



How do sensory features of places impact on spatial exploration of people with autism? A user study

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Abstract

Autism is characterized by peculiar sensory processing. The sensory features of a place may have a crucial impact on the decision a person with autism makes when choosing what to visit in a tourist experience. We present a map-based mobile app, conceived for people with mid to high-functioning autism, which exploits sensory features of places to filter the information displayed and suggest locations that may be suitable for their idiosyncratic needs. The mobile app also exploits the crowd-mapping paradigm in order to gather these features from the community of users, since they are not publicly available. We describe the results of a composite user evaluation of the app, made up of a task experiment, a field study, and an online questionnaire, which aims to understand (i) whether the explicit presentation of sensory information impacts the decision of going to a specific place, (ii) if the crowd-mapping functionality is used and how and (iii) how people with autism navigate the mobile app. The results confirm the importance of the sensory features for people with autism in the decision to go to a specific place. Moreover, they show that crowdmapping may be a good solution to collect such features, but should be integrated with other methods. Finally, the results show that the preferred modality of exploring information about places is by using the map.

Keywords Autism · Accessible tourism · Smart tourism · Personalized spatial support · Crowdmapping · User study

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1 Introduction

The European Commission estimates that about one-fifth of all persons in Europe live with a disability (Ambrose and Papamichail 2021). Recently, the travel experiences of these people with special needs have started receiving some attention (Ambrose and Papamichail 2021; Gillovic and McIntosh 2020; Darcy et al. 2020; Scheyvens and Biddulph 2018; Michopoulou et al. 2015). For the tourism sector, this represents both a challenge, in terms of creating accessible environments and services, and an opportunity for attracting novel customers and their families. At the same time, tourism has a variety of benefits for individuals with a disability, enhancing personal development, quality of life, and social inclusion (Kastenholz et al. 2015). *Smart tourism*, which implements innovative ways to collect and aggregate data from physical and digital sources, and uses advanced technologies to transform data into enhanced experiences (Gretzel et al. 2015; Hamid et al. 2021; Mehraliyev et al. 2020), can provide valuable support for this kind of tourists. However, smart tourism has paid attention especially to physical (e.g., mobility impairments) (da Silva Lima et al. 2019), sensory (e.g., blindness and deafness) (Rocha et al. 2021), and cognitive (Gillovic 2019) disabilities, but only to a lesser extent to neurodiversity (Jepson et al. 2022). In particular, Autism Spectrum Disorder (ASD) requires special attention because of its specific nature (Jepson et al. 2022; Neo and Flaherty 2019). Travel experiences of people with ASD can be extremely different from those of people with other disabilities. This is due to the fact that ASD people have atypical sensory perception (Tavassoli et al. 2014) which impacts their choices about the places to visit (Smith 2015).

However, autism is a spectrum condition, i.e., it affects individuals in different ways. People with ASD can have severe or mild learning and cognitive issues (low- and mid-functioning autism) or full intellectual capabilities and even an IQ above the average (high-functioning autism/Asperger syndrome). Thus, there is a great variety among people with ASD regarding the ways they communicate, behave, interact, learn, and the level of support they need in their daily lives (Association et al. 2013). Tourists with ASD who experience lower difficulties with novelty, change in focus, and activities may be willing to travel, yet may have unique motivations, perceptions, and experiences related to travel compared to other people (Akyildiz and An 2021).

In this paper, we present the PIUMA app,¹ which aims to support people with mid to high-functioning autism in the exploration of public spaces (Cena et al. 2021). In particular, it allows users to know a place's sensory features (brightness, noise, smell, etc.) *before* they go there and to find Points of Interest (PoIs) that match both their preferences and sensory aversions. In this sense, the app can also be used by accompanying people, friends, and family members of people with autism, who may be supported in planning in advance the visits of their autistic companion. The distinctive feature of the app is the sensory features of places, exploited i) by users as filters to select places to visit, and ii) by a recommendation algorithm to suggest

¹ The project is a joint collaboration between the Computer Science and Psychology Departments of the University of Torino, and the Adult Autism Center of the city of Torino.

“comfortable” places. The app is based on the crowdmapping paradigm (i.e., people provide data about the places they visit (Shahid and Elbanna 2015)) to collect such sensory features that are not publicly available. In a previous offline evaluation (Mauro et al. 2022), we tested a set of recommendation algorithms, showing that considering aversion for sensory features together with user preferences improves the recommendation performance. In this work, we wanted to verify with real users whether the use of a mobile app that takes into account places’ sensory features supports the users’ decision-making process, by answering the following research questions:

- **RQ1.** Does the sensory information impact the ASD users’ decision-making in exploring a specific place?
- **RQ2.** Are crowdmapping features of the mobile app used by ASD people? And, is it feasible to use them to gather knowledge about the sensory features of places?
- **RQ3.** How do ASD people navigate the mobile app? Which are their modalities of spatial exploration on a digital device?

To answer the research questions, we carried out three user studies:

1. A task experiment (**S1**) where subjects performed two tasks on the mobile app in a neutral location (**RQ1**);
2. A field study (**S2**) where subjects freely used the app for six weeks while their actions were logged (**RQ2, RQ3**);
3. An online questionnaire (**S3**) filled at the end of the sixth week (**RQ1, RQ2, RQ3**).

We involved patients of the Adult Autism Center of the city of Torino. Twenty-three people were involved in the task experiment at the beginning of 2022, and, among them, 15 participated in the field study, and 17 filled in the final questionnaire. The results confirm our previous results on the importance of sensory features for ASD people in the decision of exploring a place (Mauro et al. 2022), thus it is crucial to consider them as a support for spatial exploration. Moreover, we found that crowdmapping can be one of the possible solutions to collect sensory features of places, even if others should be considered to collect a critical mass of data (Mauro et al. 2022).

The paper is structured as follows. Section 2 describes the related work on tourism and disabilities, with a focus on autism. Section 3 recounts the data and the functionalities of our app, as well as the experiments we conducted. Section 4 provides the results of our user studies which are discussed in Sect. 5. Section 6 describes the limitations and future work.

2 Neurodiversity, tourism and IT: a review of the literature

2.1 Diverse cognitive abilities and tourism

People with cognitive disabilities experience big challenges when traveling to novel places, even though several studies have shown that the tourism experience may be significant and meaningful to them, providing them with a sense of normality, sustaining self-efficacy, and strengthening relational connections (Gillovic 2019; McConkey and McCullough 2006). In fact, intellectual disability is scarcely considered by existing tourism scholarship and industry (Mactavish et al. 2007), albeit several conceptual frameworks for describing inclusive tourism have been developed (Ambrose and Papamichail 2021; Gillovic and McIntosh 2020). The same holds true for neurodivergent people, that is individuals whose mental functions, like sociability, attention, and learning, work differently compared to those that are considered neurotypical (Jepson et al. 2022). In particular, these individuals, due to the heterogeneity of their neurodiverse condition and a lack of understanding of complex behavioral variations, are often perceived as difficult both to manage and study in the tourism industry (Fletcher-Watson and Happé 2019).

Although no studies have embraced neurodiversity in tourism as a whole, some important works have started to critique the homogeneous nature of touristic products and services addressed to neurotypical audiences, stating that they should consider the peculiar needs of ASD individuals (Hamed 2013; Freund et al. 2022). In fact, as most of these individuals show an atypical social functioning (Hobson 1993) and sensory perception (Tavassoli et al. 2014), a touristic experience implying unpredictable environmental stimuli can be challenging for them and cause anxiety (Simm et al. 2016). Autistic people have to face a variety of barriers while traveling (Deka et al. 2016), like sensory overstimulation (Tavassoli et al. 2014) mobility barriers (e.g., public transportation (Dempsey et al. 2021a; Deka et al. 2016), unfamiliarity with the destination and associated anxiety (Neo and Flaherty 2019), difficulties in social interaction (Hamed 2013), and long waiting times (e.g., lines when visiting a museum) (Freund et al. 2022).

However, when the perceived disadvantages of traveling are more than the benefits, people can lose the motivation to travel (Shaw and Coles 2004; Small and Darcy 2010): therefore, their touristic experience may be jeopardized if their idiosyncratic needs are not satisfied. In this sense, the current conceptualizations of motivations to travel developed in the tourism field may not reflect the real motivations of people with ASD. For example, Pearce (2005) categorizes major travel motivators in novelty, escape/relaxation, and relationship enhancement, and no one seems to fit people with ASD. In their case, novelty may be considered rather as a disadvantage, since they are negatively affected by the lack of routines and the unpredictable sensory issues that may arise while traveling (Hamed 2013). The main motivations for people with autism to travel, instead, may be to improve the quality of their life (Dempsey et al. 2021b) and to contribute to their overall well-being (Deng 2017), as well as to enhance personal development (Kastenholz

et al. 2015) or find comfortable places where to feel at ease (Rapp et al. 2018, 2020). Addressing the specific needs of ASD people could be a golden opportunity for tour operators to be niche players in the market by offering specialized tourism products and services (Özogul and Baran 2016). In the future, accessible tourism is expected to be a promising industry (Naniopoulos et al. 2016).

2.2 Information technology for autism

The use of information technology (ICT) has proven to be a useful support in the lives of ASD people by facilitating interaction with others and helping them organize their daily activities (Putnam and Chong 2008; Pilar et al. 2021). Users with ASD show a positive attitude towards computer technologies due to the predictability of the interaction (Valencia et al. 2019).

In general, ICT-based solutions focus on social problems, such as face-to-face conversation (Boyd et al. 2016), emotion management (Simm et al. 2016), recognition of emotions (Almeida et al. 2019) and management of social relationships (Boyd et al. 2015), because these are considered as the core characteristics of autism. Most of the studies on ASD address children instead of adults (Goldsmith and LeBlanc 2004). There are works aimed at improving the literacy (Arciuli and Bailey 2019) and language (Wojciechowski and Al-Musawi 2017) skills of ASD children using different techniques such as serious games (Khowaja and Salim 2019).

Because of the increasing number of children with ASD who are becoming adults, some research has started to focus on the adults' needs (Graetz 2010; Gerhardt and Lainer 2011) developing technologies aimed at enhancing their independence in daily activities (Pérez-Fuster et al. 2019). Other works aimed to teach teenagers to become independent in their everyday life. For instance, Caria et al. (2018) developed a web-based application that supports ASD teenagers in understanding the concept of money and applying it in practical life situations.

However, there are few ICT solutions that are personalized to individual needs, and they are mainly adopted in the educational domain (e.g., (Milne et al. 2018)). For example, Judy et al. (2012) present a personalized e-learning system that provides learning paths having different difficulty levels, based on the user's past performance. García et al. (2016) propose an adaptive web-based application that helps students with autism overcome the challenges they might face in their university life. Costa et al. (2017) developed a task recommendation system suggesting the daily activities to be performed (e.g., eating, getting dressed). In (Ng and Pera 2018), the authors propose a hybrid game recommender for adults with autism, based on collaborative and graph-based recommendation techniques.

Only a minority of technologies support people with autism in spatial exploration. The majority of services in this domain are simple informative websites. For example, Autistic Globetrotting (Francus 2020) and the Toerisme voor Autisme² give hints to families that deal with autism. They show how to pack luggage and review tourist attractions, describing what visitors can expect there. Other attempts

² <https://www.toerismevoorautisme.be/>.

revolve around designing general tourist websites accessible to ASD people (e.g., (Dattolo et al. 2016; Dattolo and Luccio 2017)). Virtual Reality (VR) technology has also been employed in the tourism domain since it can simulate presence and be used to train specific skills needed to travel (Kandalaf et al. 2013). For example, (Bernardes et al. 2015) presents a serious game based on VR that teaches people with ASD to use public buses.

Our system differs from these previous works since it offers *spatial support* to ASD individuals by focusing on the sensory features of places, an aspect that has been completely overlooked in previous ICT-based solutions. Moreover, we provide a *personalized support*, by suggesting places considering both users' interests in places' categories and aversions to their sensory features. Finally, we evaluate our solution in the field with ASD users, which has rarely been done in previous research due to the difficulties in reaching the target population.

3 The case study

We developed a location-based mobile app (Cena et al. 2021) to help people with mid to high-functioning autism, as well as their accompanying people, to move around a city and discover new places. The app is based on a geographic map that supports users in the exploration of places and collects their sensory feature ratings. The mobile app has then been tested in the user studies, which are described in the following sections.

3.1 The mobile app

The mobile app offers the possibility to explore Points of Interest (PoIs) in different ways:

- *Navigation of the map.* As shown in Fig. 1a, the user may use the map to discover new places. The blue triangle represents the user's current location while the marker highlighted in red is the selected PoI "Castello del Valentino". Moreover, if the user wants to focus on another area of the map she can either move the map with her fingers or use the search bar at the top in order to center the map on a specific address. Figure 1a shows the details of the selected PoI.
- *Filters.* By clicking on the filter icon at the top right of the user interface shown in Fig. 1a, the user can select different filtering modalities of the PoIs. Figure 2a shows the two types of available filters. In the upper part of the user interface, the user selects the categories of places to be shown on the map (e.g. parks). At the bottom, there are filters regarding the sensory features. For each sensory feature, the user can select the level she prefers (i.e., low, medium, high). Different filters can be applied together: users can search for parks or churches, or monuments with low brightness and large width, as shown in Fig. 2a.

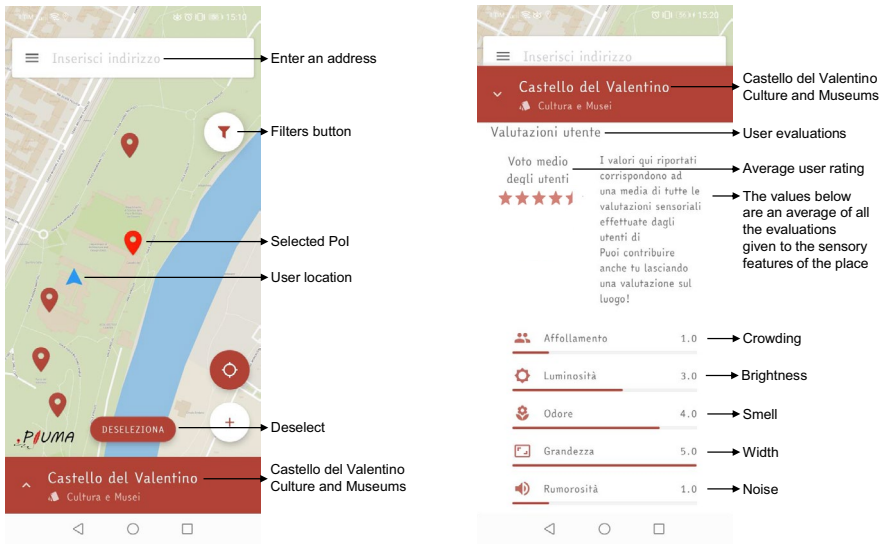


Fig. 1 User interface of the app - map-based navigation and POI details. **a** Visualization of the map with the POIs. **b** Details of the POI “Castello del Valentino”

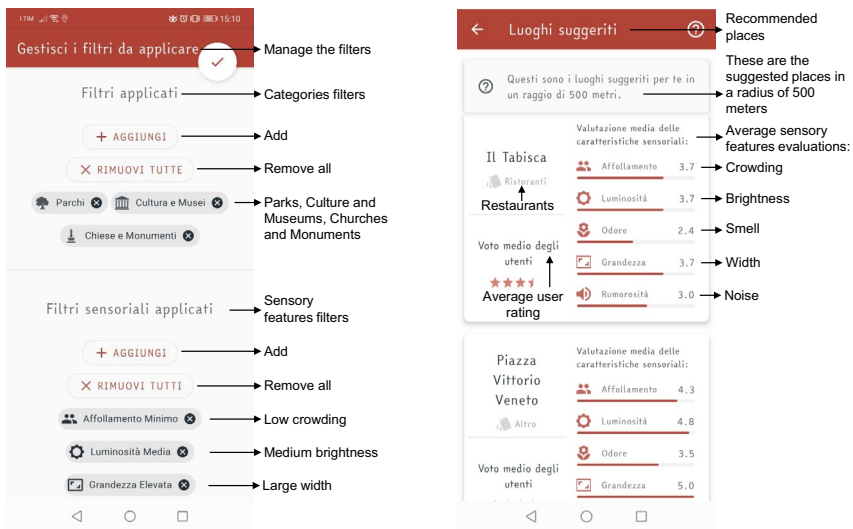


Fig. 2 User interface of the app - filters and recommendations list. **a** Visualization of the applied filters (categories and sensory features). **b** Visualization of recommendations with sensory features values

- *Recommendations.* Users can explore a place starting from the recommendations given by the system. We integrated into the mobile guide a content-based recommender system (Lops et al. 2011) that provides the user with personalized sug-

Fig. 3 Portion of the crowdmapping interface in the app

← La tua valutazione → Your evaluation

Aggiungi la tua valutazione per questo luogo. Puoi contribuire anche tu inserendo una valutazione del luogo. Add your evaluation for this place. (Other sensory features above)

👃 Odore → Smell

1 2 3 4 5

○ ○ ○ ○ ○

📏 Grandezza → Width

1 2 3 4 5

○ ○ ○ ○ ○

🔊 Rumorosità → Noise

1 2 3 4 5

○ ○ ○ ○ ○

VOTO COMPLESSIVO → Overall evaluation

1 2 3 4 5

○ ○ ○ ○ ○

◀ ○ ▶

gestions³ (Fig. 2b). To build a user model, during the registration phase of the mobile app, the user is asked to fill in a short questionnaire regarding her preferences for PoI's categories in a [1, 5] scale (e.g., park, culture and monuments, etc.) and her level of aversion to sensory features (e.g., from 1 to 5, how much does it bother you too much light?). This step is optional since a user can still use all the features of the app without personalized recommendations. For identifying the most relevant PoIs for a user, the recommendation algorithm takes into account both i) items' compatibility for each sensory feature of the place based on the user's aversions, and ii) user preferences for the PoI's category. It combines compatibility (*comp*) and preference (*pref*) evaluation of an item to estimate its rating (\hat{r}), using a weighted model that balances these two components in a personalized way tailored to the individual user. Thus, a parameter α , which takes decimal values in [0, 1], is introduced:

$$\hat{r} = \alpha * comp + (1 - \alpha) * pref. \quad (1)$$

In this work, to deal with the cold start problem, the α parameter was set at 0.8 to give more weight to the *comp* component. The user interface of Fig. 2b shows a portion of the list of the suggested PoIs. Since ASD people could feel overloaded by the information, only the five most suitable places are shown.

Moreover, the mobile app enables users to add new places on the map, specifying their category (e.g., park, restaurant, etc.), by selecting it from a predefined list of

³ For details about the recommendation algorithm, see Mauro et al. (2022).

categories defined by psychologists and ASD people. In addition, users can actively evaluate the sensory features of existing places (i.e., brightness, crowding, noise, smell, and width) on a 5-point Likert scale (Fig. 3). This is useful to collect sensory features values of places that are difficult to gather from geographical information systems, like OpenStreetMap⁴ and Google Maps⁵ since they only provide data about the category, address, and accessibility. To populate the knowledge base of the app, we collected data about places in two experimental crowdmapping campaigns at the Master's degree in Social Innovation and ICT at the University of Torino. About 120 students participated in the campaigns and we collected ratings for a total of 282 items.

3.2 Description of the user study

To answer the research questions, we carried out a user study which is composed of three parts:

- a task experiment, where users had to perform two tasks. In the first task, they had to rate recommended places where only the PoI category and its location were shown. In the second one, they had to rate the same place where also the sensory features were displayed in the user interface (S1);
- a field study where subjects freely used the app for six weeks while their actions were logged by the system (S2);
- an online questionnaire to collect their opinions at the end of the field study (S3).

We involved patients of the Adult Autism Center of the city of Torino. We selected only people with mid to high-functioning autism since the app has been conceived for those target users. No monetary or other incentive was provided as a reward for the participation in the study. All participants signed a privacy consensus according to General Data Protection Regulation (GDPR). Moreover, we obtained approval for the study from the research ethics committee of our University (protocol number 272541).

3.2.1 Task experiment (S1)

All the patients were invited via email to take part in the experiment in the Adult Autism Center on the 30th of January 2022 or the 19th of February 2022. Of over 200 invitations, 30 people answered and 23 finally came to the Adult Autism Center. Each person performed the task alone with a psychologist of the Adult Autism Center and a researcher close to her in case of need for support. After a brief introduction about the goal of the project and the mobile app, participants were asked to fill in the initial form on the app in order to collect preferences for categories of places and aversions for sensory features. The experiment was composed of two

⁴ <https://www.openstreetmap.org/>.

⁵ <https://www.google.it/maps/>.

tasks. First, the subjects were asked to inspect the list of places recommended by the app and to evaluate (on a [1, 5] Likert scale) a list of ten items. In this task, we removed the limit of visualizing only the first five suggestions since it was a controlled experiment. In this experimental configuration of the app, they could only see the category of the place (e.g., restaurant, park, museum, etc.), its location on the map, and the overall average user rating given by the community (from 1 to 5 stars). The name of the place had been removed in order to not influence the users' evaluation in case they already knew the place (Tintarev and Masthoff 2022). Then, people were invited to inspect the sensory feature values of each place and to say whether with this information they would change the evaluation of the place given before, and how and why they would change it. The task lasted approximately 20 min for each participant.

Participants. Twenty-three subjects participate in the study. They were all patients of the Adult Autism Center, aged 24–34, 15 male and 8 female (0 not-binary, 0 not declared).

Measures. We performed descriptive statistics to measure the changes in the answers.

Material. The subjects used an Android smartphone belonging to the Department of Computer Science of the University of Torino. They filled in the initial form in the app to collect preferences for places' categories and the aversions to sensory features. Moreover, they used the smartphone to visualize the recommendations (without and with the sensory features). The ratings given by the participants to the places (without and with the sensory features) and their feedback were collected by the researchers separately.

3.2.2 Field study (S2)

We then performed a field study where users freely used the app for 6 weeks, while we logged their actions on a database.

Participants. Among the twenty-three people that participated in the task experiment (S1), fifteen downloaded and used the app for six weeks. For privacy reasons, we could not connect the log files to the identity of the subjects, thus we do not have information about their age and gender.

Measures. We recorded the actions which are listed in Table 1. We then analyzed the number of occurrences of each action.⁶

Material. We developed a logger that records all the actions listed in Table 1 with a label and a timestamp.

3.2.3 Final questionnaire (S3)

At the end of the sixth week of the field study, the participants filled in a final questionnaire made of 23 items: the first 10 questions come from the System

⁶ We decided to record only the actions necessary to analyze the usage of the features of the app, avoiding possible violations of user privacy. Moreover, we informed the users that their actions were recorded.

Table 1 The actions and the corresponding labels in the log files

Crowdmapping action	Label
(1) To add a public place	PUBLIC_POI_ADDED
(2) To evaluate the sensory characteristics of a public place and give an overall evaluation of it	PUBLIC_POI_RATED
System action	Label
(1) To log in to the app	LOGIN
2) to click on a marker on the map	POI_MARKER_PRESSED
(3) To visualize the details of a place (i.e. overall rating and sensory features ratings)	POI_VIEWED
Filters action	Label
(1) To use category filters	CATEGORY_FILTER_UPDATE
(2) To use sensory filters	SENSORY_FILTER_UPDATE
Recommender system related action	Label
(1) To fill in the initial questionnaire	PROFILE_CUSTOMIZED
(2) To check the user profile	PROFILE_VIEWED
(3) To change preferences for the categories of places and the aversions for sensory features	PROFILE_EDITED
(4) To visualize the recommendation list	RECOMMENDATIONS_VIEWED

Usability Scale (SUS) (see below), while the other 13 questions (4 closed-ended and 9 open-ended) were specifically designed for our goals.

Participants. Seventeen people filled in the final questionnaire. It is worth being noticed that two people answered without using the app. Again, for privacy reasons, we could not identify them in the app and we do not have information about their age and gender. Thus, since we could not connect the identities of the users who used the app to the identities of those who responded to the questionnaire, it was not possible to remove their answers from the data.

Measures. We tested the usability of the app using a translated (Italian) and validated version of the System Usability Scale (SUS) scale (Grier et al. 2013). SUS provides a reliable tool for measuring the usability of a system. It consists of 10 statements where participants answer in the {Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree} scale, which we mapped to [1, 5] (Brooke 1996). The statements range from “I think that I would like to use this system frequently” to “I found the system very cumbersome to use”.

The standard approach to scoring the SUS is to convert raw item scores to adjusted scores: for the odd-numbered items (the positive-tone items), it is needed to subtract 1 from the raw score; for the even-numbered items (the negative-tone items), it is needed to subtract the raw score from 5. The sum of the adjusted scores then should be multiplied by 2.5 to get the standard SUS score (Lewis and Sauro 2009).

The result of the questionnaire is a number (ranging from 0 to 100) that represents a composite measure of the overall usability of the system.

Afterward, in order to gain insights about the usability issues encountered by the participants, as well as their willingness to use the app and its usefulness, we asked them to complete a qualitative questionnaire. Qualitative questionnaires have been widely used in human-computer interaction research, such as in (Spagnolli et al. 2016).

Participants were asked to answer 3 closed-ended questions about the usage of the app (*Did you use the app? Did you find the app useful? Would you use the app in the future?*) with the answer *yes/no* paired with an open-ended question about the motivation of each answer.

Then we asked participants to answer a closed-ended question about the type of support given by the mobile app. The possible answers were: (i) to discover new places suggested by other users, (ii) to discover new places suggested by the app, (iii) to save my habitual favorite places, (iv) to go out more, (v) to visit further places, (vi) to increase my autonomy in moving around the city, (vii) to discover the sensory features of the places; (viii) other.

Finally, we asked them several open-ended questions, for example:

- Which features did you use the most (e.g. navigation of the map, inspection of the details about sensory features evaluations of places, visualization of the list of suggestions)? Please explain why.
- In your opinion, by using the app, would you get out more, and would you experience the city more? Please explain why.
- Did you see the city with different eyes while using the app and with the possibility to visualize the sensory features evaluations of the places? Please explain why.

Open-question data were analyzed through thematic analysis. The answers were coded by taking apart sentences and labeling them through open coding. Then, the generated codes were grouped into more abstracted axial categories, which were eventually further grouped through selective coding into three main categories that correspond to the three main themes presented in Sect. 4.3.

Material. The survey was implemented as an online questionnaire, for ease of distribution and data collection (Courage and Baxter 2005).

4 Results

In this section, we analyze the results of each user study separately.

4.1 Task experiment (S1)

To answer RQ1 “*Does the sensory information impact the ASD users’ decision-making of exploring a specific place?*”, we investigated how many times the ratings

Table 2 Percentages of users split according to their gender and to the number of evaluation changes they made after viewing the sensory features

Number of changes	1-2-3	4-5-6-7	8-9-10
Evaluation changes due to sensory features (percentage of users)			
Females	37%	50%	13%
Males	47%	47%	6%
No evaluation changes due to the sensory features			
Females	38%	50%	12%
Males	33%	53%	14%

We highlighted in bold the higher percentage between males and females

changed after the user visualized the sensory features of places, in which cases this was caused by sensory features, and how the ratings changed.

How many times did the visualization of sensory features cause a change in the evaluation of a place?

To this aim, we collected the ratings given by the 23 subjects (230 in total, since each subject evaluated 10 places) and we measured the percentage of evaluation changes after the visualization of sensory features.

The evaluations *changed* after visualizing the sensory features of places 97 times (42.17%) and most of the times (95.8%) this was caused by the sensory information discovered about the place (“I understood that the place was not suitable, since too loud, bright, or crowded”). Only 1.5% of the times the change was not due to sensory features (“I don’t care about the sensory characteristics, I’m too curious regardless, I’ll take it and I’ll go”), while 2.7% of users changed their evaluations for other reasons.

The evaluations did *NOT* change after visualizing the sensory features of places 133 times (57.82%). This was caused specifically by the visualization of sensory features 76.79% of the times. This could be due to the fact that the recommender system suggested places with suitable sensory features. 12.31% of people instead said that the sensory features were not useful. 10.9% motivate their decision not to change the evaluation for other reasons than sensory features (e.g., “I need to physically go to the place to understand if it is really suitable for me”).

Moreover, we measured how often evaluations changed related to the **gender of people**. Table 2 shows the percentages of users split according to their gender and the number of evaluation changes they made after visualizing the sensory features. Specifically, we split the total number of evaluations (10) performed by each user, into three ranges: low rate of changes (1-2-3 changes), medium rate (4-5-6-7), and high rate (8-9-10). Previous studies (Lai et al. 2011; Osório et al. 2021) showed that females have a higher sensitivity to sensory stimuli and sensory processing. This is confirmed in our experiments where 13% of females have a high rate of evaluation changes (8-9-10) compared to the 6% of males. People explicitly declared that this was due to the visualization of sensory features. Moreover, people that changed their evaluations and explicitly said that they don’t care about sensory characteristics were all males. More specifically, 14% of males did not change their minds after visualizing the sensory features compared to the

Table 3 Variations of the values of ratings before and after the visualization of the sensory features of places

Before sensory features	After sensory features	Number of ratings after sensory features
High (4–5) 152 ratings	Low (1–2)	10
	Medium (3)	20
	Confirmed (4–5)	122
Medium (3) 49 ratings	Low (1–2)	4
	Confirmed (3)	23
	High (4–5)	22
Low (1–2) 29 ratings	Confirmed (1–2)	20
	Medium (3)	3
	High (4–5)	6

12% of females (Section “*No evaluation changes due to the sensory features*” of Table 2).

Did the visualization of the sensory features of a place increase or decrease the PoI evaluation?

In this section, we describe *how* the users’ ratings given to the places changed after the visualization of the sensory information. Specifically, we are interested to understand if the values of the ratings given to the places increased, decreased, or did not change. Specifically, the average of the ratings after having seen the sensory information goes up for 10 out of 23 users, while it drops down for 9 out of 23 users. The ratings remain unchanged for 4 out of 23 users. Thus, sensory features do not affect the evaluations in a specific direction, i.e. overall, they do not make the ratings increase or decrease. Such results can be interpreted in relation to the *performance of the recommendation algorithm* since in the tasks the subjects had to evaluate the item suggested by the recommender system. As explained in Sect. 3.1, the recommendation algorithm considers both: i) user preferences for the items categories and ii) user aversions to sensory features. In the first task (“*evaluation before seeing the sensory features*”), the users only saw the category of the recommended places, while in the second task (“*evaluation after seeing the sensory features*”), they also saw the sensory features of places.

Specifically, to analyze the ratings variations we consider three ranges of ratings values (low: values 1–2, medium: value 3, high: values 4–5). Table 3 shows the variations of the values of ratings before and after the visualization of sensory features of places in relation to the three ranges.

High ratings (values: 4–5) are confirmed after having discovered the sensory characteristics of places in 122 cases out of 230. This means that 53.04% of the evaluations given to the recommended items are correct in relation to both categories and sensory features of the places and they are appreciated by users.

Differently, 13.04% of the evaluations (30 ratings) decreased after the visualization of sensory features. In particular, 20 ratings decreased from high to

Table 4 The users' actions recorded in the log files, ranked according to the number of occurrences and for distinct users

Action	Occurrences
POI_MARKER_PRESSED	232
LOGIN	70
POI_VIEWED	65
SENSORY_FILTER_UPDATE	20
CATEGORY_FILTER_UPDATE	20
PUBLIC_POI_RATED	18
RECOMMENDATIONS_VIEWED	13
PROFILE_VIEWED	11
PROFILE_CUSTOMIZED	9
PUBLIC_POI_ADDED	7
PROFILE_EDITED	3

medium (from 4–5 to 3), and 10 ratings decreased from high to low (from 4–5 to 2–1). In this case, the recommended PoIs probably were not suitable for the users from the sensory features point of view.

Looking at the range medium (value: 3), 10% (23 ratings) of the evaluations were confirmed. Medium ratings increased from medium to high (from 3 to 4–5) in 22 cases (9.56%). This means that probably the recommended items were not suitable in relation to the category of the place, but they were better in relation to the sensory features. In fact, some people said that they did not like the place very much when they saw only its category but that they changed their mind after seeing that its sensory features were suitable for them.

On the other side, if we consider the range low (values: 1–2), 8.70% (20 ratings) were confirmed by the users after the visualization of sensory features. This means that the category is already an indicator of which places users don't like and this was confirmed by the sensory features. 3.91% of the evaluations (9 ratings) increased from low values to medium or high in the second task: 3 evaluations changed to medium and 6 to high.

Overall, we notice that the percentages of confirmed ratings are always higher than when they increase or decrease. This means that the recommendation algorithm often suggests suitable items to the users.

4.2 Field study (S2)

We analyzed the log files derived from the field study (S2) in order to answer the research questions **RQ2** and **RQ3**.

In total, the mobile app was used by 15 users, who performed 467 actions. Table 4 shows which are the performed actions on the system and their occurrences in the log file.

To answer RQ2 “*Are crowdmapping features of the mobile app used by ASD people?*”, we noticed that people don’t use these features very often: they rated the sensory features of places 18 times and they added a new place 7 times. Regarding the crowdmapping features, we could see that they added to the map (action `PUBLIC_POI_ADDED`) the following categories of places: 3 times restaurants, 2 times parks, 1 time bar, and 1 time sport. The categories of places that have been evaluated are squares and rail stations (5 times), parks (4), markets (3), restaurants (4), culture and museums (1), and sports (1).

To answer RQ3 “*How do ASD people navigate the mobile app? Which are their modalities of spatial exploration on a digital device?*” we noticed that the most performed action was the `POI_MARKER_PRESSED`, where the markers on the map were clicked 232 times, by 13 different users out of 15. This means that map is the preferred navigation modality. The `LOGIN` was done 70 times on different days, meaning that people used the app many times and not only once. Sensory filters (`SENSORY_FILTER_UPDATE`) and category filters (`CATEGORY_FILTER_UPDATE`) were used in total 40 times, 20 times each, meaning that people search for sensory information in the app. By inspecting the details of the places involved in the `POI_MARKER_PRESSED` action, we also found that parks (75 times) and markets (29 times) as outdoor spaces, and restaurants (50 times), and culture and museums (25 times) as indoor spaces are the category of places that interested mostly the subjects.

4.3 Final questionnaire (S3)

The analysis of the participants’ answers to the final questionnaire give qualitative feedback on the three RQs and led us to identify three themes: (i) User experience and usefulness, (ii) Sensoriality, and (iii) Participation.

4.3.1 User experience and usefulness

SUS scored 59.1. If we refer to the Sauro-Lewis curved grading scale (Lewis and Sauro 2009), which turns the average score of the SUS into grades, the app rated D, thus highlighting several usability issues. The answers to the other closed-ended questions highlighted that most of the participants (14 out of 17) found the application useful and would regularly use it in their everyday movements in the future (13 out of 17). About the main type of support provided by the app, nine participants stated that the app mostly gave them support to discover the sensory features of the places, two to save their habitual favorite places, one to discover new places suggested by the app, and four reported “other” as a reason. The answers to the open-ended questions pointed out some problems related to the difficulty in understanding how to add new places and their related ratings in the system, as well as the slowness of the application in responding to the user’s input, which may explain the low score: for instance, a user (P7) stated that “there were problems. I added a place but it was not saved in the app”, while P9 noticed that “when I turn on the app the map is slow to load”. Most of these problems, however, were technical issues due to the prototype status of the system and not directly related to the design of the user

interface and its usability: so they were quickly solved after the experimentation. By and large, the answers to the open-ended questions confirmed the data coming from the log analysis, highlighting that the most used features of the system were the map and the inspection of sensory features about the places.

4.3.2 Sensoriality

If most participants (9 out of 17) highlighted in the answers to the closed-ended questions that the app supported them mainly in discovering the sensory features of the places, participants' responses to the open-ended questions emphasize that the app "allows you to evaluate places with characteristics congenial to people with autism" (P1), "for us Asperger guys it makes you choose the place that suits you based on the ratings" (P6), "because then I knew which places were more crowded!" (P14), and "I could see first what the places were like" (P6), thus pointing out that the system fits the participants' needs mainly because it enables the users to understand in advance whether a place can be comfortable or harmful for them.

Fifteen participants precisely think that the sensory features prompted by the app were particularly useful to make them decide whether to go to a place or not because "they are information hardly made available by other apps, they would integrate well with the traditional photos of the environment of the place" (P10), and "I have preferences, almost necessities, for example, I prefer places with few people" (P16).

Interestingly, seven participants stressed that by using the app they would go out more, mainly because "it might allow me to find environments more suited to me that would make an outing enjoyable or at least less problematic", as P11 says. Likewise, six participants reported that the system made them look at their city with slightly different eyes because "I realized that even though I've lived there forever I still don't know it all" (P1), and "definitely with the ratings of places you get to look at the city with different points of view" (P4), somehow making them perceive the city as a comfortable place to explore. Five participants further highlighted that they discovered new places in the city by exploring the map, like "a park under the new skyscraper that I didn't know" (P1).

4.3.3 Participation

About the "crowdmapping aspect" of the system, twelve participants said that they inserted new places in the app thus contributing to increasing the number of the reviewed places available to the others. Reported reasons for participating in the crowdmapping initiative were various, e.g., "to make my contribution for the places I know" (P5), "because I was interested in being able to point out to others a quiet area or allow them to avoid an unpleasant area, but from this point of view, parks can be problematic to evaluate since they can contain distinct areas within them. (e.g., totally shaded or very well lit)", (P11) and "because I think that it is still an excellent tool for those who do not have or have not yet acquired the ability to attend places despite their sensory limitations" (P12). However, all the reasons show that people with autism have a sense of community that makes them willing to put the

effort into initiatives that may ameliorate the everyday life of individuals sharing their neurodiversity.

4.4 Comparison of log data with questionnaire results

The questionnaire showed that map-based navigation and the availability of sensory features about places were the preferred functionalities, which is confirmed by the log files (`POI_MARKER_PRESSED` - it is recorded 232 times). Likewise, the questionnaire reports that for 53% of the users, the possibility to discover the sensory features of a place was really useful, which is confirmed by the logs (`POI_VIEWED` action occurs 65 times). Moreover, in the questionnaire 13 (out of 17) participants stated that they rated the sensory features of the places they knew, and in the log files, we noticed that 18 evaluations were given, confirming that they used this feature during the study. However, the action `PUBLIC_POI_ADDED` is performed only 7 times, while in the questionnaire 12 participants claimed that they added some places. This could be due to a bug in the prototype that we later solved (as stated above) or to the fact that some people filled in the questionnaire a few days later and didn't exactly remember which actions they performed in the app. We can also comment that users were willing to contribute in principle but in reality, the crowdmapping activity could be complex and cumbersome for some of them, especially when adding new places, since it requires knowledge about the places to insert. Therefore, further mechanisms to exploit the users' willingness to contribute and to lower the workload required by the crowdmapping activity should be found in the future.

5 Discussion

We presented the evaluation of an inclusive mobile app for tourism that helps people with mid to high-functioning autism and their accompanying people in exploring new places. Through a user study composed of three parts, we aimed to gather some *insights* about the use of its sensory features and crowdmapping functionalities, as well as its overall usability and usefulness.

We discovered that the app's sensory features influence both the users' change and no change in the evaluation of the suggested places by the app, thus affecting their decision to go to a certain place. This effect appears more visible for female participants. By contrast, the app's crowdmapping features were scarcely used by the participants with reference to the addition of new places: participants probably did not add places to the map because the most popular ones were already mapped in the app or because it was a cumbersome activity. However, the participants appreciated the possibility to rate places and showed the willingness to contribute to populate the map in their responses to the questionnaire.

As for the interaction modalities, we noticed that participants preferred to use the map-based navigation and the filters rather than inspecting the list of recommended items. Moreover, we discovered that they leaned towards looking at what others say about the sensory features of places rather than rating the places

themselves. This can be explained by the fact that the mobile app has been conceived to be mainly based on the navigation of the map, while the other functionalities required more effort to be found. In fact, all the functionalities that are in the side menu have been scarcely used by the participants.

Our study extends research on smart and inclusive tourism by highlighting that people with autism make decisions about where to go by considering a specific kind of information, that is the sensory features of places. Previous research stressed that people with autism are less likely to explore new places (Smith 2015) and may feel anxious when novel situations occur in unknown environments (Simm et al. 2016). They need safety much more than novelty, and the unknown is negatively correlated with their need to feel safe, whereby the fear of the novel is mainly tied to the possibility of being in an “uncomfortable” place from the sensorial point of view. In this sense, Sherry Ahrentzen (2009) claimed that the main objectives in designing residential buildings for autistic people should be to ensure psychological safety, maximize familiarity, and minimize sensory overload. Our research highlights that the sensory features and sense of “sensorial safety” may be essential aspects also for the touristic experience of people with autism, as they use information about such features to make decisions about the novel places to visit. In this sense, the app could encourage the autistic population to undertake tourism trips, by allowing them to know in advance whether a tourist place is suitable for them, thus reducing the possible anxiety arising from a novel hostile environment (Neo and Flaherty 2019; Hamed 2013).

These findings have several *implications*. First, they point out a “new category” of users to be considered for inclusive tourism, that is people with autism. They represent a category of tourists who finds it difficult to be comfortable in places that do not match their sensorial preferences and aversions and tend to take their decisions to go to specific places on the basis of the sensory information that is available. Previous research on inclusive tourism has mostly considered people with physical disabilities and mobility impairments (da Silva Lima et al. 2019), thus focusing on physical barriers to tourism (Scheyvens and Biddulph 2018; Gillovic 2019), or those with vision impairments (Small et al. 2012). Even though researchers are increasingly paying attention to other dimensions of disability, like deafness (Rocha et al. 2021), dementia (Innes et al. 2016) or intellectual disabilities (Gillovic 2019), the phenomenon of autism has been substantially overlooked. The idiosyncratic needs of people with autism may require us to design touristic experiences for “sensory comfort”, focusing more on the sensorial features of a specific place than on its physical characteristics. Alternatively, they may lead us to support them in finding already available places that may suit their sensory preferences. The system we offer precisely aims to address the latter opportunity. It is worth noticing that the system we presented can be used by people with mid to high-functioning autism to autonomously plan their touristic experiences, exploiting the sensory information provided by it. Moreover, neurotypical people, who are friends, family members, or accompanying people of people with autism, even with low-functioning autism, could benefit from the suggestions given by the app to plan a suitable travel itinerary for their autistic companion.

Second, the system we designed may both widen the participation in tourism decision-making and change the tourism map involving new places, which are both essential goals of inclusive tourism (Gillovic 2019). In fact, our application allows people to create, annotate or otherwise enhance data that constitutes the basis of the touristic experience, which is in line with a smart tourism perspective (Gretzel et al. 2015). Not only, but the app also enables an entire “new” category of tourists that is currently underrepresented in smart tourism research, to contribute to tourism development. Research on inclusive tourism highlights that marginalized people, such as people with disabilities, have limited opportunities to contribute to tourism policy, planning, and development (Scheyvens and Biddulph 2018). By allowing people with autism to report and share the sensory features of the places they visit, as well as to rate such features, our system may contribute to create a network of places that satisfy their idiosyncratic needs, potentially promoting tourism for people with autism and accompanying people and driving the flux of autistic tourists to certain places rather than others. In this way, on the one hand, the tourism map may be changed by opening up more places and spaces as sites of tourism for people with autism because of their sensory features. Places not conventionally frequented by neurotypical tourists can be re-imagined as tourist spaces and be included on the tourist map. In doing so, people may have the opportunity to encounter new locations (Edensor 2015). On the other hand, people with autism and accompanying people could be directly involved in the development of certain places, potentially contributing to transforming activities and making them even fit more with their needs. Owners of places that are indicated as “reference points” for people with autism might be encouraged to provide further services that are suitable to them and improve the “comfort” of their locations. In fact, this may have relevant management and economic impact on tourism, also given the high number of people diagnosed with autism, as well as the number of accompanying people who can accompany them in their touristic experiences. Research has pointed out the economic outcomes that can accrue to businesses when “accessibility” is provided for (Darcy et al. 2010; Card et al. 2006), increasing the customer base and market share, reducing seasonality, improving profitability, and enhancing destination competitiveness (Darcy et al. 2010; Stumbo and Pegg 2005).

Third, as a consequence of this widened participation, the power relations in tourism may be transformed as well, which is another fundamental goal of inclusive tourism (Scheyvens and Biddulph 2018; Gillovic 2019). The system we designed may empower individuals who are traditionally marginalized, by giving them voice and opportunities to shape their own touristic experience. The active involvement of autistic persons in the collective endeavor of crowdmapping might be a way to enhance their social agency. They could feel like protagonists in the improvement of their leisure experiences, for example by letting more people know places that are comfortable from the sensorial point of view. This would make their voice more heard, and their views on the opportunities offered by the city spaces more visible.

Fourth, the findings coming from our study may also contribute to the literature on the ability of mobile apps to drive visit behavior in urban areas. Previous research indicates that users differ significantly in the way and extent to which they are driven by systems that offer a personalized guided tour or supply information about sights

on request, so it may be needed to combine different approaches (Kramer et al. 2007). Our app precisely combines different modalities, like filters, recommendations, and a map offering information on requests, and the field study shows that most people with autism seem to prefer navigating the map to see the places' evaluations provided by other users.

Fifth, as for recommender systems for tourism research, they traditionally rely on user preferences, either explicitly stated or implicitly inferred, to derive content recommendations, or the situational context of users (e.g., age, time, or weekday) to introduce additional dimension to the ratings (Gavalas et al. 2014; Ricci 2022). We contribute to this kind of research by showing that a recommender system that takes into account both the user's preferences and her aversions to sensory features may be an optimal solution for people with autism. In fact, the recommender system we developed (Mauro et al. 2022) outperforms in accuracy and ranking capability baseline recommender systems which (i) evaluate items on the sole basis of how closely they meet the user's preferences, or how compatible they are with her idiosyncratic aversions to sensory features, and (ii) uniformly manage compatibility and preference information without distinguishing the possibly different contributions of these aspects to item evaluation. The integration of possibly heterogeneous evaluation criteria concerning user interests and idiosyncratic aversions, therefore, is a promising approach to extend the adoption of recommender systems to new user groups with respect to those typically addressed in the state of the art. From a different perspective, the applicability of our approach makes it adaptable to different targets. Even though we currently focus on autistic users, our approach can be useful to people with other special needs as well. In fact, the integration of compatibility in the evaluation of the suitability of items to the user makes it possible to deal with different sources of incompatibility between places and users, and thus with other types of disability. For instance, we might apply our approach to focus the recommendation algorithm not only on sensory aversions but also on other specific user constraints and needs, such as trying to avoid architectural barriers for people with physical impairments.

Finally, we want to point out some *practical implications for the design of ICT-based solutions and recommender systems* that support people with autism in the touristic exploration of a place. Table 5 presents some design guidelines that can be followed to make such technological support more accessible and useful to people with autism (and accompanying people, if any).

6 Limitations and future work

The small sample size could be seen as a limitation of our study. However, considering the social difficulties of people with autism in taking part in such experiments (Çorlu et al. 2017), we can consider this number reasonable.

Another limitation may be found in the reliability of the results, as two participants filled in the questionnaire without having used the app. However, since this regards only two participants and the collected data were mostly qualitative (thus not requiring statistical significance), we can still consider the findings reliable.

Table 5 Design guidelines

Design guideline	Rationale
Provide sensory information about places in order to favor an informed decision	People with autism need to know in advance whether a place is suitable for them and sensory information is fundamental to this aim. Making such information accessible on request may reduce their anxiety to visit unknown places and encourage them to explore novel environments (Pearce 2019)
Provide personalized solutions	The specific characteristics of each person (Ricci et al. 2022) should be considered, since the perception of the sensory features of places is different for each person
Use sensory aversion when recommending places	The place's characteristics may hurt the sensibility of people with autism (e.g., too crowded, too noisy). Therefore, it is important to consider their sensory aversions during the process of recommendation. Otherwise, we may suggest an item that has a "negative" sensory feature that may completely ruin the person's experience
Use sensory features like filters to allow for the discovery of interesting places	People with autism may be overwhelmed by the overabundance of information, as our previous research also suggests (Rapp et al. 2018, 2020), so giving tools for reducing the amount and complexity of the information provided by the system may help them find suitable places more easily
Exploit people's willingness to contribute to their "community"	People with autism have a sense of community that encourages them to participate in initiatives that may contribute to the wellness of other neurodiverse people (Burke et al. 2010). Technology solutions for tourism may leverage such disposition by asking them to contribute to crowdmapping initiatives
Provide recommendations of places that are shown directly on the map	This suggestion may make recommendations more visible and easier to find

We also asked participants to express their willingness to go to a place, but we did not check if they actually went there. In the future, it could be interesting to analyze the users' localization and exploit the logger to learn their preferences in real-time (e.g., (Yin et al. 2015)).

A further limitation lies in the system's user interface, which did not highlight the recommendations given. In the future, we plan to adapt the user interface to the user's intellectual and perceptual capabilities (e.g., (De Los Rios Perez et al. 2018)), dynamically changing how the information is displayed on the screen. We will also explore how neurotypical users and autistic users may differently use the app, with a special focus on the interaction modalities.

Moreover, the people who participated in our crowdmapping activity were mostly neurotypical, which may perceive the places differently from autistic individuals. As

it may be difficult to collect sensory evaluations only from autistic individuals, in a previous work (Mauro et al. 2022), we extracted sensory features evaluations from textual reviews available on other map-based services, which could then be used to populate the system.

Finally, the sensory features are dynamic and they change over time (during a day, across different seasons), while the system only takes into account their average value. This might provide users with inaccurate information (e.g., a place described as very bright, as it is during the day, could be the opposite at dusk). As future work, we plan to develop a user interface that shows the value of the sensory features according to the different times of the day.

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Availability of data and materials The data that support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

Ethical approval The project was approved by the research ethics committee of the University of Torino (protocol number 272541).

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