Device-free: An Implicit Personalisation Approach for Public Interactive Displays

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ABSTRACT

Previous research on making public interactive displays more relevant to passers-by has focused on using profiles to personalise the content. However, profiles can potentially compromise privacy and may also create barriers for interaction as implementations usually require users to set up a personal profile, for example, through a smartphone app. In this paper, we explore an implicit personalisation approach for public interactive displays as an alternative to user profiles. We present findings from two evaluation studies of public interactive displays that implicitly adapt the display, based on a user's goals and characteristics. From these studies, we build on our definition of implicit personalisation and derive insights into how the user interface and content on public interactive displays should adapt in order to be perceived relevant by their users.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Information systems** → *Personalization*;

KEYWORDS

Adaptive interfaces, Public interactive displays, Implicit personalisation, Privacy, Device-free.

1 INTRODUCTION

Public interactive displays (PIDs) are often found in shopping centres, airports, and busy locations in cities. This technology is typically used to find specific information about a space, such as wayfinding at a shopping centre. Other uses include allowing communities to have their say on local issues [4, 20, 35], and to post or view user-generated content consisting of news, current events, and sales [2]. However, situated content, while relevant to a community, may not necessarily be relevant to individuals.

Ultimately, PIDs have the potential to go beyond simple information terminals and become truly smart technologies that augment the space with useful and relevant content for individual passers-by, similarly to the way public technologies have been depicted in science fiction films, such as *Minority Report* [1] and *Ghost in the Shell* [2]. To achieve this level of personalisation, the technology needs to have some knowledge of the passer-by and the location in which it is situated to make useful inferences.

Such knowledge can be achieved with user profiles that contain information about the user's preferences. This approach is commonly found in web applications, such as Google and Facebook, which create a model of the user and their preferences based on personal information such as the user's usage history to return relevant search results and display advertisements that may be of interest to the user [18, 19]. However, users typically access the web on personal devices where they are able to privately login through authentication screens to gain access to their profile. In a public context this is challenging [10, 24], as signing in with a username and password may not be very secure or convenient.

Therefore, this requires a way for the PID to either read the profile or identify the user. Personal devices, such as smartphones, have been suggested as a way to be the mediator for this process in a public context to generate *digital footprints* [7]. The information could then be transferred through RFID [29], WiFi [21, 26] and Bluetooth technologies [9].

However, we observe two main challenges that come with this approach. Firstly, getting people to provide information to create profiles requires an investment of time that may not be attractive to certain groups of users, such as time-poor citizens [16, 33]. Secondly, displaying personalised content can pose privacy issues as it can link content displayed on-screen with the user [26]. The third challenge is public sentiment towards being tracked by these technologies. Gaining consent is important to avoid potential legal issues [6, 32] and vandalism [23].

Due to these challenges, personalisation in public spaces needs to be approached differently. Therefore, our research explores an alternative approach for making PIDs relevant to individuals that does not rely on external devices for information and instead makes inferences based on explicit interactions, thus making implicit judgements on the goals of the user based on their interactions. Our research investigates how PIDs can become more meaningful and ambient in the place they are situated, transcending from being simple information terminals.

To achieve this, we posed the following question:

(1) How can personalisation be designed for PIDs to minimise the impact on privacy, while maximising usage?

[1] Minority Report - http://www.imdb.com/title/tt0181689/
[2] Ghost in the Shell - http://www.imdb.com/title/tt1219827/

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To answer this question, we defined a framework for personalising PIDs that does not rely on external devices. We tested this framework in the context of two studies and discussed the results and how this framework can be improved.

2 RELATED WORK

Content relevance is an on-going problem being tackled in public display research, as researchers try and find the right balance of how much the display knows about users and their privacy. This section reviews previous research on user profiles, proxemics and context-awareness as a means of making content on public displays more relevant.

2.1 Device-based Personalisation

Personalisation using a personal device, such as a smartphone, has been demonstrated as an alternative to signing in directly on the PID which can help retain privacy [3], while being able to provide rich data relating to the user.

Logistically, the data from personal devices can be transferred through Bluetooth [10, 34]. Personalisation can be achieved either by transferring data or using the device's Bluetooth name to specify queries or preferences. Such a method however may not be widely adopted as people's devices may already be connected to something, such as wearables, which are becoming popular [31].

WiFi is an alternative approach that allows personal devices to transfer data to others over a longer range. Previous work has investigated the use of personalisation over WiFi through custom apps that store the user's preferences [10, 21, 26], which are collected when the app is first started and can be added to later. Once set up, this allows the personal devices to automatically send data to the PIDs, which then enables them to ambiently display relevant content, such as the weather forecast from a user's hometown [21].

The device-based approach does have drawbacks however, as previous work found that a device-based approach may not be relevant, as it does not take into account the context of the situation a particular individual may be in [26], such as being called in to work. In addition, it requires that the passers-by are connected to the same WiFi network as the PID, meaning that it may only work well in certain contexts such as at universities where everyone is already connected to the WiFi. This approach also has a risk of excluding certain user groups such as tourists.

2.2 Proxemics

An alternative method for making content relevant, without the need for user profiles, is to use sensors that can detect people and assess their behaviour within close proximity of the display. Early work [29] explored the use of long and short-range RFID sensors to make an LED display change patterns based on a user's proximity. Wang et al. [37] presented a prototype that could detect passers-by with a depth-camera and would beckon them to come and interact. Once the screen was being interacted with it would then suggest items of interest according to the on-screen items selected, similar to the way Amazon and other online retailers recommend items based on customer interactions. This type of interaction can be accessed by a broader range of people as it lowers the barrier to entry compared to user profiles. Emerging face recognition also has the potential to offer off-the-shelf mechanisms for recognising repeat visitors.

2.3 Context-aware Computing and Public Displays

Dey [11] defines context-aware computing as a system that can adapt its information and services depending on the user's task. Context-aware public displays work differently from other applications, such as smartphones, as the context changes around the public display [36], whereas smartphones move from context to context [28].

To address this, Cardoso and José [7] created a framework that used different interaction mechanisms and *digital footprints* to adapt to a user. However, like the examples in section 2.1, it is device-based. Lemme et al. [22] demonstrated a simpler concept of a context-aware public display used for transport, which changed colours based on the time of day. Its interface would become brighter during the day and darker at night, and also highlighted different transit routes based on what was explicitly selected.

3 DEFINING DEVICE-FREE IMPLICIT PERSONALISATION FOR PIDS

We propose a framework for device-free implicit personalisation for PIDs that addresses two goals: (1) to reduce the impact on the user's *privacy* when personalising a PID; and (2) providing some levels of *personalisation* at PIDs without any reliance on additional devices, such as smartphones, for identification.

The framework consists of four closely related factors (Table 1) that make-up a PID: System, Environment, Person, and Time. *System* refers to the properties of the PID, such as the input methods, the representation of the stand, what is displayed on the screen, and the location of the PID in the space. *Environment* is related to the space itself, specifically what it is used for and who uses it. *Person* refers to the goals and characteristics of the individual who is interacting with the PID. *Time* is a factor that affects the environment, such as the people moving through the space and the content that is shown on the PID.

To explore our concept of implicit personalisation, we present two evaluation studies that primarily demonstrate the two aspects of the aforementioned person factor: goals and characteristics. We focus on these aspects from the person factor as they are the only aspects that differ from person to person.

3.1 Goals-based Personalisation

We implemented a fully functional prototype PID system that is personalised following our definition of implicit PIDs that adapt according to the goals of the person using them. The approach was inspired by the way Google Search responds to a search request with two responses: the result of the search plus sponsored links that are intended to be relevant. Although Google makes use of a user model, based on an individual's search behaviour and other information available to Google, we take inspiration from this work, to establish a similar idea that returns results based on contextual factors: time, location, and the explicitly chosen search query.

Factor	Property	Description
System	Interaction methods	How the PID accepts input: Example: Kinect gestures, touchscreen, smartphone-based.
	Stand	The PID is either free-standing or fixed into a wall.
	Display	Refers to the interface and content shown on the PID.
	Location	The location in the space where the PID is situated.
Environment	Purpose	What is the space used for. Example: shopping, school, events.
	Users	Who uses the space. Example: students, workers, general public.
Person	Goals	What the person is trying to achieve by using the PID.
	Characteristics	The physical traits of the person interacting. Example: height, age, gender.
Time	Day/Month/Year/Hour/Minute	This factor can affect the environment around the PID and the content it shows.

Table 1: The device-free implicit personalisation framework describing four factors that contribute to this type of personalisation.

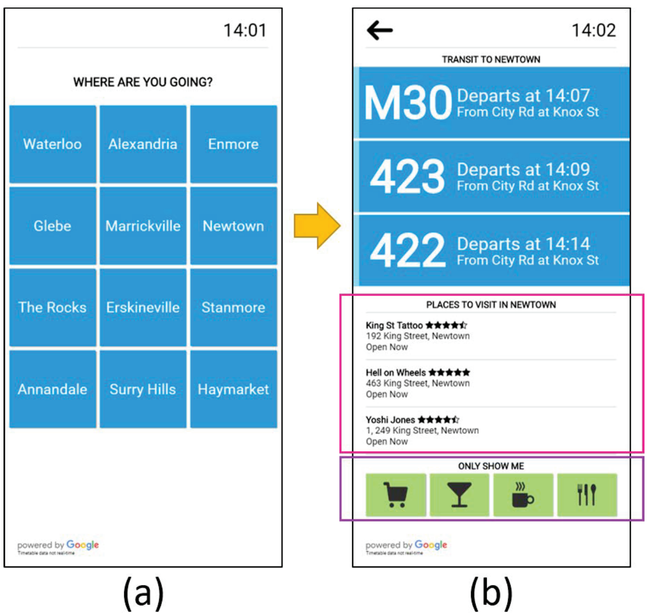

Figure 1: Upon selecting the suburb Newtown in the left screen the user is presented with a live transit timetable and recommended places to visit in Newtown.

3.1.1 Design. Our prototype system's interface consisted of two parts, suburb selection (Figure 1a) and results (Figure 1b). The suburb selection screen allowed users to quickly search without text input, alternatively offering 12 nearby suburbs to make the PID more relevant to the local area. After a suburb was selected, the results screen displayed the next three buses heading to the chosen suburb, leaving from nearby bus stops. This information is displayed in the top half of the screen, under the heading "*TRANSIT TO <SUBURB CHOSEN>*". The individual timetable results are contained in ribbons, with the following information: bus id, departure time, and the closest departing stop. Users could select the ribbons to view where the nearby departing bus stop is on a map. Essentially, the design used the selected destination and the current time to personalise the information displayed. As the individual had only to provide the broad destination, so that they would not feel their privacy was any more threatened than if they had been standing at the relevant bus stop and were seen waiting for or catching their bus.

The lower half of the results screen displayed the adaptive '*places to visit*' feature. It displayed the top three recommended places based on three factors: (1) what is open at the time; (2) Google's user rating, where preference is given to the higher ratings; and (3) places from the selected suburb. Users can then filter the places specifically by selecting one of the four different category buttons under the results: general stores, bars, cafés, and restaurants. The places are presented as three rows and include name, opening hours, address, and a 5-star scale rating of the particular place.

After users have finished using the display they can walk away. After being idle for one minute, it automatically returned to the main suburb selection screen. Alternatively, in the top left corner of the results screen, users can press the back button to go back to the previous screen.

In addition, we also logged all interactions on each elements on the screen, including each time a suburb button was selected and follow-up actions tied to it, such as filters selected and maps opened.

3.1.2 Study. We deployed the prototype PID indoors at the main entrance of the School of Architecture building (Figure 2). This location is in close proximity to a bus stop (approximately 100 metres away).

Ideally, the prototype would be deployed at an actual bus stop. This would have the advantage of being in the place that people need to wait for a bus anyway, and so have time to interact with a PID that can deliver information relevant to their bus route and bus departure time, as well as the place they are travelling. However, we opted for an indoor deployment for two reasons: (1) as the touch interaction is enabled by an infrared touch panel it would be prone to interference from sunlight; (2) strict council and traffic authority regulations and the prototype nature of the PID made it impossible to gain approval for such a deployment.

This location had several advantages for this work. It is a major thoroughfare for staff and students, as there is a cafeteria, main entrance, and lecture theatre nearby the PID. This means many people pass it. It is also a place many people do wait in, for example, between classes, to meet friends to eat at the cafeteria or to travel away from campus. We aimed to provide information that such people might find interesting.

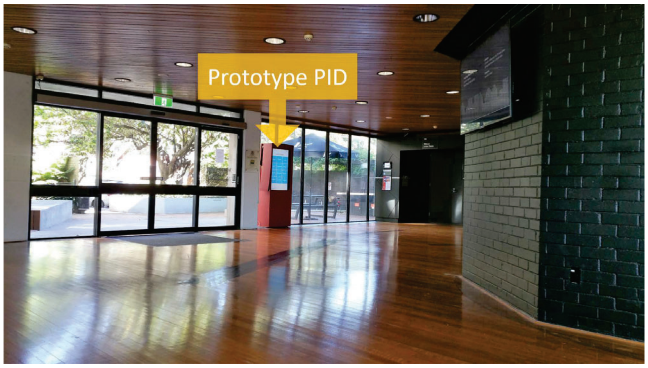

Figure 2: Touchscreen prototype setup next to the main entry/exit of the building.

The prototype was deployed for ten days, from Tuesday through to the following Thursday. The researcher was present every day to observe user interactions for one hour in the morning and one hour in the afternoon - excluding Saturday and Sunday. The screen was placed next to the main entry for the Sydney School of Architecture, Design and Planning building at the University of Sydney. We kept the screen running 24 hours per day as well as over the weekend to find out what times people interacted.

Outside of the observation times, the researcher interviewed people after they finished using the PID. The interviews focused on the usefulness of the personalisation, privacy, and design aspects related to the PID.

3.1.3 Results and Discussion. We interviewed 12 people (4 female), all staff and students at the university. The system also logged the number of sessions and interactions with the implicit *'places to visit'* feature.

Figure 3 shows that the number of sessions did gradually drop over the week the PID was deployed despite the spikes occurring Friday and Tuesday. On average, there were 25 sessions daily with 7 (28%) of those sessions involving interaction with the implicit *'places to visit'* feature.

Participant feedback indicated that, despite being in *close* to the bus stops, the participants did not value the bus information. Their comments suggest that if they had been waiting at a bus stop, the convenience of exploring multiple bus departure times might have been useful. However, in the current location, participants felt they would prefer to use smartphone apps. With widespread adoption of them [13] and their deeply personal nature, the precise location of PIDs may be critical for their usefulness. Furthermore, our participants were regular travellers and some felt they might have already determined their route and what they will do at the destination at the time of the interaction: "*I might already have somewhere I am going - why do I need to use the display*". Participants suggested that the recommendation of future events would be more useful, as it may be hard to change plans at the time of the interaction.

However, there are situations where smartphones are less convenient than PIDs. Smartphone apps are great for planning, but not for time critical decisions [8, 30]. The small screen of smartphones means that when a user needs more information than gracefully fits on one screen, there may be considerable navigation, potentially to and fro. In that case, PIDs offer an opportunity to complement smartphone usage. To best achieve this, they should adapt their content in a way that capitalises on the shortcomings of smartphones, such as making the information easy to read and relevant to the context, such as giving preference to trains leaving soon or displaying dining options at lunchtime based on the businesses in the local area.

Participants did give examples of cases where they thought that such a feature would be useful, such as visiting a new place and viewing information about things to see and do. Reflecting on this feedback, we under-estimated the impact of the distance from our display to the relevant bus stops. We also over-estimated the potential to make use of time when people were waiting in the foyer and contemplating catching a bus. Participants did appreciate the simplicity of the interaction and they felt that it enabled them to access the information quickly. Although feedback on the interface was positive, responses on the relevance of the content was mixed with five (of the 10) participants stating that the transit information was relevant to them, as they used public transport regularly. In addition, one participant commented that the recommended places helped them discover a new bar in their suburb *"there was one bar that I didn't know was listed in my area so I thought that was interesting. So that was good, it was relevant"*. However, another participant suggested that the *'places to visit'* feature could be improved by displaying the place on a map when it is selected, rather than only displaying the address.

The ability to read reviews about the recommended *'places to visit'* was another requested feature, which is commonly found on social media and search engines. One participant suggested that reading recent reviews helps with decision making: *"I was expecting somewhere to read the reviews. A quick overview. The things that I normally look for in say Google Maps, is just quickly what people have said, but also the date of the last reviews"*. Therefore, it appears that the content displayed in the *'places to visit'* feature may have been too similar to features that people use on websites and mobile devices, making our participants expect the same functionality and content provided by Google Reviews.

When asked if they had any concerns about privacy, none of the participants indicated that they had concerns. Nor were they aware of others around them, despite previous work suggesting that this is a potential detractor [5, 27]. When asked about this, one participant stated that there is not really any private information displayed but "*there is a chance for someone to know where you are going, which may be dangerous late at night*". We also asked participants about personal information they would be willing to share and view on the display. Every participant was against any personal information being shared that could be linked back to them, such as their full name, email, phone number, and specific address: "*I don't like the idea that it has anything that relates to me. I like that it is absolutely anonymous*", "*I'm more worried about my name than other data, because my name is like a handle, you can search me*

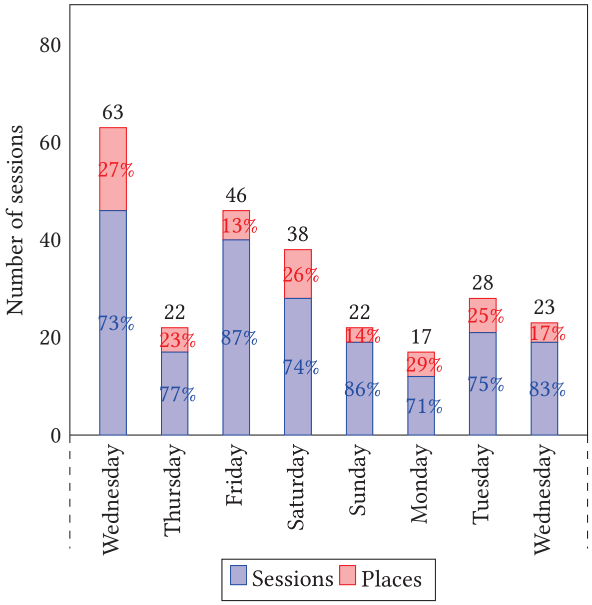

Figure 3: Total sessions (blue) and sessions that involved interactions with the *'places to visit'* feature (red).

on Google and find out who I am". In addition, participants were clear about being wary of providing personal information, with one participant stating, "*I am not sure about giving too much of my personal information because it is a public display and I am not really sure who made it and where all my information is going. So I am not sure if it is clean and clear after I leave*". This could potentially be resolved by making the display look more official with well-known branding or some form of trust certification, similar to certificate authorities that are used to certify genuine websites.

3.2 Characteristics-based Personalisation

To test our characteristics-based definition of personalisation, we implemented and evaluated a system that is height-aware and therefore personalised based on the height characteristics of a user [25]. This method works by not directly prompting the user for their personal information but implicitly gains this information through their usage.

3.2.1 Design. We designed a semi-functional public display prototype around the playful concept of taking self-portraits [14, 15]. This functionality can be found in public display applications and kiosks in cities and at airports around the world. The concept was chosen as it represents a realistic scenario and for its simplicity – as the focus of the evaluation was not on the interactions but on the height adjustment mechanisms. The prototype consisted of four components, which were housed in a custom-made stand: (1) a 50-inch touchscreen in portrait orientation; (2) an Apple Mac Mini – running Microsoft Windows 7 and the public display interface; (3) a webcam for taking selfies; and (4) a dummy Kinect for imagining automatic height detection and assisted reaching, which was mounted on top of the display. The selfie application was coded as a webpage and consisted of an on-screen selfie box (Figure 4) that would either move to where users touched on-screen or automatically move to a reachable position according to the user's height.

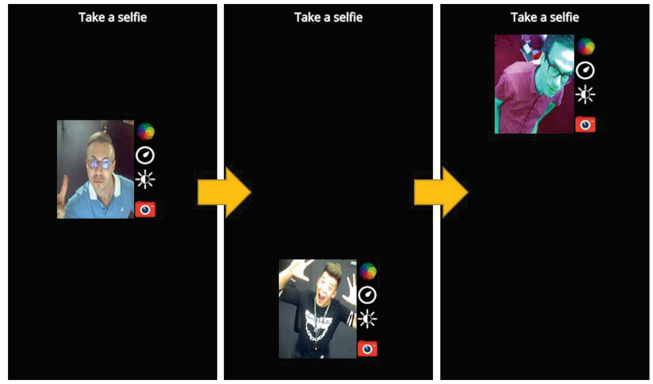

Figure 4: The on-screen selfie box moves corresponding to the touch location or the user's height.

The prototype responded to a user's height through three types of interactions: (1) Touch (Figure 5a); (2) Proximity and Height Sensing (Figure 5b); and (3) Reaching (Figure 5c). These were chosen as touch input and depth cameras are commonly used for interaction with public displays.

3.2.2 Study. We recruited 10 design experts (4 female) between 24 and 50 years of age as participants in a think-aloud study. Eight participants were lecturers and tutors in design from The University of Sydney, while the other two were from industry (one web designer and one user experience designer). Participants individually interacted with our prototype following the set task of taking a selfie with each interaction method, while both standing and sitting in an office chair, to simulate scenarios where someone could not reach, such as those that are wheelchair bound. The interaction method was counterbalanced across participants.

Each interaction method was first completed standing, followed by sitting in the chair. Participants were asked to think-aloud while they were performing the task and all sessions were audio-recorded. After completing all the interaction methods, we interviewed each of the participants, asking them about their experience and to evaluate the four modes.

3.2.3 Results and Discussion. Overall, the on-screen adjustments were appreciated with one participant mentioning that physical adjustments could cause potential social issues by drawing attention to a user's physical limitations, therefore embarrassing the user and potentially making them feel like they are *"bothering others"*. The participant further suggested that on-screen adjustments are better as it *"gives a welcoming feeling that works the same for everyone else"*.

While seated in the chair, all participants were observed as having trouble reaching the screen. One participant specifically mentioned that it was hard to reach the screen at times, stating *"imagine if I have paralysis and I need to bend over to reach this"*. Another participant managed to find an easier way around reaching by using

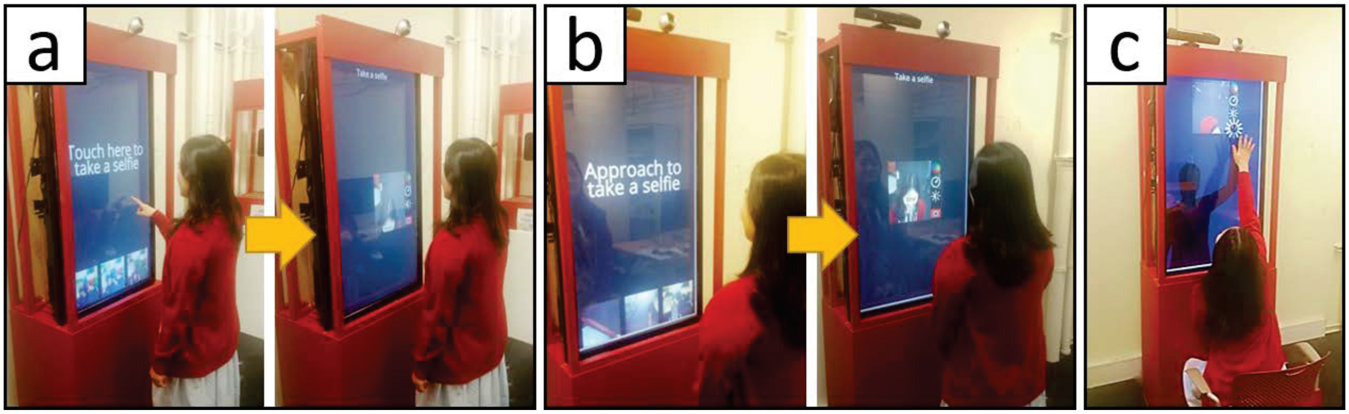

Figure 5: (a) Touch mode: height is implicitly detected based on the touch position; (b) Proximity and Height Sensing modes: height detection is implicitly determined through on-body (e.g. RFID) or on-display (e.g. Microsoft Kinect) sensors; (c) Reaching mode: A digital mirror representation provides assistance to users that are reaching and activating on-screen elements.

the display from the side while sitting in the chair so they could get closer.

Participants were observed to not immediately understand that the on-screen selfie box moves with the touch position, with one participant mentioning that there needs to be *"tap suggestions around the screen"* to help people realise the functionality. However, another participant mentioned that tapping may not be intuitive to most and that a more accessible interaction would be to *"have some type of magnetic effect to gravitate elements towards the touch point"*.

It was suggested that reaching should involve more cues indicating that it is an option, such as an on-screen Kinect skeleton, echoing findings from previous research [17]. An alternative suggestion was for the silhouette to grow from the user's arm on-screen, rather than a whole-body silhouette. This would provide a better indication about how to perform this interaction. One of the participants tried to reach from afar when they saw the Kinect, stating that they were *"familiar with the Kinect and therefore expected that functionality"*. This may be resolved with more specific on-screen and physical clues, such as a sign on the ground indicating the location of where to stand.

Apart from the concerns with where selfies are going and how long they stay on-screen, which are not being investigated in this study, there were no privacy concerns related to an individual's height. However, participants pointed out potential privacy concerns around using an NFC card in the proximity mode, which would store specific information about someone's disability. One participant mentioned that if the card had a purpose other than *"exclusively being utilised for a public screen"*, such as height information stored on a driver's license or conference badge, then it may be fine. However, this interaction would be limited to only those with cards and therefore having an automated depth-camera or touch based height detection system would lower the barrier for interaction.

4 DISCUSSION

The two studies are discussed in relation to displays gaining an understanding of the user through the device-free implicit framework we defined in section 3. From an analysis of the findings from these two studies, we revisit the question posed in the introduction: *How can personalisation be designed for PIDs to minimise the impact on privacy while maximising usage?*.

Complementing smartphones. While these were small studies, the first study appears to have been less successful than we had hoped. All participants judged the interface was easy to use. Even so, for this group of participants, the PID was less useful than we had hoped. This was partly because many of the participants knew the location of the bus stops that were relevant for them. In addition, this was not the place that they wanted to explore information about the places to visit. In this location, these participants felt their smartphone provided similar functionality. Therefore, PIDs should provide content that is unavailable or inconvenient to view on smartphones. This would make PIDs useful in very precisely situated places that are a good match to the information needs of the people who are in that location and to match the time they have.

A PID like ours might well be valuable at a bus stop while people need to wait anyway and have time time to explore an information space. Similarly, it needs careful definition of information needs in a particular building or shopping centre.

Conveying personalisation. With the current state of technology, people may not be aware that PIDs can be personalised, as in our second study. Therefore, it is important to convey this ability to passers-by. This could potentially be achieved through on-screen prompts, demonstrating how the PID works, or physical signs on and around the PID, explaining that it is personalised. If the user does not expect personalisation, they may not notice these and adding playful elements, such as skeletons, may mean that people will be distracted and play [1].

Keeping it private. One major issue with both of these studies is that there is potential for shoulder surfing [12]. When personalising a PID based on their goals or characteristics the information displayed on-screen may reveal their intentions, such as visiting a certain shop, or abilities, such as their height in the case of the second study. Therefore, designers need to revisit methods to help mitigate this issue, such as using cameras to black out parts of the screen the user is not viewing [5]. Augmented reality may well become another viable approach [26]. However as it is device-based, it may not be fully-inclusive until it becomes integrated into widely owned consumer devices.

5 CONCLUSION

In this paper, we presented two studies to test our implicit personalisation framework. This utilises the users' goals and characteristics to provide them with personalised content and interactions. Our results showed that there is much potential for this type of personalisation, however, more consideration is needed towards the types of contexts that exist within public spaces, concerns around privacy, and how users' needs change over time. From these two studies, we discussed design suggestions that may further improve the effectiveness of personalised PIDs and add an additional layer for designers to consider when applying this framework. Future research opportunities in this area include further exploring methods to better detect user behaviour and characteristics while not being intrusive yet still useful and relevant.

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