**Part B-1**

## 1. Excellence

* 1. ***Quality and pertinence of the project’s research and innovation objectives***

Social robots have the potential to enhance human well-being, improve the quality of services, and address societal challenges, ultimately contributing to a technologically advanced society. However, real world impact of social robots is **lacking**, as over 75% of research is conducted in controlled laboratory settings, primarily in urban areas of developed countries[[1]](#footnote-2). I have identified an **impactful use-case** leveraging social robotics technology that aims to address a **global** public health issue related to hand hygiene. Annually, half a million children die from gastrointestinal and respiratory diseases, with **8 million** infections, diarrhoea alone causes **272 million** missed school days[[2]](#footnote-3). Hand Washing (HW) with soap can prevent nearly half of these deaths and infections[[3]](#footnote-4). However, educators struggle to promote and monitor consistent hand hygiene compliance among children at scale. Evidence suggests education alone may not instil lasting habits; the environment must engage, be enjoyable, and foster social norms[[4]](#footnote-5). Consequently, an **innovative** and **interdisciplinary** approach is required to influence healthy and consistent HW behaviour. Social robots have demonstrated promise in educational settings, with their physical presence having a **stronger impact**[[5]](#footnote-6); however, their potential in HW interventions is **unexplored**.

**The proposed project, "HandHygieneBots", aims to create a social robot for improving handwashing behaviour for school children, investigating its effectiveness, and explore the commercial opportunity.**

**State-of-the-art in hand hygiene interventions**: Previous hand hygiene interventions mostly focus on educating people about health, germs and disease using tools such as games, radio/TV campaigns, books, songs, posters, leaflets, and charts[[6]](#footnote-7). Such methods can be **resource intensive**, cumbersome to monitor at scale, measurements are **unreliable** due to self-reporting, and these approaches **rarely** result in positive, sustained behaviour change[[7]](#footnote-8). In developed countries, hand hygiene interventions have investigated the use of electronic message boards[[8]](#footnote-9), visual and audio prompts as a reminder to perform hand hygiene[[9]](#footnote-10), emoticon-based feedback, and vision-based system for tracking people’s activity in hospitals[[10]](#footnote-11). Commercially available [SureWash](http://www.surewash.com) system (price £30K), utilizes computer vision for hospital staff hand hygiene training, is bulky and confined to indoor settings. In summary these approaches are expensive, have **limited interaction** capabilities, **fail** to address sustainability and target school children.   
**Novelty:** HandHygieneBots goes beyond the state-of-the-art in three ambitious ways. First, it pioneers the **creation** of a social robot using interdisciplinary methods (Human factors, A.I, Psychology) for technology-based hand hygiene interventions, a **unique** endeavour. Secondly, it aims to **address the scientific gap** in our understanding of how individuals from diverse cultural and socioeconomic backgrounds engage with social robots by involving participants from both developed and developing nations. This marks a substantial advancement beyond the current state-of-the-art, as most studies involving social robots have predominantly focused on single populations, often centred around WEIRD (Western, educated, industrialized, rich, and democratic) participants[[11]](#footnote-12). Thirdly, it pushes the boundaries of social robotics by deploying a social robot in **ecologically valid** settings, examining novelty effects and sustainability.

*A collage of people in different poses

Description automatically generated***Proof-of-concept**: Given the ambition and the risks in this research vision, I have developed a **first-of-its-kind** low cost (£300) social robot *“WallBo”*, a portable robotic platform designed with a hand-like shape eliciting a symbolic meaning relevant to the intervention (handwashing). WallBo has been trialled in a school in India[[12]](#footnote-13) (pre-COVID, reported by [BBC News](https://www.bbc.co.uk/news/av/technology-51360642)) and 2 UK schools13 (see Figure 1). The results showed a **40% improvement** in hand hygiene compliance within a rural Indian school, which was sustained 6 days after WallBo robot was removed12. Furthermore, recent pilot work in 2 Glasgow primary schools yielded further promising results, demonstrating **90% HW compliance** during 1:1 training with WallBo, a **60% increase** in time spent washing hands and **35% improvement** in hand hygiene knowledge and technique[[13]](#footnote-14). However, all the trials conducted thus far have been carried out using Wizard of Oz studies (WoZ), where the researcher remotely controls the robot’s actions. This project will build upon this foundational concept and push the boundaries of hand hygiene interventions by developing **cutting-edge autonomous** social robotics technology.

*Figure 1: (from left) The WallBo robot instructing pupils near handwashing stations in India and Scotland; Handshaped WallBo with motorised eyes (yaw/pitch), graphical animated mouth (on a small screen) and speech; school children in Scotland.*

* 1. ***Soundness of the proposed methodology***

**Overall methodology**: HandHygieneBots will employ an interdisciplinary approach drawing upon methodologies from robotics, A.I, human factors, and behavioural science. The main objectives of this project are: **(O1)** Development of AI-based system for autonomously assessing HW compliance (WP1); **(O2)** Designing the interaction strategy using behavioral science theories (WP2); **(O3)** Enhance the design by integrating perception and synthesis modules into a comprehensive architectural framework (WP3); **(O4)** Assess the influence and perception of the social robot on children's HW habits in two schools, (UK and India). Investigating cross-cultural implications, as well as evaluate the sustainability of HW practices beyond the intervention period (WP4); **(O5)** Explore the commercial opportunity of this research by developing WallBo into a product with the potential to benefit school children across Europe and the globe (WP5). These objectives are both **measurable and achievable**, as evidenced from my experience in developing and deploying autonomous A.I. systems in ecologically valid scenarios (see 2.1) and validated research guidance by my supervisor Prof. Emily Cross (see 1.3). I will utilise findings from the previous research conducted by my supervisor, Prof. Emily Cross from ETHZ, as part of the ERC Starting Grant project ***SOCIAL ROBOT***[[14]](#footnote-15). Cross explored the psychological and neurocognitive mechanisms involved in perceiving and interacting with physically embodied robots, designed to engage people on a social level. Cross's prior research investigated topics such as **(i)** the influence of the initial introduction and social context on a robot's role[[15]](#footnote-16), **(ii)** critical elements of verbal communication that facilitate trust between humans and robots[[16]](#footnote-17); **(iii)** the constraints associated with Wizard of Oz (WoZ) manipulations to seamless transition towards autonomous social robot interactions[[17]](#footnote-18); **(iv)** factors influencing positive human social interaction with social robots. I aim to apply and further develop these aspects in HandHygieneBots, culminating in an innovative and practically applicable health intervention with the potential to significantly benefit children’s lives. Precisely, my eﬀorts will encompass formulating optimal behavioural strategies for introducing physically embodied robots to individuals, ensuring the optimisation and sustainability of social engagement[[18]](#footnote-19). Moreover, I will **pioneer** participatory design methodologies that enable the collection and incorporation of diverse cultural and intricate participant experiences and expectations relevant to their interactions with social robots16. HandHygieneBots will follow a user-centred iterative methodology to achieve the objectives in 5 work packages as follows.

**WP1: Developing the autonomous handwashing assessment system**- The key technical challenge for the autonomous WallBo robot involves the accurate recognition of hand gestures within diverse and unstructured environments. To address this, I will develop a **cost-effective** sensor system, utilizing mmWave radar technology[[19]](#footnote-20). Unlike camera-based methods, mmWave radar excels in low light, high splatter, and detecting multiple children's hands, while also addressing privacy concerns. To mitigate risk associated with recognition accuracy with radar system, I will also investigate use of oﬀ-the-shelf camera less sensors e.g. Ultrasonic[[20]](#footnote-21) and LiDAR. I will collect datasets of hand washing examples gathered with sensors radar/ultrasonic/LiDAR. An algorithm will be developed using deep learning methods, convolutional neural network (CNN) and Long Short-Term Memory networks (LSTM)[[21]](#footnote-22). The goal of the algorithm will be to provide performance scores forhow well the hands are being washed according to the WHO’s HW steps[[22]](#footnote-23). The algorithm will be evaluated for performance, accuracy and benchmarked for the choice of the best performing sensor to be integrated into the system. **Technical robustness (AI):** The system will be designed to operate **accurately** in diverse situations, encompassing various HW methods, lighting environments, and hand gesture variations. The dataset used to train the machine learning model will include hand features. This dataset will **respect privacy**, skin tone agnostic representing diverse demographics, inclusion, and adhere to the principles and compliance standards set forth by the EU’s AI ethics guidelines.

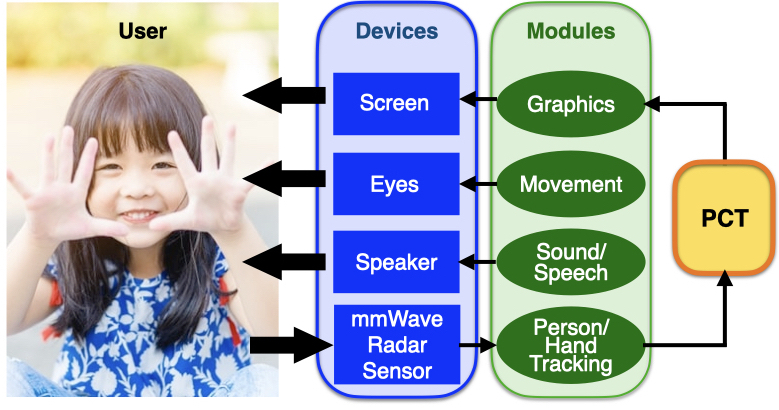
**WP2: Designing the interaction strategy**: The prototype system, already showing promise in short-term interventions12, will undergo further refinement. To **enhance engagement** and sustained HW compliance, I will focus on gamification, an approach proven effective in technology-based education and health contexts[[23]](#footnote-24). This involves incorporating game-like elements to motivate behavior and improve learning. Importantly, gamification has not been explored in HW using social robots before. I will utilize my previous work involving social reinforcement38 to implement both verbal and non-verbal incentives aimed at encouraging the correct HW technique (e.g., the robot expressing social praise by saying for e.g. *“You are doing a great job, keep it up!”* while showing a happy expression). The gamification strategy will incorporate real-time feedback (for **single user only**) and adaptive learning. As individuals interact with the robot, an AI-based HW assessment system (WP1) will evaluate their HW steps, identifying accurately executed steps and steps that may need improvement. Utilizing this information, the AI model can fine-tune the interaction and offer guidance. This dynamic learning approach aims to sustain user motivation and involvement, fostering better HW compliance and enhancing knowledge retention over sessions. The initial system will be pilot tested in an Indian primary school (Study 1, n=50).

Figure 2: System Architecture

**WP3: Refine design and integration**: This WP involves: **(1) Physical design:** The appearance of the robot will be refined following feedback from 2 focus groups (one comprising children, and the other parents and teachers) in Study 1. The robot will be powered using Raspberry Pi, a **cost-eﬀective** computer, and will also feature a screen to display a graphical mouth. **(2)** **Synthesis**: Both verbal and non-verbal strategies such as using speech, sounds, eye movement and engaging animations (expressions) to demonstrate the HW steps. Due to the absence of regional text-to-speech systems, I will utilize human voice recordings by manipulating the pitch to achieve a gender-neutral and child-like voice, as earlier research indicates these voices are most effective in fostering child-robot interactions[[24]](#footnote-25). **(3) Perception**: Non-verbal behaviour cues (body pose, hand movements) will be assessed using the sensor output, and then used by the control system to activate appropriate robot behaviours. I will employ a co-design approach with schoolteachers and students to improve the interaction strategy, ensuring teacher involvement in both design and implementation phases. **(4) Architecture**: The perception and synthesis modules will be combined into an overall system architecture (Figure 2). I will apply my previous work based on Perceptual Control Theory (PCT), which considers measurable and machine-detectable phenomena[[25]](#footnote-26). PCT's advantage is its implementation through feedback loops, processes that have been thoroughly studied and modelled from a mathematical point of view.   
**WP4: Evaluations- Measuring the influence and perception of WallBo:** The aim of these field studies is to investigate the **(1)** influence, perception; **(2)** hand washing knowledge and compliance; and **(3)** sustainability. One field study will be carried out in a rural school in India (n=50, age: 6-10) during the first phase (Year 1) and one school in Zurich during the return phase (Year 2) (n=50, age: 6-10). These field studies will be conducted in schools in Zurich and Teach for India[[26]](#footnote-27). I already have a strong collaboration with them with my previous work. Evaluations will also capture the **cultural** and **socioeconomic factors** that is likely to impact the perception and influence of the social robot (a topic explored as part of the Prof. Cross’s previous work[[27]](#footnote-28)). A 5-week (20 school day) intervention will be carried out in each participating school at a communal handwashing station. Each study will be divided into three phases, **(i)** pre-robot intervention (baseline, no robot, 3 days), **(ii)** WallBo intervention; the robot will be placed at the HW station (15 days), and **(iii)** post-robot after WallBo is removed (2 days). **Methods**: Timestamped system logs of events during the interaction between robot and hand washing events recorded by the sensor (fully anonymized); gather pupils’ and teachers feedback using individual semi-structured audio interviews (thematic analysis)[[28]](#footnote-29), to capture the perception and acceptance of the robot using Technology Acceptance Model (TAM) questionnaire[[29]](#footnote-30). HW knowledge will be measured (pre/post) using improvised version of questionnaire *Bacterfree*29. **Analysis**: **(i)** which verbal/non-verbal robot actions positively co-related to user’s HW compliance; Social signals such as head pose, body movements (frequency, duration), like those studied and characterized as part of the Prof. Cross’s previous work[[30]](#footnote-31), will be further assessed to measure the degree of engagement with the robot. **(ii)** hand washing compliance will be measured pre/during/post intervention from HW assessment system. **(iii)** I will gather HW data three months post-study, comparing infection-related absenteeism before and after the intervention to evaluate its overall impact and sustainability. A taxonomy of behavior change techniques across diverse cultures and socioeconomic backgrounds will be used to synthesize the results[[31]](#footnote-32). Additionally, I will systematically measure the number of HW sessions required to develop HW technique competence.

**WP5: Commercial Exploitation:** The activities in this WP focus on creating commercial opportunities for WallBo as a product for HW interventions. **(1)** Prototype testing and development: Upgrade the Technology Readiness Level (TRL) to TRL5. Test the prototype with schools to build further evidence and gather feedback for further refinements. **(2)** Market Analysis: Conduct a comprehensive market analysis using online surveys, focused groups to understand the demand for solutions targeting improved HW behavior among school children. Assessment of the product-market fit, identify potential customer segments, including educational institutions, NGOs, healthcare facilities, and parents. **(3)** Partnerships and Collaborations: Seek collaborations with educational institutions, technology companies, and healthcare providers to co-develop the product. **(4)** Distribution: Identify distribution channels that reach the target customer segments effectively. Explore partnerships with educational supply companies, and collaborations with government agencies, NGOs responsible for public health in schools. **(5)** Regulatory Compliance: Investigate relevant regulatory compliance, certifications standards, particularly those related to child safety and data privacy.Engage with [Swiss Entrepreneurs Foundation](https://swissef.ch/en/foundation) (SwissEF) that provides a Swiss innovation ecosystem with support for the commercialisation of innovative technologies. **(6)** The intellectual property strategy will be focused on developing trade secrets, patents, design rights, trademarks, and copyrights (see 2.2 Exploitation for details).  
**Integration of methods and disciplines to pursue the objectives:** HandHygieneBots is **highly interdisciplinary**, involving robotics, A.I, human factors, and behavioural science. I will employ a mixed-methods approach, combining qualitative and quantitative methods. This includes surveys, observations, interviews, and HW data analytics to gain a comprehensive understanding of HW behavior. I will incorporate behavioral science theories and models to better comprehend the factors influencing HW behavior33. This includes the use of psychological frameworks to such as the Behavior Change Wheel (BCW)[[32]](#footnote-33), which offers a solid foundation that is both theoretically driven and empirically grounded for developing holistic hand hygiene interventions. **Gender dimension and other diversity aspects:** HandHygieneBots provides a **unique opportunity** to understand and design social robotic HW interventions that are culturally sensitive and inclusive, regardless of user’s gender or socio-economic background. Gender norms can influence how children perceive hygiene behaviours. For instance, in some cultures, boys and girls might be taught diﬀerent attitudes and practices related to cleanliness[[33]](#footnote-34). All studies conducted will rely on gender balanced samples and in accordance with [MSCA-NET Policy Brief on Gender Equity](https://msca-net.eu/wp-content/uploads/2023/04/Task-3.6-Gender_Policy_Brief.pdf). A gender-neutral voice for the social robot will be incorporated to mitigate gender perception biases. **Open science practices**: I will employ the following open science practices. **(1)** Data Sharing: Anonymized HW dataset via [Kaggle](https://www.kaggle.com/) and European Open Science Cloud for global research access. **(2)** Pre-registration: Document research design and objectives in advance, promoting transparency on platforms like OSF. **(3)** Data Reproducibility: I will outline analysis methods, share code scripts for reproducibility. **(4)** Open Access Publications: Publish findings in open-access journals/platforms (PLOSone, Elsevier, Open Research Europe, MDPI etc). **(5)** Open-Source Software: Host software and AI-related code on GitHub for review and collaboration. **(6)** Long-term Accessibility: Create a dedicated website for continued access to project materials and HW toolkit (see 2.2). **Data management**: All data (i.e. HW sensor raw data, audio interviews, questionnaire responses from participants), will follow strict and ethical data management procedures as per [ETH-Open-science-policy and Research Data Management Guidelines](https://ethz.ch/en/research/open-science.html). **Anonymization** will be implemented across all databases, participants will be assigned unique IDs, no personal information. Ethical considerations will be overseen by the ETHZ (Internal Review Board), and data will be stored on **encrypted** hard drives with **restricted** access.

* 1. ***Quality of the supervision, training and of the two-way transfer of knowledge between the researcher and the host***

**Quality of supervision**: This project is perfectly aligned with the ongoing research programme of Prof. Emily Cross (ETHZ) a **world-leading** experts in social robotics for health care, child-robot interaction, embodied communication, human-centred design, and interdisciplinary research (psychology, robotics, and artificial intelligence). I will pursue a career development plan in collaboration with my supervisor to achieve my career goals. This plan will encompass training needs, research objectives, publication planning, and conference engagement. Regular career development meetings (weekly, see Gantt section 3) with my supervisor will enable to monitor progress and necessary adjustments. My supervisor will guide my research, and interactions with their research team and collaborators will offer valuable feedback and guidance.My overarching goal through this fellowship is to enhance my scientific expertise and gain knowledge in science entrepreneurship to drive practical applications for social robots into the real world.During this project there will be a significant three-way transfer of knowledge between me, host, and associated partner for outgoing phase. **Transfer of knowledge from the host institutions to the applicant:** At ETHZ, I will acquire valuable skills working closely with my supervisor Prof. Emily Cross on behavioural research methods and participatory design methodology. Prof. Cross has an established track record of training senior postdoctoral fellows in social robotics and social neuroscience methods, as well as in a range of meta-academic skills required for leading one’s own research group, such as grant writing, professional networking, and how to cultivate interdisciplinary research collaborations. I will benefit from regular contact and dedicated meetings (weekly) with Prof. Cross regarding my own professional development goals, as well as more project-specific knowledge transfer of research methods.**Training on transferable skills**: At ETHZ, I will undertake the following courses **(1)** Machine Learning for Health Care at the Institute for Machine Learning[[34]](#footnote-35), which will allow me to learn state-of-art in this area. **(2)** Certificate of Advanced Studies (CAS) in Development and Cooperation[[35]](#footnote-36) which will help me to acquire conceptual and empirical knowledge with courses e.g., Strategies for Behaviour Change, Impact Evaluation, Qualitative and Participatory Research Methods, Social Entrepreneurship. Additionally, **(3)** The Certificate of Advanced Studies in Entrepreneurial Leadership in Technology Ventures (CAS ELTV)[[36]](#footnote-37) to develop skills e.g., Entrepreneurial mindset, leadership skills to lead and manage a team, communication, decision-making, conflict resolution, and technology commercialisation. I will learn how to bring technological innovations to market, including intellectual property protection, fundraising, and marketing. Courses and workshops 1-8 are one-day sessions. These training activities will play a pivotal role in developing my career and skills.**Transfer of knowledge from the applicant to the host institutions:** At ETHZ, **(1)** I will engage with other researchers and students from department, give a talk on social robotics and the technical challenges of deploying robots in real-world environments *“in-the-wild”*. **(2)** I will run a one-day seminar on interaction design and data analysis, research methodologies for social robotics that will be open to students and researchers at Institute of Robotics and Intelligent Systems (IRIS). **(3)** I will share the insights from HandHygieneBots in two open seminars for students and researchers, thereby enhancing ETHZ's expertise in technology-based interventions. **(4)** Present at the annual ETHZ research and ETH Zurich Information Days.

**Qualifications and experience of the supervisor:** **Prof. Emily Cross** is a cognitive and social neuroscientist, whose innovative application of theory and methods from these disciplines to human—robot interaction research. More recently, her work in the field of social robotics has earned her recognition, including being named on RoboHub's and Insight Analytics' annual lists of **top women in robotics**. Prof. Cross has held a variety of academic and leadership roles at Europe’s leading institutions for exploring the human brain and behaviour, including the Max Planck Institute for Human Cognitive and Brain Sciences (DE), the Donders Institute for Brain, Cognition and Behaviour (NL), and Bangor and Glasgow Universities (UK). Her work has been funded by several national and international bodies, including a prestigious UK Future Research Leader Fellowship and an ERC Starting Grant. Cross has 84 peer reviewed journal articles and conference proceedings, 16 invited book chapters, and an edited volume on social cognition published by Cambridge University Press. Her h-index is 37, citations 6260, m-index is 2.6. To date, she has supervised 10 postdoctoral research fellows (3 current and 7 past- past fellows have gone on to permanent academic appointments at Utrecht, Paris Sorbonne, and Swansea Universities, founded their own start-ups, and received prestigious ERC funding), and 19 PhD students (4 current and 15 past – past PhD students have gone on to work for industry (e.g., Amazon).Cross's research explores how attributing human-like traits to robots impact our learning and perception of robots, in complex social contexts. She develops educational and therapeutic social robots to teach skills and aid individuals with disabilities or mental health issues and brings social cognition and social robotics expertise to the project. The synergy between my background, the scientific expertise of my supervisor, the resources and training provided at ETHZ fosters an environment that is ideal for pioneering and **high-impact** research and my career progression through this fellowship.

***1.4*** ***Quality and appropriateness of the researcher’s professional experience, competences and skills***

I am a **roboticist** with qualifications in computer science (MSc A.I. and robotics), Electronics (BSc), and a PhD in Human-Robot Interaction, my current scientific expertise aligns seamlessly with the goals of the proposed project. My key scientific expertise is to analyse how people interact with robots, build autonomous robotic systems that can interact eﬀectively and influence human behaviour using user-centered design approaches. During my PhD working on EU project [LIREC](http://lirec.eu/project) I developed an autonomous system for a social mobile robot and investigated social verbal feedback strategies to influence user acceptance. This was one of the **rare** long-term social robotics studies carried out in a real-world workplace setting[[37]](#footnote-38). I have worked on multiple European Union projects involving social robots in schools studying the eﬀects of aﬀective feedback on robotic tutors to enhance the learning experience for children in schools[[38]](#footnote-39), and in public spaces ([MuMMER](http://mummer-project.eu/))25, developing and investigating human perception of non-verbal behaviours (parametrised gestures) for a humanoid robot[[39]](#footnote-40). I have published **55** (**23 as first author, 408 Citations, h-index 13, i10-index 16**) peer-reviewed papers and journal articles internationally and reviewed numerous journal articles and conference papers. I am an editorial board member for the open access [Journal of Future Robot Life](https://www.iospress.com/catalog/journals/journal-of-future-robot-life) (JFRL). I was the finance chair for the IEEE Robot and Human Interactive Communication (RO-MAN) conference in 2014 and a special session chair in 2019; student design co-chair at International Conference on Human–robot interaction in 2023. I have supervised 10 M.Sc. student projects. I have always pursued independent research ideas that create a real impact in people’s lives outside lab environments. I have **led teams** and pioneered human-robot interaction research in developing countries[[40]](#footnote-41). The research resulted in 4 publications and global media coverage such as, the BBC[[41]](#footnote-42), [IEEE Spectrum](https://spectrum.ieee.org/robot-teaches-kids-hand-washing-skills-in-rural-india), and 50+ media articles. I chaired the inaugural workshop for [Social Robots For Developing Countries](https://robotics4good.github.io/socialrobots4development/) (RO-MAN 2019) with a aim to **promote inclusiveness** within the social robotics community. I **won** the design competition award at International conference of social robotics in 2021 for the category *Innovation as potential response to COVID19 Pandemic* (proposed idea for this fellowship). I have been successful in securing research grants, £5K from the Wellcome Trust COVID Response Fund and £10K from the ESRC Impact Acceleration Account (IAAs) for HW robot trials in Scottish schools in 2020. This groundwork has laid the foundation for the proposed project. Recently I have delved into the commercialisation of social science research by participating and **winning**[[42]](#footnote-43) University level business competitions[[43]](#footnote-44). I am excited by the potential to exploit research through commercialisation and seek more training through this fellowship. In summary, my strong scientific background, innovative thinking, and training I will receive will form a strong foundation for significantly enhancing my career, enabling high-impact contributions to science as well as to the real-world during and after the fellowship.

## 2. Impact

***2.1 Credibility of the measures to enhance the career perspectives and employability of the researcher and contribution to his/her skills development***

**Expected contribution of proposed skills development to the future career of the researcher:** My long-term ambition is to develop cost effective, high impact social robots as agents for positive behaviour change for societal benefits. This prestigious Marie Curie fellowship will allow me to broaden my knowledge in research methodologies and leadership skills and help to establish myself as a **world-leading** and a **pioneering** expert in social robotics developing innovative solutions for wider impact. **(1)** The interdisciplinary training, I will receive (See 1.3) will allow me to expand my knowledge and skills regarding quantitative and qualitative methodologies for conducting social robotics research in the real-world. **(2)** Social robotics research in developing countries is extremely **rare**, with this fellowship I stand to become a **leading expert** in technology driven interventions using social robots. It will provide me with opportunities for career progression over the coming years, both in academia and in Industry (given significant demand for A.I. expertise). **(3)** By further developing my entrepreneurial mindset through the training at ETHZ’s support, my objective is to translate scientific insights into practical solutions to benefit European and global society more broadly. **Expected impact on the researcher’s career**: **(1)** Research on social robots as persuasive agents within the context of HW research will enhance my competitiveness in the field of technology-driven health interventions. **(2)** I expect that this project will foster collaboration among ETHZ, and other European institutions, thereby creating a foundation for pursuing an ERC starting grant. **(3)** The fellowship will cultivate my scientific expertise to attain professional maturity and be in a good position to compete for tenure-track positions in Europe. **(4)** The outcomes of HandHygieneBots will provide ETHZ with evidence of the effectiveness of interdisciplinary approaches and this will help them to push their research forward. This fellowship will allow me to build a strong international scientific network and bolster my scientific reputation.

***2.2*** ***Suitability and quality of the measures to maximise expected outcomes and impacts, as set out in the dissemination and exploitation plan, including communication activities***

I will work with ETHZ’s Public & Community Engagement Advisor to design an evaluation strategy for all my engagement activities, allowing me to monitor their success and impact. **Dissemination**, **(1)** I will present in events: machine learning meetups and Scientifica/Science Slam Zurich at ETHZ. **(2)** Demo at Science festivals, **(3)** I will write a blog for [Global Handwashing Day](https://globalhandwashing.org/global-handwashing-day/), a global advocacy day dedicated to increasing awareness about handhygiene. **(3)** Utilize EU’s [Innovation Radar platform](https://innovation-radar.ec.europa.eu/) and [Horizon Results Booster](https://www.horizonresultsbooster.eu/) for disseminating results. **(4)** Seek to form partnerships with stakeholders working to improve water, sanitation and hygiene (WASH) services, e.g. UNICEF, WaterAid who are engaged in HW programs worldwide. **(5)** Run a public engagement activity with a primary school to increase awareness of hand hygiene through interactive games with the social robot. I am a STEM ambassador *“Science Connects”*, with links with all the primary and secondary schools in the West of Scotland. **Communication** **(1)** Present at EXPLORATHON European Researchers’ Night provides a perfect opportunity for private and public sector organisations to experience innovative science and engage with public. **(2)** Social media: The results will be communicated through social media channels through ETHZ Twitter account (135K followers), Facebook (325K followers), press releases, local meetings and workshops in local schools in Zurich. A dedicated twitter, Facebook page and a website will also be made for the project. **Exploitation** **(1)** Intellectual property: Potential patentable IP is foreseen in algorithms and AI defining child-robot interaction. Consideration extends to design and trademark protection, including “WallBo” trademark, design copyrights and know-how that underpin the WallBo’s commercial proposition, this will be explored in WP5. **(2)** Stakeholder Engagement: I will create a school HW toolkit featuring interactive elements and activities, posters, videos, and a HW song with WallBo character. Work in collaboration with teachers, pupils, and educators to integrate the toolkit into the school curriculum and make it **publicly accessible**. **(3)** HandHygieneBots has the potential to expand its reach into wider sectors (e.g. nursing, food industry, hospitals) and other use-cases. For instance, it could function as an interactive tool to improve tooth brushing skills for children through its foundational hand tracking technology. WP5 will delve deeper into exploring these broader applications. **Intellectual property:** Before the start of my fellowship, ETHZ will set out terms relating to the ownership and management/commercialization of results and IP that arises as part of the fellowship, as well as defining any Background IP each party will introduce to the project, and any material or equipment transfers between the parties during the project. ETHZ Technology Transfer Office (TTO), the IP & Commercialisation team, will work with me to identify IP arising from the project and, where possible, to protect project IP prior to publication of project results. TTO comprises experienced IP & Innovation managers that can assist with the further translational development of any project IP, that may need further proof-of-concept or validation work prior to IP protection, through accessing various translational grants and Impact Accelerator Accounts that have been awarded to the University and managed internally. The team also supports the subsequent commercialisation of project IP through licensing or spin-out company formation and has strong links with industry partners and investors to facilitate IP exploitation.   
***2.3. The magnitude and importance of the project’s contribution to the expected scientific, societal and economic impacts*** **Scientific Impact:** **(1)** The anticipated scientific outputs from HandHygieneBots are conference publications (CP) and peer-reviewed journals (JP). **CP**: 2Conference publications: **(i)** Human-robot interaction, **(ii)** International Conference on Robotics and Automation (ICRA), **JP**: 1 Journal publication: Journal for Social robotics **(2)** The project is expected to provide new insights into HW behaviour and children's responses to social robots in public health contexts, particularly among diverse socio-economic groups, which represents a **novel contribution** to the scientific community. **(3)** I envisage that the research methods devised from HandHygieneBots (e.g., new questionnaire designs for children, methodologies for collecting quantitative, qualitative data) will be valuable for many other researchers in social robotics. **Societal Impact:** **(1)** Following the intervention in each school, the robot will visit classrooms to showcase its functions, fostering student curiosity in STEM fields. **(2)** Data collected by the robot can provide valuable insights into HW behaviour, which can be used for research on public health interventions. This research can further inform policies and practices aimed at improving hygiene. **(3)** HandHygieneBots has a potential to increase hand hygiene compliance, which in return could reduce germ transmission, save public healthcare costs, decrease infection-related absenteeism in schools and **save lives**. It will also contribute towards meeting UN’s sustainable development goals (SDG 6.2) targets around sanitation, hygiene, education, nutrition, and child survival in developing countries. **Economic/technological Impact**: A case study in the Netherlands reported that only 31% of children comply to hand hygiene guidelines, with the economic burden of gastroenteritis and influenza-like illness attributable to children attending day care centres estimated at **€25 million** and **€72 million** per year, respectively[[44]](#footnote-45). In a developing country like India, the annual net costs from improper HW are estimated at **€20 billion**. Expected net returns to national hand washing programmes in India would be **€4.74 billion**, an estimated **92-fold return on investment**[[45]](#footnote-46). Good hand hygiene can lead to reduced illness rates fewer missed school days, and parental time off-work. Across UK and Europe, more than a third (36%) of parents take unpaid leave from work to look after a sick child at home, costing 1 in 7 parents over **€585/year**[[46]](#footnote-47). HandHygieneBots, if scaled up, could potentially create a wider social and economic **impact globally**.

## 3. Quality and Efficiency of the Implementation

HandHygieneBots is distributed into 5 work packages (WPs), the outcome of some WPs informs the strategy for the next WP. Some WPs can run in parallel to some extent as some activities can be carried out independently. Throughout the fellowship, the time is split into: 70% research, 20% training and transfer of knowledge, and 10% dissemination, communication and institutional responsibilities. The work plan is described in Gantt Chart Figure 3.

A screen shot of a computer

Description automatically generated

Figure 3: Gantt Chart: Horizontal bars show the duration (Months) of each Work package (WP); D = Deliverable; M=Milestone; CD = Career Development; CP=Conference Publication (see 2.3); JP= Journal Publication (see 2.3); R = Risk Management (see 3.2). For Communication (see 2.3); Dissemination (see 2.3); Training and transfer of knowledge activities (see 1.3); X = back-up time for unforeseen delays/pause.

**WP1: Hand-washing assessment system Months (M)1-9:** Ethics approval at ETHZ M1-2 for data collection and Study 1 (pilot), M16-17 for Study 1 (India), and M19-23 for Study 2 (Zurich). Deep learning algorithms applied (VGG16, VGG19, InceptionV3) on HW datasets (1000 examples for each HW step at ETHZ) from sensors. Benchmarking for performance and accuracy for the selection of final sensor. Deliverable D1 in M8. An initial intellectual property (IP) assessment for the hand tracking algorithm will be conducted in M9.

**WP2: Designing the interaction strategy (M1-6, M10-12)**: Gamification and social re-enforcement strategies development. Results from the pilot deployment from Study 1 will be used to refine robot behaviour. This WP will be refined in Year 2 (M13-15) informed by results from Study 1. Deliverable D2-M12. CP1 submission M12.

**WP3: Refine Design and integration (M13-18):** **(1)** Physical design of robot refinement and integration development M13-M15. **(2)** Fabricate 2 copies of the social robot at maker space available at ETHZ. **(3)** Development of the overall architecture which integrates the perception and synthesis modules from WP1 and WP2. Deliverable D3-M19. Conference Paper CP2 submission.

**WP4: Field studies and evaluations (M19-M23):** Study 1 with initial system will be deployed in one school. 5 days intervention in one school in India using the social robot. For Study 2 the refined system on the robot will be deployed over long-term in 2 schools (ETHZ M19-M23). Conference Paper CP2 submission. Results from all studies will be consolidated (meta-analysis), cross-cultural evaluation and guidelines for HW interventions using social robots in JP1 submission. (Data analysis for all studies see 1.2 WP4). Release HW toolkit on project website.

**WP5 Commercial Exploitation: (Months 22-24):** (1) Freedom to Operate (FTO), IP investigations; (2) Market research surveys and focus groups for customer discovery/validation; (3) Identify an appropriate business model and possible funding sources, evaluate fundamental commercial viability. (4) Applications for European Institute of Innovation and Technology (EIT) [Jumpstarter](https://eitjumpstarter.eu/) and [Social Impact Pioneer fellowship](https://eth4d.ethz.ch/research-projects/entrepreneurship.html) pre-accelerator programs tailored to assist in exploring potential commercial applications from research. Deliverable D3-M24.

**Milestones**: **M1**: Career Development Plan drawn up; Hand tracking algorithm completed. **M2**: Integrated system ready for first long-term deployment. **M3**: Study 2 and data analysis completed. Publish code on github and data on EOSC Portal. Meta analysis and commercial viability completed.

***3.1*** ***Quality and effectiveness of the work plan, assessment of risks and appropriateness of the effort assigned to work packages-*** ETHZ has the overall responsibility for the administrative and financial aspects of HandHygieneBots, the grant agreement preparation and partnership agreement phase. Its Research Support Oﬃce has extensive experience in managing EU projects and will give support to manage the grant and to communicate with the Research Executive Agency. This support will be aligned with the principles of the European Charter for Researchers. The EU team at ETHZ will also monitor project implementation, ensuring obligations under the Grant Agreement are met. ETHZ also has an Overseas Team specialist, IP & Commercialisation Team, Research Impact Manager, Public and Community Engagement Advisor, the Employee Development Service provides training to staﬀ, there is Data Management support for researchers and Open Access support. I will also access tailored career development reviews from a qualified coach identifying skills gaps and training to address them. **Financial Management:** I will manage the budget under the guidance of Prof. Emily Cross, in accordance with the terms and conditions of the Grant Agreement and following ETHZ’s financial guidance and regulations. A highly experienced and well-resourced EU Funding team will support Prof. Emily Cross and me with all administrative, financial and legal aspects. The EU Funding team will set up the project budget in line with the SNF unit cost categories. Expenditure will be closely monitored to ensure that only eligible project costs are met from the budget and be successfully delivered. Prior to starting the project, Prof. Cross and me will confirm the objectives and goals of the project including specific tasks, milestones and deadlines (based on the Gantt chart provided). I will meet Prof. Cross at ETHZ weekly. Prof. Cross will help me monitor the progress of my project, support me in the implementation of my career development plan, contribute to my publications and presentations, and help me in broadening my research network. **Risk Management**: Risks associated with HandHygieneBots will routinely be reviewed and updated throughout the project to reflect progress made in implementing the mitigation actions (RM See Gantt). **Risk 1 (medium):** Challenges with accuracy of hand gesture recognition: *Contingency*-Experts from Institute for Machine Learning at ETHZ will guide me with new deep learning techniques. Additionally, my preliminary testing with the mmWave radar sensor has provided encouraging results[[47]](#footnote-48) (~80% accuracy with a small sample, n=20). **Risk 2 (low)**: School closures due to COVID-like pandemic: *Contingency*-Technical progress with perception and synthesis capabilities could still carry on working from residence and rescheduling of school trials. I also have back-up times for unforeseen delays/pauses(See Gantt days marked ‘X’)**. Risk 3 (high)**: Commercial outcome deemed to be not viable after IP investigation and market research: This risk is strongly outweighed by the potential **scientific impact** of the project and direct measurable impact on children’s HW as evidenced with my previous pilot trials12,13.  ***3.2*** ***Quality and capacity of the host institutions and participating organisations, including hosting arrangements*** At ETHZ, I will be joining the Social Brain Sciences laboratory which is based within the Department of Humanities, Social & Political Sciences (D-GESS). I will work in Prof. Cross’s lab with a dedicated office space, have access to high-performance computing resources to train machine learning models at the Institute for Machine Learning (IML), they have three powerful and reliable computing clusters with around 80,000 CPU cores available for scientific calculations. I will also have access to their maker space for building prototypes, IT, and library resources. ETHZ oﬀer a wide range of training courses and platforms to provide researchers with exceptional support to enhance their potential to become world leaders in their field. ETHZ is the best institution for me to accomplish the aims of this fellowship.

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