to highlight the critical issues that could cause discomfort.

With the distribution of a questionnaire it was possible to assess the degree of staff satisfaction and collect useful suggestions (Fig. 2).

Fig. 2. Neonatal Intensive Care. S. Giuseppe Moscati Hospital Avellino Italy.

5 Results

By comparing the analysis of critical issues with similar experiences in other hospitals, it emerged that there is an analogy in numerical terms and that in many cases it is also possible to adopt the same solutions. In a study carried out at the TIN of the S. Gerardo hospital in Monza, maximum noise levels of 89.8 dB were found with an average value (L50) of 78.6 dB. The same study analyzed the behavior of preterm infants with a gestational age of less than 32 weeks, highlighting that in 80% of cases there is a response to noisy stimuli that in 80% of cases transits in tears. For children over the 37th week, a reaction to stimuli was noted in only 17% of patients. The latter evaluation could be explained by a habit of environmental stresses matured by the children during the weeks of hospitalization. In the same study, the insulating effect of the incubator was also evaluated: with an environmental value of 83.1 dB inside the incubator, a value of 73.6 dB was measured with the door open and 71.8 dB with the incubator completely closed.

For lighting, criticalities were found regarding the type of lighting which, being generalized, does not allow for the control of intensity on the single station.

For the thermo-hygrometric control it was highlighted that the air conditioning and ventilation systems are centralized and the parameter adjustments can only be made by the main thermal plant.

The presence of windows that can be opened can also lead to the entry of unfiltered and non-thermally regulated air.

6 Discussion

Scientific studies demonstrate the effectiveness of interventions for improving the comfort of the newborn. The NICU of Avellino has recently introduced the experience of the nursery open to parents, which if on the one hand complicates the management of the ward a little, it helps to improve the hospitalization of young patients who do not abruptly interrupt that relationship with the mother and in part with the other members of the family unit (Fig. 3). The goal is to adopt noise reduction and light stress reduction procedures because the first acoustic measurements carried out at the TIN of the Moscati Hospital in Avellino seem to be comparable to those recorded in Monza. Staff training will be the main activity and parents are also given precise instructions to prevent their entry into the ward from creating discomfort for newborns. In particular, the need to reduce noise will be highlighted by reducing the volume of the alarms and setting them in ways that allow the reduction of "false alarms". Particular attention must be paid to the intensity of the voice, the handling of objects and all interactions with the incubators are often underestimated sources of noise but which can also be extremely harmful to the health of patients. The lighting will have to be rethought and made independent on each care station. Finally, the staff must be informed about the operation of the ventilation and conditioning system in order to be able to promptly report the malfunctions to the technical services. The future technical implementation will therefore have to provide for a continuous monitoring system of the noise level to attract the attention of operators to the need to adapt the activities, an improvement of the lighting system, with the possibility of varying the intensity without affecting all the hospital stations.

After the improvements, it will also be necessary to develop a Follow-up program to determine how the changes have affected the well-being of patients and healthcare professionals [5–7].

Fig. 3. Neonatal Intensive Care. S. Giuseppe Moscati Hospital Avellino Italy. Nursery open to parents.

7 Conclusions

The new scientific knowledge has made it possible to better understand the factors that affect the well-being of workers and, in this specific case, that can significantly interfere with the progress of newborns. The well-being of patients is also closely related to that of healthcare personnel who share the same environment and lighten their work when patients' health improves. The neonatal intensive care must strive to resemble more and more the conditions of the maternal uterus, which the newborn should have attended longer. In this direction are framed initiatives such as the NICU open to parents, the kangaroo therapy but which cannot ignore technological innovations that allow to modify the well-being of patients and workers.

The future of neonatal intensive care should be the creation of family rooms for the personalized care of each newborn but at least for the moment the staffing and the availability of space are holding back this project.

This work made it possible to carry out an evaluation of the activities of the neonatal intensive care and the operators were able to become aware of the criticalities present and of the possible solutions that in many do not require important structural interventions and that can often be reduced or even eliminated by corrections of behavior.

The operating procedures for the staff and the information material that is provided to parents who access the Tin contain the information necessary to not alter the comfort of the little patients and to favor their development (Fig. 4).

Fig. 4. Nursery open to parents. Information booklet.

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Patient Safety Walkrounds for Improving Safety and Quality of Care in the Penitentiary System of the Tuscany Region

Giulia Dagliana[1(✉)], Mateo Ameglio[2], Luca Amoroso[6], Sara Bellachioma[6], Tommaso Bellandi[3], Roberto Bocchieri[5], Valerio Cellesi[3], Domenico Cerullo[4], Paola Morganti[5], Sandra Rogialli[4], Antonella Vassalle[5], Angela Venezia[7], and Franco Scarpa[8]

[1] Centre for Clinical Risk Management and Patient Safety-WHO Collaborating Centre in Human Factor and Communication for the Delivery of Safe and Quality Care, Florence, Italy
daglianag@aou-careggi.toscana.it
[2] Local Trust Unit Tuscany South-East, Florence, Italy
[3] Local Trust Unit Tuscany North-West, Florence, Italy
[4] Local Trust Unit Tuscany Center, Florence, Italy
[5] Health Department of the Tuscany Region, Florence, Italy
[6] Reference Regional Centre for Relational Critical Urgency AOU Careggi, Florence, Italy
[7] Regional Penitentiary Administration, Venice, Italy
[8] Mental Health Depart, Tuscany Center, Florence, Italy

Abstract. The Health Department of the Tuscany Region, under the resolution of the regional council, n. 862 of 30th July 2018, approved a MoU between the Tuscany Region and regional Superintendence of Penitentiary Administration, aimed to carry out, with the scientific coordination of the regional Centre for Clinical Risk Management, a series of visits to most of the prisons of the region, with the purpose of evaluating the quality and safety of health assistance provided to people in prison. The method followed was that of Patient Safety Walkarounds adapted to the context. Each visit was conducted by a multidisciplinary team of experts from the field of patient safety and risk management, penitentiary medicine, mental health, primary care and representative of the penitentiary administration. Information were collected in a template that allowed a categorization according to the following factors: technology and work environment; organisational & management, team, communication and training. For the categorization of the information was used the London Protocol by Taylor-Adams S, and Vincent. Preliminary results related to 12/18 prisons showed that main risk factors for safety and quality of care were related to the organization and management followed by team factors and communication.

Keywords: Safety of care · Human factor · Penitentiary system · Multidisciplinary · Improvement

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1 Introduction

1.1 Background

"It is said that no one truly knows a nation until one has been inside its jails. A nation should not be judged by how it treats its highest citizens, but its lowest ones".

Nelson Mandela.

Several European and international Institutions have been working since decades on the rights to health of prisoners and on defying principles for prison health care. In the first place, the provision in Article 12 of the International Covenant on Economic, Social and Cultural Rights (United Nations, 1966) establishes "the right of everyone to the enjoyment of the highest attainable standard of physical and mental health". This applies to prisoners just as it does to every other human being. Those who are imprisoned retain their fundamental right to enjoy good health, both physical and mental, and retain their entitlement to a standard of health care that is at least the equivalent of that provided in the wider community [1].

The WHO Health System Framework encompasses several standards that should be accomplish while providing care in prisons in prisons and that are related to the following domains, or building blocks:

- Service delivery
- Health workforce
- Information
- Medical products, vaccines and technologies
- Sustainable financing and social protection
- Leadership and governance

In addition to these major domains the WHO framework foreseen two crosscutting principles that have been identified as specific to the prison context and which influence all the major domains mentioned above:

- Adherence to international standards for human rights
- Good prison health and Reducing health inequalities and addressing the needs of special populations [2]

Although the work done by the WHO to raise awareness on the need to harmonized standards of care no matter the setting where it is provided and despite the fact that attention on the right to health in prisons has been strengthening over time, poor attention has been directed toward patient safety and quality of care in correctional settings than it has been in the community. One barrier to a more rapid spread of the patient safety movement to correctional settings is that standards designed for the community setting may not translate seamlessly to correctional health system [3].

In 2010 a group of correctional health care experts and researchers in the United States of American developed a list of quality of care standards (with a focus on patient safety) through a consensus process. The group recommended 47 standards for immediate and 13 standards for subsequent implementation. Standards focused mainly on

issues as creating safety cultures at organizational, supervisory, and staff levels through changes to policy and training and by ensuring staff competency, reducing medication errors, encouraging the seamless transfer of information between and within practice settings, and developing mechanisms to detect errors or near misses and to shift the emphasis from blaming staff to fixing systems. Standards belongs to the following domains:

- Access to and availability of care
- Culture of safety
- Personnel
- Medication management
- Transitions and communication
- Patient involvement
- Specific conditions [3].

This list can be considered the first attempt to customized to the penitentiary context standards of care that were born for being used in hospitals or at the community level.

The Tuscany Region in 2012 created a Permanent Observatory (updated in 2017) for monitoring the health status of people detained in the prisons of the region in accordance with the Regional Law of 2005 and for implementing the directions of the national law that in 2008 finally defined the passage from the Ministry of Justice to the Ministry of Health of prison health-care responsibility and administration [4]. This marked an important step in recognizing prisoners' right to health and to encourage the construction of a homogeneous and synergistic regional organizational model for the protection of prisoners' health and to reduce health inequalities in our society.

Since the entry into force of the 1 of April 2008 National Law, Tuscany has monitored the state of health of the population in prison on its territory through the administration of an *ad hoc* survey conducted by the Regional Health Agency in collaboration with health personnel operating in prison institutions. The survey is conducted within the framework of a cross-sectional study, with an assessment of the state of health and carried out every three years [5].

The study uses a computerized tool on which socio-demographic and clinical information (using the International Classification of Diseases - ICDX-CM) and associated pharmaceutical prescriptions are recorded.

From the last survey emerged that the 58.7% (N = 1,821) of the cohort examined is affected by at least one disease, even mild. By dividing the diagnoses according to the large disease groups (ICD - IXCM), psychiatric disorders continue to represent the first diagnostic group (38.5%), followed by infectious and parasitic diseases (16.2%). Out of 3,100 people undergoing medical examinations, 912 have at least one psychiatric disorder (29.4%) among which substance addiction disorders represent the most common disorder (14.5%) followed by neurotic and adaptation disorders (5.4%) [5]. The work done by the Observatory in the last 10 years has revealed a very complex picture of the Tuscan penitentiary system in line with the national one where a chronic delay in the adaptation of infrastructures, both from the health and detention prospective, has made the appropriate treatment of some pathologies very difficult. The lack of infrastructures, medical technology and instruments comparable with those present at a territorial or hospital level often makes necessary the transfer of prisoners in an extra-prison setting,

with possible diagnostic and therapeutic delays and organizational issues for the local healthcare facilities. Furthermore, the problem of suicides and attempted suicides inside prisons has become a health emergency and the provision of suitable preventive measures is an absolute priority. The high number of suicides committed in the penitentiary is an international problem. In the general population residing in Tuscany aged between 19 and 74, the suicide rate is 0.7 deaths per 10,000 people (year 2014). Tuscany, in line with what was established at the national level (July 2017), approved the regional plan for the prevention of suicidal behaviours in the adults and minors penitentiary system and the guidelines for the implementation of local plans (resolutions of regional council n. 451 of 24th April 2018 for the adult penitentiary system and n. 996 of 10th September 2018 for the minor system). Over the years, the trend shows a steady decrease with a figure that is at least 4 times lower than in 2009 where the recorded value was 39 attempts per 1,000 inmates. (2009–2017) [5]. The regional resolutions approving the above mentioned guide lines, also introduced a monitoring system, conducted by the Regional Health Agency which produce half-yearly reports showing the achievement of goals by the application of the local plans, in every penitentiary institution.

From the prospective of risk management and prevention and safety and quality of care, the Regional Centre for Clinical Risk Management and Patient Safety, in the view of harmonising the efforts for promoting safety within our health system, including the assistance to people in prisons, periodically analyses data related to adverse events that happened in the prisons. Adverse Events and Never Events are collected using an advanced reporting and learning web-based platform. The system has been realized with the aim of collecting adverse events and sentinel events directly from front line health workers and for analysing the narrative through a human factor approach for identifying contributing and latent factors [6]. From the analyses of the 10 Never Events occurred between 2012 and 2017 in the regional prisons for adults, emerged that the main reported contributory factors were related to poor communication, inadequate environment or technology, poor guidelines, protocols and procedure[1].

1.2 Objectives

In this framework the Health Department of the Tuscany Region and the Regional Penitentiary Administration undersigned a Memorandum of Understanding (MoU), deliberated by a resolution of the regional council, (n. 862 of 30 July 2008), with the main goal of evaluating the quality and safety of health assistance provided to people in the regional prisons and to define and implement improvement strategies for the most risky areas. The approach that laid behind all the phases of the initiative was that based on principles of human factor and ergonomics science (HFE): identifying potential latent and risk factors from a system perspective, involving all the actors of the setting from the very beginning. HFE takes indeed the scientific discipline concerned with the understanding of interactions among humans and other elements of a system taking into account physical, cognitive, sociotechnical, organizational, environmental and other relevant factors, as well as the complex interactions between the human and other humans, the environment, tools, products, equipment, and technology [7]. Considering the complexity of

[1] Source: SiGRC, Tuscany Region System for collecting adverse events and never events.

the health care domain, the approach of HFE science contributes to provide a holistic analysis of risky situation and possible failures of the system.

While the initiative was born as a project dedicated to understanding how the assistance was provided as a whole, during the visits emerged the need to give special attention to patients with mental health disorders and to understand whether there were all the conditions in terms of clinical competences, infrastructures and system organization for ensuring a proper assistance to prisoners with this kind of necessities. Special attention was also dedicated to the evaluation of the strategies in place for the prevention of suicide and suicide attempt. Finally, the availability and accessibility of primary health services to give support or to take in charge special requests arriving from the penitentiary institutions also emerged as an important aspect to deepen.

2 Methods

The method followed for the evaluation of safety and quality of care in the target prisons was that of Patient Safety Walkrounds (PSW) to be conducted in all the 15 prisons for adults of the region. This method is based on a visit to a healthcare unit or department of a hospital or local facility with the purpose of discussing with healthcare workers, directors of units and hospital managers points of weakness and point of strength in terms of safety and quality of care using a systemic approach oriented to the continuous improvement. PSWs aims at creating a "safe, blame-free and not-inspection-oriented" space where all the actors of the system can share idea, discuss care issues and identify strategies for overcoming barriers to safety [8].

This method is very much used at the hospital level and several studies reported the positive impact that this kind of activities have on quality and safety of care. Frankel et al. said that where conducted PSWs have stimulated the spread of a no-blame culture for the discussion on adverse events and consequently the increase in the use of the reporting and learning systems for reporting adverse events [8, 9].

In our regional health system PSWs have been formally recognized as a method for improving safety and quality by a regional law in 2008 [10].

The peculiarity of our visits consist in the fact that for the first time also the personnel of the penitentiary administration was involved in the rounds and discussions and was considered as a fundamental actor for understanding organizational dynamic within the penitentiary system and for identifying improvement strategies. Each visit has been indeed conducted by a multidisciplinary team of experts from the field of patient safety and risk management, penitentiary medicine, mental health, primary care, nursing and representative of the penitentiary administration.

The multidisciplinary group designed a template for the collection of the information during the visit. The use of a template allowed the categorized the information collected on the field according to the domains suggested by Taylor-Adams and Vincent in the London Protocol adapted to the context [11].

The following are the factors identified as those that could influence the assistance at most:

1) technology and work environment factors (i.e. equipment design, availability and maintenance of infrastructures, physical environment);

2) organisational & management factors (i.e. organizational structure, staffing and mix of skills, workloads, patient safety practices implementation, Ministerial Recommendation application, availability and use of procedures and protocols);
3) team factors and communication factors (i.e. verbal communication, written communication, team structure, leadership);
4) training (i.e. availability of continue training on technical and non-technical skills, safety and quality of care, risk management).

The domains were chosen also in accordance to the three main kinds of interactions among human beings and systems as defined by HFE science:

1) cognitive interactions: among the elements of a system;
2) physical interactions;
3) organizational interactions.

3 Results

Between October 2018 and January 2020 the multidisciplinary group visited 12 out of 18 prisons for adults. Due to the COVID-19 outbreak in January 2020 the group could not visit the remaining 4 ones.

All the visits conducted by the itinerant multidisciplinary group foreseen an initial briefing of about 90 min with representatives of the prison medical team, including always the psychiatrist and when possible the psychologist; the nursing team, the risk manager, the juridical-pedagogical officials, the director of the prison and the chief of the penitentiary police. During the briefing the visiting group asked questions following the standardized template and facilitate the discussion trying to underling point of strength and point of weakness related to the above mentioned domains. After the briefing, the group was conducted to visit the area of the prison dedicated to health assistance where the group could meet the other members of the clinical staff, make additional questions and observe all those aspect related to environment, organization of work, availability of medical devices and instrument, accessibility to informative systems, implementation of patient safety practices,.

A short debriefing was conducted at the end of the visit to provide first feedbacks and give some preliminary advices on possible improvement actions to be implemented for strengthening safety and quality of care.

The group then conducted a thematic analysis of the narratives of the 12 visits Applying the systemic analysis and the human factors approach, the group.

The analyses showed that main risk factors for safety and quality of care are related to:

1) organizational and management factors such as:

- clinical handover processes;
- relations with primary health services and in particular with the mental health services;

- limited time dedicated to mental health assistance;
- coordination with social services for managing the release from prison;
- lack of linguistic and cultural mediators;
- accompanying detainees to local health services;

2) team factors and communication factors such as:

- structured communication between the clinical and the penitentiary staff;
- limited opportunities for discussion between health workers and penitentiary staff;

3) technology and work environment factors such as:

- technological deficiencies for the use of the electronic record;
- inadequacy of spaces dedicated to healthcare mainly for those detainees who are affected by mental health problems;

4) training such as:

- limited opportunities for joint training between health workers and penitentiary staff in particular for the management of critic patients.

4 Discussion

Although the limit of the small sample, from the preliminary data available, we can affirm that the visit on the ground confirmed the data reported by frontline heath workers in the regional website related to never events.

Most critical events that have been narrated during the visits can be associate with poor communication among healthcare staff and between healthcare staff and penitentiary staff, organization and management of the assistance and in particular to what concern guidelines and protocols and finally to environment and technology such as small or not well-located rooms for the doctors and nurses and technological barriers to the use of the electronic chart. It would be worthy to dedicate a special reflection to the assistance given to detainees suffering mental health problems. The poor conditions of the prison environment and the lack of adequate wards could make them worse and their treatment more complex. Furthermore it would be fundamental that the network of the Community Mental Health services was involved more deeply inside the prison with the aim of ensuring a smoother admission to hospital services for acute patients and thus ensuring personalized therapeutic and rehabilitation plans that can be realized as outpatients when the juridical status will make it possible.

5 Conclusion

The ethnographic approach used during this research, if compared to the reporting system, allowed researchers to collect information from all stakeholders that act in a penitentiary system. The staff of the penitentiary administration, from all level and grade, has

contributed actively to the understanding of the potential hazards inherent in the system through their precious knowledge on the social and organizational dynamics of a prison. Moreover, PSWs allowed participants to underline points of strength of the system: in several prisons emerged a very good collaboration between the healthcare staff and the penitentiary administration especially when it comes to deal with the management of acute patients.

Finally, several improving actions have been identified in order to mitigate potential risk factors:

- improvement in the electronic records;
- structural changes to the rooms dedicated to nursing and medical assistance;
- prevision of an ethno-clinic dedicated to the take in charge of foreigners prisoners with mental health disorders;
- improving connections with external health services, particularly mental health services, social services and dependency contrast departments;
- training courses on the theme of suicide prevention dedicated to health staff and penitentiary staff conjointly;
- redesign of protocols related to the availability of the primary healthcare services to host patients coming from the prison;
- monitoring of the aggression episodes against prisons' operators.

Acknowledgement. We would like to express our thanks to all the operators who work in the penitentiary institutions we met during the visits: directors of the institutions, staff of the penitentiary administration, legal-pedagogical officers, doctors, nurses, facilitators of clinical risk, risk managers and administrative staff.

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Design and Developement of Safety Walkrounds in a Local Healthcare Trust: Methodological Approach

G. Terranova[1(✉)], T. Bellandi[2], I. Razzolini[1], C. Rigali[1], V. Gelmi[1], and F. Bellomo[2]

[1] Patient Safety Unit, Tuscany Northwest Trust, Florence, Italy
giuseppina.terranova@uslnordovest.toscana.it
[2] Tuscany Northwest Trust, Florence, Italy

Abstract. Safety Walkrounds are a clinical risk management tool originally designed to help healthcare leaders learn "on the job" about safety issues and implement effective solutions. The authors present the results of a project carried out, during the years 2017–2021, in a Local Healthcare Trust to learn about the perception of operators with regard to safety, promote the adoption of patient safety practices (PSPs) and recommendations of the Italian Ministry of health (HMRs), share the results of self-assessments carried out by facilities and a plan for improvement/consolidation of PSPs/HMRs for which critical issues had emerged. Barriers to PSPs/HMRs implementation were then classified according to Vincent's contributory factor categories, in order to identify priority areas for intervention using a systems approach, which is particularly useful for planning interventions at the strategic level.

Keywords: Safety culture · Contributory factors · Safety walkrounds

1 Introduction

1.1 Safety Walkrounds: A Knowledge Tool for Management in the Tuscany Healthcare System

Introduced by Allan Frankel, a physician at Brigham and Woman's Hospital in Massachusetts, for the safe management of drug therapy, Safety Walkrounds (SW) were subsequently developed by the Institute for Healthcare Improvement as a tool to engage management and healthcare professionals in the discussion about safety issues and in sharing improvement plans [1–4].

After a first pilot experience in the former Local Healthcare Trust 5 (Pisa, Tuscany Health Service) to promote the Safety Practice "Hand Hygiene" and the prevention of infections from multi-resistant microorganisms [5], SW were introduced in 2017 in the newly established Tuscany Northwest Trust with focus on the oncology pathway and other strategic areas (obstetrics, surgery and emergency-urgency), in order to collect informations and data useful for the implementation of Patient Safety Practices (PSPs)

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and Recommendations of the Italian Ministry of Health (HMRs) in the most critical contexts in terms of clinical and organizational complexity [6]. From October to December 2017, the SW team carried out a relevant number of visits in the selected facilities: 25 in the South provinces and 13 in the North ones with about twenty healthcare professionals involved, on average, for each visit. After the observation, the collected data were recorded and categorized on the basis of contributory factors, according to Vincent's taxonomic model [6, 7]. Final reports were presented to Medical Directors and Nurse Coordinators of the facility and sent to the Healthcare Trust management in order to design improvement plans for structural and organizational adjustments.

In 2019 we adapted SW opening it up to patient representatives and to patient safety officers from other hospitals, creating a form of active patients' participation and benchmarking, in order to improve public support to patient safety and systems' change.

Visits were conducted during normal performance of the clinical activities at ten facilities. Unlike previous experiences, a major analytical part was dedicated to underline proactive initiatives taken by healthcare professionals to meet citizens' requests. Public events were organized to report follow-up measurement of improvement actions and to improve networking.

Safety Walkrounds became part of our supporting activities to help frontline workers and embed safety practices within patient pathways.

In 2020, the Covid pandemic interrupted the usual scheduling of the Safety Walkrounds, resumed in 2021, in order to share the self-assessment of compliance with PSPs and HMRs in a sample of 5% of the corporate facilities and, with the occasion, testify the support of the Management to frontline operators. The monitoring of PSPs and HMRs and the reporting of compliance data to the Regional Center for Clinical Risk Management and to Agenas (the Italian National Agency for Regional Healthcare Services) is an information obligation which Italian Healthcare Trusts are required to fulfill, according to art. 3 paragraph 2 of Law 24/2017, by the month of November.

1.2 Objectives

The purpose of the Rounds is to develop, sustain, and maintain a culture of safety across the Organization, with the gentle "push" of citizens and patient representatives.

Since 2019, our Rounds have been systematized through a corporate procedure including careful planning and providing supporting tools (an information flyer, a structured questionnaire, a report form); coordinated by the Patient Safety Unit they are an integral part of the corporate system of quality and safety management, planned and carried out annually on a sample of care pathways/facilities agreed upon with the Healthcare Trust Management and the Participation Committee (a corporate committee in which patient advocacy associations are represented), identified and prioritized on the basis of the clinical risk mapping process.

The objectives of the Visiting Group are multiple:

- to identify risk/vulnerability situations and threats in the system;
- to share the criticalities encountered in the realization of healthcare activities and to identify opportunities for improvement;

– to gather the perception of frontline operators and patients representatives regarding safety;
– to improve team communication and the organizational climate;
– to reinforce the principle that "safety must be everyone's concern".

2 Materials and Methods

As a result of a clinical risk mapping process based on qualitative and quantitative data (such as number and type of sentinel event reports and other adverse events, incident reporting data, frequency and characteristics of claims and complaints, medical record analysis' results and quality assurance reports) the Patient Safety Unit in collaboration with the Healthcare Trust Management structured a project aimed at promoting the adoption/monitoring of PSPs of the Center for Clinical Risk Management and Patient Safety of the Tuscany Region and HRMs and, at the same time, testing "on the ground" healthcare professionals' compliance to patient safety standards by means of well-designed Safety Walkrounds (SW).

First of all, the "tables of pertinences", assigning to each facility the PSPs and HMRs to be applied in the specific context, were reviewed and published on the corporate intranet, in the Patient Safety section. A note was then sent to Department and Area Directors and to the Quality and Safety Referents (professional figures operating transversally at departmental level) inviting them to evaluate the pertinences and provide feedback by filling in a form available online. In a second phase, the data entered in the form were processed, the tables of pertinences were re-evaluated on the basis of observations/requests for changes, and republished on the company intranet together with a "guide to self-assessment", to be completed by the end of November.

The third step consisted in the self-assessment by facilities of their compliance with the PSPs and HMRs shared in the tables of pertinences, and in the insertion of compliance

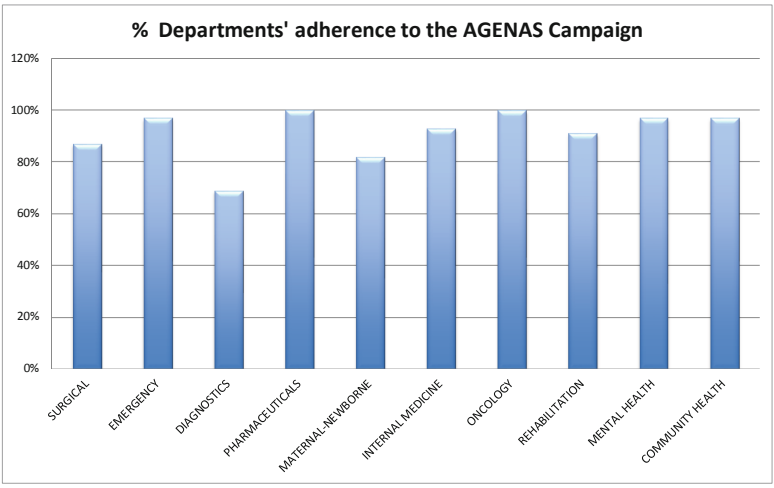

Fig. 1. Adherence to the AGENAS Campaign, by Department.

data on the company database available on the intranet. Facilities' adherence to the Agenas Campaign was generally good (average about 90%), which allowed us to meet our reporting obligation on time (Fig. 1).

In the fourth and final phase 21 facilities, distributed in all 5 territorial areas of the Northwest Healthcare Trust, were identified, and a calendar of visits was drawn up, announced by email to Medical Directors, Nurse Coordinators and Department Directors. We chose to visit all of the Primary/Community Care facilities, particularly involved in the territorial management of the pandemic phase and in the organization of the vaccination campaign, and various facilities of the Surgical, Medical, Maternal and newborn health, Mental health, Emergency and Rehabilitation (Intensive) Departments.

During the visit, the self-assessment chart was shared and verified and a structured interview was proposed to assess the general safety climate, the strengths and weaknesses encountered in the implementation of PSPs and HMRs, the innovations introduced, the staff perception of risk areas.

The visit concluded, where possible (consistent with restrictions due to the pandemic), with a "Tour" of the facility. The data collected through the visit and the structured interview were systematized into a report containing a SWOT analysis and a separate improvement plan for PSPs and HMRs. The report was forwarded with a request for any additions/changes. All the facilities received the report by December, appreciated the initiative and many gave positive feedback on the improvement actions undertaken.

A further work of analysis carried out after the conclusion of the SW was to identify, for each report, barriers to safety and critical issues emerged from the meetings, categorizing them according to Vincent's London Protocol revisited [8]. This classification makes it possible to identify priority areas for intervention using a system approach, which is particularly useful for planning interventions by the strategic level.

For each type of contributory factor, actions have been identified to be brought to the attention of the Trust Management and discussed with the Departments at the preparatory meetings for budget discussions.

3 Results

The reports forwarded to facilities contain action plans to improve/consolidate PSPs (79%) and HMRs (21%).

At the top of the list, in terms of frequency of objectives assigned, are PSPs that deal with the prevention of healthcare-related infections and transversal PSPs, such as handover and interruption prevention, which presuppose staff education and workflow reorganizazion (Fig. 2). The complete set of PSPs of the Center for Clinical Risk Management and Patient Safety of the Tuscany Region is available online [9]. With regard to HMRs, the most frequent objectives concern medication management (HMRs 1–7–17–19) and suicide prevention (HMR 4) (Fig. 3 and Table 1).

The classes of contributory factors most frequently represented are those related to management and work organization, human factors of the healthcare workers, Staff and technologies (Fig. 4).

Four critical areas of a strategic nature emerged from the analysis: 1) the maintenance and updating of skills/knowledge 2) the organization of work and 3) closely linked to the previous one, the cohesion/organization of the Staff, 4) technology management.

4 Discussion

By analyzing classes and subclasses of contributory factors (Fig. 5) it is possible to make some reflections on the most recurrent areas of criticality:

1) Human factors of the healthcare workers; Maintenance and updating of skills is often reserved for "key" figures such as Quality and Safety Facilitators, Managers/Coordinators, relying on a "cascade" transmission mechanism of information/knowledge that is not always easy in a context where people work in shifts, with limited staff, with few opportunities for an effective confrontation on issues of a technical-professional nature, little time and no tools for bibliographic research (both for lack of institutional access to scientific journals and lack and obsolescence of computer equipment).

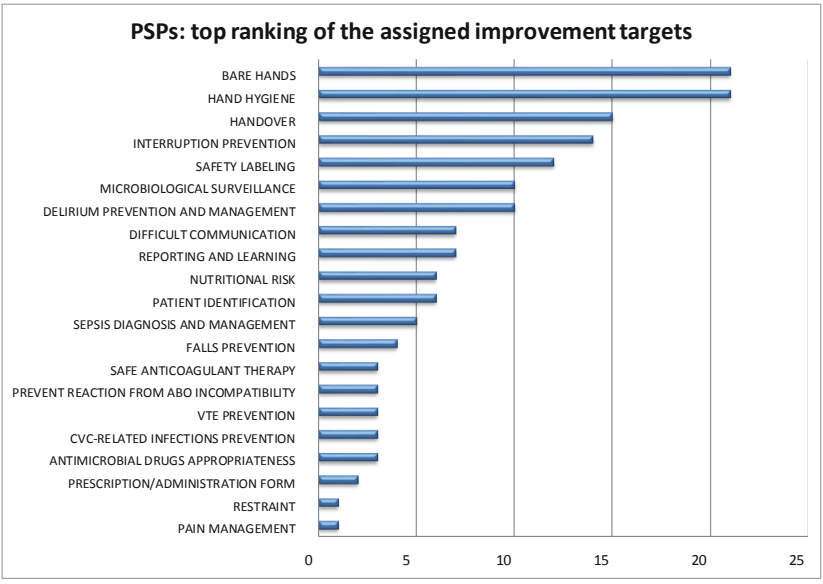

Fig. 2. Frequency of objectives assigned to facilities with regard to PSPs.

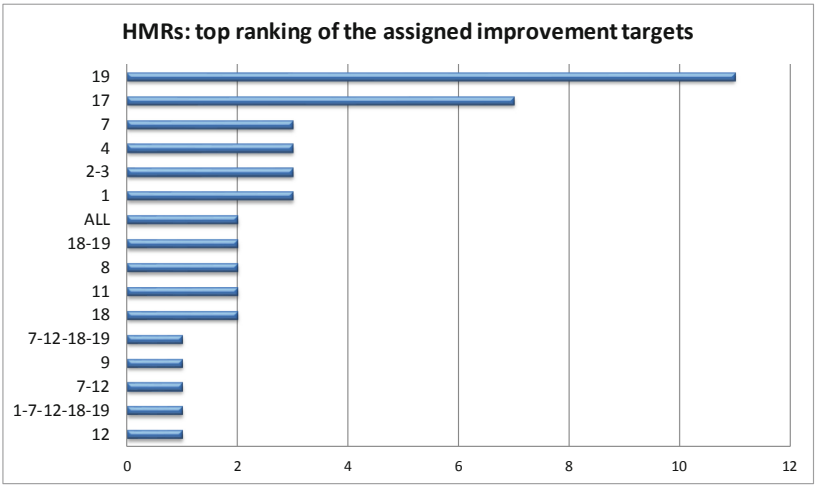

Fig. 3. Frequency of objectives assigned to facilities with regard to HMRs.

This long-standing situation has been exacerbated by the pandemic, a long phase during which the maintenance and updating of skills have been strongly oriented towards the pandemic theme in an organization that simultaneously addresses all other health problems related to chronicity, the management of time-dependent diseases, in a scientific context constantly evolving in terms of opportunities and therapeutic strategies. With regard to the quality of training, the use of simulation, which is essential to train the organization's resilience and rapid response to emergencies, is marginal.

Table 1. Focus of Italian HMRs

N. 1	*Safety of concentrated potassium solutions*
N. 2	*Prevent retained surgical items*
N. 3	*Correct identification of patient, surgical site and procedure*
N. 4	*Suicide prevention*
N. 5	*Prevent transfusion reactions from ABO incompatibility*
N. 6	*Prevent maternal death related to labor and/or delivery*
N. 7	*Medication safety*
N. 8	*Prevent violence against healthcare workers*
N. 9	*Prevent adverse events from malfunction of medical/electro-medical devices*
N. 10	*Prevent maxilla/mandible osteonecrosis due to bifosphonates*
N. 11	*Prevent death or serious damage resulting from a malfunction of the transport system*
N. 12	*Prevent therapy errors with "Look-alike, sound-alike" drugs*

(*continued*)

Table 1. (*continued*)

N. 13	*Falls prevention*
N. 14	*Safety in therapy with antineoplastic drugs*
N. 15	*Prevent death or serious damage from incorrect attribution of the triage code within the Emergency Department*
N. 16	*Prevent death or permanent disability in healthy newborns weighing > 2500 g not related to congenital disease*
N. 17	*Medication reconciliation*
N. 18	*Prevent errors in therapy from the use of abbreviations, acronyms, symbols*
N. 19	*Safe handling of solid oral pharmaceutical forms*

2) Management and work organization; For a long time now, a productive vision of the organization has been perceived as dominant, which puts in first place the "emergency" management of the pandemic, a vision that is more than legitimate and even necessary in a public health company that must respond to needs with the tools available in a logic of sustainability, a vision that nevertheless reveals all its historical limits: if the middle management perceives that the directional mandate focuses on numbers, quantity, costs, production, often obtained through an expansion of working hours contractually allowed but still detrimental because it contracts the necessary rest periods of operators who perform delicate activities, on the daily management of various emergencies (the pandemic one, the PNRR one….), and that everything else can wait because it is not a priority, means that the highest strategic level, i.e. the governing body of health policies, has in fact adopted an "emergency" logic in which the issues of quality and safety of care are in fact delegated to the grassroots, to the goodwill of operators and to their spirit

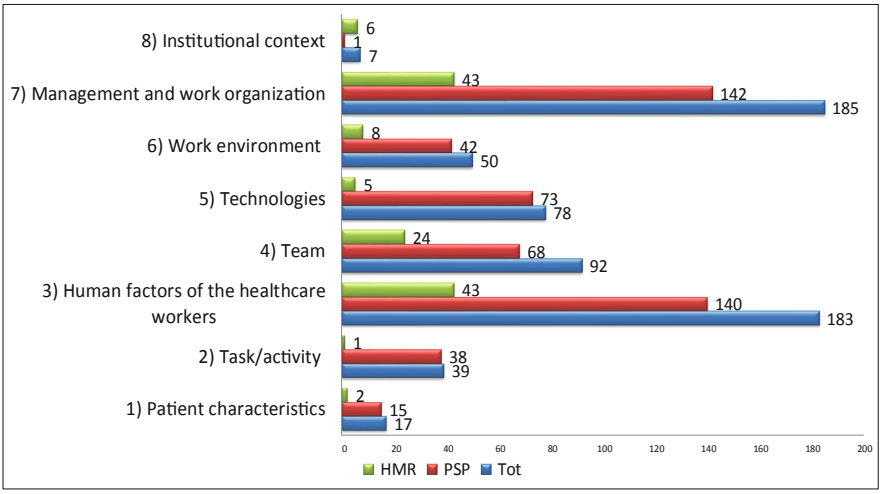

Fig. 4. Distribution of identified contributory factors, by PSP/HMR.

of service and respect for ethical codes. The factual demonstration of this vision can also be deduced from the audits carried out: the only improvement actions that can be monitored and implemented are those that do not involve the strategic level, so much so that, by now, no actions are even proposed that cross the threshold of the "structure" or the individual team.

3) Team; Organizational health and often the good outcome of care depend on good relationships/communication within and between teams; the PSP Handover has been a stimulus to change relationships and team communication, but there are still many critical issues related to the lack of structured briefings, the poor attitude to inter-professional comparison, the consolidation of hierarchical logic for professional/management "silos" that prevent a real integration and, above all, a coherence of action in the field. Literature and history teach us that, in the most resilient organizations, the chain of command is short, the organizational structure is simplified, decisions are based on competencies and not on outposts and potentates that often break up teams, preventing univocal, timely and effective actions. When too many opinions have to be heard before a decision is made, the decision, although right, risks being at least late. At the micro level, hierarchical fragmentation is particularly evident in those areas that are more "sensitive" to hierarchical/organizational issues, such as surgical settings, where team briefings are non-existent.

4) Factors related to technologies; The really sore point of our SW is given by the almost ubiquitous complaints about non-interoperable applications, obsolete technologies, a top-down design approach that does not take into account the real needs of

Contributory factors	
1) Patient characteristics	**5) Technologies**
Conditions (complexity and seriousness)	Involvement in selection and design
Language and communication	Equipment availability
Personality and social factors	Usability and reliability
	Ordinary and extraordinary maintenance
2) Task/activity	**6) Work environment**
Design and structural clarity of the task/activity	Staffing and skills mix
Avalaibility and use of procedures	Workload and shifts organization
Avalaibility and accuracy of diagnostic test	Administrative and management support
Support in decision making	Physical environment
3) Human factors of the healthcare workers	**7) Management and work organizazion**
Knowledge and skills	Financial resources and costraints
Competence	Organizational structure
Physical and mental health	Policies, standards and objectives
4) Team	Safety culture and priorities
Verbal communication	**8) Institutional context**
Written communication	Economic and regulatory context
Supervision and help opportunities	Health policy
Team structure (compatibility, consistency, leadership etc)	Links with external organizations

Fig. 5. Classes and subclasses of contributory factors [8]

professionals who are "subjected" to rigid technologies and often already obsolete since their installation.

5 Conclusions

The project made it possible to initiate improvement/consolidation plans at the facility level and also to present proposals at the system level, thanks to a risk management report that was delivered to Management prior to budget negotiation, together with a series of quality and safety objectives identified for all Departments.

The results of the visits, in line with the literature on the subject, have confirmed the usefulness of the SW as a source of information and ideas for improvement and as an effective tool to allocate resources in the areas of greatest risk and to promote a culture of safety, all the more so in a phase in which we can see the possibility of coming out of the pandemic tunnel, reconnecting with front-line operators who have suffered in the field, helping them to recover confidence and to redesign a normal management of health activities, taking advantage of the experience.

As noted also in previous contributions [7] a strong commitment by strategic management to carry out systemic actions is a critical and sometimes inconstant variable that, if not supported by the central political level both in terms of direction, health programming and funding, could frustrate any effort to analyze patient safety issues with a participatory tool such as the SW. We do not expect, unfortunately, any acceleration in the acquisition of technologies and human resources, in the adaptation of spaces and in the optimization of services, the timing of which does not follow the inputs of the SW but we hope at least to stimulate management by offering cues for the prioritization of interventions, wishing that in 2022 representatives of patient advocacy associations can be invited again, as was the case in 2019, to ensure transparency and also to strengthen the effectiveness of these initiatives.

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Understanding and Communicating Risk: The Case of COVID-19

Davide Coraci[1,2(✉)], Alessandro Demichelis[1], and Gustavo Cevolani[1]

[1] Models, Inferences, and Decisions (MInD) group – MoMiLab Research Unit, IMT School for Advanced Studies Lucca, Lucca, Italy
davidecoraci@imtlucca.it

[2] Institut d'Histoire et de Philosophie des Sciences et des Techniques (IHPST), Paris 1 Panthéon-Sorbonne University, Paris, France

Abstract. In the past decades, research in cognitive science has increasingly improved our understanding of human cognition and decision-making processes. On the one hand, the "heuristics and biases" research program highlighted how human reasoners often fail to conform to normative standards of rationality, falling prey to systematic and predictable "cognitive illusions". On the other hand, further research explored how to design communication strategies and reasoning tools that are more ergonomic - that is, that make easier and more transparent the processing and evaluation of complex information. Here, we report on a preliminary analysis (including a pilot study) of understanding and communication of statistical information concerning COVID-19-related risks among the public. Our tentative conclusions are as follows: first, in line with previous literature, transparent communication using a "natural frequency" format (instead of percentages or probabilities) does improve understanding; second, many important institutions do not employ cognitively ergonomic communication strategies, leaving much room for further improvement.

Keywords: Cognitive ergonomics · Risk communication · Heuristics · Base-rate fallacy · COVID-19

1 Introduction

Cognitive ergonomics is the study and design of environments and systems that match the cognitive capabilities of users (Hollnagel 1997, p.1170; (Dempsey et al. 2006)). As such, its effort would be futile without an understanding of the underlying cognitive processes of users. Even if we cannot claim to have fully deciphered the multifaceted enigma of human cognition, nonetheless we have reached some conclusions that appear to be quite robust. One such discovery is that people routinely employ a series of strategies called *heuristics* in their everyday decision-making (Kahneman and Tversky 1972; Tversky and Kahneman 1974; Kahneman 2011). Heuristics allow us to take quick and resource-efficient decisions. They could have been evolutionarily selected in cases where an approximative, but fast and easily applicable solution is preferable to a more accurate one that however requires more time or effort to be reached. Heuristics are very effective

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in avoiding unnecessary complexity in decision-making and reasoning but can lead to systematic errors called *cognitive biases.* The study of heuristics, and how to avoid the cognitive pitfalls of biases, represents an interesting direction for research in cognitive ergonomics. When we design a system that requires the users to make decisions, we should have clear in mind that their choices will at least in part depend on the interaction between our design and their heuristic reasoning, resulting in turn in possible cognitive biases.

In this respect, a crucial issue attracted much attention in psychology, behavioral economics, and cognitive sciences: how human subjects reason and make choices in conditions of (severe) uncertainty (Kahneman 2011; Gigerenzer and Edwards 2003). One main finding of these lines of research has been that humans – both experts and laypeople – tend to depart from the prescriptions of our best theories of rationality, based on classical logic, probability calculus, and rational choice theory. In a wide array of experiments exploring different conditions (Gigerenzer et al. 2008), participants systematically and predictably violated some of the basic rules of logic and probability, thus displaying a sub-optimal performance in reasoning and decision-making as prescribed by normative models. For example, the well-known "framing effect" (Tversky and Kahneman 1981) amounts to the fact that conveying the same information in different ways, e.g., in terms of losses or gains, affects how people evaluate the provided information and decide upon it. Framing information in terms of losses prompts decisions way more conservative, on average, than information framed in terms of gains. This is especially important considering how it is often impossible to present frameless information. The recent COVID-19 situation represents a relevant case study for assessing risk communication, both from institutions and media. While this line of research is, to the best of our knowledge, still partial (Warren and Lofstedt 2021; Pighin and Tentori 2020; Tentori et al. 2021), it seems fair to say that institutional communication about COVID-19 only achieved mixed results. Indeed, while it managed to provide much raw information to the public, different voices have raised concerns about its effectiveness, emphasizing the risk of misunderstanding and the need for a more transparent way of communicating information (e.g., Noar and Austin 2020; Wang et al. 2021; Wodak 2021).

In this paper, we first survey recent research across critical thinking, psychology, and the study of ergonomics and human factors, illuminating how people reason about (medical) risks and how different communication strategies influence their reasoning and decision-making (Sect. 2). Then, we report on two preliminary studies on risk communication in the context of the COVID-19 pandemic. The first one (Sect. 3) is an assessment of the type of communication used by various institutional organizations through their official online dashboards. The second one (Sect. 4) is a pilot survey that we administered to compare diverse formats that can be used in spreading information on risk. In Sect. 5, we conclude with some general comments.

2 Assessing Effective Risk Communication

In several works, Gigerenzer and his collaborators (Hoffrage and Gigerenzer 1998; Gigerenzer 2014) tackle the problem of how people perform statistical inferences and how the format with which information is provided can improve these types of reasoning. Indeed, mathematically equivalent formulations of the same data can entail different

cognitive computations (Gigerenzer and Hoffrage 1995). Therefore, there is room for both reconsidering the information representation in a format that is more manageable for how people elaborate information and introducing more ergonomic strategies to approach statistical reasoning. One possibility is the use of natural sampling of frequencies ("natural frequencies" for short) instead of standard probabilities, e.g., stating that "40 people out of 100", instead of "40% of people", have some condition. This deceptively little change can nonetheless make a great difference: for example, in the understanding the results of clinical test (e.g., mammography), a case widely discussed in the literature (Eddy 1982; Gigerenzer and Hoffrage 1995; Hoffrage and Gigerenzer 1998; Hoffrage et al. 2000; Hoffrage et al. 2002; Gigerenzer and Edwards 2003; Gigerenzer et al. 2008; Hoffrage et al. 2015). Translated in an example more fitting for the current context, the problem revolves around this point: a person who undertakes a screening for COVID-19 needs to understand the real risk of truly having it (event C), if her test comes out as positive (event P). In order to do so, however, she needs to calculate the conditional probability $p(C|P)$, a calculation that requires a straightforward, but often not easily feasible, Bayesian calculation. Gigerenzer, Hoffrage 1995 and colleagues found out that people, even those supposed to be familiar with these types of reasoning (for instance, clinicians), make mistakes when asked to solve this problem and fail to provide even approximately correct estimates of $p(C|P)$. They also argue that using natural frequencies instead of probabilities in presenting the relevant statistical information can improve people's performance in these scenarios (Gigerenzer and Hoffrage 1995). In what follows, we are interested in how people (mis)understand statistical information and probabilistic evaluations of risks as related to the COVID-19 pandemic, e.g., when reasoning about the interpretation of a positive test result from a standard swab test.

Before starting our discussion, it is important to recall a few fundamental concepts, and how they can be misunderstood: the *base rate* or *prevalence* of a disease in the population, the *hit rate* or *sensitivity* of the test for that disease, and the *false alarm rate* of the test. Consider for example the following information:

1) In a region, 4% of the people has COVID-19, the presence of which can be discovered with a test. If an infected person is administered the test, the probability that the test results positive is 80%. If a non-infected person is administered the test, the probability that the test is still positive is 3%.

The base rate of a disease in the population can be represented in the form of a single-event probability, in our case 4%. For what regards the test, sensitivity is computed as $p(P|C)$, which is the probability P of having a positive test conditioned on the probability C of having the disease or, in other words, the proportion of people (here, 80%) rightfully diagnosed by the test with the disease. Conversely, the false alarm rate, or false positive rate, can be represented as a conditional probability $p(P|\neg C)$, that is, the probability that a person results positive when *not* infected, in our case 3%. As underlined by Gigerenzer and Edwards (2003), all such probabilities can be easily misunderstood, both because people can have an erroneous comprehension of what probability is, or because they fail to identify the relevant class which the percentage is referring to (i.e., the *reference class*). As a consequence, some well-known biases can occur, like the so-called *base-rate fallacy*, which is to disregard the general prevalence of a given condition when estimating

its probability given some piece of information. As an example, when encountering the problem of estimating what is the probability for a woman who has received a positive result for her breast cancer screening to really have cancer, most of the physician (95%) contacted in Eddy (1982) gave an answer one order of magnitude higher than the correct one. This error resulted from including in the computation only the true positive and false positive rates of the test, disregarding the fact that the base rate of incidence for breast cancer was around 1%, which meant that it was quite unlikely for a woman to have breast cancer to begin with, without taking into consideration the results of the test.

As suggested by Gigerenzer and colleagues, people's probabilistic reasoning can be improved by translating the same statistical information in a natural frequency format, as follows:

2) In a region, 40 people out of 1000 have COVID-19, the presence of which can be discovered with a test. If those 40 people were to be administered the test, 32 would result positive. If the other 960 non-infected people were to be administered the test, circa 29 would still result positive.

The formulation above is a much more ergonomic way to convey information easily handled by human cognition, leading to a higher number of correct estimates of the conditional probability $p(C|P)$ and mitigating the base rate fallacy, making explicit the relevant reference class. To keep the discussion on the mammography example, in Hoffrage and Gigerenzer (1998) representing information through natural frequencies increased the number of physicians that correctly guessed the predictive power of the test from 10% to 46%.

Another well-known problem related to communicating and understanding risk is given by the systematic use, both in the scientific literature and in institutional communication, of so-called relative risks. For instance, a formulation like.

3) Wearing a mask decreases the risk of being infected from COVID-19 by 60%.

is problematic because it is unclear what the 60% figure actually means. People usually do not understand that *Relative Risk Reduction* means that if we compare the two groups of people, for instance, those who wear the mask and those who do not, the risk of being infected decreases by 60% in the first group compared to the second. Instead, people often think that a person wearing a mask is still 60% likely to be infected from COVID-19, or that it is 40% likely to get COVID-19 despite the mask. Again, such typical misunderstanding can have serious practical consequences. One example is the famous case of the contraceptive pill scare, which occurred in England and Wales in 1995 (Furedi 1999; Gigerenzer et al. 2008). In 1995, the U.K. Committee on Safety of Medicines (CSM) issued a warning for a 100% increased risk for thromboembolic disease in third-generation oral contraceptive pills, compared to second-generation contraceptives. The public reaction to the information saw an increase in unwanted pregnancies and abortions in the following years. Unfortunately, it was not specified what that 100% actually referred to. If it were, it would have been evident that 1 out of 7,000 women who took the second-generation oral contraceptive pills developed a form of thrombosis, while 2 women out of 7,000 of those who took the third-generation pills were affected. Even if a

100% increase sounds scary, re-wording the information in natural frequency format is immediately less daunting. The information provided by the CSM was not wrong *per se*, but the failure to provide a reference class resulted in a less-than-ergonomic landscape in which the public could take decisions.

Again, such a problem can be eased using a natural frequency formulation instead of standard probability. A frequency format combined with an estimate of the absolute risk would allow a better understanding, and consequent better cognitive manipulation, of the problem. A clearer formulation would be:

4) In two groups of 100 people at risk of contracting COVID-19, the first composed only of people who do not wear a mask and the second of people who do, if in the first group there are going to be 5 people contracting COVID-19, in the second group only 2 people will be infected.

It is worth noting that the tendency of conveying information via percentages rather than natural frequencies allows for shorter, more concise, and apparently more elegant formulations. This is the reason why that communication format is often chosen by general media and even official communicates. It is not our intention to suggest to always solve this unavoidable trade-off in favor of natural frequencies: however, we would like to emphasize how seemingly inoffensive concessions to style can dramatically hamper the informative content of communications. Given the ineludible role played by this kind of information in institutional and public communication, designing "cognitively ergonomic" (Hollnages 1997; Dempsey et al. 2006) environments would allow institutions, organizations, and media to better communicate and interact with citizens and users. While some research on how to implement ergonomic strategies in the light of cognitive studies of risk communication and understanding is ongoing (Williams and Noyes 2007; Branaghan and Lafko 2019), much remains to be done.

As previously mentioned, an analysis of the communication by institutional actors during the COVID-19 pandemic reveals that there is ample space for improvement. The communication format that was preferred varied significantly through different interfaces, websites, and dashboards, both online and in print. The format chosen was not always the most apt to prompt understanding and ease of manipulation in the public. In what follows, we are going to present two studies aimed understanding institutional communication and developing interventions to improve it. First, we assessed how institutions and health organizations communicated risks concerning COVID-19 to the general public. Second, we administered a pilot online questionnaire, based on Gigerenzer and Hoffrage (1995), to study how people understand probabilistic information about COVID-19 when conveyed in different formats (in particular, percentages *vs* natural frequencies).

3 Communicating Risks About COVID-19: Dashboards Analysis

In order to evaluate how institutions and health organizations communicated risk concerning COVID-19 we overviewed different dashboards available online. In particular, we focused on statistical information reported on four different dashboards: that of the

World Health Organization (WHO), the European Union (EU), Google (GG), and the Italian Government (IG). We investigate what types of data were provided, in what format (percentage *vs* natural frequency), and whether useful information, such as the reference classes to which the data refer, was presented or not (see Table 1). For the types of data provided, we specifically considered three variations: single-event probabilities, such as the probability to contract COVID for a single person; conditional probabilities, such as the number of diagnosed patients upon the total number of tests performed; and relative risk, such as increase of risk expressed in percentage. On these dashboards a qualitative analysis was performed by comparing them and reporting their main differences. Table 1 below represents a summary of the relevant aspects discussed so far to perform a correct and manageable communication of statistical information under uncertain conditions according to Gigerenzer's "fast-and-frugal" heuristics perspective. The table considers, for each dashboard, the type of critical information, i.e., single-event probabilities, conditional probabilities, and relative risk, and if any, the format type through which it is provided (in the standard statistical format "perc", in frequency format "freq" or both "perc/freq") and whether it is presented with an available reference class.

Here an overview of the dashboards analyzed:

- *The WHO dashboard*: this dashboard, daily updated with the worldwide COVID-19 situation, shows an overview of the pandemic on the front page. Here, the global and national numbers of new cases, deaths, and daily and weekly increases are reported in a choropleth map. For the current analysis we focused on the front page and two other available sections, i.e., "Data Table" and "Explore". The second page, in particular, gives the opportunity to navigate the data in more detail through the plots in the "Regional Overview" section;
- *The EU dashboard*: the front page of the COVID-19 dashboard of the European Union compares the numbers of cases and deaths worldwide and in EU and, below, makes available three further links. For the current analysis, we consider these three sources of information respectively titled "Weekly maps showing 14-day notification rate, testing rate and test positivity", "Weekly situation update, map, and case count", and "Daily and weekly update, country overview". Other pages are not considered;
- *The GG dashboard*: the COVID-19 Google dashboard reports the total and last 14-days worldwide data on a map in the upper part of the front page. Below, specific information (i.e., total cases, new cases, deaths) is sorted by country and arranged in two graphs. For the current analysis, we first considered the data currently presented on this page and, separately, we considered the Wikipedia "Template: COVID-19 testing by country" page, as a relevant source of information indirectly mentioned by the GG dashboard;
- *The IG dashboard*: the COVID-19 dashboard, updated every day by the Italian Government, shows the national and regional information related to the current Italian pandemic situation. The upper part of the front page displays the total numbers of the actual positives ("Attuali positivi"), recoveries ("Dimessi/Guariti"), deaths ("Deceduti"), total cases ("Totale casi"), and the related increments ("Incremento") with respect to the day before. More detailed information (e.g., COVID-19 cases quarantined at home, number of swab tests done) is provided at the regional level through the interactive map in the center of the page.

Table 1. Information can be presented in standard percentage format (perc), natural frequency format (freq), in both formats (perc/freq), or completely absent (N/A). The reference classes to which the information refers can be not available (N/A), reported in unclear way (unclear), or clearly stated (clear). By reported in "unclear way" we mean that the reference class is not explicit in the related information and needs to be calculated by the user.

	Type of information			
	Single-event probabilities		Conditional probabilities	
Dashboard	*Format*	*Ref. Class*	*Format*	*Ref. Class*
WHO	perc/freq	unclear	perc	unclear
EU	perc/freq	clear	perc	clear
GG	freq	clear	N/A	N/A
IG	freq	unclear	N/A	N/A

Discussion: All the considered dashboards mainly reported data as single-event probabilities, whereas the report of conditional probabilities was much less common. With respect to the format, these probabilities tend to be provided both in percentages and natural frequencies in the WHO and EU dashboards, while we observe a shift towards natural frequencies in GG and IG dashboards. As far as the reference class is concerned, in all the cases information is lacking. Moreover, at the moment of the analysis, the prevalence of COVID-19 in the population and the number of tests performed (either in percentage or in natural frequency format) are absent. Instead, the spread of the disease is usually shown in terms of deaths out of a certain number of people (e.g., 1 million). The dashboard analysis emphasized that, despite decades of literature on cognitive biases and decision-making, and a growing consensus on the most complete, ergonomic, and ecologic ways to engage in risk communication, much of these results have yet to be fully implemented by institutional actors. Sometimes, the format communication problem is inelegantly solved by avoiding providing information difficult to present. For instance, only the WHO dashboard reports the "crude fatality rate", a conditional probability representing the proportion of deaths given the total number of people diagnosed with the disease over a particular period. Conversely, in the case of prevalence, for which it was difficult to provide an estimation at the beginning of the pandemic, no dashboards explicitly compare new cases with the actual population of the country or region considered or take into account the prevalence of the disease and the number of tests done.

4 Understanding Risk About COVID-19: Experimental Survey

We developed a between-group, exploratory questionnaire (based on Gigerenzer and Hoffrage 1995) to assess how information framing impacts people's understanding of risks regarding COVID-19. The pilot questionnaire had the scope of investigating how the different types of information discussed in the paper (relative risk and conditional probability in particular) and the different formats through which they can be provided

to the general audience (standard percentage format *vs* natural frequency) may have impacted the understanding of statistical information about the recent pandemic situation. According to the relevant literature on the topic, we expected to observe two main results: (1) people estimate statistical information much better when presented in natural frequency format rather than percentage, and (2) when they try to manipulate statistical information, people make mistakes (e.g., fail to consider the correct reference class) resulting in well-known fallacies (e.g., the base-rate fallacy).

People's understanding of probabilistic information (dependent variable, DP) was manipulated by the format (independent variable, IV) with which information is presented, i.e., either percentages or natural frequencies. We developed two different versions of the questionnaire, both containing questions with identical mathematical and informative content, but with a different formulation. One version reported information in percentages format (Control) and the other in natural frequency format (Treatment). Each version contained 4 experimental questions, where subjects had to use some relevant amount of cognitive computation to provide the answer, and 4 filler questions, where the answer was trivial. The filler questions were used as an attention and basic numeric literacy test. For both groups, the questions pertained to risk prevention provided by personal protective equipment (PPE), swab tests, serological tests, and vaccines. Participants had to provide an open answer as the solution to the question. Some questions were to be answered with an integer, others with a percentage. The survey was administered in Italian and submitted online with QualtricsXM platform (www.qualtrics.com). Data were collected in November 2020 and in September 2021, during some events of scientific divulgation, and through snowball recruitment via social media.

We collected 110 adult subjects, who provided privacy consent and who were able to comprehend the instructions, correctly completed the filler questions, and answered all questions. Fifty-seven subjects (mean age = 43.4, SD = 15.6; Females = 31; Males = 25, Undeclared = 1; for the education level, 70% of them had a degree) were randomly assigned to the Control group. Fifty-three subjects (mean age = 46.2; SD = 15.5; Females = 24; Males = 29; 56% had a degree) were assigned to Treatment.

After the welcome page, the general purpose of the study was explained to all participants, who had to provide privacy and data protection consent. Then, subjects were randomly assigned to one of the two groups of questions. Before starting to answer, subjects received instructions, followed by a comprehension check. Questions were randomized and presented singularly. The first two questions regarded conditional probability as explained in Sect. 2. As an example, let us consider the swab question. Table 2 presents the question for the two groups:

Table 2. Text of the swab question for the two groups.

Group	Control	Treatment
Question	The swab test is the standard test for assessing infections from COVID-19. Suppose that, in a region, 4% of people has COVID-19. Suppose further that the entire population in that region undergoes the swab test. If a person is infected with COVID-19, the probability that the swab test results positive is 80%. If a person is not infected with COVID-19, the probability that the swab test is still positive is 3%. Consider a person that undergoes the test and results positive: what is the probability (in percentage) that that person is effectively infected with COVID-19?	The swab test is the standard test for assessing infections from COVID-19. Suppose that, in a region, 40 people out of 1000 have COVID-19. Suppose further that the entire population in that region undergoes the swab test. Among the 40 people infected, 32 result positive to the swab test. Of the remaining 960 people not infected with COVID-19, still 29 result positive. Of the total of positives, how many people will be effectively infected with COVID-19?
Correct Answer	53%	32 out of 61

For the "swab" item and the "serological" one, structurally similar, participants were instructed to provide an answer as a single percentage (Control) or two values as natural frequencies (Treatment). For the "swab" question, in the Control group the right answer ("53%") was provided by 5 subjects out of 57. For the Treatment group, 18 people out of 53 provided the complete right answer ("32 over 61"). It should be noted that 23 subjects provided the right answer only for the truly positive tests ("32"), and 28 only for the total number of positives ("61"). The mode answers were "77%" and "80%" for Control, while, for the Treatment, the mode corresponds to the correct answers. In the "serological" question, the correct answers were "44%" (Control) and "45 over 102" (Treatment). The right answer was provided by 2 subjects in Control, and by 13 subjects in Treatment. The results of these two questions were generally expected according to previous literature, with a higher number of correct responses for the treatment condition.

The other two questions investigated the relative risk as discussed in Sect. 2. Table 3 shows the text for the "PPE" question and the correct answer.

For the "PPE" item and the "vaccine" one, participants for both Control and Treatment were instructed to provide an answer as a single natural frequency. In the "PPE" question, 33 participants out of 57 answered correctly in the Control, while 39 out of 53 provided the right answer in Treatment. The mode in both groups corresponds to these answers. The results discussed so far were generally expected according to previous literature, with a higher number of correct responses for the treatment condition. However, for the "vaccine" item, whose wording was analogous to the "PPE" item, the results are deviating from those of the first three questions. The correct answer was provided by 33 subjects in Control, and only by 27 subjects in Treatment.

Table 3. Text of the PPE question for the two groups.

Group	Control	Treatment
Question	Suppose that, in the general population, COVID-19 infects 5% of people. A recent study has shown that wearing the mask reduces the spread of the virus: the contagions decreased of the 60% between those wearing the mask compared to those who do not. Consider a sample of 1000 people wearing the mask. How many of them will be infected?	Suppose that, in the general population, COVID-19 infects 50 people out of 100. A recent study has shown that wearing the mask reduces the spread of the virus: the contagions decreased from 5 among people not wearing the mask to 2 among those wearing it. Consider a sample of 1000 people wearing the mask. How many of them will be infected?
Correct Answer	20	20

Discussion: It may be useful to remind that we expected to observe two main results: (1) people estimate statistical information much better when presented in natural frequency format rather than percentage, and (2) when they to manipulate statistical information, people fail to consider the correct reference class resulting in base-rate fallacy. Our expectations have been mostly met by the results of the pilot study. For what pertains to the first and second questions of the survey, related to swab and serological tests, subjects in the Treatment condition outperform Control in providing the right answer, even if they had to provide two different numbers instead of one. However, it is worth noticing that these two questions - as compared to the other two items – required a Bayesian computation to be solved correctly. Indeed, as instances of diagnostic reasoning, the right answer represented a conditional probability $p(C|P)$, i.e., the posterior probability of suffering from a certain condition C, such as COVID-19, given that the test result is positive (event P). To calculate it, subjects were asked to (i) assess the prevalence or base rate $p(C)$ of the COVID-19 in the general population, (ii) consider the sensitivity or hit rate $p(P|C)$ and the false alarm rate $p(P|\neg C)$ of the test, and, finally, (iii) perform a Bayesian computation by using the Bayes' Theorem on such estimates. For what pertains the base-rate fallacy, in both questions the overwhelming majority of subjects in the Control group provides an answer that is compatible with committing such a mistake. For example, in the "swab" item, 32 out of 57 participants gave an answer (either "77%" or "80%") that can only be reached if the prevalence of COVID-19 in the population is not included in the calculation. That cognitive pitfall is avoided by subjects in the Treatment group.

Albeit formulating information in natural frequency seems to help in arriving at the right answer, it is interesting to note that the trade-off between ease of cognitive computation and wording fluidity remains unavoidable. While it is true that in the answers provided by the Treatment group the mode coincides with the right answer, it is also true that in both questions less than half of the subjects (44%) managed to provide it. This is slightly worrying, considering that in both cases one of the correct numbers (the

number of truly positives) was directly provided in the text of the question and thus it did not have to be calculated.

The difficulty of handling probabilities in percentage format can also explain the result of the third question concerning "PPE". Relative risk estimates and the mistakes related to this kind of information were indeed mitigated by the presentation of data in natural frequencies. Indeed, 39 out of 53 (74% of the total) provided the right answer in the Treatment, while 33 participants out of 57 (58%) answered correctly in the other condition. Interestingly, in this case the majority of people from the Control group was able to provide the right answer: the impact of base-rate fallacy on the answer provided is negligible for both groups. It should be noted that for this and the next question, Control performs much better than in the first two items. Such a result can be due to the fact that, in the latter questions, subjects were asked to provide the answer in a natural frequency format, rather than in percentage, as it was the case for the former two questions. This factor could as well have played a role in the fact that the results provided by the fourth item were diverging from our expectations. Even though the formulation was completely analogous to the "PPE" item, only 27 over 53 (51%) participants in Treatment gave the right answer, while 33 out of 57 (58%) of subject in Control were capable to do so. The number of subjects that provided a right answer in Control is not surprising, given how it is the same rate that was seen in the "PPE" item: indeed, 25 out of 57 Control subjects were able to answer correctly to both questions. The discrepancy is evident only for Treatment: only 24 out of 53 Treatment subjects managed to provide an exact answer to both "PPE" and "vaccine". However, given the existing literature and the limited scope of this preliminary pilot study it is difficult to provide a clear and comprehensive explanation, or even to tentatively suggest an interpretation of this data. In order to shed light on these results, we plan to collect more data and perform further analyses.

5 Conclusions

When subjects reason under condition of partial or severe uncertainty, they commit mistakes, as the recent literature underlines. In particular, the understanding of probabilistic data has attracted a wide discussion among psychologists, economists, and researchers on decision-making. The effort put so far upon communicative strategies suited to facilitate people in handling probabilistic information appears to meet the aims of cognitive ergonomics. In the present work we explored such a field of research in between critical thinking, psychology, and the study of ergonomics and human factors by focusing on risk communication concerning information about the recent COVID-19 situation. In this respect, we qualitatively analyzed several tools used for institutional communication and, in particular, dashboards providing information in different formats and through a variety of stylistic strategies. Then, we directly explore people's understanding of risk and probabilistic information by means of a pilot study administered online. The efficacy of the public, institutional communication during the COVID-19 showed mixed results and the platforms considered in our study seem to confirm such a general trend.

As far as data are presented to the public, we can highlight the key role of different aspects. First, we can notice that it is important to clearly define the terms and concepts used to report them, in particular when such information concerns conditional probabilities. Second, it is relevant to adopt accurate, practical strategies for representing

information according to the case, in order to increase transparency in the communication. Third, it is useful to limit the use of percentages and relative information to those cases in which frequencies are verbose or may lead to confusion. Overall, the frequency format should be preferred, given that it forces to make reference classes explicit.

To further enquire into how different communication formats can influence the understanding of data provided on risk, we developed a between-group pilot study, where the same information content was conveyed to two groups either as percentages or as natural frequencies. In line with pre-existing literature, we found that the use of natural frequencies improves rates of understanding and manipulation of such information. Interestingly, these results hold true for three out of four items of our survey: the data provided by the fourth item diverge from what was expected. However, the limited nature of our survey does not allow us to provide a strong interpretation for this result, which remains a question open to further research.

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Natural Surgeon Interfaces: Perspectives and Examples of Intuitive Laser Control Systems in the μRALP Project

Giacinto Barresi[1](✉), Darwin G. Caldwell[2], and Leonardo S. Mattos[2]

[1] Rehab Technologies Lab, Istituto Italiano di Tecnologia, Genoa, Italy
giacinto.barresi@iit.it
[2] Advanced Robotics, Istituto Italiano di Tecnologia, Genoa, Italy

Abstract. This paper aims at discussing the opportunities offered by the perspectives of natural and reality-based interaction design in robot-assisted microsurgery. Specifically, it presents the "Natural Surgeon Interfaces" (NSIs) designed during μRALP (European project on Micro-Technologies and Systems for Robot-Assisted Endoscopic Laser Microsurgery). The goal was to make the experience of controlling a laser similar to handling a scalpel. In terms of cognitive ergonomics and neuroergonomics, the NSI systems in μRALP were based on the enactive coupling of perception and action that occurs when humans handle a tool. Accordingly, μRALP proposed a Virtual Scalpel and a Haptic Scalpel, which became part of a Neurotraining Scalpel setup too. Such exemplary cases of visuo-haptic paradigms of μRALP can truly make a physician a "natural surgeon".

Keywords: Robot-assisted surgery · Augmented reality · Natural interaction · Reality-based interaction · Haptics

1 Introduction

This paper describes the approach of μRALP – European project on Micro-Technologies and Systems for Robot-Assisted Endoscopic Laser Microsurgery (Mattos et al., 2021) – to "Natural Surgeon Interfaces" designed for tasks of laser phonomicrosurgery (LP). The next sections will introduce the background and rationale of this user-centered perspective, three exemplary solutions proposed by the project team according to this approach, a discussion on their potential impact, and a conclusion with hints to future work in this area.

2 Background

Hand tools (Hedge, 1998) like scalpels have always been intuitively designed to match human capabilities of eye-hand coordination to achieve high dexterity. A physician can learn how to skillfully handle these blades because their design is highly ergonomic,

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https://doi.org/10.1007/978-3-031-28390-1_12

enabling safe and precise interventions in a risk-sensitive professional domain (Wu et al., 2009).

We can assume that the dexterity in using such tools depends on embodied and enactive processes (Hipólito et al., 2021; Varela et al., 2017). These processes, based on the coupling of perception and action, are enabled, in this case, by a direct visuo-haptic experience of the surgical site under the surgeon's eyes and hands. By inheriting the enactive role of the hand (Gallagher, 2013), a tool can enable the physicians to "feel" the target through their action on it. Consequently, high levels of sensorimotor control can be naturally achieved during the professional learning and practice. However, tools for microsurgery do not typically behave as intuitive instruments as the common scalpels and they need improvements in ergonomics, especially in case of robot-assisted operations (Mattos et al., 2016; Mattos et al., 2015). Indeed, microsurgeries are mediated activities: an endoscope brings the view of the surgical site to the physician, who operates through devices extended into the depth of the body, beyond any direct and natural coupling of action and perception as the one we described above.

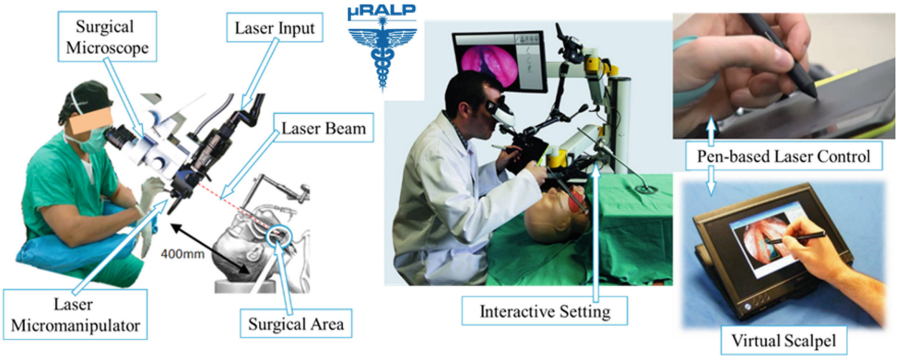

Fig. 1. Left: a typical setting for LP. Right: an interactive setting of μRALP with its Virtual Scalpel

Such a condition is particularly true when we consider contactless microsurgeries, mainly in case of laser operations (Fichera, 2021; Renevier et al., 2016). Indeed, the laser energy burns tissues to remove anomalies without providing the user with any feedback typically offered by a blade in the surgeon's hands. This makes specific training or specific tools necessary for enabling the surgeon to visually recognize the effects of the instrument use. However, considering how the activity of the laser could visually mimic the one of a blade (with the advantage of thermally sealing the cut), the μRALP project (Fig. 1) proposed a scalpel-like control of lasers for LP (Mattos & Andreff, 2013).

The μRALP approach in this domain is based on the class of natural interaction paradigms, typically based on voice and gestures as means to control a Natural User Interface – NUI (Liu, 2010). However, NUIs cannot always be intuitive if their use is not spontaneous in a certain context (Malizia & Bellucci, 2012; Norman, 2010): for instance, gestures are natural in many daily activities, but they could not be considered so to perform activities like surgeries. However, the design perspective of Reality-Based

Interaction (RBI) (Jacob et al., 2008) can help to adjust this approach by getting inspiration from human actions with a meaning in the physical world, according to concepts of naive physics and (bodily, environmental, and social) awareness and skills of individuals in real contexts.

Designing a reality-based NUI leads to a user experience closer to real world behavior, especially if it exploits the sensorimotor capabilities of the user for manipulating real objects into their setting by providing the expected physical feedback.

This mindset led the design of Natural Surgeon Interfaces (NSIs) in μRALP, as presented by the examples in the next section.

3 Natural Surgeon Interfaces

This section presents examples of NSIs designed, developed, and tested during μRALP project and in its further developments. Specifically, this section will discuss the "Virtual Scalpel" and the "Haptic Scalpel", and an application of the latter as a "Neurotraining Scalpel". These solutions are mainly based on the control of a pen-like device in order to provide the user with the feeling of controlling a blade (a surgical scalpel) while the real activity is performed by a laser.

The Virtual Scalpel introduced this concept in order to ease the surgeon's activity in LP by means of a touchscreen and a pen connected to a robot controlling a laser.

The Haptic Scalpel offered further features in terms of tactile exploration and stereoscopic view of the surgical area.

The Neurotraining Scalpel integrated the previous solution to obtain a system to improve the surgeon's mental focus control through a reality-based neurofeedback.

3.1 Virtual Scalpel

The NSI design approach in μRALP was initially adopted for implementing the Virtual Scalpel (Fig. 2) as a surgeon-machine interface for laser control based on the activity of holding a tool and moving it over a surface instead of changing the position of a red dot through a manual micromanipulator.

This system (Mattos et al., 2011) was designed to replace the micromanipulator with a motorized one, controlled through a stylus and a touch-screen tablet showing a live video of the surgical area. This setup advantageously enables the control of laser aiming and activation through the stylus instead of, respectively, the micromanipulator and the footswitch (as in traditional LP settings). This way, the users should not split their attention between two actions performed with different limbs, obtaining higher dexterity.

The user handled the stylus across the touchscreen to define the trajectory that the robot must follow to move the laser on the surgical site. This system was assessed (Barresi et al., 2013) in user tests with surgeons burning in teleoperation 2D lines on plaster blocks (Fig. 3), and compared to a typical system – AcuBlade – for LP, as in Fig. 1 on the left. The assessment was based on (i) the subjects' responses to usability questionnaires (including the request to estimate the task execution time) like the System Usability Scale (Brooke, 1996) and (ii) the users' performance in terms of precision and

Fig. 2. The Virtual Scalpel

accuracy (Deshpande et al., 2013). In (Barresi et al., 2013), these measures were proposed within an integrative protocol for a comprehensive user-centered evaluation of surgeon-machine interfaces. The combination of the subjective assessment and the objective metrics enabled a rich usability analysis by considering the surgeon-technology system performance as a whole.

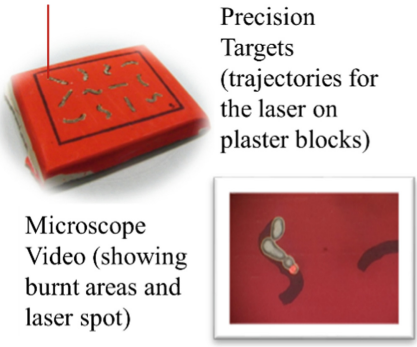

Fig. 3. The plaster blocks and their visualization

The results of the trials (involving 24 surgeons as subjects) demonstrated the advantage of using the Virtual Scalpel setup over the traditional one, as listed below - see (Barresi et al., 2013; Mattos et al., 2014).

1) The Virtual Scalpel system showed significantly higher subjective global scores in terms of usability than the AcuBlade interface.
2) The unified score of objective metrics highlighted the significant advantage of the Virtual Scalpel over the AcuBlade interface.
3) The subjects estimated that it takes significantly less time to perform cuts by means of the Virtual Scalpel than the AcuBlade interface. However, the actual time for

performing a cut was longer with the Virtual Scalpel than the AcuBlade interface. Thus, it was inferred that the Virtual Scalpel interface generates a lower mental workload in the user than the traditional system.

Furthermore, the longer time spent to perform cuts could have been caused by the desire to exploit such a responsive and easy to handle tool for achieving even greater precision and accuracy.

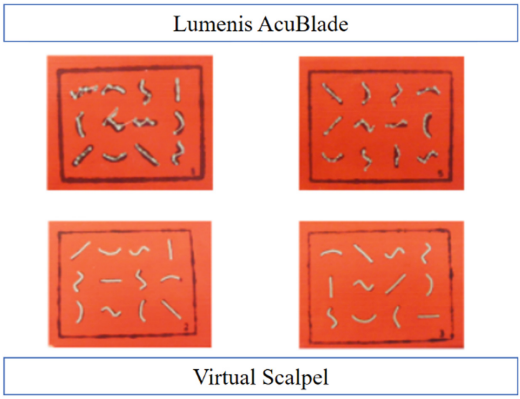

Fig. 4. Plaster blocks with lines burned by means of the Virtual Scalpel (bottom) and the AcuBlade (top)

Overall, these results highlight the superior usability of the Virtual Scalpel over traditional laser control systems for LP. In terms of objective measures, Fig. 4 shows the difference between the performance with the Virtual Scalpel (bottom row) and the AcuBlade interface (top row).

The project team also implemented different versions of the Virtual Scalpel system, including a setup based on a head-mounted display and a touchscreen (as in Fig. 1, on the top right corner). Among other features, the Virtual Scalpel enables a surgeon to simply define the trajectory of the laser for subsequent automatic execution by the robot, avoiding risks linked to human hand tremblings or errors when repeating the same trajectory multiple times for achieving deeper laser cuts. This planning feature increases the safety of the system alongside its performance.

Furthermore, a planning system was devised and developed in terms of co-operative features like the possibility for another physician to draw safe areas on a secondary screen (according to bioimaging views over the surgical site) (Deshpande et al., 2014).

Over those areas the laser cannot be activated, achieving a further solution for the patient safety. This cooperative multi-display solution extends the NSI concept to secondary screens where the user can intuitively draw the safe areas by means of another stylus, experiencing a further level of RBI involving multiple individuals within the same shared operative context.

Furthermore, this versatile "drawing" paradigm of NSI has been explored[1] through innovative solutions like a handheld/mobile version of the Virtual Scalpel (Fig. 5) for tele-surgery and tele-collaborative intraoperative planning. This way, remote surgeons can observe the execution of procedures, possibly participating through portable smart devices (e.g., defining laser trajectories through graphical overlays).

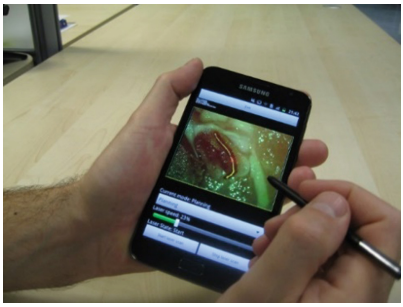

Fig. 5. A Handheld/Mobile Virtual Scalpel

In general, the Virtual Scalpel approach demonstrated its value as innovation in surgical robotics. As subsequent developments over the μRALP setup, these concepts were implemented in the CALM system (Acemoglu et al., 2019), which was used for 5G robotic transoral laser microsurgeries on a remote cadaver (Acemoglu et al., 2020). It also became a milestone before exploring haptic solutions as in the system discussed in next sub-section.

3.2 Haptic Scalpel

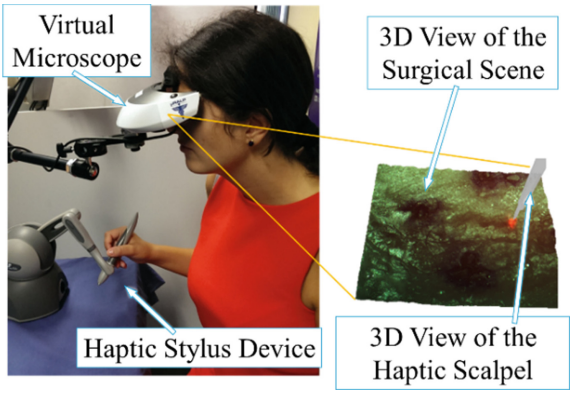

Fig. 6. The Haptic Scalpel

[1] https://advr.iit.it/virtual-scalpel-system-for-laser-microsurgery.

The tactile component of the Virtual Scalpel was surely an improvement in terms of maneuverability more than perception of the surgical site because it lacked a tactile feedback to be a full-fledged NSI. For this reason, μRALP proposed another solution to enrich the surgeon experience with haptic features: the Haptic Scalpel (Olivieri et al., 2017)[2] (Fig. 6), which extended the RBI approach of mimicking a scalpel. In this case, a haptic device – the Phantom Omni, constituted by a pen-like tool connected to a mechatronic arm – provided the surgeon with the feeling of actually handling a surgical tool across the surgical site. This happened thanks to an augmented reality (AR) scalpel with a tip located on the laser spot in a stereoscopic view of the surgical site (observed through a head-mounted display).

The system was designed for making the stylus held by the user (i) follow the shape of the surgical site surface and (ii) control the orientation and the position of the AR scalpel. Beyond a scalpel-like control of the laser (activated by pressing a button on the pen), this system also enabled an innovative mediated procedure for medical palpation with the same tool used for burning and cutting anomalies in tissues – demonstrating an even greater value in terms of ergonomics, usability, and safety.

The research activities that led to this system were initially based on previous research about the advantages of kinaesthetic and vibrotactile feedback (Fichera et al., 2016). This study highlighted how the lack of haptic feedback in laser surgery prevents the physicians from accurately discerning the depth of the incisions during the operations. Within a teleoperated surgical platform developed during μRALP, the authors adopted a commercial haptic device to provide the user with information on the incision depth. Subsequently, (Olivieri et al., 2017) implemented an active constraints system with a stereoscopic 3D and real-time reconstruction of surgical scenes (viewed via head-mounted display) for developing and testing the Haptic Scalpel.

This system was assessed in the same study with 17 surgeons (after preliminary tests with 20 engineers and 5 surgeons) in terms of user experience and performance within a simulated scenario of LP (removal of anomalies in vocal folds, in this case). In this simulation (Fig. 7), fictitious force feedback was experienced by to the user, who controlled the motions of the laser beam through the haptic setup and haptically perceived the surgical site.

Before focusing on the visual representation of the scalpel, this study analysed the effects of using different types of active constraints to characterize the haptic feedback (the incision can work as a valley where the stylus falls or it can be represented through a "magnetic" force field). Overall, a user experience questionnaire pointed at the advantages of these active constraints provided by the haptic paradigm.

The proposed solution was also shown to significantly improve the accuracy of laser incisions. This happened especially when the laser had to pass over the same incision line several times. Indeed, prior laser incisions worked as dynamic active constraints within the roughness and topography, improving the precision of surgeons when following the same trajectory to create deeper incisions.

The authors also envisioned how this technology can improve other types of surgical procedures based on non-contact surgical tools, such as radiosurgery and high intensity focused ultrasound surgeries.

[2] https://advr.iit.it/index.php/haptic-laser-scalpel.

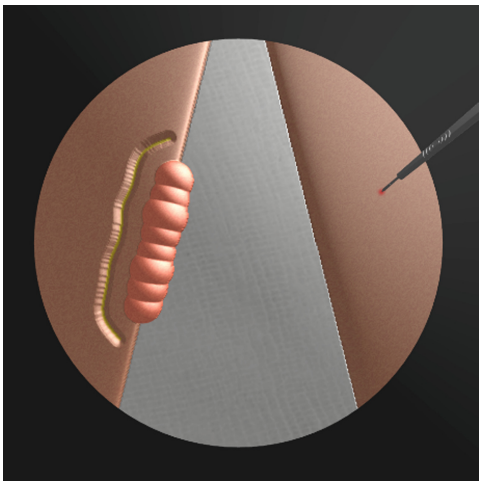

Fig. 7. The simulated surgical site with active constraints used to test the Haptic Scalpel

Considering the overall results of a user experience questionnaire, the general lack of statistical significance in the differences between a condition with and a condition without the Haptic Scalpel was compensated through the semi-structured interviews with the surgeons. Overall, they complained about an unexpected vibration on the haptic device and they asked for improvements in the AR tool design. This criticism pointed at the request to replicate the feeling that the blade "makes its way" through the tissue encountering almost no friction and leaving a bleeding wound behind. It must be noted that the lasers work on a totally different way because the incision is performed with a vertical orientation and without bleeding.

Interestingly, this confirms how the solution made the users expect that the system would fully work as a scalpel, projecting on them expectations on its behavior according to their experience with scalpels. They also asked for testing more comfortable commands to activate the laser and for a semi-transparent Haptic Scalpel to avoid occlusions (trying to take advantage of the possibility of visually manipulating a non-physical tool as a real scalpel). In general, the study in (Olivieri et al., 2017) highlighted the value of the RBI-based AR scalpel as a complete NSI with haptic features. This visuo-haptic solution made the positioning of the laser in space more intuitive, leading to an improved use of the device to sense and act on the surgical scene. During the development of the Haptic Scalpel, an iteration of this system was also used to implement a solution for training the surgeon's mental focus. This concept is described in next sub-section.

3.3 Neurotraining Scalpel

Training the mental focus of a surgeon is definitely a critical task because of its potential impact on the performance of a professional operating into hazardous settings. Indeed, preventing life-threatening errors must be achieved through improvements in user-centered design alongside user training advances. This problem was approached in

two studies (Barresi et al., 2015; Olivieri et al., 2015) based on the Emotiv EPOC**,** a commercial electroencephalographic (EEG) brain-computer interface (BCI). In this work, a new technique for surgeon's concentration training in the context of robot-assisted laser microsurgery was proposed. The solution was based on neurofeedback: the user performs a live self-regulation of brain-related indices by paying attention to their visualization (even if it could be represented through any sensory modality). Neurofeedback paradigms have been used in different types of mental training tasks (Barresi et al., 2022; Wang & Hsieh, 2013). The approach initially presented in (Olivieri et al., 2015) coupled AR features to both the BCI-based online estimation of the user's concentration and the control of a preliminary version of the Haptic Scalpel to obtain a Neurotraining Scalpel (Fig. 8).

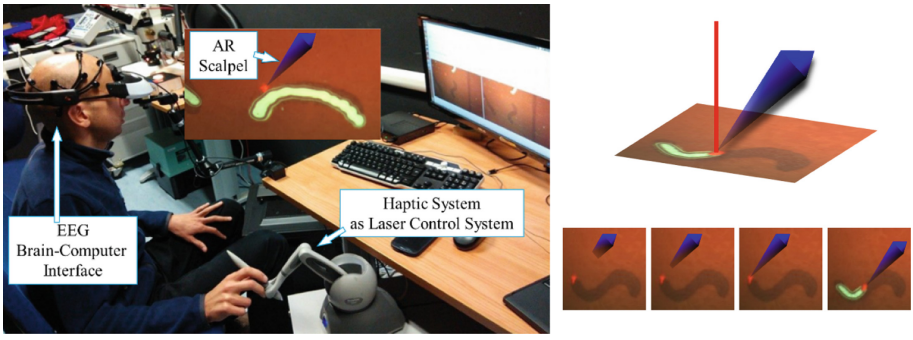

Fig. 8. The Neurotraining Scalpel (left) with a feedback example (right) while the mental focus increases

This approach was labeled as a brain-controlled augmented reality (BcAR) system. The focus stimulation was provided by modifying features of an AR item according to the real-time monitoring of the subject's mental state. Specifically, such a feedback was provided into a teleoperation scenario as the behavior of an AR scalpel that works as a "retractable" knife according to the user's mental focus: the blade retracts when the user's mental focus level falls below a certain threshold, visually highlighting that the laser cannot be activated by the user. Thus, the scalpel was "retracting" when the subject was distracted, and the participant had to focus for "extending" it to re-enable the laser control.

The design of this solution was devised according to a concept of directional compatibility (Worringham & Beringer, 1998) between the AR feedback animation and a spontaneous motion of user's attention along the AR tool (Park et al., 2013), resulting in an intuitive system for concentration training.

In (Olivieri et al., 2015), the impact of this solution over a condition of AR scalpel without neurofeedback was evaluated through the effect of the training on a set of test trials without BCI. 10 naïve subjects were involved. This was done through a task based on the Virtual Scalpel tests with plaster blocks. First, results on user experience (questionnaires) and performance (imaging based metrics, times) showed that wearing the BCI device does not affect the user experience and the setup was appreciated by the

subjects regardless of the BCI usage. In addition, the neurofeedback condition made the subjects faster during the test than the condition without neurofeedback. This suggests that the BcAR training generated high engagement, improving the subject's readiness even after a short session. After this study, the authors decided to investigate the actual impact of the RBI, pondering if a feedback design without such a quality could enhance the user performance too. Consequently, the work in (Barresi et al., 2015) was performed by adding a third condition: when the mental focus was falling, the AR scalpel became more transparent, preventing the laser activation. The subject had to concentrate for making it fully visible again. Figure 9 depicts these three conditions, highlighting how the first one was based on a concept of directional compatibility directly inspired by the RBI framework. This study involved 15 naïve subjects.

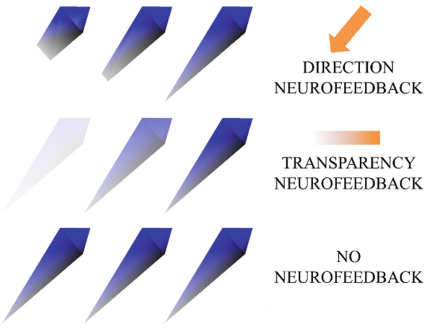

Fig. 9. The 3 feedback design conditions of the Neurotraining Scalpel

According to the questionnaires, positive judgments of the AR scalpel were confirmed. However, the participants in transparency-neurofeedback condition experienced higher stress and higher difficulty in learning to perform the task than the subjects in the direction-neurofeedback condition and in the no-neurofeedback condition. These differences could depend on the difficulty in handling a tool lacking realism (real objects do not vanish and re-appear). This could be especially true when a precision and error-prone task like surgery requires to perceive a tool as a reliable item. According to this interpretation, these results confirm the validity of the RBI approach to design the Neurotraining Scalpel according to the real-like dynamics of a "retractable" blade.

A lack of significance in most comparisons of objective metrics was caused by a high data dispersion that made the authors infer the need of a longer training to obtain results in these terms. However, the direction-neurofeedback condition made the subjects significantly faster in test trials than in the other conditions. This finding and the questionnaires suggest that the feedback design based on directional compatibility was more intuitive and produced higher engagement and less workload in the users, probably because it followed the spontaneous path of the user's attention along the tool. This enabled a more "natural" (as requested in the NSI perspective) way to stimulate the user's reactivity.

4 Discussion

The previous section quickly described a set of NSI design solutions presented in systems developed during the μRALP project or in subsequent research that extended its results.

The Virtual Scalpel was specifically assessed in (Barresi et al., 2013) to demonstrate the impact on user experience and performance (through subjective and objective measures) of using a scalpel-like system based on a stylus and a touchscreen to control a robotic system moving a laser.

The Haptic Scalpel in (Olivieri et al., 2017) explored the introduction of haptic features to approach even further the similarity of the control system to a scalpel. The use of a haptic device enabled the implementation of this NSI and its preliminary evaluation.

The Neurotraining Scalpel was fully evaluated in (Barresi et al., 2015) to define how a reality-based design of the AR scalpel behavior can be crucial to engage the user to appropriately perform the task. This points at a guideline that needs anyway further investigations for understanding its degree of generalization to different cases.

Overall, these 3 systems progressively added reality-based features to reach a higher level of plausibility even in a simulation. On the other hand, performing tests in simulated scenarios can constitute a limitation of these studies, alongside the small sample sizes (due to the difficulty to involve numerous surgeons). However, the subsequent application of these NSI paradigms in other studies – as in (Acemoglu et al., 2020) – confirms the validity of these results of μRALP in enhancing the robot-assisted laser microsurgery control.

5 Conclusion

This paper described the NSI design proposed by the μRALP project to improve robot-assisted surgical techniques. The examples offered μRALP highlight the feasibility and the opportunity of adopting this design approach for making a physician a "natural surgeon" handling a laser like a scalpel. Upcoming works should also consider the most recent NUI concepts in surgery – e.g., (Berger et al., 2018) – and, in general, in interactive environments – e.g., (Maronnat et al., 2022). This step may help to refine the NSI design approach before exploiting it in different types of surgical tools too. Additionally, all hypotheses on mental focus training and neurofeedback must be tested in further studies, pondering the perceptual and cognitive processes underlying this interaction pattern.

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Real-Time Data Analysis and 3D Representation for Postural Assessment in Manufacturing Processes

Chiara Carnazzo[1(✉)], Stefania Spada[1], Sebastiano Lamacchia[2], Federico Manuri[3], Andrea Sanna[3], and Maria Pia Cavatorta[4]

[1] Stellantis, EE HR and Transformation - Wellbeing Health and Safety – Ergonomics, Torino, Italy
chiara.carnazzo@stellantis.com
[2] Stellantis, Stellantis Production Way, Torino, Italy
[3] Politecnico di Torino – Department of Control and Computer Engineering, Torino, Italy
[4] Politecnico di Torino - Department of Mechanical and Aerospace Engineering, Torino, Italy

Abstract. Industry 4.0 passes through the concept of smart factories, bringing into the industrial context a new vision of production lines and workflows, which can now be designed considering ergonomics and thus the interaction among operators, machines, and tools, in accordance with human-centered design principles. Virtual simulations help in reproducing such interactions and in foreseeing solutions to improve the working conditions before installing tools and equipment. In addition, motion capture techniques have proven capable to guarantee the reproduction of human motion with sufficient accuracy. The present work aims at the development of an integrated tool for ergonomics risk assessment index calculation, using motion capture in 3D environments. With this purpose, starting from motion capture acquisitions, an engine for postural angle calculation, in accordance with international standards, and a Unity-based application have been specifically designed and validated. The work is part of the IM.PR.ES.S.E.D. (IMmersive PRocESs ergonomicS by wEarable Devices) project.

Keywords: Ergonomics · Industry 4.0 · Motion Capture · Virtual Simulation

1 Introduction

The fourth industrial revolution is shaping the future of the manufacturing processes, exploiting the latest innovations in the field of information technology to improve productivity, reduce costs, and offer an enhanced working environment to employees. However, this innovation process should consider the human factor as a core value, thus, the implementation of industry 4.0 principles should seek a user-centered design approach and for early adoption of the ergonomic principles in workplace design [1].

The exploitation of technological innovations is crucial in the context of today's production environments, which are characterized by a complex collaboration paradigm involving the user, the machine, and the system. The adoption of ergonomic principles

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from the design stage may prevent negative effects, such as deployment delays, low quality, and low usability in the final system, as well as additional costs due to subsequent modifications to improve or revise the system at a later stage. This kind of awareness regarding the human factor is also encouraged by numerous studies and industry trends.

Recent Eurofond data indicate that a quarter of the European working population has chronic disorders [2]. The most common occupational disorder is musculoskeletal, and the main risk factors include working postures, overload, and repetition. In particular, among the member states of the European Union, the incidence of disorders of the musculoskeletal system increased from 54.2% in 2007 to 60.1% in 2013 [3]. Pain is the most common symptom, with high percentages for the shoulder, neck, and lower back. This incidence is even more worrisome if we consider that the employment rate of older workers aged between 55 and 64 in the EU stood at 55.3% in 2016 [4]. In Italy, the economic impact of disorders on the musculoskeletal system is estimated at nearly 7.2 billion euros, with a high social cost both nationally and at the company level. Unfortunately, this cost is destined to increase if we consider that the same Eurofond data estimate that by 2021 24% of the Italian workforce will be over 55 years of age.

Research by groups such as Gartner Research highlights how the adoption of digital technologies for the creation and prototyping of products, machinery, and production lines in a virtual environment, according to the digital-twin model envisioned in the paradigm of Industry 4.0, represents a strong boost to manufacturing productivity and agility [5]. The next challenge consists of further increasing the flexibility of manufacturing systems, maximizing the production capacity, and enhancing the central role of the user and his/her problem-solving abilities, which represent an element of experience and operational intelligence to further improve industrial processes.

To this end, Virtual Reality (VR), as a high-level human-computer interface that includes real-time simulations of the real-world and multiple interactions with digital objects through multiple sensory channels [6], represents a relevant technology to exploit. Nowadays VR is applied to many application fields, such as entertainment, medicine, culture, marketing, education, tourism, and cultural heritage. One of the most relevant application fields in recent times is industrial prototyping: until a few years ago, the countermeasures adopted to address system faults and accidents were based solely on reducing risk factors.

However, the technological advances in 3D design software and virtual simulator enable designers to reduce the likelihood of damage due to technical failures a priori. Supporting the design stage with virtual reality technologies, also known as Virtual Reality Aided Design (VRAD), enable the user to try the tool to be validated in a simulated environment before the physical prototyping phase of the tool itself. An application case supporting this paradigm is provided by a research project focused on the design of a mechanical press capable of bending metal sheets [7]. The simulator not only provided the functionality of the mechanical press but also integrated and simulated the various protection systems and their impact on the sheet production cycle.

Further examples of virtual simulations which enclose a user-centered design approach involve the usage of virtual parametric mannequins, which are virtual models of human figures which respect natural proportions. Virtual parametric mannequins are obtained by measuring anthropometric values from the real reference or through a scan,

and they are adaptable to different physiques. 3D modeling techniques are widely used to recreate realistic human bodies and physiques which can be used in 3D virtual simulations to virtually represent a human model. Many techniques have been proposed to properly reproduce into a virtual environment different body builds [8]: since human models share a common basic structure, it is possible to parameterize the variables defining the different body builds by relying on a statistical analysis of data. SCAPE (Shape Completion and Animation of PEople) is a data-driven method for building a human shape model that spans variation in both subject shape and pose [9].

Virtual mannequins have many possible application scopes. A relevant use case is provided by LifeMOD, a software that enables the user to create a virtual human model and to experience it inside a virtual, simulated interactable environment. The model creation relies on different variables such as age, height, weight, and gender, and provides automatic creation of the skeleton, the musculature, and the joints. A relevant use case in the industry is provided by Tecnomatix Jack, a software that allows the user to simulate a digital environment with virtual mannequins and analyze the ergonomics of the dummy to redefine the design of an industrial product or task [10]. Jack allows the user to resize human models to match different ethnic groups of workers, as well as simulate processes to evaluate multiple factors, including the risk of injury, user comfort, reachability, field of view, energy consumption, fatigue limits, and other important human parameters. The use of Jack allows to significantly reduce costs and time, improving the design of comfortable workplaces, and enhancing the quality of life of the final user in terms of system interactions and assembly operations.

2 Objectives

The aim of the proposed research work is the design and development of an application that provides 3D postural analysis and visualizations from motion capture data. The innovative features of this application have to be identified first in the algorithms for the calculation of joint angles, which were written to guarantee compliance with the posture and joint angle definitions provided by the relevant ISO and EN standards. Secondly, the Unity-based application can be designed in accordance with the principles of ergonomic risk assessment requirements.

The application developed aims also to enable the user to automatically compute the required information for the postural section of the EAWS method (Ergonomics Assessment WorkSheet, method proposed by International MTM network for ergonomic design and analysis of workstations). The proposed module should enhance the analyst's ability to improve both workers' well-being and productivity of the manufacturing process.

The activities described in the paper are part of the IM.PR.ES.S.E.D. (IMmersive PRocESs ergonomicS by wEarable Devices) project.

3 Methodology and Design

3.1 Ergonomics Analysis Through Motion Data

For body postures with low external efforts, the technical standards of reference for the ergonomic risk evaluation are EN 1005–4 [11] and ISO 11226 [12]. These standards

define acceptable angles and holding times of working postures. In many work cases and practical applications, an analyst observes the worker and evaluates the joint angles by simple estimation of projected angles in videos or pictures of the analyzed work activities. Subjective observations can lead to low accuracy, carrying a high potential of intra- and inter-observer variability.

In the present work, data are to be collected directly from Inertial Measurement Units (IMU) attached to the worker's body. Such wearable sensors have been proven to be sufficiently accurate for posture and body movements and for conducting a quantitative ergonomic assessment [13]. The body posture and motion can be recorded during long-time operations and the joint angle is calculated autonomously by the joint position. In particular, each joint angle is computed through inverse trigonometric functions to calculate the angle between the two vectors that define the position of each one of the two adjacent limbs. A challenging task is the selection of the three relevant points to define the required posture or joint in accordance with the international standards even in the case of composite postures assumed by the manikin.

A typical case is arm elevation, which is a combination of upper arm movement in the coronal plane (abduction-adduction) and the sagittal plane (flexion/extension) [14]. Or trunk inclination, which needs to consider and identify trunk flexion, trunk lateral inclination, and trunk rotation. The identification of such angles is also required for the correct application of many ergonomic assessment methods. For example, in the case of EAWS, the degree of trunk flexion will identify the basic posture whereas trunk rotation and lateral bending are regarded as axisymmetric postures [15]. EAWS has been chosen as the approach for ergonomic assessment for its holistic approach to risk assessment.

To validate the algorithms used to compute the joint angles, a set of static postures (trunk lateral inclination, trunk flection, trunk extension, trunk upright, arm flection, arm abduction and knee flection) and dynamic activities (automotive repetitive assembly task simulation) have been recorded to ensure that data were available for all the relevant poses and postural joints.

3.2 User Interface

The first view offered to the user when the system is started allows him/her to switch between a real-time data visualization and a visualization based on pre-recorded data (Fig. 1). The first one is useful to check in real-time the postural data representing different angles that are relevant in a postural assessment. The second one is based on a synchronous recording of the activity with both RGB cameras and the IMU motion tracking system. In this case, the user selects the path to the recording source files of his/her choice. Moreover, a synchronization step is required by comparing the pose of the virtual mannequin and the pose of the user in the video. To simplify this manual synchronization process, the user wearing the IMU sensors performs a clap at the start of the recording stage.

The real-time mode (Fig. 2) shows different postural angles on the right side of the screen; the complete list of angles available to the user is provided through a dropdown menu. Selecting one of the available angles, the 3D representation of the angle is enabled, and the camera is moved to focus on the selected angle (Fig. 3). On the top left side of the screen, another dropdown menu allows the user to change the 3D camera view

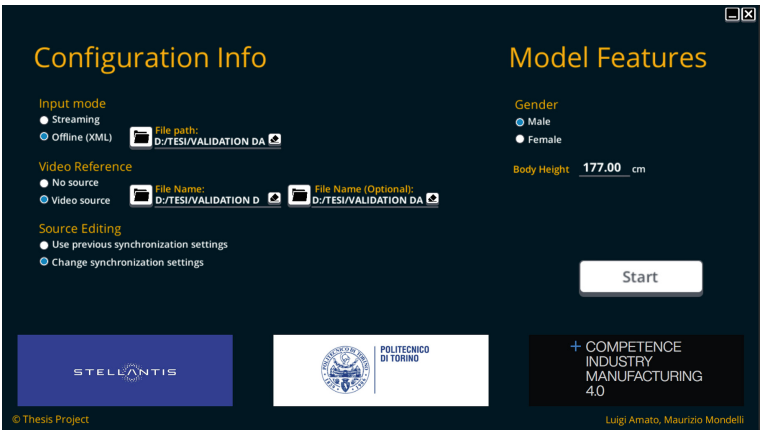

Fig. 1. Starting view of the proposed user interface

which frames the virtual mannequin. The system provides a frontal view, left and right views, a relative view, and an absolute view. Moreover, the user can visualize the virtual mannequin as a 3D simplified representation, as a sticky figure with lines connecting the spheres representing the joints, or both.

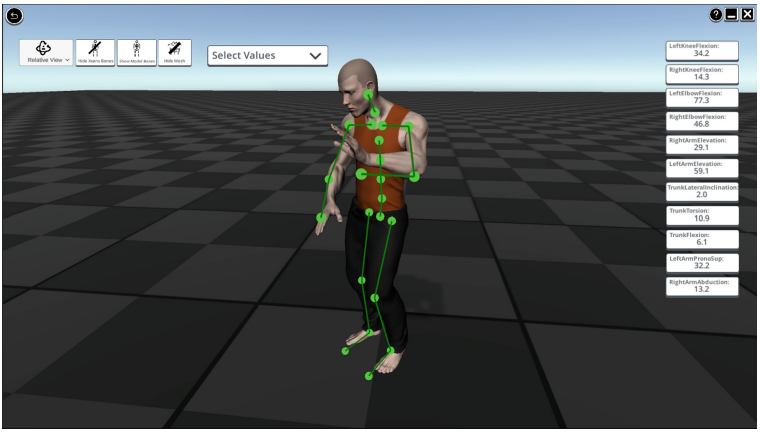

Fig. 2. Real-time view of the virtual mannequin

The pre-recorded view (Fig. 4) offers a wider set of tools, starting from a timeline interface that enables the user to pause, play or restart the recording, change the recording speed, or move to a specific frame. The RGB camera videos of the working process (on the left), as well as the view of the 3d virtual environment, can be hidden or maximized, depending on the user preferences. Through the "Download current frame details" button, the user can download the postural data related to a specific frame in the timeline, as well as a frontal and side view of the mannequin, as an HTML file.

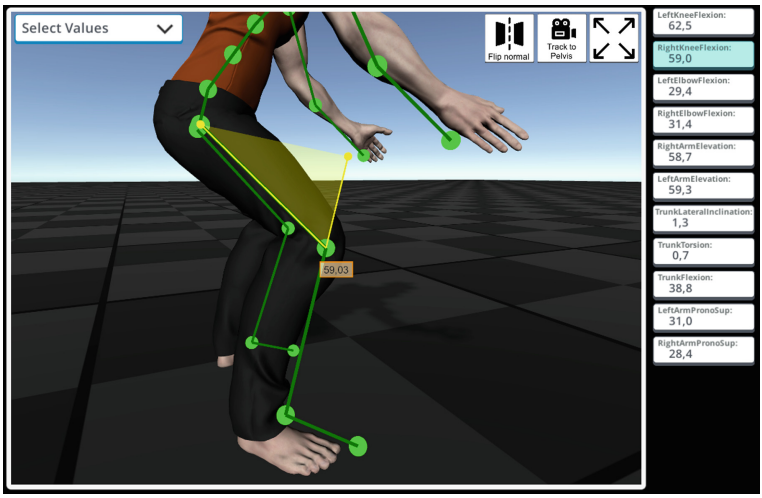

Fig. 3. 3D representation of the selected angle on the virtual mannequin

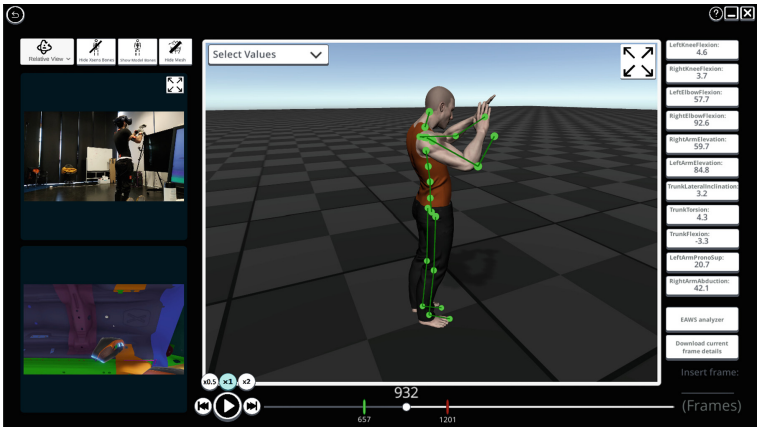

Fig. 4. Pre-recorded view of the virtual mannequin

Moreover, from this view, the user can decide to perform a postural analysis of the recorded procedure through the EAWS methodology. Selecting the "EAWS analyzer" button, a different view is provided to the user (Fig. 5). The proposed view allows the user to split the video reference into different tasks. For each task, a line is added to the evaluation table and some of the values associated with each column are automatically computed based on the postural angle data. Other values, which are not directly dependent on the postural data, can be manually inserted by the user to complete the EAWS evaluation.

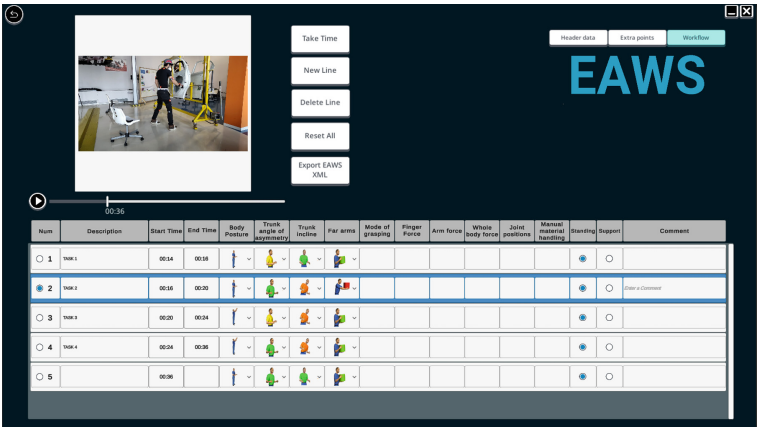

Fig. 5. EAWS Analyzer interface

4 Results and Discussion

The proposed module was specifically designed to analyze 10 different joints: neck, trunk, shoulders, elbows, wrists, and knees. For each joint, one or more algorithms have been developed to evaluate joint angles from different reference planes or for different types of rotation, as requested by the standards.

Inertial motion capture systems have been proven to enable measurement of postures and body movements with good accuracy [16, 17]. Therefore the focus of our tests has been posed on the calculation algorithms.

The joint angles for the recorded postures and body movements have been evaluated first by an analyst through the observation-based approach envisaged by the legislation for ergonomic checks in the production phase and then compared to the calculated angles. Based on a set of static postures and dynamic activities, the proposed system data was found to be fully consistent with the current observation-based approach, meaning that postures and times identified were the same as the ergonomics specialist would have been analyzed.

As a further step the design phase of a manual workstation was analyzed and the joint angles calculated by the proposed module compared to the angles obtained from the Jack mannequin present in Process Simulate [18]. Overall, the data obtained from the proposed algorithms, which are computed frame by frame, were found to be comparable to the angles obtained from Process Simulate, which are sampled over variable time frames, and approximated by rounding up decimal values to integers. However, it is relevant to discuss the angles computed for trunk flexion, trunk torsion, and trunk lateral inclination. In the case of trunk flexion, the values computed by the proposed system are appreciably overlapping to those computed by Process Simulate. Regarding trunk torsion, instead, the data proves that when the user is assuming poses that combine trunk flexion and lateral inclination, the commercial software is less precise, probably because it cannot properly identify composite poses. Comparing both the data, the virtual mannequin, and the recordings from the real user, it is possible to verify the rightness of

the data computed by the proposed systems, whereas Process Simulate cannot properly identify trunk torsion when trunk lateral inclination is also present. The last relevant case concerns lateral inclinations: the data show that the proposed system computes higher values, whereas the commercial software seems to reach its maximum at an inclination of 15°. Comparing the virtual mannequin with the real user, it is possible to assume that the values computed by the proposed system are more adherent to the real case.

During the validation session, the calculated joint angles were found to be strongly correlated with the movements of the human body. Coherence between the movements and the joint angles is kept within reasonable limits even in case of composite and/or highly incongruous working postures. This verification was considered essential to measure the robustness of the algorithm for recording posture. A further check concerned the reproducibility of the working postures in accordance with the reference legislation, taking into consideration a reasonable level of tolerance.

Similar considerations are valid for the validation of the software, which was found to meet the specific requests, capable of showing the postures assumed by the subject in real-time and instantly displaying the value of each body angle calculated.

The focus was therefore placed on determining the EAWS score of the posture section. For this purpose, the rules for determining the EAWS index (ref. Applicator manual) have been translated into computer language based on the calculated angles and speeds.

5 Conclusions and Future Works

In this paper, a Unity-based application for automatic ergonomic assessment based on motion data is proposed. The application is intended to assist analysts in the assessment of workers' exposure to musculoskeletal risks related to body postures and movements throughout an entire work activity. The proposed module applies the EAWS ergonomic assessment method to motion data obtained with IMU sensors and aims at supporting a more effective and integrated design of workstations. Special care was posed to the user interface of this Unity-based application which was specifically designed to be intuitive and straightforward to use.

Current limitations of the present work are related to two features of particular interest that can be developed in the next future: the integration of technological tools for the real-time measurement of the exerted forces and the prediction of movements and related postures on anthropometric percentiles different from that of the tested subject.

Another future development is the integration of the proposed system with an Immersive Virtual Reality environment. Immersive Virtual Reality (IVR) technologies allow for simulating real environments into virtual ones in which human-machine interaction is enabled through head mounted displays and other wearable devices (tracking systems, inertial sensors, etc.). Although a wide variety of such wearable devices are available today for industrial applications, very few automatic ergonomic assessment modules exist that make use of virtual reality technologies and that allow to process the collected data and to ensure compliance with the ergonomic principles in the early design phase.

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A Training to Relieve Work-Related Technostress: The Project "Tutela 2"

Maria Donata Orfei[1(✉)], Desirèè Estela Porcari[1], Sonia D'Arcangelo[2], Francesca Maggi[2], Dario Russignaga[3], and Emiliano Ricciardi[1]

[1] Molecular Mind Laboratory (MoMiLab), IMT School for Advanced Studies Lucca, Lucca, Italy
donata.orfei@imtlucca.it
[2] Neuroscience Lab, Intesa Sanpaolo Innovation Center S.p.A, Turin, Italy
[3] Intesa Sanpaolo DC Tutela Aziendale - Sicurezza sul Lavoro ed Ambiente, Turin, Italy

Abstract. Technostress, or the inability to deal with information technology (IT) healthily, may have a detrimental impact on employees' quality of life. The present study had the objective to develop training to facilitate the management of work-related technostress. A sample of 236 voluntary bank employees underwent an initial survey and a training protocol to mitigate and relieve technostress effects. Finally, they filled in the survey again. Within-group analyses were performed comparing pre- against post-training scores.

Furthermore, between-group analyses compared the post-training results of the experimental group to those of a control group that answered the initial survey, but did not perform the training. Results showed that in the experimental group, the post-training levels of technostress were reduced with respect to pre-training scores and were lower than in the control group. Our data showed that a multifaceted approach could stimulate the development of effective screening procedures and intervention strategies to enhance a healthy interaction between individuals and IT.

Keywords: Technostress · Coping strategies · Training · Risk management · Quality of life

1 Introduction

The rapid and relentless development of technology, particularly in information technology (IT), has provided astonishing advantages for individuals and organizations, both in private life and work activities. IT allows us to gain access to information very easily and rapidly, to keep in touch with colleagues, friends, and family simultaneously. Overall, such technologies improve our working performance (Brivio et al. 2018). The workplace has experienced significant changes in the past decades due to this subsequent digital transformation, redefining business, productivity, and behavior models (Brivio et al. 2018). Despite these indisputable positive effects of IT on the work, several detrimental side effects have been described deriving from the use of technology: increasing anxiety, irritability, frustration, fatigue, dissatisfaction, social isolation, low mood, among

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others, have been frequently ascribed to massive and constant use of IT in the workplace (Ayyagari et al. 2011). Most of these impactful phenomena constitute the syndrome of technostress, defined as the inability to deal with IT healthily (Salo et al. 2017). More specifically, technostress is a syndrome due to the relentless, simultaneous, and often massive use of IT and digital tools (Brod 1982; Salanova et al. 2013).

Technostress includes psychological, physical, and behavioral responses to technostressors. Thus, detrimental effects of technostress encompass negative health consequences and absenteeism, lowered productivity, and a lower cooperative attitude (Ragu-Nathan et al. 2008). Several dimensions and factors contributing to technostress have been highlighted (Salanova et al. 2013). The recent forced home-working revolution, imposed as a sanitary precaution during the Covid-19 pandemic, has exacerbated some specific aspects (Orfei et al. 2022). Among these, but not limited to, we cite inadequate training to deal with frequent updates of IT functions and in particular with remote work, information overload, and, last but not least, stress due to latency in technologies.

The main aims of this study were to develop and implement specific training to facilitate healthy management of IT in the workplace, thus mitigating the risk of technostress. We have planned longitudinal research involving both experimental and control groups. We hypothesized that a) in the experimental group, post-training levels of technostress be lower than pre-training levels, and b) in the post-training stage, the experimental group would show lower levels of technostress than the control group.

2 Materials and Methods

2.1 Research Design

A longitudinal web-based survey design was adopted. All participants were provided with a detailed description of the experimental procedures and required consent before participating in the study. The participation was anonymous, as each participant was assigned an alphanumeric code so that confidentiality of information was assured. Questionnaires and training sessions were evenly distributed across the national territory. No reward was given for the participation. The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and under a protocol approved by the Joint Ethical Committee for Research of Scuola Normale Superiore, Scuola Superiore Sant'Anna, and IMT School for Advanced Studies Lucca (protocol 04/2021).

The study included pre-training assessment, technostress training implementation, and post-training assessment. Furthermore, as part of a larger study including also the investigation of cognitive overload and ageing effect, the original research design involved four groups: three experimental groups (technostress, cognitive overload and ageing) and a control group. For the aims of the present paper, we will describe only the data concerning the group who completed the training for technostress (TS group) and the control group (CTRL group) who completed a training dealing with different issues.

2.2 Participants

A panel of 8.306 employees of a large Italian banking group was invited to participate in the pre-training online survey. Inclusion criteria were: a) age higher or equal to 18 years old, b) Italian mother tongue or high-level knowledge of Italian language.

2.3 Assessment and Procedure

The pre-training survey included questions to collect demographic data and three original questionnaires investigating three dimensions (i.e., technostress, cognitive overload, and aging workforce) of 20 items each. In every questionnaire, for each item, the subject was required to answer on a 4-point Likert scale (from 0 = never to 3 = always), indicating how often specific sensations and states of mind were present.

All the participants who completed the three questionnaires were randomly assigned to one of the training groups. After completing their training, participants were asked to undergo the post-training assessment.

2.4 TS and CTRL Training

All the two training courses included 18 sessions, of 15–20 min of duration each, with a recommended frequency of three times a week.

The training for technostress aimed at moderating the level of stress due to IT interaction, thus facilitating quality of life in the workplace. Specifically, it included behavioral, psychophysical, and cognitive coping strategies. Exercises focused on stressor reduction, stressor toleration, and cognitive restructuring, completing self-rating scales and self-checklists, but also stimulating the adoption of behavioral changes and habits.

The training for the CTRL group ad the same number of sessions, lenght and structure of the technostress training. However, it dealt with completely different topics, such as correct alimentation, healthy physical activity, information about human brain function, and information about stress. No exercise, activity or behavioral strategy was suggested for any of these issues.

2.5 Statistical Analyses

Descriptive analyses were performed for continuous and categorical variables (means and standard deviation). Chi-squared test was used for comparisons between categorical variables (gender). In the pre-training analyses, one-way ANCOVA was used to compare age classes on the technostress variable.

In the post-training analyses, given the progressive expected dropout rate, the comparisons between pre-training and post-training scores were performed on the final residual sample for both the TS and CTRL groups. Within-group analyses comparing technostress pre- against post-training levels were performed using paired t-tests. For between-group comparisons, we used an unpaired t-test. The level of significance was $p < .05$.

3 Results

3.1 Pre-training Survey

From the initial panel, a sample of 2573 (31%) participants answered the pre-training assessment. The sample included 51% of females. Subjects aged 18–35 years were 11%, subjects aged between 36–55 years were 19%, and subjects over 55 years were 19%. Chi-squared test showed differences between males and females on age ($p < 0.0001$) and between age classes on gender distribution ($p < 0.0001$).

The mean score on the technostress questionnaire was 15.5, and 8% of participants scored above the critical score (defined as a minimum of 10 items with a score equal to or higher than 2). One-way ANCOVA showed that technostress levels were significantly different in the three age class groups (F2.2583, 3,16; $p = 0.043$) while controlling for gender; Bonferroni's post hoc highlighted that there was a statistically significant difference between under 35 and 36–54 years old subgroups ($p = 0.044$) and between under 35 and over 55 years old subgroups ($p < 0.0001$), stressing higher level in older classes. Moreover, a statistically significant difference was highlighted between 36–54 and over 55 years old subgroups ($p = 0.006$) stressing higher level of technostress in older subjects.

3.2 Training Data

Subsequently, the sample was subdivided into four training groups (technostress, TS, n = 847; cognitive overload, CO, n = 730; aging workforce, AG, n = 495; control group, CTRL n = 501). For the aims of this paper, only the results of the TS and the CTRL groups will be discussed. The TS group included 49% of males, and the mean age was 46 years old. The mean score for technostress was 4.9 (sd = 3.7). The CTRL group had 50% of males and was characterized by a mean age of 47 years old and a mean score for technostress of 4.7 (sd = 3.6). The TS and CTRL groups did not differ for age, gender, or technostress score. Regardless of the specific training attended, 879 participants (262 for the CO training; 236 for the TS training; 189 for the AG training; 192 for the CTRL training) completed the program.

3.3 Post-training Survey

The post-training survey was completed in the TS group by 181 participants and in the CTRL group by 143 subjects (Fig. 1). The residual samples did not differ in gender and age from the pre-training samples. The residual TS sample showed a mean pre-training technostress score of 18.0 (sd = 8.1) and a post-training mean score of 15.8 (sd = 9.0). The residual CTRL group showed a mean pre-training technostress score of 16.2 (sd = 8.7) and a post-training mean score of 15.9 (sd = 15.9).

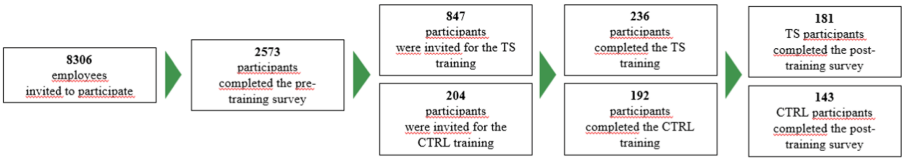

Fig. 1. Flowchart of the participants data at each stage of the study

In the TS group, about the technostress questionnaire, a significant difference between pre-training scores and post-training scores emerged ($p < 0.0001$), highlighting that post-training scores were significantly lower than pre-training scores (Fig. 2). Concerning the CO and AG questionnaires, the pre-training and post-training comparisons did not highlight any significant difference.

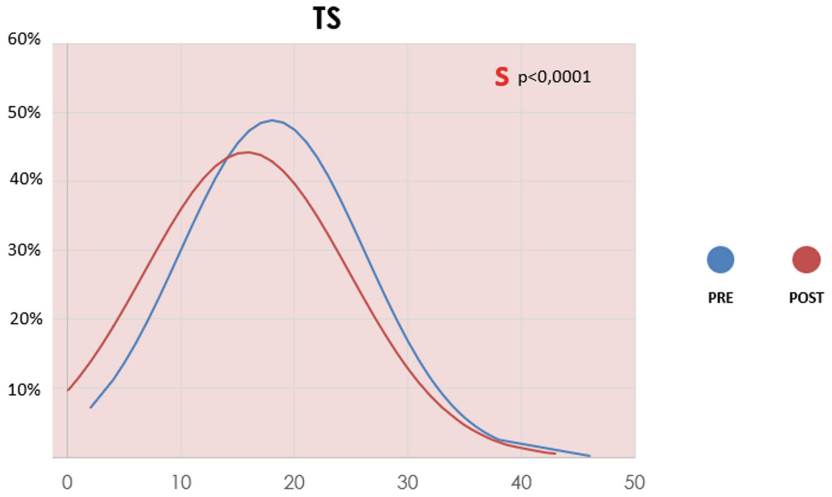

Fig. 2. On the horizontal axis are the scores of the technostress questionnaires; on the vertical axis is the percentage of participants. Concerning the pre-training scores (blue line), the post-training scores (red line) of the TS group were significantly lower ($p < 0.0001$).

The between-group analyses highlighted a significant difference between the TS and CTRL groups on post-training technostress scores ($p = 0.014$). The TS group showed scores significantly lower than the CTRL group (Fig. 3).

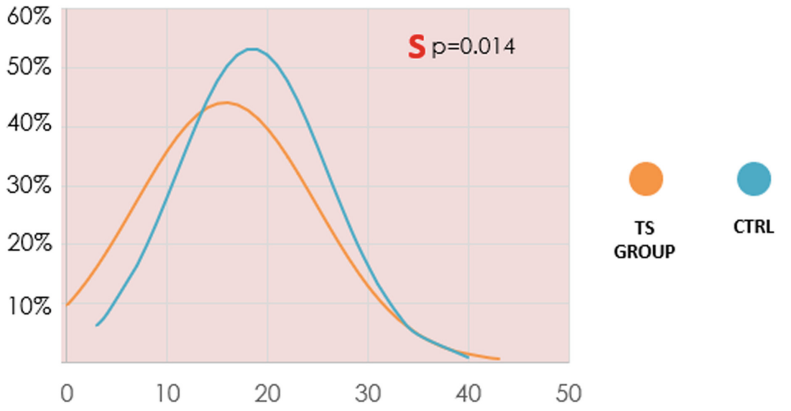

Fig. 3. On the horizontal axis are the scores of the technostress questionnaires; on the vertical axis is the percentage of participants. The post-training scores of the TS group (yellow line) are significantly lower ($p = 0.014$) than the CTRL group (blue line).

4 Discussion

Our study aimed at testing an innovative approach for the reduction and prevention of technostress in the workplace. We have developed a longitudinal research project involving a large sample of bank employees who underwent training devoted explicitly to healthy management of the interaction with IT. Two main results emerged: first, as hypothesized, the comparison between the scores on the technostress questionnaire, recorded in the pre-training stage and the post-training stage, have pointed out an improvement of the technostress index in the experimental group but not in the control group. Second, in the TS group, the amelioration was evident only for technostress but not for other dimensions, such as cognitive overload and aging workforce. Thus, our results support the expected outcome of a specific positive effect of the TS training.

To the best of our knowledge, this is the first experimental study focused on structured training for the management of technostress in the workplace. Our research presents several strengths. First, it is characterized by a multidimensional approach, encompassing cognitive, behavioral, and neuropsychological stimuli, which focuses on the individual in their entirety, thus providing support by a multifaceted perspective. Moreover, technostress is challenged as a complex phenomenon with specific dimensions rather than just as a generic form of stress. Second, we recruited a large sample, which allowed us to perform reliable statistical analyses and buffering progressive dropout effect. Third, the training was developed to be used autonomously and online by the end-users, without any active intervention of a trainer. This feature makes the training quite flexible and suitable to individual needs, especially time requirements, working patterns, and place. Fourth, the sample was made up of bank employees working in different structures and thus performing various activities and tasks in their working routine. The involvement of such a heterogeneous sample further supports the flexibility and efficacy of our TS training.

Before concluding, some limitations of our study have to be highlighted. First, the training was implemented in a specific banking context. Thus, we cannot be sure of its efficacy in different working contexts. Future studies aimed at verifying the effectiveness of the training in diverse populations of workers would shed light on this point. Second, most of the material underpinning the exercises and the stimuli of the training is visual, so workers with a visual disability may not find the training accessible. Future adaptation of the training to make it accessible to people with specific requirements is needed. Third, the training was developed for the Italian population. Thus, we cannot be sure that the training would be equally effective in different cultural and linguistic working contexts.

In conclusion, given the detrimental effect of technostress on worker's' everyday life, efforts should be made to recognize situations with a high risk of causing this syndrome and to mitigate or even better prevent its impact (La Torre et al., 2019).

Our study highlighted how to correct management of the interaction with IT in the workplace, underpinned by specific cognitive-behavioral interventions and the learning of efficient strategies to adopt in the everyday working routine, may pave the way for a better quality of life.

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Human Behavior Modelling in Socio-technical System Simulation: A Case Study on Air Traffic Control

Gabriella Duca[1](✉) and Antonella Frisiello[2]

[1] Institute for Sustainable Society and Innnovation, Naples, Italy
duca@issnova.eu
[2] LINKS Foundation, Turin, Italy

Abstract. This work discusses the methodological approach and technical results of a research study aimed at building a model of the cognitive and socio-cultural factors that influence the human performance of Air Traffic Controllers. The proposed model was integrated into an agent-based simulation tool supporting the impact assessment on the performance of alternative operational scenarios in Air Traffic Management. On the base of the specific case study of direct and free routing in southern Europe airspaces, a preliminary scenario analysis and a task-analysis were conducted to describe the environment, procedures and technical systems. After that, a set of Human variables relevant for the tasks accomplishment and Human Behaviour specification were derived. The resulting Human Behaviour model feeding the Agent-Based Simulator combines three types of variables – Personal, Cognitive and Socio-cultural ones – and proposes rules for Human Performances variability to represent a human adjustment to external and contextual conditions such as traffic complexity and pilots' behaviour in current or future operating scenarios.

Keywords: Cognitive ergonomics · Socio-cultural factors · Human performance · User modelling · Socio-technical systems · Air Traffic Control

1 Introduction

Air Traffic Management (ATM) is a high complexity field in which technical systems and human agents work cooperatively. It relies on a distributed organization, in which information and tasks are properly allocated in different phases to different agents. Technology supports human activities at all levels, enabling functions ranging from the supervision of automated procedures through formalized protocols actuation to the interpersonal communication between operators. All these activities happen in a very dynamic and variable context, that is shaped by a number of environmental circumstances (e.g. traffic and weather conditions, season or weekday), working conditions (such as the airspace configuration, the assigned role) and Human Factors (HF) [1].

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The European ATM system considers its success and overall performance strongly related to the Human Performance (HP), that are the observable results of human activities, seen as the capability to accomplish the given tasks and meet job requirements [2].

In designing such safety-critical socio-technical systems, HF contribute to tackle the research challenges posed by the adoption of new systems in a wider and more effective perspective. In particular, the design and development of evolutionary agent-based modelling solutions, integrating HF, could allow evaluating both the impact of new solutions on human performances and the trade-off between the different implementation options and solutions, recommending more effective and human-compliant procedural or technical choices [3].

The presented work describes an HF model conceived to be integrated into an agent-based simulator. It details a methodology to characterize the human agent behaviour and describes the results obtained simulating a specific case study: Direct Routing and change in Free Routing as a sample of ATM scenarios to test various architectural evolutions, where the behavioural and cognitive aspects of the controllers play a critical role for the overall system safety and efficiency.

The HF considered include personal, cognitive, and socio-cultural dimensions. The latter include both influence among peers (how the performance of one actor can be influenced by the performance of another one) and the influence of safety culture expressed by the organization. The output is a set of specifications enabling to represent and further simulate the dynamic interaction among human factors, cultural and technical environment as components of the ATM socio-technical system.

The presented work was conducted within SESAR 2020 research project EvoATM - Evolutionary ATM, a project aiming at setting up a methodological approach to support Change Impact assessment in ATM.

2 Methodology

2.1 Human Behaviour Modeling Within EvoATM Overall Model

Cognitive ergonomics enables to approach ATM complexity from the human perspective, focusing on real context, activities, organization's behaviours and individual's characteristics. In order to map these components, an early Scenario Analysis has been conducted to identify and describe Air Traffic Controllers (ATCo) roles and a set of Air Traffic Control (ATC) specific tasks. On this basis, the Hierarchical Task Analysis (HTA) is an action-oriented technique that produces operational descriptions of the job under consideration [4]. HTA allows to identify and describe tools, external conditions, triggers and outputs per each task. ATCOs activity is a strictly codified one, consisting of a set of predetermined tasks, activities and actions with predefined rules and relatively standard duration. In EvoATM, HTA has been conducted relying on real air traffic samples, flown in Spanish and Italian airspaces, for which clearance issued by ATCOs, communications with Flight Crew (FC), time and duration of each activity were recorded. From this activity framework, a set of variables describing context, tasks and ATC professionals' behaviour have been derived. Each variable has been object of a comparative examination, considering the previous analysis, and literature review including results

from European research projects in the same field. The comparison between literature and practice has brought to the specification of useful variables to model human performance.

The resulting model of HF and rules intervening in human behaviour, including personal and cognitive resources, have been delivered as actionable input to the agent-based model to simulate current and evolutionary scenarios in direct and free routing, considering the Human Performance variability in the task execution.

ATM agents modelled by EvoATM are represented according to the Functional Resonance Analysis Method (FRAM) formalism, which is particularly suitable to represent dynamic scenarios in safety-critical socio-technical contexts [5]; therefore, ATCOs Human Behaviour model has been built in order to represent HP variability of the human agents represented through the FRAM model. In the FRAM model, each action performed by a human or automated agent is described through specified dimensions: preconditions, input, time, control, resources, and output (feeding the next action and actor to be simulated).

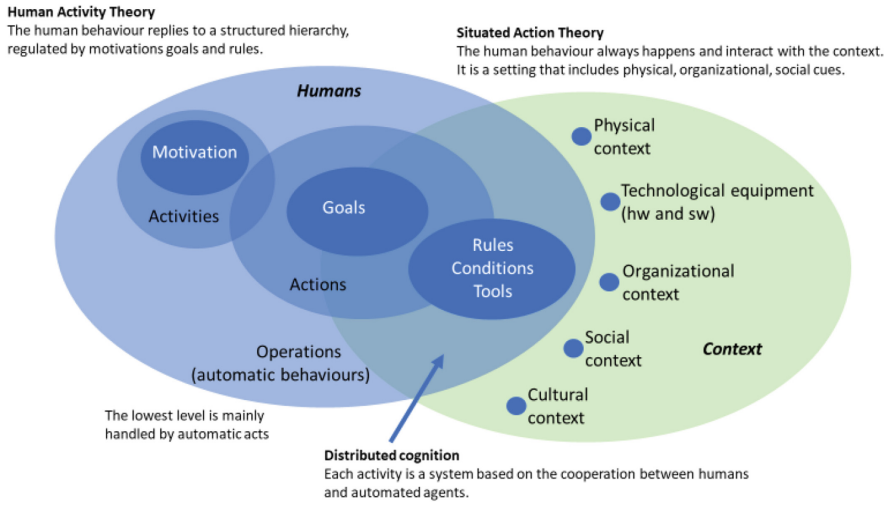

Fig. 1. Combination of the theoretical models in EvoATM HF framework.

A theoretical framework has been assumed as a background to select HF variables allowing to cope with the complexity of tasks in ATM. According to Activity Theory [6], the hierarchical task description, articulated in activities, actions and operations, is regulated by motivations, goals and conditions and has provided a reference to understand Air Traffic Controllers (ATCo) tasks under the overall mission or the ATM system to provide safe separation of aircrafts. Furthermore, the ATC has been framed as a Situated Action [7], to allow the consideration of the context in which human activity happens. In the case of the ATC, the situation includes external conditions, ongoing activities, formal procedures, contingencies over the individuals' modalities and organizational cues. The contextualization of the abovementioned theories in the context of ATM, outlines a system of distributed cognition [8, 9], as it refers to a cooperative area in

which activities are handled by humans and automated systems; task allocation (and the consequent resources allocation) is variable and depends on the task, context and individuals (Fig. 1).

3 HF Variables Modeling

3.1 HF Variables and Metrics to Model the Human Behaviour in ATC

Starting from the theoretical models selected as references for the proposed human modelling, task-driven aspects, the external conditions and HF variables have been elicited to implement behavioural variability of the modelled human agents. For this purpose, three categories of HF variables have been defined: personal, cognitive and socio-cultural ones. The selected personal factors identify slow-changing variables influencing the behaviour in terms of performance. Among these factors, age and seniority/expertise are especially interesting for the interactions with the other factors, as they result in the controller's knowledgeable extent.

Cognitive factors map out reasoning processes that are more likely to change in a shorter range of time in terms of cognitive resources expenditure. This category includes consolidated constructs, such as the mental workload [10], as well as situational awareness [11].

A relevant cognitive aspect included in the proposed model is trust in technology, associated to the confidence in the digital automated tools usage. This aspect is very relevant when the controller's task is highly technology-mediated and implies the use of information provided by an automated tool [12].

Finally, some socio-cultural variables have been identified, some of them referring to contextual aspects, in terms of culturally embedded cognition, very relevant in shaping the individual mental model. Moreover, dimensions such as cultural distance and safety culture have been included. The first aspect refers to the national culture differences [13] that influence relevant procedures such as communication style which can be a key factor for timely risk-seeking and error management, both at organizational and individual levels [14].

Safety culture is a construct crucial to determine the commitment, approach and proficiency in safety management [15]. It is the combination of values, attitudes, perceptions, skills and behaviour patterns of individuals and teams. The organization's tolerance towards deviations from procedures and rules, the uncertainty avoidance as well as the flexibility of individuals' behaviours in task accomplishment and error management are direct expressions of the safety culture of a team or organization [14]. Safety culture and cultural distance are key HF aspects under the perspective of ATCo-Pilot cooperation.

Most of the identified HF variables consist of qualitative dimensions, as they refer to complex constructs. For some of them, quantitative metrics exist; nevertheless, they do not provide a satisfactory description of the factors and how they interplay among them in the real environment. In order to provide operational definitions of HF variables, enabling the simulation of human performance in different scenarios, each variable has been specified on a binary scale (0–1 or $-1 + 1$). Each pole of the scales identifies one status of the variable. This approach allowed to keep the meaning of the variable, in

relation to the context and to extend or refine the quantitative expressions, if needed by the scenario. Figure 2 provides an overview of the elements of the EvoATM Activity model, including HF identified as relevant for the scope of the project. The hierarchical nature of human behaviour is assumed, according to the Human Activity Model. As the Situated Action Theory highlights, the nature of tasks influences human behaviour, that in summary can be described by referring to factors related to the human actors (in EvoATM described as personal and cognitive factors) and context, that in EvoATM model includes both the external conditions and some cultural aspects, expressed by the organizational context.

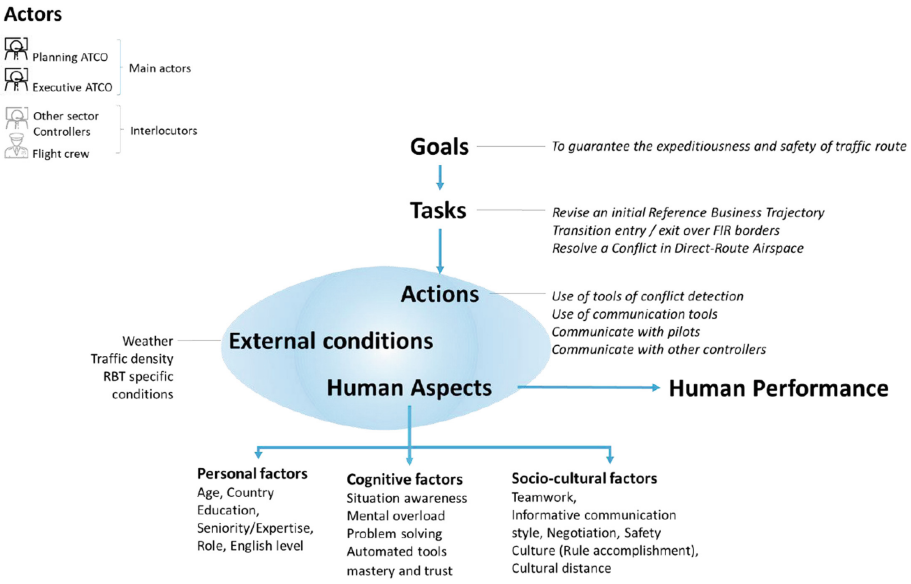

Fig. 2. Human Factors abstraction in EvoATM model.

3.2 Specification to Model the Human Performance

After the first analysis, each ATCOs task has been characterized by taking into account both human and context variables that affect its efficient accomplishment, considering the following parameters: time sensitiveness, task complexity (number of alternative and optional actions in a task), behavioural level (skill/rule/knowledge-based task [16], resources allocation (human/computer/human with computer assistance), personal variables relevant for task completion (dynamic and static), cognitive variables relevant for task completion (dynamic and static) [17], contextual socio-cultural variables relevant for task completion.

EvoATM Human Agents model focuses on Air Traffic Controllers (ATCos) in their two roles of Executive Controller and Planner Controller; variability of Pilots' behaviour is represented with a higher level of abstraction, thanks to a characterization of each airline's typical interactions with ATCos, that finally produces an effect on

ATCOs Human Performances due to, for instance, higher probability of events such as airborne communications or clearances repetition. This characterization classifies airlines/carriers according to the following attributes: location-based/not based in EU or English-speaking country, high pressure/no pressure on pilots to match business strategy, the air carrier runs/does not run safety culture programs.

As a further specification of contextual variables affecting human behaviour, the actual air traffic situation has been taken into account, considering traffic complexity level based on literature algorithm [18] and past traffic safety events that occurred in the last 20 min, such as near misses [19].

Task characterization based on the selected HF variables, airline socio-cultural characterization and actual traffic situation provide the EvoATM simulator with all information needed to calculate if the modelled human agent is able to perform a given task at a given time in the optimal way or, in other words, keeping highest safety level with sufficient traffic expeditiousness level. This resulted in 4 rules that enable the simulation engine to calculate the nominal or degraded performance of the human agent, introducing human behavioural variability in ATM simulator.

4 Results

EvoATM simulator has been validated by executing several exercises based on real planned traffic in Italian airspace on the 5th, 6th 7th of July 2016. EvoATM simulator has run the input traffic and traffic management performances resulting from simulator have been compared with actual traffic management performances of real flown trajectories. EvoATM validation activities addressed the number and distribution over the time of voice communication of Executive Controllers with Planner Controller and with Flight Crew, the number and distribution over the time of Executive Controllers' actions for separations and for conflict detections as well as the number and distribution over the time of Planner Controllers' actions for conflict detection, using several combinations of values for settings describing human variables. Simulation results demonstrated that the overall traffic capacity resulting from the abovementioned variables reflect the air traffic dynamics and capacity observed in real flown traffic samples. The accordance between simulated and actual performances confirmed the capability of EvoATM simulator to represent the socio-technical dynamics of the ATM system. For a more detailed trustworthiness assessment of the human behaviour model, a sensitiveness analysis of EvoATM simulator to human behaviour variability has been conducted, using metrics such as the number of voice communications per aircraft per timeframe, the number of actions performed for separation purposes in a given timeframe and so on, also setting human variables to extreme values. Also, this analysis confirmed the ability of EvoATM simulator to represent the variability of human behaviour and its effects on the overall ATM system performances.

5 Conclusions

Modelling human behaviour in simulated socio-technical systems is a very challenging research field. The present work proposes an operational human behaviour model, including HF and context variables and the rules explaining their interaction. Attempting to capture the human and context variability, with an emphasis on interplay among several humans cooperating in a complex system, allows to integrate the HF in current simulation frameworks currently in use to study complex and safety-critical scenarios and serve both research and design purposes.

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Human Factors and Safety Implications on Air Traffic Controllers and Remote Pilots for the RPAS Introduction in Controlled Airspace

Vittorio Sangermano[1(✉)], Gabriella Duca[1], Riccardo Rocchio[2], and Edoardo Filippone[2]

[1] Institute for Sustainable Society and Innovation, Naples, Italy
sangermano@issnova.eu
[2] Centro Italiano Ricerche Aerospaziali, Capua, Italy

Abstract. Nowadays Remotely Piloted Aircraft Systems (RPASs) represent the new frontier of air vehicle for both transportation of people and goods. The Air Traffic Management (ATM) is a complex socio-technical system relying on cooperation and coordination among human actors and distributed architectures, where all pieces shall fit together to ensure safety performances and smoothness of traffic flows. The introduction of RPASs in controlled airspaces increases the complexity of ATM system and needs to be properly evaluated from a safety and Human Factors (HF) point of view. This article discusses the approach and presents the results of Safety and HF evaluations on the RPASs integration conducted within the INVIRCAT European research project. Several safety and HF validation objectives were identified within the project and assessed through Real Time Simulation (RTS) campaigns executed in Germany, Netherland and Italy addressing different Use Cases, this article presents the INVIRCAT experimental activities conducted in Italy focusing on nominal, contingency and Automatic Take-off and Landing (ATOL) procedures.

Keywords: Remote piloted aerial system · Human factors · Safety · Real time simulation · Air traffic management · Automatic take-off and landing

1 Introduction

One of the key missions of SESAR programme is safe and efficient integration of RPASs into controlled and uncontrolled airspaces. These new aerial vehicles would be used for both transportation of people and goods. The SESAR roadmap [1] foresees the full integration of RPAS as additional airspace users from 2030+.

Even if today, it would be possible (from technological point of view) to conduct an operation with RPAS, the ATM is a socio-technical complex system which need to be further investigated for ensuring the highest safety performances and smoothness of traffic flows. The introduction of RPASs, with possible definition of new human actor

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roles, increases the complexity of this system and needs to be properly evaluated from a safety and Human Factors (HF) point of view.

The INVIRCAT project is an European exploratory research that aims at investigating the safe integration of RPASs into controlled airspaces class A-B-C with a focus on Terminal Manoeuvring Areas (TMAs) and airports.

The main scope of the project is the creation of a concept of operations (ConOps) for RPAS, assessing it through simulations and drafting a set of recommendations for rule makers and standardisation body. To achieve this goal, sixteen Use Cases (UC) have been defined, detailing technical conditions, human actors and workflow of operations in the selected, most significant, scenarios.

This paper focuses on the HF and Safety assessment activities on operational aspect of fully Automatic Take-off and Landing (ATOL) to enable the RPAS integration in controlled airspace.

2 Approach and Methodology

2.1 Safety and Human Factors Objectives

The project has identified several safety and HF validation objectives [2], to support the detailed design of validation exercises held in three European aerospace research centres in Netherlands (NLR), Germany (DLR) and Italy (CIRA) hosting the execution of RTS [3] campaign, with CIRA simulation focusing on take-off, approach and landing phase relying on the system. For each validation objective, at least one corresponding success criteria was defined. Below, the HF and Safety validation objectives:

a) To assess acceptability of IFR RPAS integration in TMA/airport in nominal and contingency conditions.
b) To assess that safety remains within acceptable levels in nominal and contingency conditions.
c) To assess that ATM procedures allowing Automatic Take-off and landing (ATOL) of IFR RPAS in non-segregated airport are acceptable in nominal and contingency conditions.
d) To assess whether the C2-Link and R/T voice latency, based on a representative value of this latency, is acceptable to keep safety conditions within acceptable levels.
e) To assess that RPA handover is transparent to the ATCO and that safety remains within acceptable levels.
f) To assess the adequacy of phraseology in communications between ATCOs and Remote Pilots in nominal and contingency conditions.
g) To assess that HMI satisfies the information requirements for Remote Pilots and ATCOs in nominal and contingency conditions.
h) To assess that requested human contribution to the overall system in nominal and contingency conditions is compatible with human capabilities.
i) To assess that ATCO workload remains within acceptable levels in nominal and contingency conditions.

2.2 Data Collection Methods

In a second step, specific data collection tools were designed, to record qualitative and quantitative data by means of different techniques including data log, audio recordings, ad-hoc questionnaires (divided for ATCOs and remote pilot) and focus group. With specific reference to questionnaires, we selected two types of questionnaires, one to be filled after each simulation (Post Run Questionnaire - PRQ), and one to be filled at the end of the whole local exercise (Post Exercise Questionnaire – PEQ). The questionnaires included standard tools such as SASHA [4], Bedford scale [5], AIM-L/S [6] CARS [7], SATI [6], SUS [8], as well as ad-hoc operations-related questions, addressing what human actors experienced during the run and possible suggestions addressing INVIRCAT ConOps at a more comprehensive level. Questionnaires and focus groups have been exploited as deeply interconnected techniques, as data collected through questionnaires have been verified and discussed during debriefings; this combination of techniques is proved to ensure correctness and reliability of the obtained results.

2.3 Scenario Description

The CIRA simulation encompassed several UC in Bari-Palese airport operating scenario, considering a combination of both nominal and contingency situations. The following contingencies were simulated:

1. ATOL failure.
2. Command and Control (C2) link failure.
3. Conflict situation.

ATOL failure refers in general to any kind of issue that this system can generate. The C2 link failure refers to a loss of command and control with the RPAS. While the conflict situation was a situation where the manned aircraft was stuck on the airway and in the meantime the RPAS was executing a landing/departure operation. In addition, different levels of latency with the RPAS have been considered: low latency (0.5 s) and high latency (2 s). The combination of all these variables, generated nineteen different runs, each lasting 40 min:

- One reference scenario without RPAS;
- Two nominal scenarios in which the RPAS does not experienced any failure;
- Sixteen contingency scenarios.

The validation facilities that were used by CIRA for INVIRCAT are FLARE (Flight Laboratory for Aeronautical REsearch) SIM, Scenario Simulator and CWP Emulator. FLARE SIM is a complete real-time HW and human in-the-loop simulator and its main goal is to perform ground testing of the Flight Control Computer (FCC) and Remote Pilot Station (RPS) HW/SW (Figs. 1 and 2).

Fig. 1. FLARE simulator – Bari Palese airport

Fig. 2. CWP Emulator – Bari Terminal Manoeuvring Area (TMA)

Finally, all these facilities were connected in the Integrated Simulation Facility (ISF) that allowed managing the exchange of data within the different simulators.

3 Results

Quantitative data, coming from both data log and questionnaires Likert rating, have been analysed according to a deterministic approach. Qualitative data, mainly from focus groups and open question in questionnaires, have been analysed highlighting the rationale behind the statements.

The simulation campaign highlighted very positive feedback coming from both ATCOs and pilot. In general, the current ATM system would permit the integration of ATOL equipped RPAS in the Terminal Area and at airports. In particular, the SHAPE Automation Trust Index (SATI) standard tool has been used for measuring human trust in the ATOL system highlighting its importance for the safe introduction of RPAS into controlled airspace (Fig. 3).

	Never	Seldom	Sometimes	Often	More often	Very often	Always
1) ...The ATOL was useful	0	1	2	3	4	5	6
2) ...The ATOL was reliable	0	1	2	3	4	5	6
3) ...The ATOL worked accurately	0	1	2	3	4	5	6
4) ...The ATOL was understandable	0	1	2	3	4	5	6
5) ...The ATOL worked robustly (in difficult situations, with invalid inputs, etc.).	0	1	2	3	4	5	6
6) ...I was confident when working with the ATOL	0	1	2	3	4	5	6

Fig. 3. SATI questionnaire

All involved actors agreed that the ATOL is a useful and reliable system. Moreover, during the debriefing sessions, executed at the end of each run, the remote pilot highlighted that the ATOL is a necessary system to safely perform critical operations such as landing and take-off. In his/her experience, even with a low latency, the absence of the pilot-in-command might generate problem in the awareness and understanding of surrounding environment. The presence of ATOL system allowed to maintain an acceptable level of Situational Awareness (SA) of both air traffic controller and remote pilot. The assessment of perceived level of SA was conducted using the China Lakes Situational Awareness (CLSA) standard tool (Fig. 4).

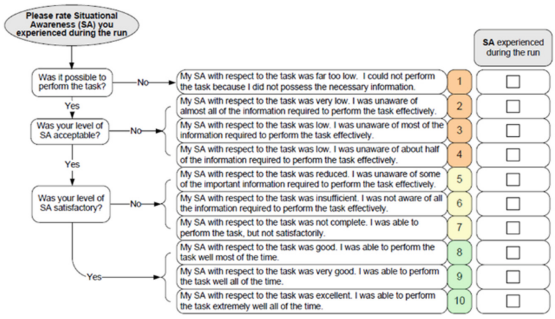

Fig. 4. CLSA tool

The scale encompasses a hierarchical decision tree that guides the actor through a ten-point rating scale (from 1 – low to 10 – perfect SA), where each point is accompanied by a descriptor of the associated level of SA. The following pictures show that for the ATCO the SA level was always excellent because for them the RPAS was managed as a conventionally-manned aircraft, while for the RPIL, the SA level was good even during contingency situation (Figs. 5 and 6).

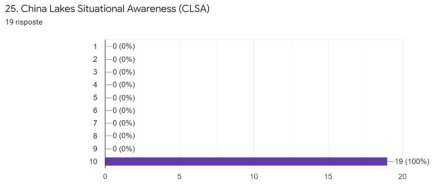

Fig. 5. ATCO SA assessment

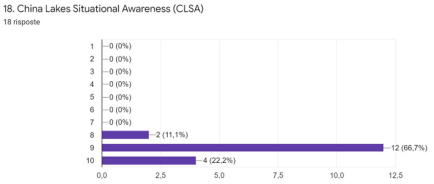

Fig. 6. RPIL SA assessment

In addition, also an assessment of perceived workload has been performed using Bedford standard tool. The Bedford Scale was used to identify the actors spare mental capacity while completing a task (Fig. 7).

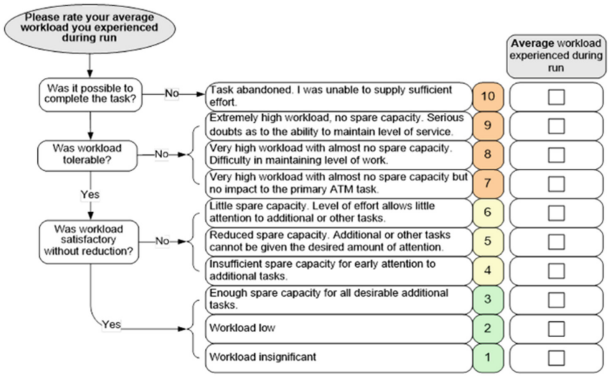

Fig. 7. Bedford scale

The scale encompasses a hierarchical decision tree that guides the actors through a ten-point rating scale (1 lowest - 10 highest), where each point is accompanied by a descriptor of the associated level of workload. The following figures show that the workload was maintained at satisfactory levels for both the actors involved in the simulation activities (Figs. 8 and 9).

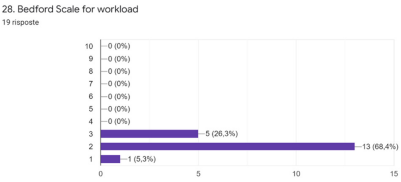

Fig. 8. ATCO Workload assessment

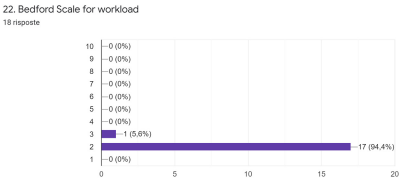

Fig. 9. RPIL Workload assessment

One of the most important results from this validation activity is that from ATCOs point of view, the IFR RPAS in nominal conditions is managed as well as a conventionally-manned aircraft. In fact, the following figures confirms that the overall level of workload perceived by ATCOs in terms of attention, skill or effort was most of time neither demanding nor undemanding. The ATCOs stated that an IFR RPAS, during management of the traffic, is the same of a common aircraft. During, debriefing sessions that were executed at the end of each run, the ATCOs highlighted this result. While for the RPIL the picture shows that the overall workload in terms of skill, attention and effort was always undemanding (Figs. 10 and 11).

The positive results regarding the RPAS integration are also confirmed by the safety Key Performance Area (KPA) in which the ATCOs stated that they were comfortable most of time. Indeed, the only run in which the ATCO was “sometimes” comfortable, is in the case of C2 link failure in which he/she can not manage the RPAS. While, from pilot point of view, stated that he/she felt “always” in a comfortable condition during the flights.

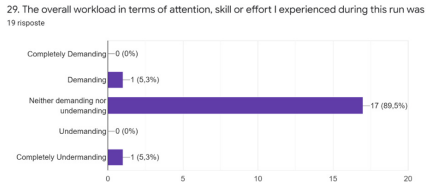

Fig. 10. ATCO Overall workload

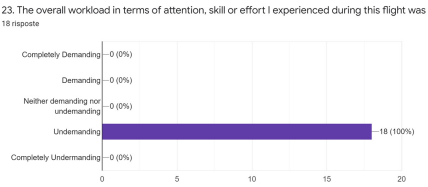

Fig. 11. RPIL Overall workload

Both ATCOs and pilot in the PEQ confirmed these findings. Indeed, ATCOs and pilot agree regarding the safe integration of IFR RPAS in the TMA with a sufficient level of safety. The following figures shown the ATCOs and pilot answers (Figs. 12, 13, 14 and 15).

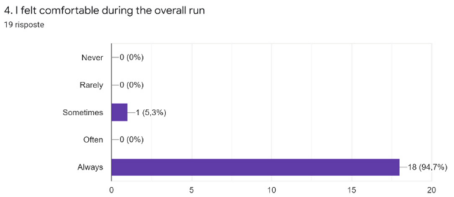

Fig. 12. ATCO perceived safety

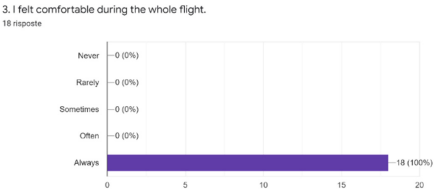

Fig. 13. RPIL perceived safety

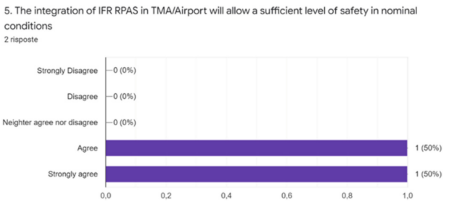

Fig. 14. ATCO IFR RPAS integration

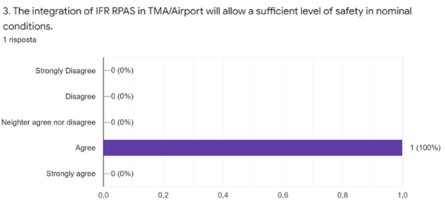

Fig. 15. RPIL IFR RPAS integration

Hence, although the simulation campaign highlighted that the current TMA system would allow the integration of RPASs, it also shows up that the C2 link failure is the most critical situation and need to be further investigated. Indeed, during a loss link with RPAS, the remote pilot can only be aware about the status of his/her aerial vehicle through the ATCO communications. Moreover, the remote pilot is not able to comply with any action required by the ATCO. If this happen during a critical phase such as landing or take-off the consequences could be catastrophic. For this reason, both the ATCOs and remote pilot raised the need to develop ad-hoc procedures and training. Furthermore, there is a need to lighten the phraseology in case of contingency.

The considered use cases foreseen for the ATOL to be enabled only in final approach. Consequently, in all of the test performed at CIRA the RPAS was injected nearby the Final Approach Fix point. Because of this, also the test with C2 link failure could only be performed with the failure happening in the final approach section generating

some concern to the ATCOs regarding how to consider the failure under test, whether an emergency or a contingency. The former foreseen for the ATCO to abort all of the other operations in the TMA since the emergency is over, as preferred by the ATCOs, while the latter foreseen the continuation of all of the operations in the TMA, as per the considered procedure. This kind of evaluation surely requires a further investigation perhaps also considering the possibility of autonomous landing during a C2 link failure under pre-determined circumstances and if enabled by the RPIL when confident on the situation.

The traffic density used for the simulations was representative for the simulated airport. Future experiments could be carried out in busier airspace in terms of traffic.

In addition, a scenario with multiple RPAs landing though ATOL one right after the other mixing the considered contingencies should be simulated to evaluate ATCO workability in future experiments.

4 Conclusions

The actors involved in the simulation felt always comfortable in the execution of runs, even during conflict situation and C2 link failure. The ConOps developed by the INVIRCAT project allows to assess the safe integration of RPAS into controlled airspace evaluating it from a safety and HF point of view.

In substance, for what stated in the results section, and also confirmed by the actors during the debriefing sessions, the RPAS is not so much different compared to a conventionally-manned aircraft. In general, all the systems worked properly even during contingency situations allowing the RPAS to be managed as an additional airspace user. However, further investigations should be conducted on the C2 link aspects in order to find a trade-off to manage this contingency during the critical phases (landing/take-off). Finally, the experiment's participants provided a set of different recommendations:

- Develop proper procedures for the C2 link failure.
- Training for the actors regarding the C2 link failure.
- Adequate phraseology for contingency situations.
- Tower controller to use a SMGCS equipment.

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Public Services Innovation Through Gamification. From Concept to Implementation

Antonella Frisiello[1(✉)], Mario Chiesa[1], Ruth S. Contreras-Espinosa[2], and Jose Luis Eguia-Gomez[3]

[1] LINKS Foundation, Turin, Italy
antonella.frisiello@linksfoundation.com
[2] University of Vic - Central University of Catalonia, Barcelona, Spain
[3] Polytechnic University of Catalonia, Barcelona, Spain

Abstract. The present work focuses on gamification applied to public service innovation, with a specific focus on the commoning paradigm as an alternative form of collaboration among citizens and public administrations.

In the proposed innovation scenario, gamification – the use of game elements for non-game contexts – is proposed and investigated as a strategy to promote the citizens' active engagement in the co-management and co-creation of novel public services. The paper outlines the core elements of the strategy, co-designed with the stakeholders. Moreover, the implementation of the "Gamification Engine" is presented as a building block enabling an open-ended gamification strategy to be applied to innovative public services.

Keywords: Gamification · Commoning · User engagement · Public-service innovation

1 Introduction

In recent years, the relationship between public institutions and citizens is changing, also due to novel socio-technical paradigms that facilitate public engagement and participation. Commoning, as defined by Ostrom (1990), is an emerging approach focused on common goods (both urban spaces and immaterial resources), where communities can arise. Solidarity, inclusion and public-private cooperation are the values that enable new forms of welfare through the co-creation and co-management of public services. In such a scenario, technology is a crucial infrastructure to connect people, places and services. Commoning is the context in which the H2020 research project CO3[1] aimed to introduce and assess some disruptive technologies for public service innovation along with citizens. Five disruptive innovations were identified: blockchains, augmented reality,

[1] CO3 stands for: Co-design, Co-produce, and Co-management of innovative public services along with citizens. H2020-SC6-Transformations-2018–2019-2020, Socio-economic and cultural transformations in the context of the fourth industrial revolution). Grant Agreement n. 822615. www.projectco3.eu.

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https://doi.org/10.1007/978-3-031-28390-1_17

civic social networks, liquid democracy tools and gamification, with the latter aimed at enhancing the active role of citizens as co-creators and co-producers of public services.

This work outlines the gamification strategy designed within the H2020 research project CO3-Codesign, Co-produce, Co-management of Innovative public services along with citizens.

2 Background: Gamification and Design Approaches

According to literature and market research, the application of gamification is growing in several public domains, such as healthcare (Johnson et al. 2016), education (Nah et al. 2019), transportation (Yen et al. 2019), government (Contreras-Espinosa and Blanco 2021), among others. One of the goals of gamification is to engage citizens as active players through micro-actions that facilitate entering and taking part in the public conversation, giving feedback to possible local government decisions, and actively meeting common objectives, like reducing the level of energy or water waste. Gamification is nowadays known and applied as the use of game elements and game thinking in non-game environments to increase target behaviour and engagement (Deterding et al. 2011). Gamification, as a nudging approach, aims to encourage desired behaviours and positive change, by designing interesting experiences and positive reinforcements. In practice, gamification intentionally applies game elements in non-game tasks and contexts. This is possible by adding an actionable layer to services, which leverages motivational drivers of specific target communities and facilitates desired positive behaviours (Robson et al. 2015).

Leveraging individual motivations, gamification aims at promoting positive decisions and behaviours, by enriching the user experience. For this purpose, gamification design incorporates and implements motivational drivers into the experience flow (Sailer et al. 2013). Several psychological theories foster the gamification design (Krath et al. 2021), among which prevail the Self Determination Theory (Deci and Ryan 2008) and the Theory of optimal experience or Flow (Csíkszentmihályi 1975). The first one provides a model of human motivation as a continuum ranging from intrinsic to extrinsic motivation, where the poles refer to the diverse origin of the motivation. The extrinsic motivation grounds on external regulations, the person accepts to follow; inversely, the intrinsic motivation grounds on the internalization of rules, that are perceived and followed as personal values. According to the authors, internalization of the rules depends on the satisfaction of three fundamental psychological needs: the need for autonomy, the need for competence and the need for relationship. On the base of this background, different models have been defined to map the motivational drivers and gamification elements. One of the most known is Bartles' matrix (1996), which identifies four main player types based on four fundamental motivations. Bartles specifies that the players' profiles (Achievers, Explorers, Socializers, Killers) are never "pure": in every player, as in the wide audience, the different motivations are all present snd active at the same time, but to a different extent. The matrix allows designers to develop a multi-dimensional description of their targets. A more recent and wider motivational model for gamification is the Octalys (Chou 2016). The model identifies eight motivations, for each of them specifies gamification techniques to activate them. The core dimensions of the framework

are further organized into intrinsic and extrinsic drivers (vertical axis) and positive and negative motivators (horizontal axis).

The theory of Flow (Csíkszentmihályi 1975) is a core reference of the gamification design, to identify the expected result of successful gamification: the optimal experience as a state in which the person experiences a full "sense of enjoyment", laying in a balance between the person's capabilities (sense of mastery) and the level of difficulty of the challenge. This construct is core to designing engaging and lasting experiences.

As a design approach, gamification leverages a multidisciplinary background, combining psychology, human-computer interaction and design, in a set of pillars that identify the main steps of a gamification design process:

1. The users' characterization, their mental model, motivations, and goals.
2. The challenges definition, including goals and desired actions.
3. The design of system capabilities, to convey useful information and mechanisms, sustaining the experience over time, including quests, feedback, and rewards.

3 Gamification of Innovative Public Services

The intersection of gamification and public services is not new. In the field of E-government and the civic sphere, gamification and serious games are systematically experimented with for various purposes (transparency, security, accessibility), to improve active citizenship and the relation between civil society and institutions. In particular, gamification is applied to engage people in concrete actions for common objectives or public interests, promote social inclusion in civic life, and share common resources, both tangible and intangible ones. These applications highlight a cultural layer that gamification must include to promote either personal or community benefit. These practices take also inspiration from European policies[2], promoting the empowerment of citizens and active engagement in new forms of participation, including the design, production and delivery of public services.

This was the focus of the H2020 research project CO3 – Co-design, Co-produce, and Co-management of innovative public services along with citizens[3]. The project aimed to develop and assess an innovative model of interaction and collaboration between Public Administrations (PA) and citizens. The innovation the project focused on refers to a phygital ecosystem able to reframe the role of citizens in the public service creation, production and management together with public servants. The digital layer of the ecosystem was predefined by a set of technologies (Blockchain, Augmented Reality, Geolocation in Social Networking, Opinion Formation) identified as enablers of site-specific service innovation collaborative practices. Concerning gamification, it is not technology nor a service per se. It was defined as an additional experience level to be built onto the services entailing local purposes, values, and experiential cues, through meaningful

[2] eGovernment action plan: https://digital-strategy.ec.europa.eu/en/policies/egovernment-action-plan.

[3] H2020-SC6-Transformations-2018–2019-2020, Socio-economic and cultural transformations in the context of the fourth industrial revolution). Grant Agreement n. 822615.www.projectco3.eu.

narratives, engaging challenges, and motivating rewards, experienced through the CO3 technologies.

A high-level scenario describes what we called the "Augmented Common". Inspired by the Ostrom definition of the Common (1990), it refers to a real place, both physical and digital, where new forms of collaboration among Public Administration (PA) and citizens give rise to and co-manage the common good through disruptive technologies, like Augmented Reality, Blockchain and Civic Social networks (Fig. 1). The CO3 meta-scenario includes gamification as a socio-technical paradigm that aims to promote and foster social interactions and exchanges among commoners, coherent with the values and functioning of the commoning theory. In particular, the gamified CO3 services have to: (1) foster common interest and cooperation over competition; (2) facilitate positive and proactive behaviours, aware of the possible impacts on both individuals and groups/communities; (3) interoperate with other technologies, encouraging digital adoption and inclusion.

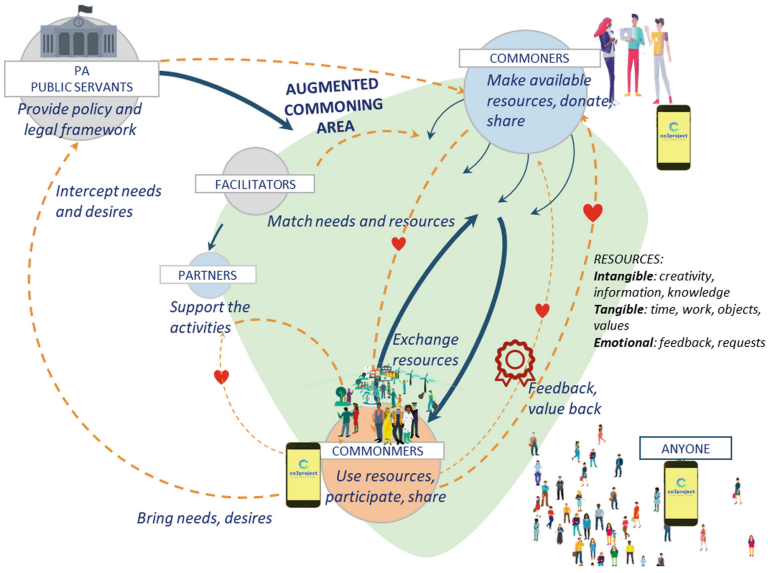

Fig. 1. Augmented commoning scenario map.

3.1 The Gamification Concept

To engage people as active players in the co-creation and co-production of public services, the CO3 gamification strategy was designed as a path in which participants evolve from bystanders to active commoners. In this concept, the common-oriented goals are reached by both individual and group gamified activities and acknowledged both as personal and collective achievements. Starting from the evolution path shown in Fig. 2 four types of desired action sets have been identified:

– *Access:* actions that guide the citizens to onboard the Augmented Common.
– *Discovery:* actions that acknowledge the curiosity and interaction with the Augmented Common (initiatives, contents, …), allowing to be informed about activities and groups as well as to share information and leave comments.
– *Participation:* actions enriching the active role, rewarding behaviours such as attendance to initiatives, co-management of services, collaboration in places- maintenance, and decision-making on topics of common interest.
– *Co-creation:* actions that acknowledge citizens proactively launching initiatives, and challenges and taking part in the creation of new services.

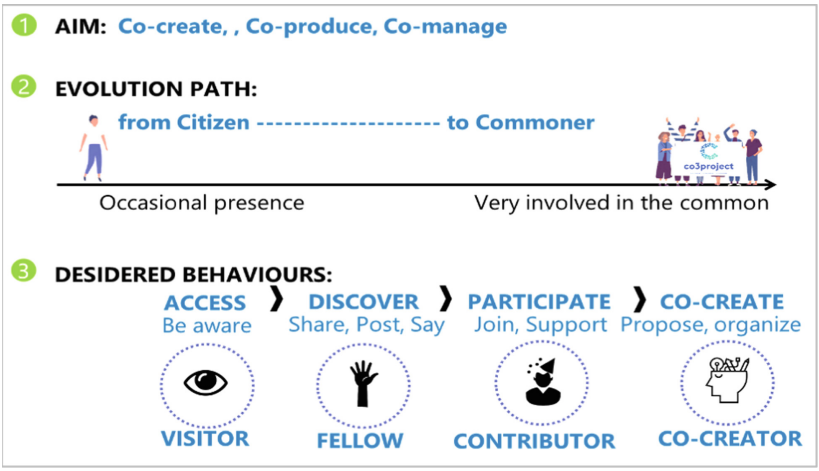

Fig. 2. CO3 gamification strategy.

The four steps include specific actions promoting desired behaviours and different degrees of engagement to be acknowledged with specific mechanics, enabled by CO3 technologies, to be experienced both in the presence and remotely.

4 Gamification Co-design Methodology

The CO3 gamification has been part of a wider co-design process, that involved a heterogeneous panel, including public administration, technology experts, local associations and citizens in the collaborative definition of commoning solutions and implementation. Inspired by the most known human-centred approaches applied in Service design, such as the Design-Thinking (Zhang and Dong 2008) and Platform Design (Cicero and Heikkilä 2020), the CO3 design process is organized in steps and iterations, starting from building a knowledge base, including background and user needs, that proceed with participatory activities, where participants collaboratively concretize their ideas (Fig. 3). Figure 3 collaborative design phases.

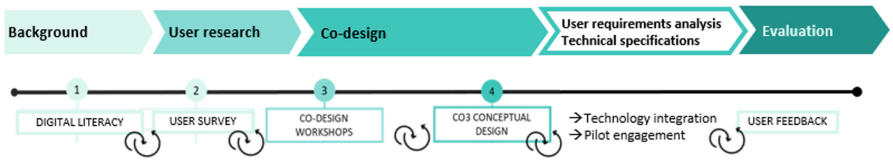

Fig. 3. Collaborative design phases.

The participatory process was applied also to the service design and the gamification design for CO3 services, through the following steps.

Background Phase. Dedicated meetings and internal dissemination activities allowed to build a common background on gamification, provide examples, and reply to questions and barriers of stakeholders.

User Research. In parallel, an online survey investigated target users, in terms of motivations and preferences, as a base to identify core elements such as mechanics, rules, and measurable variables. The data collection method was adapted for the CO3 context and based on studies by Yee (2006), including variables such as country, age, gender, media consumption and favourite games, and the gamification questions to capture the citizens' profile[4].

In total, 138 complete answers to more than 46 questions were received. Of these 46 questions, 39 are of the Likert scale type, asking to agree with statements on a range from 1 to 5.

Three game elements were preferred: "Teamwork", "Roleplay", and "Achievement" since these are where more users overlap and with higher intensity. Table 1 shows the game elements most appropriate for the gamification strategy, based on the stakeholders' responses. Those elements were elaborated in terms of user engagement via posterior data analysis.

Table 1. Recommended elements for CO3 implementation

Types	Gamification elements
Role-play	Dialogue choices, Story, Experience points, Levels, Avatars, Personal profile page
Achievement	Achievements, Challenges, Missions, Badges, Experience points
Teamwork	Leaderboards, Achievements, Real-time information, Personal profile page

Picking the best cluster for each gamification element and the statistics of the game genre played by the user, we can determine one preferred gamification element for each citizen type. To start the analysis, we picked up the best cluster determined individually

[4] The online form is available in 5 languages at: https://www.projectco3.eu/wp-content/gamificationformv4.

for each gamification element and value. Those scores are the response rates facilitated by the users from the form questions. The best cluster is composed in theory, with the users that most agree with the questions related to the current gamification element.

For each of those clusters, we collected the statistics about the game genre that the participants inside each cluster play. The main results have been previously published, extensively describing the clustering technique that enables the mapping of different user profiles in relation to their preferred gamification elements (Blanco et al. 2021) based on one taxonomy of game elements (Contreras-Espinosa and Eguia-Gomez 2022).

Co-design. The gamification co-design and implementation activities followed a well-established process to progressively specify the gamified path to the commoning. Some key questions have driven this phase involving public servants and commoners of the three pilot cities, which worked both collaboratively and asynchronously. Brainstorming sessions, idea clustering and other traditional UX methods were applied, driven by a few key questions (Table 2).

Table 2. Gamification key questions

Goals	Key questions
Raise, selection and priority of goals	What do you want to achieve through gamification?
Identify the desired actions	What participation activities are relevant to the goals?
Mapping actions on technology capabilities	What measures will be taken to achieve this objective?
Definition of rewards and rules to get them	How to recognize the actions performed?
Tuning of the loop engagement	Which steps will make the trip more interesting?
Aesthetics	Which metaphor or theme best connects the elements of the experience?

A level system setting rules, barriers, and rewards were designed, to outline the progress path towards the objective of both individuals and groups. For each desired user behaviour, detected by CO3 ecosystem, different rewards (levels, points, badges) were defined, according to the specified rules.

The focus on the stakeholders' needs brought us to define a specific type of reward, complying with the request to maximize and promote collaborative social dynamics instead of competition. For this purpose, we invented specific cooperative badges, that are rewards assigned to all members of the augmented common as a result of all the single actions performed. These inclusive mechanisms are intended to highlight the collective dimensions, introducing and supporting the community as a user, in line with the commoning principles.

A scaffolding set of challenges, actions, rules and rewards was defined, to showcase an ideal gamified path to the commoning. Once implemented, it worked as an extendable and customizable sandbox to play with and start gamifying the local public services. On this base, 3 site-specific gamification systems, for the local services were created with the public servants that selected specific elements, point systems, rewards and metaphors, co-designed to strengthen the connections between the digital contents and local contexts (see Fig. 4).

Fig. 4. CO3 gamification levels and badges (default set)

Evaluation. Iterative evaluations were conducted for testing the design process. In particular, the gamification default set allowed to progressively collect the user feedback and refine the overall gamification strategy. The overall evaluation of gamification was then carried out in the field during the pilot evaluation of the CO3 project.

5 Implementation of the Gamification Dashboard

The CO3 gamification lies on a combination of Points-Badges-Leaderboard, which are basic game elements known in the literature as PBL framework. The PBL system allowed to set the rules to implement the gamification path, that we structured to promote the use of a set of CO3 features and not to introduce penalties or barriers. In order to encourage participation through the CO3 ACA technologies, all the features are available anytime, from the beginning. In respect of Gamification aims, the overall CO3 approach in logging activities is to count rather than track events, preserving as far as possible the users' privacy. Counters are the core tools to manage and store the points achieved by each user, according to a set of rules and rewards definitions (different types of badges) that allow managing properly the gamified experience. Every time a gamified event is detected within the system, the counters are updated, but not all the events generate a notification to the user. Counters are not visible to the end-users.

The implementation of gamification elements and mechanisms is based on two main prerequisites, in order to allow the CO3 ecosystem to work properly and consistently:

– the ability of the CO3 sub-systems to detect and recognize a defined set of events;
– the ability to log and store event-related information, as previously detected and recognized.

The OnToMap Logging service and Data Hub (CO3OTM), working as a cross-application logger of user actions and as a data hub for all the applications, offers support to fulfil both. The CO3 mobile app and all the other available touchpoints, as defined within each pilot, contribute to and use data stored to update the user's gamification elements and personalize the user experience.

At the beginning, an extensive set of events is defined to support the mechanics and rules definition across all the pilots and to test possible conflicts and constraints as well as the implementation over the different subsystems. The set includes several subsets; one includes events applicable to all pilots, plus others with events specific to each pilot, and others for intermediate testing activities.

A dedicated online dashboard was developed allowing to set up and control the gamification elements within the CO3 technological ecosystem. In particular, the dashboard allows to customize the following elements:

– the rules to be triggered when defined activities (within specific conditions) are performed within the CO3 ecosystem;
– the points to be assigned when rules are triggered;
– the badges to be achieved accordingly to their type, structure and preconditions;
– the badge types (individual, collaborative or competitive) and timeframe (weekly, monthly or permanent) for each badge;
– the badge structure (or organization into levels) for each badge;
– the preconditions (points or other badges) needed to progress into badge achievement.

Born to implement and test the gamification during the project pilot, the CO3 gamification dashboard has been then adapted to concretize an opportunity that emerged during the co-design phase. With some adjustments, it was delivered as a tool for end-users enabling them to actively control some elements of the gamification of the local public services. The CO3 gamification dashboard can be managed by public servants (in the first stage), without specific IT skills. It provides templates to simplify the process of rules and badges definition, that resemble most common activities and conditions. Changes to the gamification can be done at any time while the service is in operation, preserving all the information and data about disabled rules or badges, to maintain consistency and accountability of previous achievements and corresponding activities.

6 Discussion

CO3 gamification is aimed to facilitate communing as a social paradigm, encouraging citizens and PA to collaborate and socially embrace beneficial collective actions. Nevertheless, a gamified approach is not easy to introduce to stakeholders, both citizens and PA. During the process, a strong effort was put to explain gamification paradigms, and distinguish between gamification and videogames, often confused. Moreover, some risks

and biases were identified, such as the focus on the performance not on the goal; or the competition changing the nature of the activities. Some countermeasures were implemented, like the selection of a limited number of desired behaviours to avoid massive gamification of the whole service. To this extent, a flexible management tool was implemented, enabling commoners to directly add and customize challenges, rules, badges and rewards.

In addition, an important implementation has been realized, to make the gamification approach open, that is not predefined in all its components, but enables the commoners to directly add and customize challenges, rules, badges and rewards. The CO3 gamification dashboard has allowed also the introduction of qualitatively different rewards, i.e. based on long-term challenges and more intrinsic motivation drivers. This is a relevant and unexpected result of the gamification design process applied in the CO3 project, turning end-users into co-creators.

7 Conclusion

The paper presents the early concept of a gamification strategy applied to the commoning, aimed at engaging people in co-management and co-creation of public services. The proposed gamified approach is conceived as a path, where the individuals can experiment with their routes to become commoners. A survey on interests and motivations suggested some specific gamified elements, for more meaningful experiences.

To create a gamified experience coherent with the commoning principles, the proposed strategy was only partially predefined: participants can add and launch new challenges as individuals and groups, promote on-spot local initiatives and co-created services.

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Themes of a Research Agenda for Sustainable Human Centred Design

Erminia Attaianese[1](✉) and Emilio Rossi[2]

[1] Department of Architecture, University of Naples "Federico II", Naples, Italy
erminia.attaianese@unina.it
[2] Lincoln School of Design, University of Lincoln, Lincoln, UK

Abstract. The synergies and the relevant interdisciplinary existing between Sustainability and Ergonomics (HFE) are paramount to document the cultural evolution of design interventions that can be made when creating innovative artefacts, such as products, services, and product-service systems, since both disciplines aim at investigating the interactions between humans and living ecosystems. However, studies linking Sustainability and HFE mainly tackle the problems at the macro-scales, though several interplays between human behaviours, creative practices, and contexts of use can be identified at the micro-scales within the Human Centred Design domain (HCD). Ergonomic interventions performed under the Sustainability domain should employ design-driven strategies, which means that there is the need to further investigate the interdisciplinary contributions under a HCD lens (e.g.: investigations made at the human dimension). A research agenda for future explorations on Sustainable HCD is proposed in this work. The agenda is composed by six main research themes that employ design-driven scenarios to frame the complex set of open research topics pointed out by HFE in relation to Sustainability goals. Results achieved in this study set a body of knowledge through which systematically explore the possible contributions that Sustainable HCD may produce at all design scales, and for which a choral research effort is needed of all HFE community.

Keywords: Human centred design · Sustainability · Research agenda · Research themes

1 Introduction

A holistic interplay between human behaviors, creative design practices, and the sustainable quality of contexts of use where actions are performed can be found within the official definition of 'Ergonomics' (HFE) endorsed by International Ergonomics Association (IEA) [1][1], and this relation can be observed both at the micro and the macro

[1] Ergonomics (or Human Factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.

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scale. Thus, the micro-behaviors expressed at the (inter-)personal level generate direct effects on living ecosystems, whereas products and services are usually designed to support people to achieve suitable levels of well-being; at the same time, macro-behaviors consolidated within large-scale social groups play a fundamental role on how to address the development of complex functional architectures and sets of solutions, such as systems of products and services, built environments, and product-service systems (PSS). Such relations are also echoed by interdisciplinary findings achieved within Design for Sustainability studies [2, 3] where it has been proved that negative anthropic actions significantly affect the capability of human systems to properly achieve suitable levels of Sustainable Development.

It is therefore possible to affirm that both HFE and Sustainability express common interests, values, and interdependences when included within a design domain (or scenario)[2], and the importance of humans that operate informed actions through designed systems of solutions and within defined context of use is universally recognized as a key aspect to consider [4]. It can also be observed that because Sustainability does not only refer to ecological qualities; instead, the HCD intervention should be intended as a set of actions through which operate coherent interventions linking humans and living ecosystems. The relevance of this connection is also echoed by Demirel and Duffy [5] that clearly affirm the need to employ a sustainable HCD approach to deal with the degeneration of the ecology while providing alternative criteria for considering customer requirements. Therefore, human-centered design interventions link HFE to sustainable scenarios.

The International Organization for Standardization (ISO) defines the HCD 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 HFE and usability knowledge and techniques'* [6]. HCD is one of the pillars of HFE and it is proven that design interventions centered on humans produce remarkable improvements the lifecycle of the designed solutions [7]. Over time, the relevance of HCD has also been discussed by important authors against modern design theories [8–11] since it employs multidisciplinary research frameworks that consider humans in the whole product lifecycle, from conception stages to testing and final use.

Three relevant aspects can be identified from the analysis of studies considered in this introductory part: (i) Evidence suggests that HFE and Sustainability seem to be connected, but mainly the macro-level (i.e.: Organizational Ergonomics) [12–14]; (ii) Both domains can be connected through a HCD-based lens, whereas vertical and horizontal synergies should be further investigated to understand the interdisciplinary research and design opportunities [15]; (iii) Human-centered/-oriented designs (e.g.:

[2] A preliminary bibliometric analysis performed on Scopus (April 2022) on journal articles and conference proceedings published since 2000 has revealed the existence of 214 peer-reviewed publications containing links between Human Centred Design (the design area of HFE) and Sustainability. The query used was: (TITLE-ABS-KEY ("human centred design") OR TITLE-ABS-KEY ("human-centred design") OR TITLE-ABS-KEY ("human centered design") OR TITLE-ABS-KEY ("human-centered design") OR TITLE-ABS-KEY (hcd) AND TITLE-ABS-KEY (sustainab*)) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")) AND (LIMIT-TO (PUBSTAGE, "final")).

products, services, etc.) and studies (e.g.: speculative analyses, theoretical studies, new tools, etc.) contribute to achieve the aims of Sustainability; therefore, through informed design strategies addressing the challenges of present and future society, HCD is able to converge the HFE criteria within sustainable design scenarios. Accordingly, there is the need to further explore the synergies between HCD and Sustainability to better understand mutual influences and relevant themes for future design studies in HFE.

2 Aim and Methods

This work proposes a research agenda for Sustainable HCD, which is based on the analysis of disciplinary and interdisciplinary synergies, research opportunities and promising design topics between HCD and Sustainability. The goal is to provide evidence of the most promising themes to be used within HCD domain to tackle the complexity of Sustainability at suitable design scales. Relevant knowledge developed in the last years is used to provide evidence about the validity of agenda's themes.

Secondary research methods in the form of literature review [16] and systematic analysis [17] are used to conduct the study and the preliminary research questions, as well as understanding the synergies between HCD for Sustainability. A scenario-building methodology [18, 19] – *a design-oriented methodology to discover and systematize the available knowledge to ideate likely conditions for scientific advances, alongside to build engaging narratives to communicate the promising areas to work on* – helps to set up the best conditions through which implementing the agenda. Hence, the agenda is the result of qualitative analyses resulting from the previous points. Finally, deductive considerations and cultural speculations are also proposed in the last part of this work.

At the cultural level, this study aims to raise the attention and the interest of the scientific community in the fields of Design and HFE (see: [15]) on the need to explore relevant interdisciplinary research themes for novel studies and activities that require new expertise, research skills, and competencies. Therefore, this work underlines the need to develop new investigations and common discussions to clarify terminological biases that often limit constructive debates and production of knowledge within the research communities.

3 Understanding Synergies Between HCD for Sustainability

The exploration of common research topics linking HCD and Sustainability aims to identity patterns and a set of comparable elements to be used for creating the design research scenario, useful to focus the attention only toward the most relevant domains where Sustainable HCD interventions can produce relevant effects.

3.1 The Influence of Sustainability on HCD Studies

As briefly discussed before, the role of Sustainability is paramount in Design [2, 5]. Studies developed in the last thirty years documented an evolution of the design culture that moved from materialism and the analysis of products' ecological qualities to the

investigation of systemic relations within socio-technical systems having high social qualities [2]. The attention toward the green growth [20, 21], the recognition of the value of the social dimension related to different consumption models [22] as well as the development of an agenda of actions to tackle the complex challenges of future years [23] influenced the studies in HCD with the raise of the 'Green Ergonomics' model [24, 25].

In terms of implementation of Sustainability principles into HCD, Lange-Morales et al. [26] suggest reconsidering the relevance of Sustainability's values, such as respect for human rights, respect of the Earth, appreciation of complexity, respect of diversity, respect of transparency and openness, and respect of ethical decision-making, to operate the needed (inter-)disciplinary design interventions. This interpretation is also consistent with the studies developed by Moray [27] and by Marano et al. [28], which place the discussions within global scenarios where the evolution of the human behaviors is needed to start the transition toward sustainable ways of living (Moray) and for which innovative research avenues are needed to trigger the investigation of new designable sustainable scenarios (Marano et al.).

Relevant elements that can be found within Sustainability studies (re [23]) have therefore the task to raise the attention of designers and design researchers in looking at the bigger picture. This statement seems to be coherent with a study made by Dul et al. [29], which describes the need to design systems of solutions at the micro-scale that promote a better – sustainable – well-being by focusing on instances observable at the macro-scale. However, a warning on this need is pointed out by Martin et al. [30], which say that the contribution of HCD to Sustainability is still limited to intentions and conceptual development, despite there is a rational continuity with design actions that are consistent with the goals of Sustainability (re [23]).

The last studies considered in this phenomenological analysis [29, 30] reveal an interesting affinity with the Ezio Manzini's angle about 'localism', the 'scenario of resiliency' and the need to move toward systems of enabling solutions that generate new ideas of (sustainable) well-being [31, 32]. Therefore, it can be said that Sustainability influences the HCD research by raising the attention on relevant macro-themes through which later start HCD studies, visions, and strategies for sustainable interventions that have a direct account on human scales, behaviors, and well-being conditions, which comprise the dimension where the HFE interventions can better express their values.

3.2 HCD's Responses to Sustainability Pushes

Whether Sustainability is called to identify promising areas where to address the attention of scientific communities, HCD is paramount to narrowing down the field of theories, approaches, methods, and tools needed to operatively implement the transition toward sustainable conditions at the micro-scale. However, as discussed before, the framework of knowledge on this phenomenon lacks consistent developments [23] and conjectural convergences.

In considering the HCD dimension more, Demirel and Duffy [5] provide an interesting analysis on the role of HCD within the Sustainability debate by proposing a design framework that encompasses four stages of product development. In this work, authors identify the well-being as the common element linking the two areas. This interpretation

is therefore fully coherent with studies conducted in Design [2, 28, 29, 32], whereas the emphasis is more addressed on the process, rather than on the individuation of common patterns to be scaled within research speculations. Yet, the lack of proper a contextualization seems to lead toward the recognition of an endogenous disciplinary complexity [33] suggesting the futility of perpetrating speculative terminological iterations, such as finding logical patterns to justify the 'HCD for Sustainability' idiom.

Conversely, interesting interpretations can be found in the work of Lange-Morales et al. [26] which helps to bring the attention on the cross-sectorial intersections between HCD interventions and Sustainability values, such as: the quality of life, the need of multidisciplinary approaches, and the idea of values (against needs). Interestingly, this is an exegesis already proposed by Marano et al., [28] whose study moves toward the definition of suitable design scenarios, rather than the vertical alteration of design topics having a sort of 'sustainable ergonomic quality'.

Therefore, the most coherent impact that HCD might produce in relation to Sustainability pushes is the identification of specific elements that can be used to define a design scenario where later the HCD culture can make an evolution. Conceptually, this assumption is relevant as it shifts the emphasis toward new research domains, while three interesting analyses made by Mason [34], Sherwin [35], and Sevaldson [36] support this new speculative conjecture. Synthetically, Mason discusses the limits of HCD approach in considering the contexts of use, suggesting that this lack triggers implications on the social dimensions that is paramount to consolidate a sustainable intervention because referred to human well-being; Sherwin suggests that insight-based HCD methods struggle to articulate or capture more abstract sustainability needs, and the relevance of this aspect is instead remarked by Design for Sustainability studies; finally, Sevaldson indicates that often design actions for Sustainability are not a naturally integrated result of human centric worldviews, and consequently often implying actions that are against the interests of users.

This analysis proves that HCD is mostly asked to address, through contextualized actions, all interventions that put the sustainable wellbeing at the center of the research process. Therefore, HCD plays an important role in refining the quality of design scenarios set up from Sustainability pushes, by considering both contextual features at the local scale (e.g.: the Manzini's angle about localism [32]) and methodological advances that are proper of HFE discipline [33].

4 Building the Design Scenario for Sustainable HCD Studies

It becomes clear that any HCD intervention performed under the Sustainability domain must employ design-driven learning processes needed to link local communities, situational actions often performed by technological equipment, and living ecosystems, either virtual or physical. Therefore, any design becomes an informed HCD process within a scenario of change aiming to achieve new sustainable qualities. Furthermore, the idea of design scenario is paramount when it comes Sustainability, and consequently Design for Sustainability, as it reduces the endogenous complexity of information to consider. Consequently, the design scenario is intended as a powerful instrumental element used to imagine future living conditions mixing bottom-up instances and top-down design

strategies. According to Manzini et al., [37] a design scenario is *'a designable vision of something complex and articulated based on a clear motivation – what is the aim? – and a practicality – the actions to undertake to favor its implementation'*.

Elements of the design scenario considered for this study obviously come from the previous discussed domains – Sustainability and HCD – and are needed to deal the systemic complexity of notions and interdisciplinary foci raised in the last years within transition studies [38]. Sustainable instances at the bigger picture provide evidence on the strategic trajectories that the human-centered design interventions should consider in order to produce significant and desirable effects in terms of sustainable well-being; conversely, HCD is asked to contextualize the sustainable scenario at the local scale, by applying specific methodologies and tools meeting the different contextual conditions [36, 37]. Therefore, the scenario of Sustainable HCD acts as a multiplier of the sustainable localism needed to achieve new levels of well-being.

This scenario is not only able to produce important cultural advances in terms of promising concepts to address future studies in HCD, and by extension HFE, but it is also able to identify new themes for cross-sectorial experimentations – themes of a Research Agenda on Sustainable HCD. In addition, this interpretation is coherent with the arguments discussed in the Sect. 3.2 about the mitigation of cultural biases [33].

5 Themes of the Research Agenda on Sustainable HCD

Results obtained in the previous stages show that there are promising grounds for developing new scenario-led studies and research avenues linking HFE and Sustainability, which are focused on human-centered design-oriented scopes. This remarks the need and the opportunity to define a research agenda for Sustainable HCD.

Since the Sustainability perspective in Design studies has broadened its scopes both in terms of goals and in the breadth of the fields of action [39, 40], some research themes can be assumed as particularly relevant to document the potential contribution of HCD within Sustainability studies. However, themes have a twofold nature: they are both 'detailed' to suggest clear research indications and topics for promising studies, and 'open' to give scholars the needed freedom to operate interdisciplinary personalization depending on the testing grounds considered for their studies.

The six clusters of interdisciplinary design themes proposed in this work range from product design to system design dimensions, from spatio-social to socio-technical systems, from transition studies to unexplored areas for HCD. Such areas are later compared against relevant levels of Sustainability, such as [2].

In relation to the *'product innovation'* level: Exploring innovative human-centered patterns connecting creative practices with transition studies to ideate new design approaches focused on improving the quality of existing/new products. Possible design areas to investigate are, but not limited to: Product Life Cycle Design, Eco-Design, and Design for Environmental Sustainability. These areas suggest the need to integrate more HCD qualities to sustainable artefacts, when these are made at the product innovation scale; therefore, the attention is on how to converge/integrate the ecological qualities with the ergonomic qualities that products must have at the human scale.

In relation to the *'product-service system (PSS) innovation'* level, two sub-themes have been identified: (i) Exploring the combination of HCD methodologies in Design

for Sustainability fields, which could suggest new studies on the usability of sustainable products, services, and systems of solutions that have a direct and indirect impact in relevant areas such as Design for Sustainable Behavior, Systemic Design, Sustainable Service Design. (ii) To ascertain vertical and horizontal explorations on sustainable systems, networks, and services, which might suggest the need to understand more how HCD improves the design of large-scale solutions, mainly intangible, and how HCD addresses the research on sustainable networked applications.

In relation to the *'spatio-social innovation'* level, three sub-themes can be discussed: (i) Exploring the implications made by sustainable architecture and the design of smart cities on individuals and social communities, which suggests the need to develop novel studies on how the HCD approaches can implement the current design practice, along with the analysis of human factors in the creation of living places, both at the micro and at the macro scales [41]. (ii) Understating relevant implications on Civil, Structural, and Environmental Engineering, which points out the need to assess the HCD aspects in the technical design of sustainable living ecosystems and places. (iii) Clustering the cultural design aspects belonging to sustainable reflective practices by exploring the role of HCD in relation to the evolution of speculative creative thinking and contextual studies.

In relation to the *'socio-technical system innovation'* level, four sub-themes contain innovative elements for new studies: (i) Exploring how to promote radical changes by framing complex patterns, systemic problems, and societal needs (i.e.: energy, food, water, health, job, security, transport) supporting the transition to new sustainable socio-technical systems by effectively including individuals and communities (e.g.: Co-Design). (ii) Implementing Sustainable Design Thinking and Design-Driven Innovation [42], because these disciplines may promote the adoption of creativity-led research patterns, cross-sectorial methods, and interdisciplinary developments useful to converge HCD and Sustainability. (iii) Consider more the contribution of Human-Computer Interaction (HCI) and User Experience Design (UX) for sustainable applications, which means considering the opportunity to perform studies linking humans and communities with technology-mediated artefacts and design practices. (iv) Understand the positive implications occurred in sustainable manufacturing, including 3D Printing; for example, what is the role of Sustainable HCD in the design of new sustainable manufacturing processes that use the LCA and LCD as assets for the competitiveness of SMEs? [43].

In relation to the level concerning *'social equity and cohesion'* [40], two relevant sub-themes can be found: (i) Developing consistent clarifications on the role of Sustainable HCD around topics like (Design for) human diversity, disability, special population, etc., opening to the idea of inclusive system [44], and how the design practice can benefit from the contributions of HFE methodologies to meet Sustainability-related studies. (ii) Analyze the role of User Research into transition studies in term of inter-, cross-, and multi-disciplinary interplay between HFE and Sustainability (at the human scales), including recent advances on Design for Social Inclusion.

Finally, in relation to the level of *'transition studies'*: Further investigate the contribution of transition studies to link HFE and HCD. Examples could relate to, but not limited to: Circular Economy, distributed systems for delocalised manufacturing, and product-service systems (PSS).

6 Conclusion and Discussion

This work provided evidence documenting the need to develop new studies on Sustainable HCD, to properly investigate the explicit and hidden links between HFE and Sustainability. A research agenda containing six clusters of research themes has been proposed to promote effective ergonomic design interventions (re HCD) that are consistent with the modern idea of Sustainability. As discussed by Ezio Manzini [45, 46], the transition toward Sustainability requires a discontinuity from the previous consumption models, along with focused learning processes needed to trigger holistic scenarios for sustainable living. Therefore, the role of design is paramount to properly implement these studies on HFE.

As recalled by Sevaldson [36] and by Borthwick et al. [47], to embrace Sustainability, HCD needs to switch from an anthropocentric perspective to a multi-centric position, also widening the design foci toward non-humans and more-than-human needs, including the planet protection and systems problems in general. User-Centered Design (UCD) approach has to go beyond the user/custom-oriented notion used to set up the design interventions by including the awareness of indirect – but equally relevant – subjects involved in the other stages of the system life cycle, such as people in the production, recycling, and dismission processes [48]. Thus, the consideration of systems boundaries has to be expanded within large, spatio-temporal contexts including both future impacts on (human) users in the long run and negative effects of its use and misuse on society, including risks prevention of unintended consequences [49]. Therefore, community engagement needs to be better integrated within the more consolidated individual perspective of UCD – more oriented toward Co-Design practices – in order to match people perception and behaviour, as well as individual user beliefs and reactions used to design creative solutions for multiscale problems [50, 51].

Sustainable HCD can even play a strategic role in transition studies [52]. It has been observed that the new set of research issues raised in the last years requires novel interdisciplinary methodologies that cannot employ traditional design approaches. Updates are therefore needed and must be shared with the design community to assess all possible disciplinary limitations, between research opportunities and challenges. Design-led human-centred interventions can therefore support proper interdisciplinary explorations linking the three dimensions of Sustainability – environmental, social, economic – with the four areas of HFE. The design side of the ergonomic interventions is the aspect where researchers and ergonomists can properly address Sustainability.

In conclusion, this work demonstrated that future design and research explorations on Sustainable HCD can be started (at least) in some promising testing grounds – here called as ‘clusters of research themes’ – which reflect the most contemporary design interests of the research community working on Design for Sustainability. Therefore, this work also points out the need to complete these studies and to start a choral research action toward structured convergences to rediscuss theories, methodologies, and tools.

7 Relevance of the Study

This work provides qualitative discussions and focused analyses on different sustainable scenarios (i.e.: clusters) and research themes converging HCD and Sustainability.

It introduces a set of research topics that are considered as relevant to start promising research investigations and design experimentations ranging from Product Design to Service Design, from Architecture to Urban Planning, from Computer Science to intelligent Systems, from Manufacturing to Innovation Management. This study contributes to enrich the cultural and scientific debate within the Human Factors research community [15] by providing evidence and interdisciplinary discussions needed to trigger studies on ergonomically coherent sustainable design scenarios and sets of solutions that meet both the HCD principles and the Sustainability criteria.

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Domotics for the Independence and Participation in Daily Life of People with Severe Disabilities

Edda Capodaglio[1(✉)], Alessandro Panighi[2], and Monica Panigazzi[1]

[1] Occupational Therapy and Ergonomics Service, Istituti Clinici Scientifici Maugeri IRCCS, Pavia, Italy
edda.capodaglio@icsmaugeri.it
[2] Domoti-Care, San Martino Siccomario, Pavia, Italy

Abstract. Domotics improves quality of life of people with disabilities. Maintaining independence and participation in daily life is the main goal in inclusive projects, starting with rehabilitative interventions. Complex technological systems tailored to conditions and life style of individuals with disabilities can be implemented through open source technology. This case report discusses the design features and results of domotic projects aimed at promoting independence and participation in daily life of people with severe disabilities. Crucial factors for the success of the projects were: customization of the system according to the needs of end users and its adaptation during the progression of the disease; relevance of social connections with respect to the use of technology by the individual; potential interference of unpredictable events that could compromise the user's technological experience. This field of technological application is full of opportunities but still needs proofs of effectiveness. Individualized projects require a lot of technical attention and human care, even in the subsequent stages of implementation. The numerous criticalities that could undermine the success of systems of this type must be addressed by appropriately considering individual cases, the use of resources and the technological intensity of the projects.

Keywords: Domotics · Open source technology · Severe disability · Independence · Participation · Daily life

1 Introduction

The rapid development of technology has contributed a lot to improving people's living conditions, thanks to the availability of various commercial products [1]. Domotic systems specifically adapted to individual conditions could offer significant benefits to people with disabilities [2]. With open source technology, devices and interfaces (such as touchscreens, voice receivers, keyboards and special buttons, etc.) can be specially selected and combined according to individual needs and residual capacities. Accessibility, portability, adaptability over time, in addition to comfort, safety, acceptability, usability, determine the success of projects of domotic systems for people with disabilities. In this report, we present the details of three domotic projects aimed at people with

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severe disabilities and based on open source technology, and discuss the results with respect to the main goal of user's independence and participation in daily life.

2 Materials and Methods

The projects presented are part of the interventions implemented by Domoti-Care© in the period 2011–2019. The three cases presented refer to people with severe disabilities (with a Barthel Index <50) suffering from the following pathologies: congenital malformation (case #1, female, 54 years), spastic quadriparesis with mental retardation (case #2, male, 18 years), quadriplegia (case #3, male, 28 years old).

The domotic systems have been designed and built by a Systems Engineer, who collaborated in a team consisting of a Physiatrist, an Occupational Therapist, an Ergonomist. The team followed each case, analyzed the needs and abilities of the user, the context of life and his interests, then identifying the areas of activity that needed technological support. The technological choices, specific for each case, have been grafted on to these indications. After installation and delivery of the systems, their usability was monitored at one year through the administration of subjective evaluation questionnaires: VAS (Visual Analogue Scale) [3], SUS (System Usability Scale) [4], NASA (National Aeronautics and Space Administration) [5], IPPA (Individually Prioritized Problem Assessment) [6]. In addition to this, semi-structured interviews conducted with end users made it possible to highlight the aspects that influenced the outcome of the projects for each case.

3 Results

For each case, the design and implementation phases took a total of about 5–8 months.

In case #1 (lady with a three-limb prosthesis who lived alone in the renovated apartment) the domotic system consisted mainly of simple functions, dedicated for example to accessing the home, security and setting domestic environmental parameters. The system was mainly created through a HAI-LEVITON control unit compatible with the standard KNX (KNX Association) domotic system for the control of electronic devices in the apartment. Figure 1 provides a schematic of the installation of the system created.

In case #2 (young male with severe physical and cognitive impairment, living with family) a higher level of complexity was required based on the KNX/RF domotic protocol (KNX on radio frequency) relating to the control of TV and PC given by the user via tablet from different rooms of the house and from different postures (sitting, lying down). In this regard, a special system has been created by combining several devices, since a finished product suitable for the case was not available on the market (Fig. 2).

For case #3 (wheelchair bounded adult male with quadriplegia, living in apartment with family) a complex KNX-based system was designed for the control of all domestic functions and appliances (external and internal doors, windows, elevator, TV control and lights, etc.). The essential levels of functionality were guaranteed through a voice command system managed through the web server and the Google Home voice recognition engine. The command was deliverable both from inside and outside the house, and compatible with all extended users (the condominiums, and the seven family members who lived in the apartment).

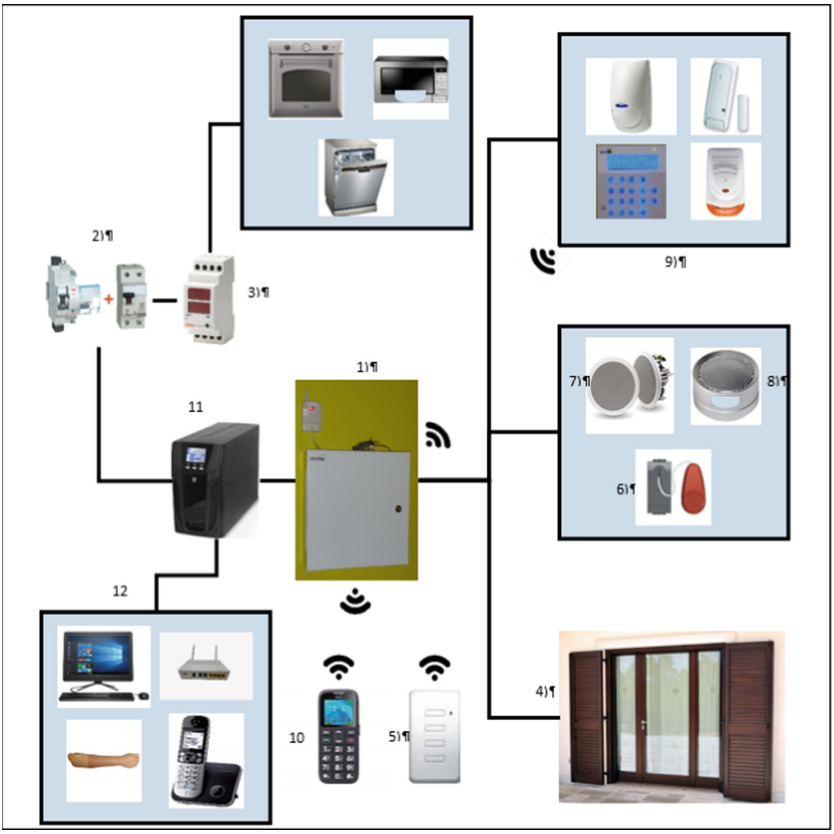

Fig. 1. Diagram of the domotic system implemented for case #1. 1) Control unit; 2) Automatic reset system; 3) Load control system; 4) Automation of doors and windows; 5) Ergonomic radio remote control; 6) Pull push buttons for help; 7) Speakers; 8) Microphone for environmental listening; 9) Wired and radio anti-theft system; 10) Ergonomic mobile phone; 11) UPS emergency power supply system; 12) Sockets that power electronic devices and prosthesis chargers.

In cases #2 and #3 the HSYCO web server was used, which includes flexible software for the creation of APPs that support JAVA and Javascript languages, manages KNX domotic systems completely, and allows the creation of GUIs (graphical user interfaces). Of course, in all cases special precautions have been taken with regard to the safety of the user and of the devices too. For example, all the devices - in addition to respecting the basic safety requirements - have been carefully chosen to be compatible with the motor and cognitive abilities of the end user, without causing any overload. Their correct use was also verified during test sessions, conducted by the system engineer himself in the presence of both the user and the caregivers. The electrical operation of the devices was protected from any possible blackouts, in order to guarantee continuity of performance.

For case #2, in addition to the functions previously described, the project aimed at facilitating communication with family members/caregivers. The special portable keyboard built on the basis of the motor and cognitive skills of the user (special keys and

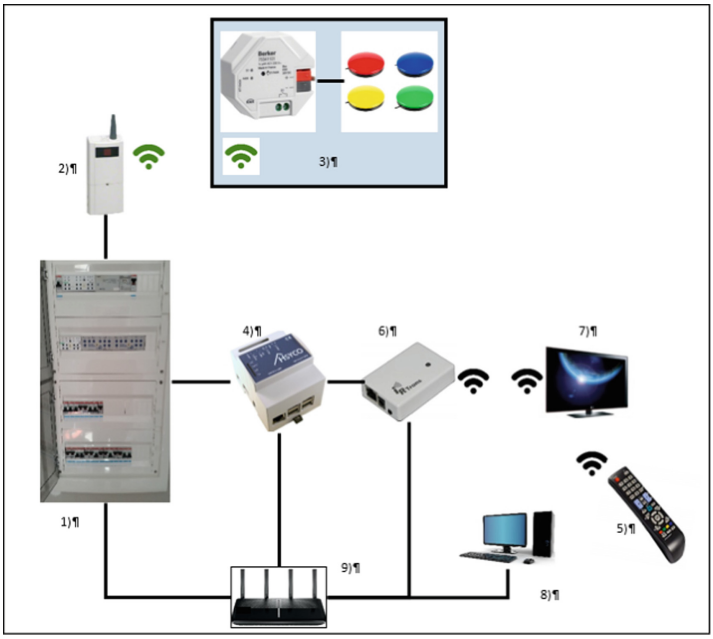

Fig. 2. Diagram of the domotic system implemented for case #2. 1) KNX domotic panel; 2) KNX/RF interface; 3) Ergonomic wireless buttons interfaced to the KNX/RF system; 4) Domotic webserver; 5) TV remote control; 6) IRTrans interface; 7) TV; 8) PC and tablet; 9) Modem router.

scanning system) has been designed to allow the user to express specific fundamental requests (e.g. "I would like to take a walk") or to express states of soul (e.g. "I'm happy"). The visual icons selected by the user, linked to an audio diffusion system, caused the emission of associated acoustic messages picked up by family members from different rooms of the house. This triggered a sort of dialogue to facilitate the meeting, even in conditions of not immediate physical proximity of the family members. In reality, this function was tested only in the laboratory, and not at the customer's home, due to the sudden change in the boy's health conditions.

In case #1, it was hypothesized that the greater autonomy of the user in controlling domotic functions could have facilitated interpersonal interactions with friends and neighbors. The user, on the other hand, stated during the interview that this outcome did not materialize. She attributed the causes to the neighborhood's low sensitivity towards disability, and essentially to the lack of real opportunities for personal encounter, even if facilitated by technology.

Despite these missed objectives, the overall results of the questionnaires administered to users at one year show a good level of satisfaction with the ease of use, adequacy and effectiveness of the systems provided (mean scores VAS 8.4; SUS 63; NASA 20.2; IPPA 13.6).

The VAS (*0–10; not at all-fully appreciated*) investigated the appreciation of the system by the user. The SUS (*0–100; not at all-fully usable*) the degree of perceived

usability. The NASA (*0–100; low-very high workload*) the physical, cognitive and perceptive commitment linked to the use of the system. The IPPA investigated the effectiveness of the system relating to the performance of daily activities (*the score expresses the difference - without and with technology - of the perceived difficulty in performing relevant activities*).

The users interviewed highlighted some critical issues relating to the initial phases of interaction with the system, mainly due to the acquisition of new habits regarding the use of devices. These aspects had been foreseen by the designers, and were effectively overcome both thanks to the commitment of the user and through the training material provided by the designer from the beginning of the supply, as well as by the support offered by the team throughout the running-in phase.

The projects envisaged a certain adaptability towards the changing conditions of the user, due to concomitant factors or the evolution of the disease, thanks to the use of open source technology and the changes on the software of the APPs. In case #2 the scanning push-button panel was set up to manage increasingly complex functions (for example, choosing and playing a video from the web, or composing and sending texts via messaging). Unfortunately, the worsening of the boy's health conditions prevented progress towards these later stages, also limiting the level of independence achieved. For project #3, applied in a condominium context, it was necessary in a particular phase to also involve the builders of the systems for public use (video intercom) and of the systems in use in the home (lift), to make specific changes that allowed integrated operation of the voice control system.

Finally, the cost of the domotic systems built (between 4,000 and 30,000 euros) varied mainly according to the degree of complexity required by the system and the extension of the residential area concerned. Any interventions necessary for the maintenance or updating of the systems could represent an aggravation of the expense. In any case, the cost of the projects was partially covered by state contributions, specifically allocated in Italy for technological interventions in favor of people with disabilities.

4 Discussion

This article presented three domotic design cases characterized by particular complexity relating to adaptation to users with severe disabilities. The objectives of the projects were set in response to specific requests received from users, in hospital discharge, and from family members, to satisfy the basic needs linked to maintaining the levels of independence and participation in domestic life, the management of free time and facilitation of interpersonal communications. The particular challenge of the projects consisted in providing simple and usable solutions for the users, and possibly adaptable over time according to contingent life situations or the progression of the disease. In all the cases described, the greatest difficulty encountered during the design was that relating to the identification of control devices that were suitable for the user's characteristics, with a good level of usability and with minimal maintenance required. The experience reported can be emblematic of the transition in progress in economic exchange from the "goods-dominant logic" to the "service-dominant logic" [7]. The value of the domotic system made available is not in fact established a priori by market rules, but is defined

when the user actively takes possession of the product, and uses it in his activities and interactions. In this dynamic process of "co-creation" between user and designer, in addition to technology, the people involved, the context, the information shared and the built value assume importance. In the context of long-term rehabilitation, this approach represents a challenge, and runs counter to the dominant logic of the major producers.

The technological choices implemented (KNX standard, open source devices, web supervisor) have allowed the creation of systems with which the user can interact safely in various domestic scenarios. However, as reported in the literature [8], the adaptability of systems to the changing needs of the user represents a critical point of domotics, even with the use of open source technology. Adaptability to the user, especially those with severe disabilities, requires a high degree of flexibility and modularity in the design, with high costs both for professional commitment and for economic investment. The success of domotic projects dedicated to people with severe disabilities could easily be compromised by the impact of concomitant events. Sudden changes in the user's health or living conditions could cause possible disruptive effects on the usefulness and effectiveness of the technological systems implemented. Furthermore, the social and cultural context of reference can pose obstacles to the achievement of the inclusive objectives of the domotic project, also weakening the results of independence made possible by technology in the context of domestic life.

The users who participated in our projects show a good level of general satisfaction with domotics, in line with what reported in the literature [9]. The potential impact of domotics on the quality of life of people with severe disabilities is considerable. However, this field has been little explored in the literature. Indeed, there is a lack of precise indications on the determinants of the success of domotic projects for people with severe disabilities, and there is little evidence of their effectiveness in promoting and supporting independence and participation in daily life.

5 Conclusion

This report, which concerns selected cases of original individualized projects for users with severe disabilities aimed at maintaining their independence and participation in daily home life, offers a contribution to the empirical knowledge of the application of open source technology in this area. This field of application sees the interaction of different professional figures who are interested in disability and inclusion, and touches on different aspects (social and economic, technological, regulatory, ethical). Despite the wide opportunities for innovation, this application area still constitutes a niche. Given the growing impact of disability in today's reality, with its related economic, health and social costs, it is desirable that interdisciplinary research intensifies efforts on this issue, to clarify the impact that domotics can have on the quality of life of people with severe disability, and to establish evidence to support inclusive projects implemented using assistive technologies.

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Design, Inclusion and Sustainable Development: Guidelines for the Creation of a People-Centred Urban Park

Francesca Tosi(✉), Alessia Brischetto, Ester Iacono, and Alessandra Rinaldi

Laboratory of Ergonomics and Design (LED), Department of Architecture, University of Florence, 93 Sandro Pertini Street, 50041 Calenzano, Florence, Italy
{francesca.tosi,alessia.brischetto,ester.iacono, alessandra.rinaldi}@unifi.it

Abstract. Nowadays society, increasingly oriented towards actions to enhance its urban contexts, tries to promote better lifestyles and increasingly inclusive social practices. The work proposed in this article presents the results of the research project: "Guidelines for the review of the park project aimed at social inclusion, sustainability and usability of the cultural and sporting activities of the Carpugnane area", funded by the Municipality of Calenzano and conducted by the Ergonomics & Design Laboratory of the University of Florence. The research used the methodological tools of Ergonomics for Design, Human-Centred Design and Inclusive Design and the collected data allowed the design of a people-centred park, suitable for citizens of all ages, which is sustainable and inclusive. The approach, adopted in this work, has provided an effective strategy in allowing the assessment and design of urban environments, ensuring safety, psycho-physical well-being and healthy lifestyles for all, taking into account human diversity and social inclusion factors.

Keywords: Human-centred design · Active ageing · Environmental sustainability · Social inclusion · Smart park

1 Introduction

In a world experiencing continuous technological and cultural revolutions, raising awareness of issues related to improving the quality of life is one of the main drivers of technological and social innovation.

Today's society, increasingly oriented towards actions for the enhancement and regeneration of its urban contexts, seeks to promote better lifestyles and increasingly inclusive social practices.

Within contemporary reality, the concept of urban public space no longer includes only the connotation of a physical space designed to perform certain functions but the connotation of relational space. It is intended as a place of social and cultural meeting and exchange, whose prerogative is to satisfy every individual's needs, necessities, and desires.

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This approach allows, for example, to increase the identity of entire neighbourhoods, give new centrality to what was previously considered marginal, and improve the quality of urban life in terms of health, environmental sustainability, etc.

Furthermore, as has been amply demonstrated in recent research conducted in England, the quality of public space has a significant impact on citizens' health and healthy lifestyles [1].

Critical elements to the definition of urban quality, as a concept of sustainable development of an innovative urban context, are urban accessibility [2], Ergonomics for design [3] and the Human-Centred Design approach [4], which allow the assessment and design of an urban environment, of specific components and associated services, capable of:

- promote usability, safety, psycho-physical well-being and healthy lifestyles for all potential users;
- deal with problems related to the different physical, cognitive and perceptive characteristics of individuals, the active ageing of the elderly, and discomfort related to the physical and cognitive development of children;
- promote socialization and independence, even for more fragile categories of individuals.

The work proposed in this article presents the results of the research project: Guidelines for the review of the park project aimed at social inclusion, sustainability, and usability of the cultural and sporting activities of the Carpugnane area, funded by the Municipality of Calenzano and developed within the Ergonomics & Design Laboratory of the University of Florence.

2 Background and Research Objectives

The research project involved the area called "Carpugnane Park" (Fig. 1), located in the urban context of Calenzano (FI).

In the early 2000s, this area already presented a master plan drawn up by the Autostrade Company to implement the lost wooded areas with the expansion of the motorway passage. There were many trees in the project and a space reserved for the excavation of the tunnel.

However, the project was not carried out because the needs of the Autostrade company and the Municipality have changed, in particular, due to the high management costs that it would have involved. Therefore, the Municipality's goal was to give a new identity to the park. For these reasons, the park review project was entrusted to the Ergonomics & Design Laboratory (LED) team of the University of Florence.

The general objective was to provide indications and guidelines to create an inclusive and welcoming urban environment geared to the needs of the citizens of the affected municipal area and the neighbouring municipalities of the Florentine plain. All this considering the broadest possible audience.

From the analysis of the current state of the art, it emerged that the area, despite the absence of a continuous cycle path and pedestrians along the park's border, is currently frequented by young people on bicycles. In addition, the more internal areas of the park are frequented by adults and the elderly for long walks in nature with dogs.

All these considerations and observations regarding the intervention area made it possible to identify and hypothesize, in the various phases, the possible destinations of use and any activities of the park.

Therefore, the specific objectives of the research were:

- redevelop the green areas of the park with interventions on the vegetation and the design of relaxation areas and related furnishings;
- create areas equipped for playful, recreational and sporting activities;
- define the cycle-pedestrian paths and connecting routes to the park's various areas and the existing urban fabric.

Fig. 1. State of the art of the current area intended for the Carpugnane park.

3 Methods

The research used theoretical and methodological tools of Ergonomics for Design, specifically those of Human-Centred Design and Inclusive Design [5], to define design solutions and project guidelines.

As reported by the ISO 9241-210: 2019 standard, the Human-Centred evaluation process provides for the knowledge and interpretation of the context of use, defined as

the set of the following variables: products and services examined; direct and indirect users involved in the interaction with the product and service; planned or hypothetical activities; physical, technological and social environments in which the product and service are used.

This design approach characterized the working method of the LED team in all phases of development and intervention of the activities carried out.

In particular, the research, developed over several phases, envisaged the involvement of the various types of users of the park, using a participatory design approach aimed at associations interested in sporting activities, some groups of active citizens and institutions strongly linked to the territory.

This involvement made it possible to focus attention on their needs, expectations, points of view and the skills of the professionals involved in the planning and managing services relating to the park's various areas.

The research, precisely, followed the following operational phases:

Phase 1: General framework of the intervention area and analysis of the critical issues;
Phase 2: Identification of areas for the different activities;
Phase 3: Development of project concepts;
Phase 4: Drafting of guidelines.

3.1 Phase 1: General Framework of the Intervention Area and Analysis of the Critical Issues

In the first operational phase, which allowed the analysis and assessment of state the art and the critical issues of the current intervention area, the meetings with the municipal administration and sector institutions were fundamental through various inspections. These allowed the collection of valuable information for understanding and, subsequently, for solving the problems and constraints related to the intervention site inherent to the accessibility and use of the space.

In particular, the methodologies applied in phase 1 were:

- *Direct observations* [6, 7] with photographic and audio-video material collection; it made possible to understand how the citizens of Calenzano currently live in this naturalistic area, which is not yet equipped and designed to be a pole of attraction for many.
- *Semi-structured interviews* [8] on diversified users who carried out different activities within the context of use; made it possible to embellish the analysis of the activities with further details and bring out critical issues and unexpressed needs that otherwise would not have emerged.

Specifically, these methods have been used to conduct activities aimed at:

- analysis of the area understood as a context of use and interaction with the territory;
- identification of naturalistic limitations and constraints regarding the physical environment (presence of rolling mills, differences in height, private buildings, olive groves, etc.);

- analysis of the social and behavioural dynamics of the urban context;
- identifying key concepts in terms of accessibility, usability, and safety of development support.

3.2 Phase 2: Identification of Areas for the Different Activities

Fig. 2. Summary scheme of the park's activities and potential users.

The second phase of research was of an exploratory type. Based on the initiatives promoted by the Municipality of Calenzano, it envisaged the involvement of citizens to activate processes of dialogue and citizen participation.

The methodologies used to conduct the activities of this second phase of research, on the other hand, are aimed at generating ideas and defining spaces for the various recreational, cultural, sporting and gaming activities concerning the interaction with the different types of users (Fig. 2). Specifically, the following were conducted:

- *Focus group* with sports associations, public and private. It allowed the collection of suggestions and information regarding the social dynamics between neighbourhoods and local activities (markets, cultural events, sports activities) and indications regarding the functions to be implemented and inserted into the area of interest. For example, groups of older citizens shared their experiences in vegetable garden management and

the behavioural dynamics of sharing the land. The presence of groups of families has also made it possible to frame the methods of use of the current green areas, especially as regards play dynamics for children.
- *Participatory planning activities* involved the inhabitants of the Municipality of Calenzano and some subjects residing in neighbouring municipalities to create a project that could also be a pole of attraction for the neighbouring municipalities of the Florentine plain. This participatory planning experience encouraged the emergence of new ideas through discussion and the creation of shared collective knowledge.

In this exploratory phase and for the process of territorial transformation, the common knowledge of citizens, not professional and technical, which the team could not know because it derived from living in their own territory/neighbourhood daily, was indispensable. Moreover, these meetings were crucial for defining the following work phase, which involved developing design concepts.

3.3 Phase 3: Development of Project Concepts

The development, instead, of phase 3 (Fig. 3) has allowed the definition of design concepts through:

- *Design workshop* with a graphic rendering of the results, which involved the involvement of architects and young designers. The workshop, held within the Design Campus, took place in three phases (brainstorming, concept maps, design). The *brainstorming sessions* [9] allowed the participants to analyze critical issues and formulate new ideas. Each participant wrote down suggestions and observations, which were subsequently discussed with the whole group and allowed to generate new insights. In the next phase, through the *concept maps* method [10], it was possible to pay attention to the general themes to work on and to the design aspects, using plants and photographic surveys. This working method stimulated the creative abilities of the participants, who, through the association of colours and images, had the opportunity to find new meanings and generate new design scenarios developed in the final phase of the workshop.
- *Definition of design orienting scenarios* [11, 12] which led to the elaboration and visual articulation of "plausible" and "questionable" visions and proposals. This tool, therefore, made it possible to describe the team's strategic vision regarding the possibility of developing an innovative park system aimed at directing people towards an increasingly active and healthy lifestyle, favouring playful, recreational and sports activities.
- *Participatory planning activities* with the involvement of the project partners and the stakeholders of the Municipality of Calenzano. The participatory path allowed to enrich the intervention proposals giving space to any suggestion from the city. The will of the LED team was to collect these results so that the activities of the park could integrate with the life of the neighbourhood and offer additional services for the city, responding to a need for places to meet, discuss and relax in total security possible.
- *Discussion sessions with citizens.* The information sessions, which allowed the participants to have a general picture of the research team's analysis and the intervention

hypotheses, were followed by sessions of comparison and debate with the participating subjects representing the most varied professions. In this phase, it was possible to collect the observations and comments of citizens in two different ways: interventions and discussions on the spot relating to the proposals expressed by potential users; a collection of suggestions through the compilation of anonymous forms.

Fig. 3. Development of design solutions within the design workshop.

3.4 Phase 4: Drafting of Guidelines

The data that emerged from the various operational phases allowed the development of design solutions and guidelines (Fig. 4).

4 Results

The Carpugnane Park was designed as a People-Centred Park, suitable for citizens of all ages (from children to the elderly) and inclusive for various types of users. It is also sustainable regarding environmental and economic resources, in all its phases, from construction to maintenance.

Essential concepts such as active ageing, environmental sustainability, social inclusion, smart park, sustainable mobility, and smart technologies have made the new park innovative and totally "people-centred".

The park, located in the inhabited centre of the Municipality of Calenzano, will allow all users to take advantage of this green urban area (about 40 hectares) through accessible routes and services designed for the active participation of citizens in the many activities proposed: from the activity physical outdoor area, for all generations, to recreational and playful activities, such as city gardens, inclusive play areas for children, dog areas, which can become an urban green area, a reference point for those looking

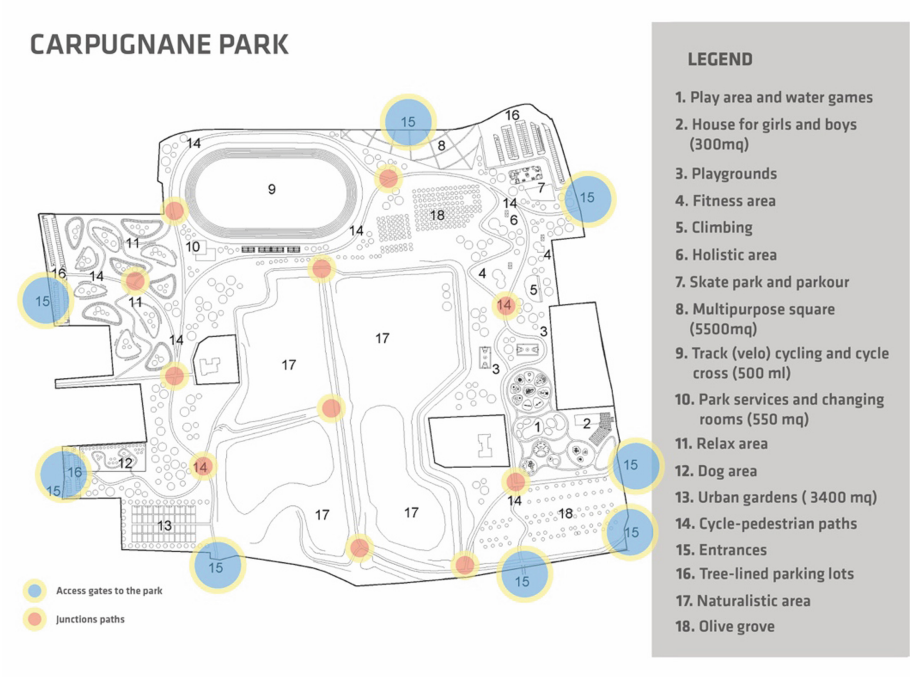

Fig. 4. Functional diagram with preliminary analysis of the access routes/junctions and the primary uses.

for a relaxation area or parkour for skateboarding, a fitness area, but also a track for cycling and cyclo-cross or a naturalistic area and a cycle-pedestrian path (Fig. 5). The main areas planned are the following:

1. **Naturalistic area** that allows for preserving part of the vegetation currently present in this area, making the park an active lung within the city. This natural area provides wildlife observatories and accessible footpaths concerning the regulation on accessibility and compliance with the D.P.R. 503/96.
2. **Play area for children**, characterised by three macro-areas: motor, cognitive/emotional, creative and socialisation activities between normal-born and non-normal children. For the development of the Guidelines for the playground, in addition to a careful analysis of the literature, sector regulations, European and American safety standards relating to playgrounds and equipment [13–15], various international recommendations and guidelines were also analysed [16–18]. The design of this area, as it is inclusive, also takes into account users with various types of disabilities (motor, visual, auditory and related cognitive disorders) and with different needs, not only physical but also sensory and social. In the choice of equipment, the following will be privileged: cognitive and sensorial games [19], which allow favouring collaboration and sociability; water games, to make it enjoyable even in

the hottest seasons; a house for girls and boys, to play indoors; rest areas for family members and carers.

3. **Sports areas** for different age groups favour physical activity and "Active & Healthy Aging" (A.H.A.), or rather the active ageing and independent life of citizens, through lifestyle education healthy and dynamic. Specific equipped areas have been designed for these objectives, taking into account the needs of the various users and choosing types of activities that can satisfy everyone's needs.

   For the young and more sporty, some sports have been included that can be defined as "extreme" (skate track, parkour and a climbing wall) and also more traditional areas (velodrome, an area for cyclocross and athletics).

   In addition, life courses have been provided for adults and older people that favour social aggregation and an area for holistic outdoor activities (yoga, pilates, etc.) for psycho-physical well-being. Also, in this case, an analysis of the sector regulations in terms of safety helped elaborate the Guidelines for the sports area relating to equipment selection.
4. **Multi-purpose area**, foreseen in part facing the residential area and adjacent to the area dedicated to holistic physical activity outdoors and life paths, constitutes a strategic service hub. It is designed as a paved space to be furnished in such a way as to make it flexible and adaptable to the different events that will be organized: local markets, street food facilities, festivals, etc. Furthermore, the proximity to the olive grove, present in this specific intervention area, makes it possible to extend some events to the latter, respecting its natural characterization.
5. **Relax area** (Fig. 6), characterized by light movements of the earth to form greenery hills, furnished with benches, flower boxes and tables for socializing.

   It constitutes the part dedicated to breaks in the open air, where to spend free time for meetings, socialization, and quiet walks. This area has been conceived and

Fig. 5. Graphic representation of the various areas of the new People-Centred Park.

designed for everyone, but mainly it is aimed at a more adult, elderly and less sporty range of users.

6. **Dog area,** fully equipped with furnishing accessories functional to its intended use (drinking fountains, benches for accompanying persons and specific services).
7. Areas intended for seasonal cultivation "**urban gardens**" aimed mainly at adult users and as an educational area for children and young people who want to learn the "secrets of the earth", thus becoming a generational link.

Driving the positioning of the areas above was, above all, the desire to create a connection with the existing urban fabric (supermarkets, gyms, universities, libraries, schools, student housing, bus stops, etc.) to implement significant connections between the park and the rest of the city.

Fig. 6. Relax area.

5 Discussion and Conclusion

Despite the results achieved, a further study linked to deepening of materials, street furniture, lighting, and irrigation systems would be desirable for guaranteeing the quality, safety, and service for citizens and the fauna allocated in the naturalistic area.

Further elements emerged from the data collection concern, for example, the use of smart technologies to create control systems at all levels - from monitoring the quality

of the area to the state of health of the plants and to the safety of users at different times of the day. Also, creating a service APP for visitors, which can send and receive news in real-time, would allow the acquisition of essential data and information to be used for the continuous improvement of the area.

For this reason, further studies and developments to be activated with participatory and co-design processes, which involve diversified and enlarged users, would be desirable to make the park more inclusive, safe and sustainable.

Overall, the research has highlighted the effectiveness of applying methodologies typical of Ergonomics for Design, Human-Centred Design and Inclusive Design in allowing the evaluation and design of urban environments, guaranteeing safety, psychophysical and healthy lifestyles for all, taking into account human diversity and social inclusion factors.

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Nudging Joyful and Active Ageing in Workplace: Framework and Dissemination

Ilaria Oberti[1(✉)], Francesca Plantamura[1], and Isabella T. Steffan[2]

[1] Dip. ABC, Politecnico di Milano, Milan, Italy
ilaria.oberti@polimi.it
[2] Studio Steffan - Design and Research, Milan, Italy

Abstract. With the ageing of population, healthy, safe and pleasant workspaces can be useful to nudge joyful and active ageing, instead of coercive actions to force people not to retire. Embracing this vision, the Indoor Quality & Ergonomics Lab (Dip. ABC - Politecnico di Milano) is engaged in research and dissemination on friendly workplace design, for all ages, with contributions from Ergonomics and Design for All. Design, knowingly or not, has always influenced user behaviour, playing a key role in improving decisions about Health, Safety, and Happiness. Ergonomics makes this process aware and offers method and tools to optimize interactions between people, organizations and environments. With the aim of spreading culture and tools for all ages friendly workplaces to design and management professionals, as well as to the academic world, a framework is constructed as basis for planning of training interventions, and a pilot course is designed, both reported in this paper.

Keywords: Ergonomics · Design for all · Older worker · Wellbeing · Learning

1 Introduction

The design of environments and products influences the health, well-being and behaviour of the occupants. Conscious design of living or working spaces can therefore be the gentle goad to direct towards behaviour that improves both the well-being of people and society as a whole. In the field of working spaces, using this peculiarity of the built environment can contribute to addressing the problems linked to the increasing age of the working population, with the aim of improving the well-being of workers at all ages and encouraging them to live longer, with personal and social benefits.

Embracing this vision, the Indoor Quality & Ergonomics Lab, a unit of ABCLab (ABC Department, Politecnico di Milano) is committed to researching the culture, method and tools for designing age-friendly workspaces.

Issues related to older workers have become emerging due to the increasing ageing of the population, which therefore translates into an ageing working population. Particularly in industrialised countries, there is a substantial increase in the population considered older for work (aged 65 and over) compared to the working age population [1, 2]. This trend will continue in the coming decades and it is estimated that, in the European Union,

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the share of the working-age population in the total population will decrease further, from 65% in 2018 to 55% in 2100, while that of people aged 65 and over will continue to increase, from 20% in 2018 to 31% in 2100 [3].

The social need is therefore to extend working life in order to maintain a balance between the working and non-working population and to avoid the collapse of the retirement system. To this end, policies are being developed in industrialised society to delay the exit from the world of work. Some of these policies take the form of coercive actions, such as legally raising the minimum age at which a worker is entitled to retire. However, if such solutions are pursued without taking into account the well-being of older workers, they result in a worsening of their personal situation and, consequently, also in a deterioration of their work performance with consequences for the whole labour system.

More effective are actions aimed at supporting the free choice to remain at work beyond the minimum retirement age, creating more favourable conditions also for older workers through actions aimed, for example, at facilitating the simultaneous management of work and care or through partial retirement programmes [4]. Within this scope of action, the design of healthy, safe and pleasant workspaces, which also address the needs of older workers, can be a valuable tool to support the free choice to remain active from a working point of view.

The use of conscious and user-oriented design for age-friendly workspaces, instead of coercive actions, is in line with the current nudge concept developed in behavioural economics to steer people towards more sustainable choices in terms of personal and societal well-being [5]. A choice of this kind, if made freely, would not only bring undoubted benefits to society by avoiding the collapse of the retirement system, but would also benefit the elderly themselves, who could thus continue to enjoy an active and independent life.

In the light of the above, this paper reports the proposal to disseminate, in the professional as well as in the academic field, the results of research on age-friendly work environments, through awareness-raising and training actions addressed to professionals in the fields of design and management of workspaces.

2 Materials and Methods

In order to respond to the objective set, the work was carried out in two phases, one aimed at the construction of a scientific reference framework on the topic in question and the other at the design of a pilot training intervention.

The construction of the reference framework was carried out starting from an analysis of the literature on the topic which led to the identification of the disciplinary fields involved and to a mapping of the knowledge on the ageing of the working population and its well-being in relation to the physical space of work.

The identification of the fields involved and the information collected were the basis for the design of a pilot training course, addressed to professionals in the design and management of workspaces. The training event was included in the programme of permanent training courses, held annually, organised by Indoor Quality & Ergonomics Lab on the themes of ergonomic design of workplaces.

3 Results

The results of the construction of the framework for the design of training interventions and the description of the activated pilot course are given below.

3.1 The Framework

Identification of Areas. For an all ageing friendly design approach of workspaces, the main areas identified are technological design and ergonomics. While architectural design contains all the elements needed to create quality environments, technological and ergonomic design focus more attention on the design process as a response to user needs, through the definition of and compliance with specific design requirements.

Ergonomics also shares methodological aspects with the Nudge Theory [5], such as the search for solutions aimed at guiding user behaviour in order to maximise effectiveness, efficiency and overall well-being, and the reference to key concepts such as affordance (which can be translated as the ability of an object/environment to invite, suggest its own way of use), here declined to the theme of all ages. This concept, which originated in psychology at the end of the 1970s, was quickly and widely adopted in ergonomics to improve the interaction between user and product/system through design solutions capable of suggesting effective and efficient behaviour [6–8].

In addition, ergonomics extends the field of action to the organisational system in which the relationship between the user and the environment/product is embedded, proving successful in analysing and optimising the complex system of interactions between the worker, the organisation and the physical working environment. Another area of reference for age-friendly environments is Design for All, a design approach that, by making the most of physical, perceptive, gender and cultural differences, helps to provide compatible responses in terms of autonomy, safety and comfort for all workers, at all ages.

Further areas of reference, in order to better understand the psychophysical characteristics of the worker, at all ages, and his interaction with the work environment at 360° in safety and well-being, are on the one hand physiology and psychology, on the other hand occupational medicine, organisation and safety at work.

Knowledge Mapping. In order to map knowledge about the ageing of the working population and its well-being in relation to the physical workspace, a two-stage process was undertaken. The first focused on the analysis of physiological changes linked to advancing age, the second on the needs arising from these changes in relation to the characteristics of the workspace.

Physiological Changes Associated With Advancing Age. On the one hand, advancing age leads to an increase in some of the worker's capacities, the increase of knowledge and expertise. At the same time, however, it leads to a decline in functional capacities, albeit with subjective differences, both in terms of the initial age and the extent of the decline. The following is a summary of the physiological changes, both physical and psychological, from studies which systematically deal with this subject [9–15].

One of the systems most affected by physiological changes with advancing age is the musculoskeletal system, with a reduction in aspects such as muscular strength and power, bone strength, flexibility, and endurance. These changes can create problems in performing heavy physical work, such as moving and lifting heavy loads, especially in awkward positions. Sense-making abilities are also reduced, such as visual capacity, with a reduction in the ability to see or focus on certain distance (near-vision) or to perceive the peripheral visual field and colours and a higher sensitivity to light and glare.

With regard to hearing, changes can lead to greater difficulty in listening in environments with excessive background noise, but also to balance problems, with an increased risk of slips, trips and falls. Changes also occur at the dermal level, reducing the ability to thermoregulate capacity and lowering tolerance to hot and cold environments.

Psychological changes involve a reduction in certain cognitive abilities. These, together with physical impairment, may lead to increased stress and reduced ability to interact with others. Among the cognitive functions, memory and the ability to learn and concentrate may be reduced, with an impact on completing tasks on time or process and memorise new information.

The perceived lack of ability to perform work tasks and to cope with rapid changes in the work process, for example due to the introduction of new ICT devices or programs, is a high stress factors for ow, compared to younger employees who, on the contrary, are more affected by factors such as too much work. These difficulties, together with other stressors such as poor control over working time, lack of career advancement, risk of unemployment, can also affect interpersonal relationships within the workplace, exacerbating the stressful situation of older workers (OWs).

Older Worker and Workspace Requirements. The physiological changes linked to advancing age are matched by specific needs inherent in the workspace, here perimeterised by tertiary work environments, and in particular offices. The scientific literature, although very wide-ranging on the influence of building characteristics on the well-being and performances of workers, is not so wide-ranging with regard to the specific needs of the OWs in relation to the physical work environment. In particular, the studies are mainly qualitative and report subjective data on whether or not users like one or more aspects of the workspace. In addition, the studies focused on older workers do not always include data on other age groups, which means that it is not possible to know whether the results refer exclusively to the group of older workers or whether they relate to workers as a whole. We report the results of the most significant studies on the subject, subdivided according to the following thematic areas: Indoor Air Quality (IAQ), Comfort, Health & Safety, Ergonomics, Personal Control, Privacy, Recovery.

The aspect of air quality is not among those most felt by the population of older workers, apart from the need for fresh air [16], but more as a relationship with the external environment than as concentration of pollutants harmful to health.

The aspects linked to comfort are very much felt, with particular reference to thermal comfort, with the need for well-heated rooms [16–19], and to visual comfort, with the need to interventions for personal lighting control, a good balance between dark and light exposures, the need for access to sunlight, and to have adequate lighting to supervise [16, 17, 20–22]. Acoustic comfort is also important, with a particular sensitivity to high

noise levels for the elderly [17, 19]. Background noise is one of the most critical aspects [16, 20, 23]. The ability to control noise in the workplace was found to be decisive on workers' perceptions of their productivity, with a reported strong negative effect of noise from telephone calls and informal meetings in open offices [16].

For health issues, shared and open-plan offices are associated to a higher risk of sickness [24], but with no significant interaction with the age of the workers. Instead, With regard to safety, instead, one of the most important issues for OWs is the difficulty in maintaining good posture and balance, with an explicit request for space with low physical effort to avoid dangerous efforts and falls and request of a space that encourages regular exercise spaces [16]. Safety and cleanliness were also important for OWs [17, 18].

In reference to ergonomics, postural well-being is one of the most critical issue for older worker, with a request for ergonomic workstations and seats and a preference for height-adjustable seats and for sit-stand desks [16, 25]. Another critical issue is the physical and cognitive readability of environments and devices the requests, with the request for instructions in larger fonts and for clear layout, signage, and colours to facilitate wayfinding [16].

One of the most important requirements is personal control over the environment and its elements, such as the control of brightness, noise and temperature [16, 20, 23], also by recreating personal environmental niches within shared spaces.

Privacy also turns out to be a determining element for OWs, and it is one of the main requirements for work that requires concentration [16, 19, 26]. The main demands are to have an enclosed working space [17–19, 21] more personal space [22], and larger desks and storage space [20]. A negative answer is expressed towards open spaces and interventions in which the height of the partitions delimiting the cubicles is lowered [20, 27, 28] and about the paperless office and "empty desks" in reference to productivity, and the need for backdrops and walls to hang graphs and tables is stated (20).

The need for recovery, with spaces for relax and recover from work, is also expressed by OWs [20], with the request of more interaction with the outdoors views of the outside, greenery, and fresh air [16], recognised as elements for physical and psychological well-being.

3.2 Dissemination Action: The Pilot Course

The identification of the areas of reference and knowledge related to age-friendly workspaces allowed the planning of the pilot course, the identification of the teachers and the precise design of the interventions carried out according to an iterative process, with the collaboration of the individual teachers of the different lessons in the programme.

The aim of the pilot course is to provide a knowledge base useful for making explicit and using the potentiality of the built environment to improve the well-being of workers of all ages and of the work organisation.

The course was designed for 24 h of training divided into three modules.

The first module focuses on ergonomic design for workplaces, the second module on ageing of the working population and tools to maximise well-being in the workplace at all ages, and the third module on case studies. The precise design of the interventions within each module was carried out according to an iterative process, with the collaboration of the teachers involved.

Specifically, the first module offered wide-ranging notions of occupant wellbeing in the design and management of workspaces and the disciplinary basis for managing the interaction between the multiple components involved. In fact, the course aimed to promote an interdisciplinary approach, albeit within a short training intervention for professionals. To this end, the vision was illustrated and the basic knowledge for a design aimed at satisfying the needs of the users was communicated, which is typical of the technological approach to design, ergonomics and Design for All.

The second module focused on the issue of the ageing of the working population and possible strategies for age-friendly working environments. The teaching contributions dealt with demographic changes and their consequences for the population in terms of safety, prevention and accidents at work, with a focus on the physiology of ageing in relation to work activities. In order to deepen these changes, a multi-pronged approach to active ageing and occupational health promotion was proposed and basic elements for risk assessment in relation to workers' age were provided, with design ideas, and an overview of the professionals involved in the process, starting with the specialist physician.

The third module, finally, aimed at providing the learners with practical as well as scientific knowledge on the subject, was organised with theoretical lectures accompanied by the presentation of case studies and workshops, covering areas such as the management of ageing staff in health care, work and ageing in high-risk sectors, tertiary and industrial spaces. The course ended with an evaluation of the knowledge achieved, an important feedback moment on the effectiveness of the intervention delivered.

4 Conclusion

The Indoor Quality & Ergonomics Lab has launched a research line on the health and well-being of workers of all ages, through user responsive design and management of the workspace that supports the extension of a fulfilling working life, avoiding coercive actions but adopting 'gentle push' strategies.

With the aim of disseminating this topic to the professional world, a continuing education course was launched that included the creation of a general framework for training on the outlined topics and the design and delivery of a pilot course.

The pilot course offered an overview of ergonomics and Design for All applied to work environments, thus expanding the knowledge and skills of designers and managers of workspaces. By bringing professionals closer to the discipline of ergonomics and the Design for All approach, the training intervention can be the starting point for a professional opening in this direction.

The course also offered an in-depth study on the theme of the ageing of the working population which, besides widening the knowledge of designers and professionals not trained in ergonomics, constituted a moment of professional updating and specialisation for the ergonomists themselves, offering them specific competences on a theme of great interest and topicality.

In this wake, Indoor Quality & Ergonomics Lab is continuing with the planning of further interventions aimed at the training of professionals dealing with ergonomics and meeting the training needs identified in recent years.

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Author Index

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