Design Methodology for the UX of HRI: A Field Study of a Commercial Social Robot at an Airport

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ABSTRACT

Research in robotics and human-robot interaction is becoming more and more mature. Additionally, more affordable social robots are being released commercially. Thus, industry is currently demanding ideas for viable commercial applications to situate social robots in public spaces and enhance customers experience. However, present literature in human-robot interaction does not provide a clear set of guidelines and a methodology to (i) identify commercial applications for robotic platforms able to position the users' needs at the centre of the discussion and (ii) ensure the creation of a positive user experience. With this paper we propose to fill this gap by providing a methodology for the design of robotic applications including these desired features, suitable for integration by researchers, industry, business and government organisations. As we will show in this paper, we successfully employed this methodology for an exploratory field study involving the trial implementation of a commercially available, social humanoid robot at an airport.

CCS CONCEPTS

• **Human-centered computing → Interaction design process and methods**; • **General and reference** → *Design*; • **Computer systems organization** → *Robotics*;

KEYWORDS

User Experience Design; Human Robot Interaction; Social Robots

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1 INTRODUCTION

Airports are truly unique environments. Often overwhelming due to the high volume of screens, signs, announcements, and people within a relatively small space, airports are considered a breeding ground for confusion, stress, and anxiety [32]. In this situation, a social robot may be uniquely positioned to provide assistance in ways that other technologies cannot. They may elicit social and emotional responses [35], and people may anthropomorphize the robot[14].

Bringing into this environment a new technology for use, such as a social robot, has to be managed in a careful manner so as not to create a situation where people feel negatively impacted. The ideal situation is that a social robot positively enhances the in-airport experience for people. Indeed, the importance of creating positive user experiences with social robots has been raised in previous Human Robot Interaction (HRI) research [3, 48]. However, a positive user experience (UX) has to be systematically and purposefully designed [3, 16]. How to actually design the UX of social robots so that they do provide a positive experience is an area that has been identified as being of benefit to the HRI field and is still a challenge waiting to be addressed[25].

In fact, it is not just airports that require this purposeful UX design. Any public space or public environment, such as a hospital, train station or office place, where there may be societal impact from a social robot, would benefit [48]. Furthermore, it has been suggested that positive user experiences are required to enable the increase of robot numbers in society [48].

To encourage an expansion of social robots present in society, potential commercial applications are required that can be taken up by industry. The real world application of social robots is an aspiration in the HRI field [5], and allows research regarding HRI to advance. Therefore exploration of the viable applications of social robots in a specific environment is required.

This paper puts forward a practical methodology for firstly identifying viable, and potentially commercial, applications for a commercial humanoid robot in a specific environment focusing on users' needs and then comprehensively designing the user experience for the application and environment. We put forward that these two current issues in HRI, *(a) the issue of identifying viable applications for social robots* and *(b) the issue of how to create a* *positive user experience* are intrinsically related and should be addressed in conjunction. This is inline with the thinking by Alben, that quality experiences come about "when the design of a product is undertaken and developed as a whole" [2, page 14]. We suggest that addressing these two issues together with an iterative design process enables a greater chance of creating a long term, robotic solution that makes peoples lives better.

The purpose of this paper is not limited to present the results of a specific field study for a particular robotic platform. Instead this paper aims to provide a detailed methodology suitable for the design of *robotic commercial applications* for any style of commercially available *social humanoid robot*. The described methodology (i) identifies commercial robotics applications addressing real users' needs for the considered context; (ii) maintains the focus on designing an optimal user experience; and (iii) easily integrates with the majority of design processes widely used in today's organisations regarding customer experience. It has been noted that there are limited studies detailing user experience design which have been adapted for use in HRI [3, 25] and we seek to address this gap.

Additionally, the proposed methodology allows an iterative design life-cycle with continuous user feedback. We will argue that this is a critical feature for designing effective robotic applications. In fact, we suggest this is a crucial first step for experiments in public spaces, before any evidence-based evaluation is performed.

We begin our paper by providing the background, describing User Experience: what it is, why is it important and how we have interpreted it for HRI. Following, we give a description of Lean UX, which combines Design Thinking, Lean Start-up and Agile Methodology, which inspired our UX for HRI design methodology. We argue the case for a combined robotic application and UX design methodology. Then, we provide a description of our full UX design methodology, putting it in context using our field study at an airport. We include details regarding how we suggest adapting the design process to make it specific for use in HRI, based on the HRI literature and practice in the field. This is followed by a brief discussion of the limitations of the methodology and conclusions for the future.

2 BACKGROUND

2.1 User Experience for HRI

User experience can be defined as "The totality of the effect or effects felt by a user as a result of interaction with, and the usage context of, a system, device, or product, including the influence of usability, usefulness, and emotional impact during interaction and savoring memory after interaction" [16, page 5]. UX is about the users' internal feelings that arise and hence is subjective.

A description of user experience and its role and relevance in HRI is well summarised by Lindblom and Andreasson [25]. Understanding the user and the usage context, and designing the interaction with these in mind, it may be possible to positively influence the UX [25].

The importance of the situated context in UX is referred to by Hassenzahl and Tractinsky [17] and likewise situational context has also been identified as important in HRI research [3, 37, 39]. Furthermore, the social context in which a social robot will function has also been identified as of critical importance [22].

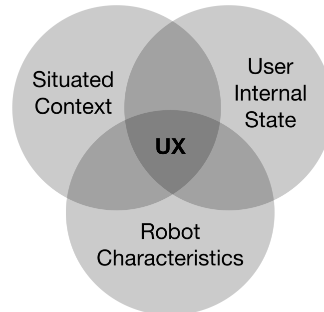

Figure 1: Visualising the focus for UX in an HRI setting, adapted from Hassenzahl and Tractinsky [17] and Alenljung et al. [3]

To summarise understanding of UX for HRI we have adapted and visualised Alenljung et al. [3]'s and Hassenzahl and Tractinsky's [17] descriptions, supported also by the ISO definition of UX [1], and Sabanovic et al.'s[39] HRI description, in the diagram Figure 1.

Positive user experiences are regarded as critical to the widespread adoption and use of social robots [48]. Consideration of the UX is important in HRI, as a negative user experience may prevent users from further interacting and accepting of the robot [9]. Hence designing for a positive user experience is vital.

2.2 User Experience Design

In recent years the shift in UX Design has been towards Lean UX practices, acknowledging the need for streamlining the process. Reducing the amount of documentation produced by the traditional UX process, reliance on one UX designer and the rise of "Start-Up" culture have also been key factors. We look to two practices for designing the UX of HRI. 1) Lean UX and 2) Agile Science[18]. We suggest that Lean UX can be used as a basis to create a UX design methodology for HRI that both assists in creating a viable applications and an enhanced user experience. In addition, our suggested UX design methodology can be used as an important first step for experiment planning, as per Agile Science philosophy.

Lean UX is the combination of Design Thinking, Lean Start-up and Agile methodologies [15]. Lean UX is faster and cheaper then traditional UX design as it does not require the creation of detailed documents or long user studies. Instead, Lean UX's philosophy is rapid building of Minimum Viable Product (MVP) prototypes that are iteratively built, released and tested with representative users. Hypothesis are used to validate the solution. MVP's are the smallest prototype you can create to learn if your hypothesis is valid. Lean UX uses continuous feedback from users to guide the design process. A two stage process, Lean UX has Design thinking as the first phase. Design Thinking is a non-linear design process for solving problems [7, 31, 43] and assists in finding solutions for the pain points of users based on the way they think, feel and behave. The second phase of Lean UX is composed of two practices: Lean Start-up & Agile Methodology. Lean Start-up incorporates defining hypotheses for testing with rapid prototyping and iteration

[1] https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-1:v1:en:sec:2.15

[33]. Agile methodology is a fast iterative method for time boxed software development [1].

What is needed to be stressed here is that the quantified results from the hypothesis testing of Lean Start up *do not necessarily provide statistically significant results*. Instead, they are used to assess the feasibility of the application prototype *from a commercial standpoint based on a set of criteria defined during the design process*. The process may be repeated until a feasible application is confirmed. It is possible to then conduct an experiment in a more classical manner to investigate social and psychological effects of the proposed application and it is during this stage that Agile Science methodology can assist.

Agile Science emphasises rapid, iterative development of a product within a highly specific context. It includes the cycling of two phases, a generation phase and an evaluation phase. The generation phase focuses on the development of operational definitions and constructs which are assessed for feasibility using Lean Start-up methods [18] and concludes with the development of a MVP.

During the evaluation phase, the MVP is presented to relevant populations and/or stakeholders and the previously defined assumptions are assessed. Effect size estimates, causal inferences, and general feedback can then be fed back into the generation phase for the next iteration.

It should be noted that Agile Science methodology does not have an ideation phase, the product concept is already established. It is in this perspective that the first stage of Lean UX can enhance.

2.3 Incorporating HRI research into UX Design

We propose that the Lean UX process may be used as a basis to systematically design a positive user experience for HRI. In addition, incorporating the philosophy of Agile Science into the process' Lean Start-up stage, allows for classical statistically significant experimentation to then be performed as a final step. In our study we have provided the example of a first iteration of the Lean UX process. That is, testing the feasibility of the proposed applications from a commercial standpoint.

Moreover, making our methodology novel and specific for HRI, we incorporate learnings from the field of HRI. We do this by including a *Personality design* and *Interaction design* stages. We additionally base the process for these on the ideas of co-design, which can be thought of as an extension of participatory design [40]. The idea is to attempt to involve all participants in the design process. Value has been found in the participatory design process in other HRI studies [4, 22, 34]. For example, participatory design has been used to identify social structures and contextually meaningful robot applications in studies with older adults suffering depression[22].

The underlying basis for all of the above processes is the need for iterative design based on continuous user feedback. The idea of iterative design is nothing new, Nielsen demonstrated the benefit for iterative interface design in 1993 [27]. Iterative design has also been described and used in HRI studies previously [24, 38, 39]. The Lean Startup field also identifies iterative design based on user feedback as crucial to success [15, 33]. As such, we highlight the iterative design process as critical to our UX for HRI methodology. In fact, we found it to be a critical feature for designing feasible robotic applications.

Our methodology provides creation of feasible robot applications for commercially available social robots that address pain points of users in specific environments. Additionally, by basing the processes on Lean UX we actively design for the user experience. In our methodology the application and UX design are actively intertwined. In the next section we present our example study using a commercial humanoid social robot and detail our proposed methodology for designing the UX for HRI.

3 DESIGN METHODOLOGY

In this section we describe the processes for designing a comprehensive user experience for a social robot application, inspired by the theory and methodology outlined in the previous sections.

What follows is a descriptive "How to" for social robots that we used for designing our proposed robot application and user experience. This is provided in full detail, with examples and a summary guide so it may be easily trialled by others in the HRI field. This methodology may assist in both designing and testing social robot applications that address real needs of users and assists in developing a holistic, comprehensively designed, user experience.

All of the steps were performed by a mixed team of skills and capabilities, collaborating together, at different times. It is suggested the whole team—designers, developers, researchers and all other team members—go on the field research together to ensure all are on the same page. This is in accordance with Lean UX philosophy [15]. Our methodology is presented linearly, as per our field study trial, but it is not required to be that way. What the methodology does allow is a high-level view of the different components that enable a comprehensive user experience to be created and trialled. Different components may be picked out and selected for use, and may also be applied to situations where a robot is already in situ.

It should be noted our HRI-adapted Lean UX design methodology is specifically for commercially available, social robots. In light of this, a pre-step to the methodology is the selection/purchasing of the robotic platform to be used. This may be dependant on availability and affordability, political or environmental considerations. In some cases there may be no choice in the purchase for the researchers or the design team. We urge that a strong consideration be given to the social robot chosen, as the appearance/affordances of the robot, including its possible range of dynamic motion, has significant impact on user interaction expectations and subsequent experience [19].

We used a commercially available social robot for our field study, a PAL REEM humanoid service robot[2]. The robot is wheel-based, 1.7m tall and has a pair of 4-degrees of freedom (DOF) arms and 7-DOF hands, allowing it to gesture in a human-like fashion (Figure 2). The height and the ability to gesture were significant as we required the robot to be able to attract attention in a noisy airport environment. The ability to use non-verbal, human-like gestures may also assist in the intuitiveness of the interaction [6], reducing the amount of cognition required by users to understand the robot, which we considered as important in what may be a stressful situation for some users. In addition, the robot incorporated a touch screen on its chest, allowing the display of images and text that complemented the robots speech and gestures, branding, and

[2]http://pal-robotics.com/wp-content/uploads/2016/03/REEM-Datasheet.pdf

Figure 2: The robot used in our study.

importantly provides the utility for an accessibility option for the hearing impaired.

3.1 Define the Challenge

We firstly started with the situated context and the question: *What is the specific environment the robot will feasibly be interacting in?* This is used to then describe the overarching issue to be addressed. For example, in our study the environment was the airport and the specific areas accessible for the robot were the Check-In counters, Premium Lounge and Gate. Hence we defined our statement as the following *"How might we use social robots to enhance the in-airport customer experience in the Check-In, Lounge or Gate environments?"* Another, hypothetical, example of an environment may be a hospital and the statement may include a specific user group *"How might we use social robots to improve the experience for patients in the surgery prep room, overnight ward or visitors room environments?"*
Outcome: Situated How-Might-We statement.

3.2 Observe

Secondly, we visited the environment with the team and spent time at different hours of the day at the specific locations "needfinding" [30]. This allows team members to experience the environment and empathise with customers, listening to their feedback and observing, and immersing in the status quo. It allows an understanding of the social context and an awareness of the social facilitation effects [49] that may be at play in the environment.

Our visits were timed with departing flights, allowing us to experience the customer journey from check in, lounge, to gate. Team members paired up and took turns, either taking notes or interviewing and observing the people present in those locations. Interview questions asked to the people present included:
"How did you feel when you arrived at the location and why?"
"How does the current experience at the location make you feel and why?"
"What's the worst part of being in the location and why?"
"What's the best part, or a previous good experience, you've had at that location and why?"
"If you could change anything about the experience at that location, what would it be and why?".

Every person present in the location is considered relevant to the experience of being there; however, the interview questions differ slightly. For example, when a staff member was interviewed the questions would change to *"How do you think customers feel when they arrive at that location and why?"*, *"What's a previous good experience you've had helping a customer and why?".* Staff members at the locations were especially relevant as they have the most knowledge from their day-to-day interactions with customers, accumulated over time. Only speaking to the intended, direct users of the robot may miss the insights that can be gained from others who are regularly present in the environment where the robot is intended to be located.
Outcome: 1. Team members with an awareness and experience of the environment and understanding of the social context of the environment; 2. Observations and feedback notes.

3.3 Form Insights

Once back at the lab, each team member read out their notes taken and each item was written on a Post-it note and placed in the relevant quadrant on an Empathy Map[28]. Think aloud synthesising of the information also occurred. The Empathy map contains the 4 quadrants: Say, Think, Do and Feel. Insights into opportunities and pain-points, especially from surprising tensions, were noted. Also the overarching emotion/s at that location. Next, the end-to-end (e2e) customer journey at the specific location was mapped according to Activity, Emotion and Insight, example Figure 3.
Outcome: 1. Empathy Map with Insights into pain points and opportunities; 2. End-to-end customer journey for each location.

3.4 Frame Opportunities

From the insights into pain-points and the e2e journey , specific How-Might-We (HMW) statements were created. For example, in our airport example, we discovered customers feel simultaneously anxious and bored when waiting in the gate area. Hence one HMW statement was *"How might we make time seem to go faster when waiting in the gate environment."*.
Outcome: How-Might-We statements for each location.

3.5 Brainstorm

In the Brainstorm ideas phase we used the How-Might-We statements that we generated from the customer pain-points and insights as platforms for idea generation. Adapting standard design thinking we applied a constraint to the beginning of our HMW statements - "How might we *use a social robot to*". A combination of brain-writing/brainstorming was used, where ideas that will solve/address the HMW statement are silently written down on Post-its by team members, then voiced, built on and blended, without judgement [28, 43]. We generated over 250 ideas as to how a social robot could enhance the check-in, lounge and gate environments. These were then grouped into concept themes, voted on by the team, and the most promising 10 concepts brought to life through storyboards. We filtered the concept ideas via *feasibility, viability, ethical and commercial value*. Importantly, we evaluated possible privacy impacts and risks, as this becomes particularly relevant when designing the UX of robotic applications [36, 42, 44, 45]. We then mapped the ideas on a high/low quadrant of Ease of Implementation vs Impact. Two final concepts were chosen and a full end to end storyboard created. A name for the role played by the robot in the storyboard was chosen. For example, at the gate, the

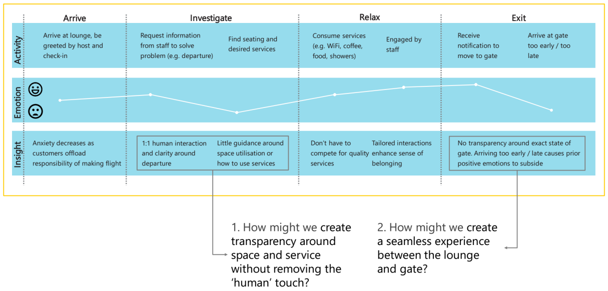

Figure 3: Example Customer Journey in the Lounge

name chosen for the role the robot could perform there was "The Gate Guru".
Outcome: Concept applications with full end-to-end storyboard.

3.6 Experiment

Next hypothesises were articulated for testing the viability of the two final concept applications from the Brainstorm step. The measures and criteria for success of the hypothesises were established. These criteria were based on both the standard practice of our commercial partner and theory from the HRI field, which included factors from the USUS framework [47]. The USUS framework provides guidance for evaluating usability and UX, and assists in determining which methods are appropriate to use for single aspects of HRI.

For example, the main hypothesis for the check-in environment was "Customers will have a more enjoyable check-in experience, with the robot present, then currently". Agreed measurements to test this hypothesis were via direct customer feedback, with customers rating their experience on a 7 point Likert scale, after the check in process was complete, on flight check-ins with and without the robot present. Additional testing included sub-hypotheses such as "Customers will engage with the robot and interact in a social manner". Measures included observation, counts of the number of people approaching and interacting with the robot and counts of people then agreeing to hear a joke from the robot. An example criteria determined for success for this was - ">50% of customers who are engaged by the robot interact and request a joke". For some sub-hypotheses there may be no initial criteria for success as the measure itself is a trial.

Defining the hypotheses meant a list outlining the MVP could be created and used to create a prototype of the concept applications from the Brainstorm, to validate the hypothesis. A suggested HRI adaption can be made to the process here, as the robot may be considered by users to be a social actor [8] and the robot is actually performing a role in the environment much as a social actor. Hence it is suggested that it could also be referred to as the Minimum Viable Role (MVR) that we are creating for the robot. In our airport field study, the MVP list for the robot at the check-in sounds very similar to a role description, and included the following:

(1) The robot welcomes customers as they approach the check-in area
(2) The robot introduces the process to customers and gestures towards the self-service kiosks

A point it is essential to understand here is that the standard experiment process in HRI generally relies on reporting significant effects via p-values [5], which may be suitable for controlled experiment environments. However this is not what is required initially in this commercial setting. The iterative process provides quick turnarounds and rapid feedback to help direct design. Descriptive statistics can provide guides as to what is working and what isn't, and these are used to then re-formulate new hypotheses for the next round of testing.
Outcome: 1. Hypotheses, Sub-Hypotheses, Measures and Test Success Criteria; 2. Minimum Viable Product/Role outline.

3.7 Design Personality and Identity Principles

Once the concept application was established, the iterative development of a prototype application starts. This is carried out in conjunction with continuous user feedback. The process of designing the robot personality and identity principles began with establishing a foundation personality for the robot that is representative and in-line with the airline company branding and values and the role the robot is going to perform. The design entails an iterative process involving paper prototyping, role play, and soliciting user feedback. The location of the development and the one of our study gave us an advantage to gather users' feedback. The innovation lab where the development took place has a steady stream of visitors able to provide instant feedback on role played prototypes and interactions. Similarly, the airport environment is one that has been experienced by a large proportion of the everyday population, thus giving access to much important feedback from representative users.

Personality has been identified in the literature as essential for social robots [23] and hence is considered an element contributing to the success of a robot in public spaces. It has been found users may automatically attribute a personality for the robot themselves [8, 46] and personality attribution may be difficult to avoid and is in fact advisable to expect [26]. Indeed, as we are systematically designing the user experience for the robot, the design of the personality must also be in-line with the intended experience. This is especially important in our field study working with an airline, where brand values are an essential consideration in all parts of customer experience design.

Using the categories Who, What and How, the personality principles for the robot were forged.

Firstly, the MVP outline and the end-to-end storyboard were used to complete the role description for the robot. Under the heading "What", what the robot should do was listed out with the expectations for the robot in the specific role, much like a job description. For example: "Work alongside, in collaboration, not competition, with human staff".

Then, using the role description and the airlines values and branding guidelines, we were able to describe personality features that would be suitable for the role description. For example in our field study, identified were the descriptors: Friendly, Helpful, Jovial, Fallible. This was the "Who" stage.

Thirdly, a description of how the robot should interact, based on its personality and role description, is outlined for the "How". For example in our airport study, the robot was to interact in the following manner. "Give people a reason to smile", "Ensure everyone knows it is imperfect" and "Create a sense that it is different to humans, in an amusing and humble way".

Also decided in this stage is the identity design for the robot. This is similar to corporate identity design - applying logos, colours and other visual elements. Identity has been described as communicating the values of a product, due in part to how it looks and the associations it invokes [20]. In our process it is also based on the idea of surface credibility, that people form "an initial judgement about credibility based on first impressions of surface traits, from a person's looks to his or her dress" [13, page 132], and that people will perceive the robots communications as credible when they can identify it as associated with a credible source (in our case, the airline) [11]. In addition, it aims to provide consistency of appearance with the robots role, as a representative of the airline, and behaviour, inline with that suggested by Walters and colleagues [46]. In our field study this meant the robot wearing a badge that identified it as a 'Trainee' for the airline, and the logo of the airline appearing on the screen at all times.

In addition, the identity design also allowed the creation of consistent marketing material for the release of the robot in the airport. This comprised short video segments, online news articles and media releases. The marketing material assisted in setting customer expectations of the robot. Setting user expectations in this way goes toward preventing an 'expectations gap' [21] and shapes user belief's about the capabilities of the robot [29].

Outcome: 1. Personality Principles - Who, What, How; 2. Identity Design - The visual styling of the robot. 3. Marketing materials to set user expectations

3.8 Design Interaction Behaviour

The Interaction design stage may be thought of as the most complicated. It comprises creating the behaviour flows for the end-to-end journey of the user in the environment. This entails the necessary movements, speech and multimedia that the robot will be employing. In addition it provides the position and mapping schematic of where the robot may travel in the environment. As with the Personality design stage, it involves continuous user feedback, and utilises sketching, paper prototyping, mapping and role play. See Sirkin et al. for good list of references to assist [41].

It should be noted that this stage is not limited to a tightly scripted interaction, though if that is required it will work too. What it does provide are guidelines for the interaction behaviour, that can be used for development. For example, if the robot has specific phrases it should use for fulfilling its role, those are articulated. However, it might be that the speech of the robot will be provided dynamically, from the cloud or environment specific sources, or the conversation with the user, or the physical location of the robot in the environment. Business rules, such as recognising and greeting returning customers, may be included in the speech behaviour.

All of the interactions are based on the situational context, the robot's form and personality and the storyboards that outline the concept that fulfils the HMW statement. The robots form and movement is an important consideration here, as it provides context for the interaction affordances[19]. The interactions may be developed with actual users, informing the design, using methods such as participatory design or co-design. In fact, co-design has been described as an ideal companion to Lean UX, albeit with children as the participants [10].

In our field study a typical outcome of this stage was a behaviour flow at specific locations within the environment of interest. By co-designing with the airline staff, specific locations were easily able to be identified as being of the most appropriate for an interaction. For example, within a gate area, there would be a position where the robot could stand and address the seated customers, waiting to board their plane. In the behaviour flow for this specific location, one of the topics the robot may provide information about was the weather at the destination city. An example is provided in Table 1.

Table 1: Example of a Behaviour at the Gate

Behaviour	Destination Information (*Example only*)
Screen	The four day weather forecast for the destination city. Randomly rotating images of the destination city at different times of day.
Motion	Points to sky to indicate weather, General talking movements when describing location. Moving along predefined path p1 or p2, stopping at predefined points in a random fashion.
Speech	[if raining] Hope you packed an umbrella, it's raining and [18] degrees in [destination] today. Too wet, for robots.

The screen itself also involved a mini iterative, interface design process, for each behaviour. The different screen interfaces that would be displayed during the speech were also interactive and able to be delved into by customers using the touch screen. In this area for our field study we were fortunate as the airline was able to provide web and TV screen interface examples that could be customised for use on the robots touch screen. Considerations to account for included the sizing of graphics that were appropriate for viewing at a distance and up close.

The position and mapping schematic also provided detail as to which areas could be used autonomously by the robot and which areas were deemed too risky. An example from our field study can be seen in Figure 4.

Outcome: 1. Position and Mapping Schematic; 2. Behaviour Flow for each specific location/activity detailing the speech, motions and screen expectations for the behaviour.

3.9 Prototype and Build

Again this stage involved continuous iteration and testing with users. In our field study the building of the prototype behaviours was actually running concurrently with the interaction design stage. The reason this stage is pulled out of the personality and interaction design stages is to highlight the impacts technology can have on a robot application. In addition, some teams maybe smaller in size and only able to progress one stage at a time. The interaction design of the robot is underpinned by technological aspects such as text to speech, speech recognition, robotic localisation and mapping, and computer vision. In some cases, what was thought possible with the technology was too slow or error prone when tested in a

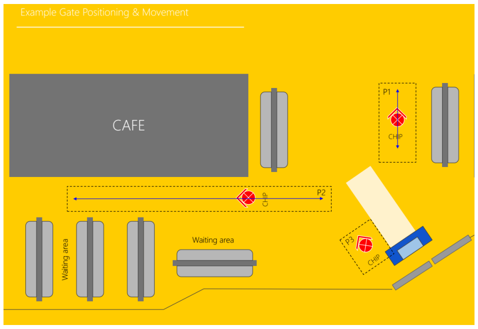

Figure 4: Example positioning and schematic diagram

prototype build. Due to the iterative, continuous testing nature of the process, this would be discovered almost immediately, and the interaction changed appropriately. This prevented taking a robot to the field that would put off users, due to seeming unresponsiveness. It also allows for technologies to change and progress. For example, a different method of scanning the boarding passes by the robot was able to be identified in the lab during testing, this behaviour was then put back into the interaction design process. The high level summary guide presented in Figure 5, highlights the repetitive nature of this stage and the novel, HRI specific design stages. It is suggested that there is no strict rule for the iteration process or heavy documentation, other than the outcomes from the previous steps, in this stage. As all team members have different perspectives yet share a specific agenda to work towards, a fluid style of working together allows for quick prototyping and development.
Outcome: 1. Minimum viable product prototypes for testing with users.

3.10 Measure and Learn

In this phase the robot is deployed with its new capabilities to the environment. The hypotheses are tested using the measures and success criteria defined in the 'Experiment' stage. For our example study, the USUS evaluation framework [47] was employed, where possible, for use.

The robot was trialled for one week in the airport check-in and gate environments for the first iteration of in-field experiments. Four team members were actively observing people's responses to the robot and taking notes along several pre-defined categories, including people's reactions and emotions, instances of touching and interacting with the robot, and entertainment and technical aspects. Additionally, people's comments were noted. Customer feedback questionnaires were conducted in both environments.

To provide a baseline, customer observation, counts and feedback questionnaires were also conducted for the same departing flight times in a different week, without the robot present.

Surprising and unexpected behaviour were noted. For example, counts of voice interactions were surprisingly low, and voice interactions occurred in unexpected ways or at unexpected times. This type of learning provides valuable insight for further iterations and possible applications.
Outcome: 1. Learning's from the experiments. 2. Validated/Invalidated hypotheses.

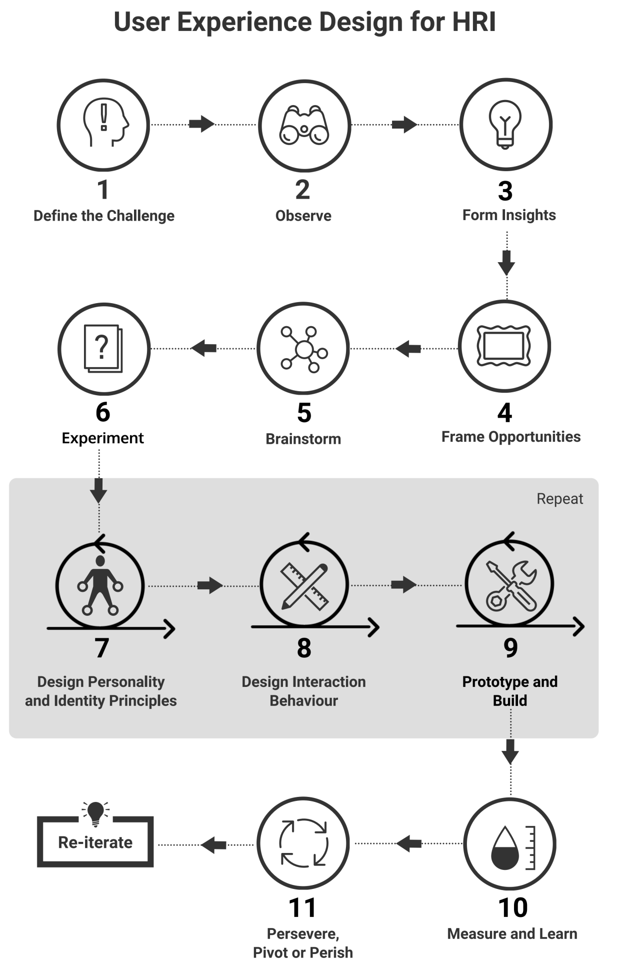

Figure 5: The UX of HRI Methodology. Note HRI specific, novel contributions, Steps 7 and 8

3.11 Persevere, Pivot or Perish

In this final stage the insights and implications from the experiments are reviewed and the next steps decided. This may be iterating again from any stage, generally however from either Steps 4 or 6 upwards. There were unforeseen behavioural changes (a calming effect) as a result of the robot's presence. These require a second, longer experimentation period, and larger data sets to be able to confidently validate. Additionally there are a variety of learnings around navigation, speech recognition, and the computer vision interaction design. The question is whether to tweak the current experiment based on insights and learnings discovered, for validated hypotheses, and hence persevere with the concept application. Or pivot the experiment to other areas, environments and applications, if it was perhaps only partially validated. For example in the check-in environment, it was found of the users who engaged and were aware of the robot, >50% of users interacted with it via touchscreen or voice to request a joke. However actual voice interaction was very low. Therefore greater work is required to make the voice interaction more obvious and seamless, as customers tended to fall back to the touchscreen if voice appeared to not function effectively, and this would be tested in the next iteration.

Otherwise, when experiments were found to be invalidated, the behaviour and or concept application could be considered perished. For example, not one person accepted the robots offer to check their carry-on baggage size. Hence, rather then continue with progressing behaviours or applications in this area, greater benefit can be found in enhancing the behaviours where people did interact and reported an increase in enjoyment of their experience instead.
Outcome: 1. Next Steps - which behaviours and concept applications to progress, what to pivot towards or drop, and which stages of the methodology to return to.

4 DISCUSSION

Our UX of HRI methodology outlines methods and processes for the design and development of commercially viable robotic applications, with an effective designed user experience, for commercially available social robots. It uses an iterative process and draws inspiration from Lean UX, rapid prototyping methods and incorporates and synthesises many findings from HRI research and literature. This results in the development of a MVP, which may be either assessed for commercial viability in the wild, used in evidence based studies within a lab, or taken by a commercial company, depending on how far along the design process has run.

In our study we provided an example of the steps leading up to, and first iteration of, real life testing for a feasible commercial application, with a social robot in an airport. Our MVP applications were situated in the check-in and gate environments of the airport and we had a range of hypotheses regarding how the new experience would address the customer pain-points which were identified in the first steps of the methodology. By collecting a range of data, observations and customer feedback, we were able to validate or invalidate our hypotheses as appropriate, giving us insight as to which aspects of our MVP merited persevering, where we needed to pivot our thinking, and validate where commercial value may exist. By using the UX of HRI methodology we were able to ensure our trial application avoided negative impact on the customer experience at the airport and in fact improved the experience. Customer feedback from the check-in environment found that the experience was made more enjoyable, for some customers, by the robot. As per the methodology, additional iterations and testing would be required to further assess and hone the value of this for commercial application.

The role and personality developed for the robot was considered as integral and at the end of the trial it was even reported by an employee that the robot was a part of the team now, and would be missed. Our example field study required involvement from the Airport and Airline, Management and Operations, CX, PR, Brand and Digital teams. It consisted of over 50 hours of field experimentation, 28 flights, around 3000 airline passengers and collected over 200 pieces of customer feedback. The methodology and the collaboration it engendered, was regarded as highly successful on a number of levels, by all involved, demonstrating the methodology's effectiveness for working with industry.

It is widely accepted that investigation into HRI requires a multidisciplinary approach in order to allow significant advancement in the field [12, 23]. Our proposed methodology encourages the whole team, i.e. designers, developers, researchers, industry partners and all other team members, to work together during all the phases of the methodology, ensuring all are on the same page. Further, all disciplines are involved in the implementation and evaluation of the product within the real-world setting.This promotion and emphasis of the inclusion of varying disciplines throughout each stage of our methodology honours the call for different perspectives and a much needed multidisciplinary approach within the field of HRI.

We suggest that our UX for HRI methodology makes as a priority robotic applications that can be successfully integrated into public spaces by emphasising the importance of a comprehensive consideration of user pain points and feedback during the design stage of a MVP. Our UX for HRI methodology provides a greater focus on considering a viable end product in the wild, that in turn allows further controlled environment research for HRI with a greater chance of external validity.

While the UX of HRI methodology offers many benefits to further developing the field of HRI, it is not without its own limitations. Namely, it is apparent this style of design has only been utilised for standard platform robots that are humanoid. In our field study we had the benefit of working with highly experienced individuals from the industry partnership, streamlining the effectiveness of our methodology. Future studies involving different teams will confirm if the methodology works effectively across multiple domains.

5 CONCLUSIONS

Years of research in HRI is now giving us the potential to employ robots for commercial applications. Although HRI literature provides crucial insights for the design of robotics applications, industry partnerships are demanding more profitable design methodologies that are able to develop viable commercial applications for robots through the integration of UX best practices.

In this paper, we presented our UX of HRI methodology as a way to fill this gap. This methodology was successfully employed for an exploratory field study involving the trial implementation of a social robot at an airport. We showed how, by bringing together 'Lean UX' with HRI research, it was possible to work with industry to design practical, real-world robotics applications and an effective, comprehensive user experience.

Our future research will continue to use the UX of HRI methodology described in this paper. Specifically, we aim to investigate social and psychological phenomena around the designed technologies by proposing appropriate controlled experimentation. This way, we will not only provide additional valuable evidence to identify effects in human-robot interactions, but also develop commercial applications for robots, paying particular attention to the users needs and the user experience.

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