Holistic User Models for Cognitive Disabilities: Personalized Tools for Supporting People with Autism in the City

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ABSTRACT

This paper presents a personalized interactive map aimed at supporting people with Autism Spectrum Disorder (ASD) in their daily transfers within urban environments. To this end, it aims to model a "complete" representation of the ASD individual by merging a variety of information in a unique user model. Moreover, it exploits crowdsourcing mechanisms to enrich the representation of places that may be considered "safe" by ASD people. As a result, the system is specifically designed for helping them manage stress originated by breakdowns from "spatial routines", by providing recommendations about safe places to reach and giving personalized tools to manage unexpected events.

CCS CONCEPTS

Human-centered computing →Ubiquitous and mobile computing → Ubiquitous and mobile computing systems and tools

KEYWORDS

Adaptive support, recommender systems, assistive technologies, maps, autism, real world user model, holistic user model.

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1 INTRODUCTION

In an era of connected technologies, smart cities have the potential to be built to respond to our needs [9]. However, currently cities are designed mainly having needs of "normal" persons in mind. This is a big obstacle for those with some disabilities, both physical and cognitive. While in relation to mobility some attempts to address physical issues have been done [10], cognitive disabilities are still unexplored. On the one hand, the lack of information about the urban environment and its accessibility (from both the physical and cognitive point of view) represents a barrier. On the other hand, the ways we represent the urban environments to give people advice for their daily movements, namely the maps, are cognitive representations of space. Even though maps are allegedly considered a form of scientific knowledge, the same "space" can be represented in diverse ways. Kevin Lynch emphasized that human cognition affects how we represent spatial areas and urban landmarks. From this point of view, having different cognitive skills might impact how we appraise the city environment, and consequently people with cognitive disabilities may need diverse representation modalities for receiving support. A category of people with peculiar cognitive abilities is that of persons affected by ASD (Autistic Spectrum Disorder). ASD is widely considered a health problem, with currently 1 in 68 children affected by ASD in United States [21]. ASD individuals have problems in communication, attention, practical skills, and interacting with others, being keen on withdrawing from the social world. They also tend to be engaged in a reduced range of interests, as well as have the need to find reassurance in rigid habits, consequently being unable to manage unexpected events. Moreover, ASD people manifest different forms of (dis)abilities, where limitations may range from multiple impairments to no precise cognitive deficits: even within similar levels of skills, the ways ASD affects behavior, perception, and interests widely vary making a one-size-fits-all technology approach not viable [17]. Nevertheless, personalized technologies for autism are still difficult to find [34].

To understand ASD individuals' needs about daily movements, we started from a series of semi-structured interviews [28] addressed to explore their daily "spatial habits", the landmarks they considered important in their city, and their peculiar modalities of representing the urban spaces. Results highlighted that ASD individuals have fixed routines in terms of daily movements, whereby unexpected events may lead to anxiety. Other findings pointed out their willingness of visiting places that have "safe" characteristics. Such characteristics appeared to be highly idiosyncratic.

This has been confirmed by a series of twenty further interviews, where we precisely explored the features that places need to have to be perceived as safe by an ASD person. The findings confirmed literature results, by highlighting that ASD people feel uncomfortable in places that elicit high sensory stimulation [30]. However, the results pointed out that each ASD individual shows her own aversions, and there are no places' characteristics that may reassure the whole ASD population. For example, P4 stressed that she mostly ignores the visual aspects of a place, such as strong lights, rather being negatively influenced by noises and voices, entailing a strong avoidance of trafficked streets and crowded places. On the contrary, P7 highlighted that she avoids silent environments, being also negatively influenced by their narrowness. In sum, the safe nature of a place is a matter of idiosyncratic dispositions that require tailored interventions.

PIUMA (Personalized Interactive Urban Maps for Autism) project has the goal of developing a set of personalized solutions that account for the ASD individuals' idiosyncrasies helping them move across the city where they live, and of improving their autonomy when moving and managing everyday activities.

More precisely, the project aims at creating a "complete" representation of the ASD user as well as of the urban environments in which she moves, by merging heterogeneous data coming from mobile phones, wearable sensors, crowdsourcing, and open data. It gives a technology-enabled orientation support to adult individuals with medium (who may present moderate-impaired cognitive skills), or high functioning autism (who present normal mental abilities), or with Asperger's Syndrome (now categorized as a form of ASD in the DSM-5[1]).

PIUMA supports such people in their daily movements within urban environments, helping them manage anxiety and stress originated by routine breakdowns and unfamiliar situations. It provides an interactive map that is i) personalized, i.e., able to provide just-in-time recommendations about "Safe" Point-of-Interests (SPOIs) according to users' preferences for and aversions to places' sensory characteristics; ii) assistive, i.e., capable of enabling tools (e.g. a direct call to a caregiver or an alternative path to be followed) tailored to the user's cognitive skills, as well as her "external" context (e.g. what the user is doing) and her "internal" states (e.g. her level of anxiety and stress) in case of routine breakdowns; iii) crowdsourced, i.e., enriched with comments and reviews by people with ASD and their caregivers.

2 RELATED WORK

Computer-based interventions are particularly promising for helping ASD people, since their particular affinity to technology [27], entailing the use of interactive tools for supporting their social communications [1], emotion recognition [15], and learning [37]. Nevertheless, most of these works focus on ASD children [3, 11], leaving apart autistic adults. PIUMA instead addresses the specific needs of ASD adults. Moreover, technological interventions mostly preferred to address social behavior issues [29]. PIUMA aims at supporting them in their everyday transfers and tasks. Finally, technological interventions often treated ASD deficits in artificial environments, making the transfer of improvements gained during the treatment to the real world difficult [15, 36]. We propose, instead, a set of tools integrated into their daily environments.

One of the main goals of PIUMA is to provide personalized instruments to ASD adults. Applications exploring the adoption of personalization strategies for ASD users are mostly related to the educational domain [23], for example [19] is a personalized e-learning system exploiting semantic web technologies, and [24], is an adaptive Web-based application for supporting autistic students in succeeding in university studies.

The idea of providing ASD people with tailored recommendations is investigated by Hong et al. [18], who proposed a social network aiming at increasing the independence of young adults with autism. Differently from this work, which is mainly based on crowd-based suggestions, our approach merges diverse data about the ASD person to better drive the personalization and support process. The effectiveness of personalization in this domain has been shown by Khosla et al. who investigated the impact of an adaptive humanoid robot

[1] Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

able to change its behavior (voice tone, expressions) on the basis of the ASD individuals' activity patterns and preferences [20].

As to spatial support, commonly, crowdsourced maps allow for reviewing the physical accessibility of specific POIs, such as Wheelmap[2] [5, 10]), and RouteCheckr [37] and mPass [26]. Finally, there is research in the field route recommendation, which consider both user and context model [13, 14, 22, 32, 35], but no applications focuses on recommending POIs and routes that are perceived as safe by people with certain cognitive disabilities.

3 A "HOLISTIC" USER REPRESENTATION

PIUMA supports ASD people's everyday activities and movements (home-relatives, home-work, etc.) by providing tailored helps to face breakdowns from routines. In this perspective, such support is personalized not only according to the user's preferences and interests, but also taking into account her aversions towards sensorial modalities, in order to provide comfortable "safe" POIs, as less annoying as possible. Moreover, personalized support is provided according to the user's current level of stress and anxiety, as well as her current situation.

In PIUMA, the ASD individual is represented by a user model which aims to capture different aspects of her cognition [6], affects, and habits, according to the Real World User Model perspective, which stresses the opportunities for exploiting the data coming from the "real world" (e.g. not just from the web) to build a "complete" representation of the user [7]. The user model contains both short-term and long-term information:

i) *Cognitive status and skills*: this part embraces all the information related to the user's momentary cognitive status (e.g. her level of attention) and her cognitive skills assessed over time (e.g. her difficulties in reading verbal instructions when the light is too strong, which will lead the system to adapt the user interface according to the environmental features, e.g. by providing audio instructions)

ii) *Spatial activities and habits*: this part contains information about where the user is in a specific moment and the path she is following (where she is coming from and where she is directed), as well as her patterns of movement over time in order to detect her "spatial routines" (.e. the places and the paths she finds reassuring) and recognize interruptions of such routines (e.g. the system recognizes that the user cannot take the usual bus line due to a strike and provides an alternative path based on routes that she already knows).

iii) *Affects*: this part models data about the current emotional status of the user, by leveraging wearable technologies to detect e.g. the level of anxiety through the monitoring of the heart rate, or by automatically recognizing anomalies in her movements, exploiting the smart phone's sensors (e.g., identifying wandering, or prolonged stays in the same place, which may point to a state of confusion and loss of orientation)

[2] http://wheelmap.org/en/

iv) *Interests and aversions*: this part of the user model contains all the data related to the user's attitude towards places, e.g. the sensorial characteristics that negatively impact on her sense of comfort about a place and those that instead make her feel "safe". At present, the information about the user's aversions is acquired by explicitly asking the user to rate those aspects that she bears less in a given environment, chosen among those that emerged as most stressful during the interviews: quite/noisy, isolated/crowded, cold/warm, narrow/big, bright/dark. Further, data about user's preferences of specific categories of places are collected by asking her to rate from 0 to 4 some photos representing important categories of "urban daily living" (e.g., restaurants, bars, libraries, parks,), extracted from OpenStreetMap[3]. However, we plan to acquire such information by exploiting Facebook Graph API[4], which allows developers to access information about check-ins and likes about places.

Such a representation of the user is used to recommend POIs according to the current context (e.g. GPS coordinates). For example, if the bus line the user commonly takes is canceled for any reason, the system will provide her with suggestions about how to reach the target place (e.g. suggesting an alternative "safe" path), or recommendations about alternative "safe" places to be reached, or a communication channel with a caregiver who can provide help. Such spatial support is personalized on the basis of the user's preferences (what she likes and dislikes, for example by recommending a less crowded route if she does not like other people), habits and current emotional status (e.g., thanks to wearable sensors that detects the level of arousal or stress).

4 REPRESENTING SAFE PLACES USING OPEN DATA AND CROWDSOURCED DATA

In case of a routine breakdown, which may yield a state of stress, the system can suggest an alternative "safe" path to reach the target place, or an alternate "safe" POI to be reached, according to the user's preferences. A safe POI is defined as a reference point location identifiable and/or reachable in case of user's reorientation is in need, being familiar for her, comfortable (e.g., not too noisy, according to the idiosyncratic user's sensory dispositions), and easy to reach (visible and well placed: e.g., no crossings needed, clear and accessible entrance from the street, etc.).

These POIs include both places that the user already knows and appreciated in the past, and new places suggested by the recommendation engine, based on crowdsourced information provided by other people through the interaction with the map. We exploit open data made available by web sites like OpenStreetMap and public administrations (Municipality of Torino[5] and Regione Piemonte[6]) in order to gather information about the typology and "quality" of the places on the map (for

[3] http://openstreetmap.org
[4] https://developers.facebook.com/docs/graph-api
[5] http://aperto.comune.torino.it
[6] http://www.dati.piemonte.it

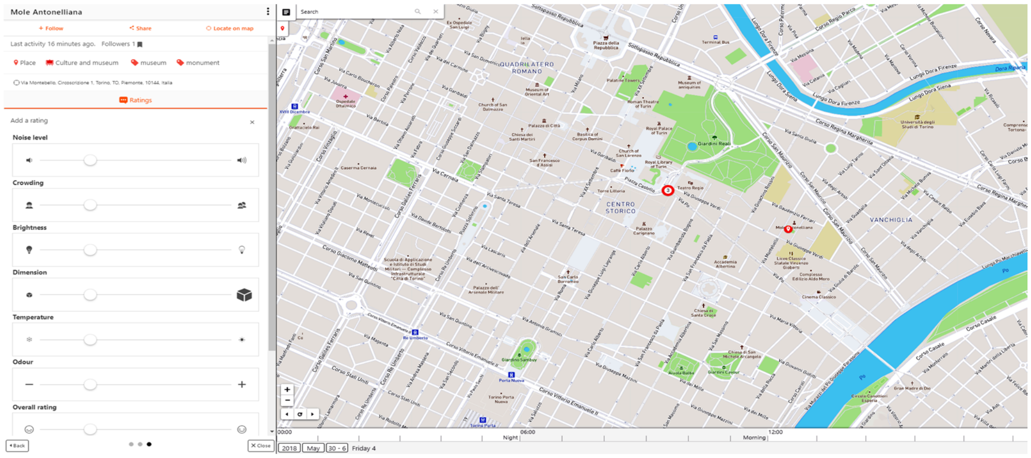

Figure 1. The crowdsourced map

example, to know where the open markets, schools, pedestrian, road works are, as well as the level of traffic in the main streets).

However, these data are often incomplete and, more important, they do not contain information about those perceptual features that ASD individuals consider essential to define a place as safe, as we have seen in the interviews. Thus, in order to have this crucial information to define a place as safe, in PIUMA we decided to exploit also a crowdsourcing mechanism, allowing people to provide rates, comments, and reviews about places. These reviews can be given by people with ASD and their caregivers, and by anyone wishing to contribute to the improvement of ASD people's lives. In order to collect these data, we then developed an interface embedded in the map[7], where the user can rate through a slider a place with reference to the following five features: i) level of noise; ii) level of crowding, iii) temperature, iv) level of brightness, v) spaciousness. Moreover, she may comment on the "comfort" of the place. All these data, which aim to model all the places of potential interest for ASD individuals, is then used to provide personalized recommendations about the safe place to reach according to the user's preferences and aversions.

The implementation of the crowdsourcing mechanism is based on FirstLife[8], a social network made of interactive maps (see fig.1). The interactive map is built on AngularJS, Ionic, Leaflet and OpenStreetMap. FirstLife is a flexible platform that can be adapted to different aims. Its architecture is composed of an interactive geographical map-based interface as a frontend and a backend aimed at managing and searching geographical data. It allows to insert and manage different kinds of POIs directly from the map, and supports crowdsourced data collection. The same rationale is followed for the definition of "safe" paths, i.e., paths that satisfy the perceptual needs of ASD people. So, for example, for those who are inclined to avoid noisy places, trafficked routes are not selected, as well as routes near schools, hospitals, or shopping areas, marketplaces, road works. To have this information, we merge tags and annotations in OpenStreetMap open data made available by the Municipality of Torino with ASD people comments. A detailed description of this part goes beyond the scope of this paper.

5 CONCLUSION

With the recent advancements in ubiquitous and wearables technologies, the amount and type of data that can be gathered about users and used to build user models are expanding. User model can now be enriched with data regarding different aspects of people's everyday lives. All these changes bring novel opportunities for personalization. We think that this enriched user model can particularly benefit people with special needs and abilities, such as people with ASD, as well as individuals affected by Alzheimer's disease, spatial agnosia, and mild cognitive impairment. In fact, to provide useful recommendations to such individuals, we need many different information, much more than that needed for "neurotypical" individuals. Traditional information about interests and preferences should necessary be combined with aversions, habits, idiosyncrasies, cognitive skills and abilities, as well as emotions felt in a particular situation. Thanks to such information it would be possible to avoid providing wrong suggestions, which in this case could have critical effects of the person, given her "fragility", causing for example stress and anxiety, or irritation and anger with unpredictable consequences. Moreover, all these data may be used to enrich the notion of user similarity used in Collaborative Filtering, where it commonly only depends on having rated the same items similarly. Here, this notion could become a wider concept, including similar aversions, habits, movement patterns, etc.. This would allow for the delivery of more tailored suggestions on the basis of "holistic" similarities, i.e., similarities based on multiple characteristics [8].

7 http:// www.maps4all.firstlife.org
8 http://www.firstlife.org

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