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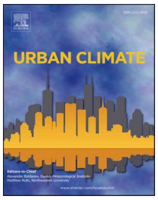

Navigating urban heat – Assessing the potential of a pedestrian routing tool

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ABSTRACT

Cities are experiencing unprecedented climate impacts related to increasing temperatures, which vary within a city due to the heterogenous nature of urban environments. Adapting urban areas to heat requires efforts on multiple levels from urban governance, spatial planning and design to adapting everyday activities. This paper presents the prototype of a pedestrian routing tool to support citizens in navigating urban heat, and the results of tests and interviews with 24 practitioners and experts in Portugal and Sweden. The study aims to assess how and to what extent a navigation tool on urban heat could support urban climate risk management, and to evaluate the potential of the tool to support everyday adaptation and increase citizen engagement. We explore what functionality and additional information would be required to make the tool useful and relevant for different user groups. Results indicate that (i) climate services that fit in your pocket increase access to climate information and have potential to guide everyday adaptation practices; and (ii) applications need to be contextualized and tailored to match the needs and decision contexts of the user through integration of relevant information or tools.

1. Introduction

The expansion and growth of cities worldwide, puts an increasing share of the population at risk for negative health impacts related to high temperature (Campbell et al., 2018; Kovats and Hajat, 2008). Urban materials such as concrete, stone, metal and asphalt are impermeable surfaces and, therefore, documented as a main cause of the urban heat island effect (Deilami et al., 2018). However, the share of impervious surfaces, dense built structures and limited green and blue infrastructure, vary geographically within cities and thus also the risk of urban heat islands (e.g., Amorim et al., 2021; Mohajerani et al., 2017; Rød and Maarse, 2021; Santos et al., 2021; Sun and Chen, 2017; Zhao et al., 2021). While climate adaptation literature increasingly focuses on urban planning and the role of

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green spaces to mitigate the effect of urban heat islands (e.g., Connors et al., 2013; Cortekar et al., 2016; Gago et al., 2013; Graça et al., 2022), the potential impact of heat on human health requires likewise awareness and behavioral adaptation to cope with heat in everyday urban navigation. In line with this, a recent study from Germany (Beckmann and Hiete, 2020) found that people who know more about heat waves are more likely to perceive heat as a risk and take adequate adaptation measures.

The effects of climate change vary geographically, in particular within a city (e.g., Amorim et al., 2021; Pioppi et al., 2020; Rød and Maarse, 2021), and many climate services[1] are therefore map based. The maps provided in climate services are, however, seldom on a street-level scale. Map-based climate services, that are tailored to guide urban citizens in their movements around the city, could support awareness of temperature variations within the urban fabric, and initiate a dialogue on climate adaptation and the potential need for behavioral change, between citizens, urban planning, and governance. Downscaled climate services that offer timely, tailored information and knowledge, are considered important to minimize climate-related losses and to increase awareness of and capitalize on benefits (Vaughan and Dessai, 2014). Specific practical implications for tailoring climate services include, for example, that it is imperative that climate service providers adopt the terminology of their potential clients and understand the cultural contexts built on more intensive collaboration and communication between providers and users (Lourenço et al., 2016). The call for climate services to adapt to the demands and needs of users has been raised in the 'Roadmap for Climate Services' (European Commission, 2015) as well as in an increasing body of literature concerning aspects encompassing the usability and usefulness of climate services (e.g., Bremer et al., 2019; Jacobs and Street, 2020; McNie, 2013; Vaughan et al., 2016). Vincent et al. (2018) outline three characteristics for climate services, namely decision-driven, process-based, and time-managed. Decision-driven means that climate services need to relate to the decision context of the user. In the case of a pedestrian routing tool, decisions would refer to aspects of everyday adaptation practice with consideration to the impacts of heat (Bisaro and Hinkel, 2016; Fuller and Bulkeley, 2013; Oppermann et al., 2018). In turn, process-based refers to the knowledge exchange between producers and users of a climate service. While this is specific to the co-production process, motivating collaborative assessments and iterations with different types of users, this is particularly relevant for the development and assessment of a climate service for citizens, and requires the integration of multiple aspects to ensure relevance and usability for the intended target groups (e.g., Ballantyne et al., 2018; Lorenzoni et al., 2007; Shaw et al., 2009). Lastly, time-managed concerns the timely provision of a climate service in relation to the decisions that it supports. While Vincent et al. (2018) refers specifically to the temporal aspects of e.g., seasonal forecasts, the time perspectives for a pedestrian routing service could be relevant if integrated with e.g. real time observation sharing or sensor measurements (Navarra et al., 2021; Opach et al., 2021).

While still rare in climate services, route planning functions are more frequently found in web-based mapping and decision support tools and tailored to portable devices to support drivers, cyclists, or pedestrians (e.g., Gavalas et al., 2017; Opach et al., 2021; Rußig and Bruns, 2017). As most cities in Europe and elsewhere are expected to experience more heat stress in the future combined with increasing urbanization, future research directions are likely to include various means to increase urban resilience towards heat stress. Examples that aim to guide pedestrians in case of high temperature (Rußig and Bruns, 2017) address the risk of extreme heat which can occur over large geographic areas and can in combination with other factors, such as humidity, increase the risk of negative health impacts and death (Campbell et al., 2018; Kovats and Hajat, 2008), highlighting the relevance of pedestrian navigation tools that facilitate planning daily activities during heat events. In order to increase urban resilience, several cities have engaged in projects developing web tools that can guide inhabitants and visitors to less heat exposed places. Examples of these are a map showing the temperature variation within Amsterdam city[2] or the Extrema[3] app, which provides for the city of Paris about 800 places to escape the heat. The Extrema app guides individuals to cooler places and includes a background map showing the warm and cool places. Another approach is provided by an app developed for Barcelona[4] that aims to guide pedestrians by providing information on shade in urban areas for different times of the day. Users may select different paths based on their preferences, such as the 'Vampire mode' that will select a path that avoids direct sun radiation. The approach presented in this study combines the innovativeness of these examples. We developed the Wayfinder$^{\text{Heat}}$ app as a routing device, with a background heat map overlay based on land surface temperature instead of the binary shadow/sunlight approach used for Barcelona, and with a possibility to select between routes having various levels of heat exposure.

This study is part of the Citizen Sensing project,[5] focusing on the development of climate services to increase urban climate resilience. The Wayfinder$^{\text{Heat}}$ prototype was developed as a derivative of the WayFinder tool (Opach et al., 2021) and aims to support urban pedestrians in navigating urban heat, and to enable the assessment of the added value of linking this type of climate service to other local information.

The aim of this study is to assess how and to what extent a navigation tool on urban heat could support urban climate risk management. Based on tests and interviews with practitioners and experts in Sweden and Portugal, we evaluate the potential of the Wayfinder$^{\text{Heat}}$ tool to support everyday adaptation practices and assess what additional functionality and information would be

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[1] We refer to Climate Services in accordance to the broad meaning, outlined in the European Commissions' 'Roadmap for Climate Services' (EC 2015:10) "which covers the transformation of climate-related data — together with other relevant information — into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation, and disaster risk management (DRM)."

[2] https://www.ams-institute.org/news/a-map-that-shows-where-to-keep-your-cool-during-heatwaves-in-amsterdam/ (web archive link,)

[3] https://www.apc-paris.com/actualite/extrema-paris-decouvrez-lapplication-qui-localise-lieux-fraicheur-a-paris

[4] http://www2.bcnregional.com

[5] http://citizensensing.eu

required to increase the tool's usefulness and relevance for different user groups. In this study, we tested the tool in cities with different climatic contexts. While Porto has a temperate climate throughout the year, thermal stress conditions prevail between June and September with hot or very hot days, the two Swedish cities, Norrköping and Linköping, have moderate but rising summer temperatures, and experienced an extremely long heatwave in the summer of 2018.[6]

2. Methods and material

2.1. *The Wayfinder^{Heat} application*

The WayFinder tool provides guidance to pedestrians in urban spaces and assists them in selecting routes that minimize the distance and time in areas exposed to extreme environmental conditions such as urban heat islands or flooding. Wayfinder^{Heat} provides users with a set of routing suggestions containing information about the length of the sections of the routes through risk areas with higher heat levels, as well as the total length of each suggested route. The user is provided with a set of points of interest to choose as destinations, at a distance of 400–1000 m from the user's current geographical position. The points of interest are selected as locations such as public libraries, museums, or cafés, to which a pedestrian would seek shelter from high temperatures, being situated within an adequate distance. After a user selects a destination, the tool provides a number of suggested routes retrieved through the Google Directions API and Open Route Service API (Fig. 1).

The associated heat exposure for each of the suggested routes is computed by intersecting the route with the Land Surface Temperature (LST) classified route network. This is achieved by employing the Turf.js API that calculates the intersections between the route and the different LST sections which are classified into very hot, hot, and slightly cooler.

The route suggestions are listed in the app in a randomized order with respect to their length to avoid that the shortest route would appear as the default 'first option' and risk that users would always select that option when asked to perform the task multiple times. When the user selects one of the suggested routes, only the selected route is displayed on the map interface. The prototype has been developed using the Angular framework in combination with Google Maps API and is described in detail in Opach et al. (2021).

The WayFinder^{Heat} prototype is tailored to navigate in areas exposed to heat. Based on the method developed in Madureira et al. (2021), LST was used to identify areas with high temperatures that were implemented in the Wayfinder prototype to compute the intersections with the route suggestions received from Google Directions API. An open-source script on Google Earth Engine (GEE) (Ermida et al., 2020) has been used to compute LST from Landsat 8 thermal infrared sensor data.

A single Landsat 8 TIRS band has been used for each of the case studies. The selection criteria were the hottest day without cloud cover coinciding with the available Landsat 8 data to achieve a possible scenario of an extreme heat event. The dates selected are 2016-07-15 for Porto, 2018-06-29 for Norrkoping and 2018-07-15 for Linkoping. LST is computed using the Statistical Mono-Window (SMW) algorithm developed by the Climate Monitoring Satellite Application Facility (CM-SAF). Landsat's thermal infrared (TIR) bands, with 100 m resolution, are resampled to 30 m spatial resolution. The resulting LST raster data has been pre-processed using standard GIS techniques. First the raster has been vectorized, reclassified in four different heat classes, the polygons with the same values have been merged, and a 15 m buffered street network was used to clip the result.

2.2. *Data collection and analysis*

The prototype was tested by participants in Porto, Portugal and in two adjacent Swedish cities, Linköping and Norrköping. Porto is a city with 232,000 inhabitants (INE, 2021), situated on 41°N latitude on the Atlantic Coast with a mean maximum temperature of 26 °C in July and August (Madureira et al., 2021). Norrköping (144,000 inhabitants) is situated on the Baltic Sea coast, whereas Linköping (165,000 inhabitants) is 40 km inland, situated on 58°N latitude, featuring on average 20–22° maximum temperature during June–August (SCB, 2022, population numbers refer to the municipalities). As for many areas in Europe, climate scenarios show an increasing maximum daily temperature during summer, as well as increasing number of days with heat waves for the coming decades. For Norrköping and Linköping the maximum summer temperature (based on RCP 4.5) is expected to increase by 2–2,5° between 1971-2000 and 2071–2100, with a doubling of the expected longest period with heat waves from 20-22 days to 40-42 days (SMHI, 2021).

Twenty-four practitioners and experts participated in user tests and interviews, comprising 10 practitioners of municipal organizations - in Porto (3), Linköping (3) and Norrköping (4), and 14 experts on climate science, climate adaptation, environmental and sustainability science, or urban planning, based at the University of Porto (7), Linköping University (5), and the Swedish National Knowledge Centre for Climate Adaptation (2). The 16 female and 8 male participants were selected based on their role as practitioners and experts and did hence not represent the age span of potential users, as they were not selected to be representative of the user group. The municipal participants represented organizations with a potential stake in adaptation to extreme heat and the experts had in-depth knowledge of climate and/or sustainability related issues making both credible and knowledgeable groups to assess the relevance, accuracy, and potential of the tool to support urban resilience to extreme heat. The tests and interviews were conducted in April and May 2021, and hence not during periods with high temperature. As such, the assessment was solely focused on obtaining the perspectives of practitioners and experts on the role of the tool, as well as the contextual use of the tool in the different settings and for

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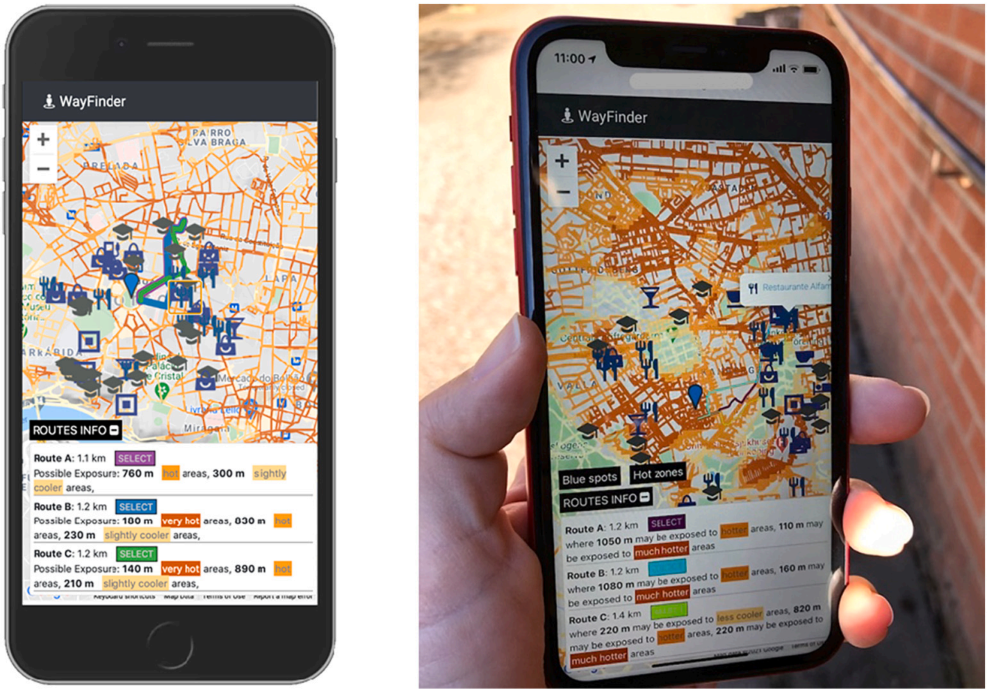
[6] https://www.smhi.se/klimat/klimatet-da-och-nu/hur-var-vadret/q/Malmsl%C3%A4tt and https://www.smhi.se/klimat/klimatet-da-och-nu/hur-var-vadret/q/Norrk%C3%B6ping-SMHI



ROUTES INFO

Route A: 1.1 km SELECT
Possible Exposure: **760 m** hot areas, **300 m** slightly cooler areas,

Route B: 1.2 km SELECT
Possible Exposure: **100 m** very hot areas, **830 m** hot areas, **230 m** slightly cooler areas,

Route C: 1.2 km SELECT
Possible Exposure: **140 m** very hot areas, **890 m** hot areas, **210 m** slightly cooler areas,

ROUTES INFO

Route A: 1.2 km SELECT
where **1050 m** may be exposed to hotter areas, **110 m** may be exposed to much hotter areas

Route B: 1.2 km
where **1080 m** may be exposed to hotter areas, **160 m** may be exposed to much hotter areas

Route C: 1.4 km
where **220 m** may be exposed to less cooler areas, **820 m** may be exposed to hotter areas, **220 m** may be exposed to much hotter areas

Fig. 1. The Wayfinder^{Heat} Tool for Porto (to the left) and in a photograph for Linköping (to the right).

various user groups. While tests during heat waves with intended end-users of the tool would be of relevance in a subsequent step, this was not possible to conduct with practitioners and experts due to lack of time flexibility.

The assessments were organized in the format of 'Wayfinder-Walks' accompanied by semi-structured interviews with the participant while walking and using the prototype in an urban environment. Each 'Wayfinder-Walk' lasted from 45 to 60 min, and during that time 1–3 separate walks with individually selected routes were conducted. Before, during and after the walks, the interviewer posed three sets of questions, covering (i) the profile of the participant in relation to the survey (ii) the experience of each walk, and, lastly, (iii) an overall assessment of the Wayfinder tool. The answers from participants were collected in the native language and subsequently translated by project researchers into English, allowing for a complete and comparable material for analysis.

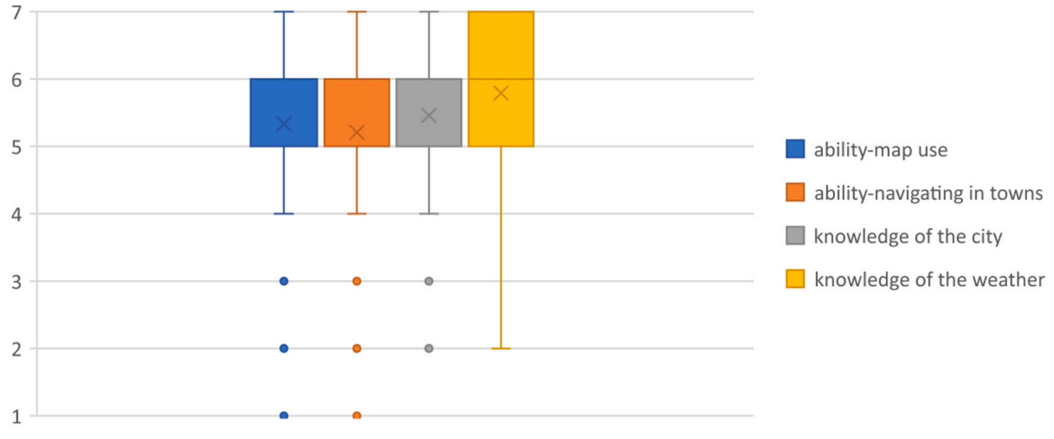


Fig. 2. Participants' self-rating of map use and navigation abilities as well as knowledge of the city and the local weather conditions on a scale from 1 to 7 ($n = 24$), x indicating the mean value.

3. Results

3.1. Participant profile

Prior to the walk, participants were asked to rank their own abilities in map-use and navigation in urban areas as well as their knowledge of the city and local weather, on a scale ranging from 1 (no skills / no knowledge) to 7 (expert / very familiar). The results of this self-assessment were on average high, ranging between 4.9 and 6.3 for the participants from both Portugal and Sweden (Fig. 2). Three Swedish participants ranked their map use and navigation abilities relatively low (1–3) which resulted in a slightly lower average for the Swedish respondents (4.9) compared to the Portuguese respondents (6.0), while one Swedish and one Portuguese participant also ranked their knowledge of the city low (3 and 2 respectively). Most respondents ranked their familiarity with the weather conditions of the city relatively high (4–7), while one Swedish participant selected a low rate (2).

In order to assess how acquainted participants were with other types of climate or weather information and services, we asked, what kind of climate related information they currently had access to, and if they used different types of tools, such as long-term weather forecasts, warnings of extreme weather events, indications on how to avoid dangerous areas, recommendations of actions or information on assistance, or preventive actions to take during extreme weather events.

All but three of the Portuguese participants reported that they had access to long-term weather forecasts, and all but two of the Swedish and one of the Portuguese participants had access to warnings of extreme weather events or explained that they would know where to access this information. Sixteen participants also confirmed that they had access to recommendations of actions to be taken during extreme weather events and 13 responded that they had access to information of how to avoid exposed areas. For both types of information, two respondents mentioned that they did not have access but know where to access this information. Seven participants confirmed that they had access about available assistance during extreme weather events, and two of the Swedish respondents argued that this information would surely be provided by the Swedish Met office or media in case of an extreme weather event. Eleven participants had access to information on preventive actions to reduce the impact of extreme weather events, while others argued they would know where to obtain this information but have never searched for it. While this does not necessarily indicate that respondents were more concerned or informed about these issues, this background information indicates some degree of interest and use of available information on weather warnings and extreme events, which could be expected given that the 24 participants represented practitioners and experts that to some extent engaged with climate change and climate adaptation.

Furthermore, participants were asked what possible effects of climate change they are concerned would affect them personally. All but four participants (two Swedish and two Portuguese) named heat, in terms of health impacts from high temperatures or increased occurrence or length of heat waves, but also mentioned other impacts that might be aggravated by high temperatures. Other dominant themes that respondents mentioned were the risk of cloudbursts, floods, storms, and other extreme weather events that could have local impacts, generate increased risk of health impacts, and indirectly affect them when occurring in other locations.

3.2. Route selection and assessment of the walks

A total of 64 paths were selected by 24 participants in their 'Wayfinder-Walks,' 18 in Porto, 14 in Norrköping, and 32 in Linköping (Supplementary Material Fig. S1). All participants responded that they followed or partly followed the paths during their walks, which might have been influenced by the presence of the interviewer with whom the goal of the walk as well as the selection of routes were discussed prior to starting the walk.

Participants walked on average 0.74 km (Porto), 0.8 km (Norrköping) and 0.89 km (Linköping) per walk which was in line with the delimitation of goals that were available at a radius between 400 and 1000 m (see Section 2.1). The selected paths for all Wayfinder Walks in Porto, Norrköping and Linköping are presented in Fig. S1 in the Supplementary Material. After each walk, the participants were asked to explain their route selection. Nine of the participants expressed that they had selected the shortest route, two of which explained that they made their choice among the shortest routes with least heat. Moreover, three of these participants argued that they selected the shortest route since distances through warm areas did not differ much between the given choices. Four of the Swedish participants selected the shortest routes, arguing that the distance through hot areas would not be very long, or that the temperature on that day made that choice irrelevant. Thirteen of the participants explained that they selected the route that had the shortest section through hot areas, or explicitly that they picked the longer route with the higher thermal comfort, while one of the participants argued that hot areas could be acceptable if there were also some cool areas along the route to cool down. One participant explained that the 'first option' that was displayed was selected since that was expected to be the 'best one', and another participant was only provided with one option, due to the location, and argued that this single option was significantly longer than what the respondent considered the 'best route'.

For each walk, the participants were asked to reflect upon the data on heat zones provided on the map overlay and whether they disagreed with or were missing any information on the map or had suggestions on information that could add to the functionality. While most participants assessed the background map as rather or very accurate, heat zones often coincided with impermeable surfaces such as concrete and asphalt, while temperatures were lower in green areas or where building height varied creating increased airflow and shade canyons. However, some commented that they observed some areas that were not accurately represented in terms of temperature – e.g., when asphalted areas and green areas had the same heat level in the map overlay, or different sides of the street should have been zoned differently to represent the effect of shade from tall buildings or similar. This was, in particular, highlighted by a Porto participant for narrower streets where shade makes a distinct difference in experienced temperature. Another participant expressed a lack of connection between the displayed heat zones and the time of day, weather conditions and the distribution of sun/

shade along the paths. Others commented that it was hard to assess, while one participant argued that the heat overlay provided more precise information for the cooler areas than for the hot/very hot sections of the route.

Several participants noted that they missed additional information such as street names (which are visible in the tool, but only at a certain zoom level and to some degree covered by the heat zones), or that the extent of smaller walking- or cycle paths was hard to determine. One participant pointed out that a satellite map layer, rather than the ordinary street map (see Fig. 1) would have better contributed to the orientation and usability of the tool, which is a default option, but was not used as part of the walks to avoid the risk of visual clutter.

3.3. Assessment of the Wayfinder^{Heat} routing tool

After the 'Wayfinder-Walks', participants were asked to provide feedback on functionality, usefulness and how engaging the tool was (Fig. 3).

3.3.1. Functionality

The tool's functionality was ranked by most participants between 3 and 5 (on a scale ranging from 1 – very bad, to 7 – very good), with an average ranking of 3.9. The majority of participants were able to interact with the Wayfinder tool relatively easily, while raising a number of aspects that influenced their experience. One of the frequently raised functionality aspects was however not linked to the tool itself, but to the accuracy of the GPS location, as participants complained that the location indicator 'jumped' on the map. This can be caused by multipath, that is when the GPS signal is reflected from the ground and/or from nearby objects. Examples of reflecting objects that often generate multipath is buildings, cars, and the ground. Incorrect positions, or even signal disruptions, may also happen due to poor satellite geometry, poor dilution of precision, which may easily happen when the user is in an urban canyon if the receiver can only receive signals from satellites in zenith (Rød, 2015). During the walks some users might have experienced this kind of positional inaccuracy, which influenced their experience when testing the app, since they were asked to follow the suggested route closely to comment on the map overlay and features of the surrounding area.

Several participants remarked that they considered the display of the selected route to not be sufficiently visible, as it lay above the streets' heat zones (see Fig. 1). Two participants experienced an overload of information and icons for available destinations on the map that they felt created a visual clutter which obstructed their orientation. Other participants expressed that the tool was hard to navigate, and that they had difficulties when zooming and panning. While this was introduced by the interviewer as a design feature of the prototype, which automatically re-centres to the place indicator when zooming or panning in the map view, participants argued that zooming and panning was necessary for them to be able to orientate and navigate. While the design of the prototype has been focused to guide and provide information to the user in the current geographical position rather than giving the possibility to navigate the city surroundings, this feature presents an evident trade-off between two different functionalities.

One participant also considered the legend not intuitive for understanding the different heat categories. Suggestions for improvement included that the map view should adapt to the direction in which the user is moving rather than remaining in North-

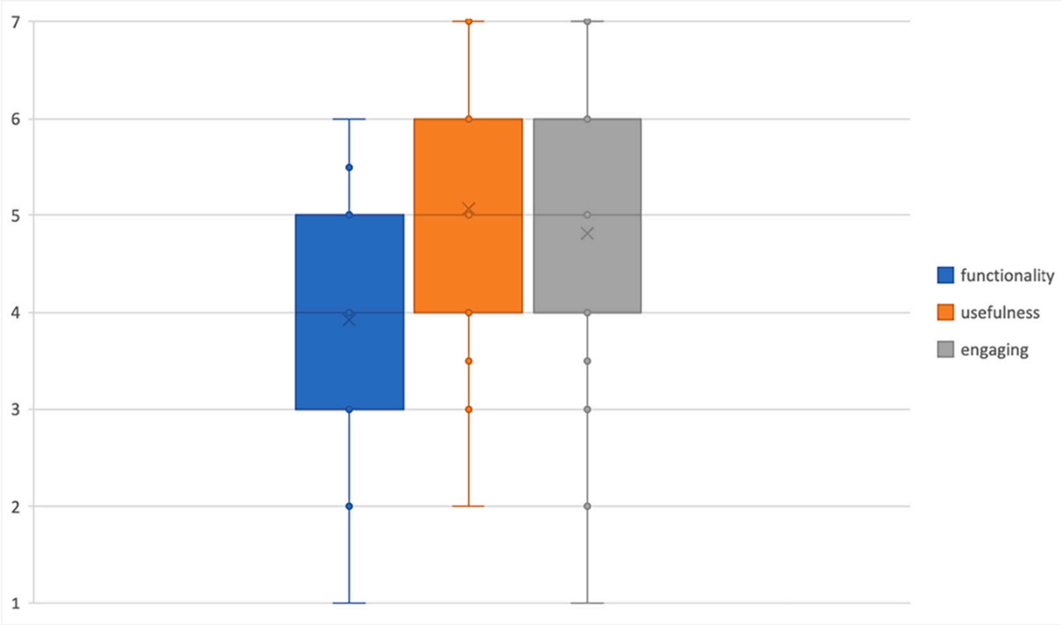


Fig. 3. Participant's rating of the tool in terms of functionality, usefulness, and engagement on a scale from 1 to 7 (n = 24); x indicates the mean value.

South and that the user could set criteria for their walk after which the app could prioritise a route based on these criteria.

3.3.2. *Usefulness, users and engagement*

In terms of usefulness, the average ranking of the tool was at 5 (on a scale from 1 – no use at all, to 7 – very useful). Participants argued that the tool is particularly useful for people that are not well acquainted with the city and would require or appreciate navigation support in the city tailored with heat information, such as new residents or visitors. Several participants argued that it would be most relevant for individuals who are sensitive to heat or need to avoid heat, e.g., vulnerable groups such as the elderly or people with health issues. While one Swedish participant claimed that the tool would not be useful at all in Sweden due to the climatic preconditions, several other participants argued that it could be relevant during the hot months of the year, but also that it will increase in relevance in the future as the occurrence of heat waves is expected to intensify. Participants also raised the argument that the information and functionality is useful but should be integrated with other types of applications, e.g., for touristic or sports activities, or as part of an app that also addresses other extreme weather events, such as flooding.

When asked about how engaging the tool was, participants ranked the tool on average just below 5 (on a scale ranging from 1 – very little engagement, to 7 – very large engagement). Participants that assessed the tool as less engaging, explained that they generally preferred to walk without an app, and one of the Swedish participants, who set the lowest score (1), expressed that 'these types of tools are not for me'. Most participants however argued, from a more general perspective, that Wayfinder$^{\text{Heat}}$ is engaging as it encourages the user to reflect on local heat conditions and features an 'interesting concept'. An additional argument that was raised in terms of engagement was that it would be highly depending on the weather conditions, and in case of multiple longer heat waves, participants explained that the app would increase in usability and engagement.

In reference to potential user groups that could benefit from the Wayfinder$^{\text{Heat}}$ tool, most respondents agreed to its usefulness for pedestrians in general as well as tourists. While several respondents suggested elderly persons as a potential user group due to their vulnerability to heat, others disagreed due to the complexity of the app or lack of experience with these types of digital tools. Most participants proposed that the tool could be relevant for people with health impairments, wheelchairs users or pedestrians with strollers, but several argued that this would only apply if the app also integrated additional information. Only few respondents listed students and cyclists as potential user groups. Participants named additional potential users including home care staff that are walking with their clients, mail carriers, people who are exercising and dogwalkers. Participants also suggested urban strategists and decision makers and urban traffic planners.

One frequently raised opportunity for the Wayfinder tool was the integration with other information that would increase the usability and engagement for different user groups. In the three cities, participants noted the potential value of including information on accessibility, e.g., if a certain path is accessible for wheelchairs, or pedestrians with walking aids or strollers, and to include, in the case of Porto, a city with significant topographical features in the urban landscape, to include topographical signifiers e.g., of steepness (Alves et al., 2021, 2020).

Other relevant information of interest that participants suggested were trails or nature walks that aid users not only to avoid heat, but to also explore urban green areas. Other participants would appreciate information on transportation and other types of climate impacts, as well as a feedback function to allow users to comment on the heat zones presented on the map. This latter function was only discussed to a limited degree during this study as the timing only allowed for a theoretical assessment of the urban landscape in relation to the overlaid heat map, rather than feedback from experiencing heat exposure.

4. Discussion

This study set out to assess how and to what extent a navigation tool on urban heat could support urban risk management. Based on the results of the walks and interviews, when testing the routing mechanism in action, we discuss the functionality and usefulness of the tool, and how participants assessed its potential to support different groups of citizens and what additional functionality, content or integration would be required for increased relevance.

The Wayfinder$^{\text{Heat}}$ pedestrian routing tool was assessed as an application to support urban climate adaptation, constituted as everyday adaptation practices. Climate services of this kind aim to support the - more or less spontaneous - everyday adaptation decision making, in this specific case, the navigation of pedestrians in heat prone urban areas. The results of this study reflected the importance of developing and assessing climate services in close collaboration with end-users, to unravel their "decision context" and gain a greater understanding of the type of decisions that the climate service could support (Vincent et al., 2018:53). While this study tested the tool in two different climatic contexts, the main challenge outlined by the respondents was evidently related to adapting and tailoring the tool to different user groups and their specific decisions, as highlighted in previous studies (e.g., Opach et al., 2021; Vaughan and Dessai, 2014). Participants identified multiple elements that specific groups would require to increase the tool's relevance for certain users. Firstly, the integration of additional information such as route accessibility and topography were emphasized for people with health and/or mobility constraints. Secondly, for tourists or people with limited local knowledge, contextual elements, such as information on nature walks, pedestrian friendly areas, such as parks, or other relevant features were proposed. Although a high share of participants indicated they had or could access relevant information on extreme events and available help if needed, being able to directly view heat zones in an app increases information accessibility. Moreover, these participants were practitioners or experts in fields related to climate or environmental science, or urban planning, and therefore can be considered users with privileged information on these topics. For non-expert users, the tool may offer added benefits related to orientations on how to proceed during extreme events. The participants' additional suggestions indicate that the tool would be even more usable with integrated and accessible information tailored to the needs and interests of specific groups.

Our study showed the need of assessing both tool functionality and content with a variety of users to be able to tailor it to specific user requirements (Brasseur and Gallardo, 2016; Donnelly et al., 2018; Vaughan and Dessai, 2014), as a process-based climate service (Vincent et al., 2018) needs to respond with flexibility and reflexivity to users' requirements and priorities. While our study focused on an assessment with practitioners and experts and not potential end-users, it provides insights into their perspectives rather than a usability study. The assessment of potential user groups and related challenges presented in this study, can however guide future research with end-users, which would contribute new aspects regarding needs and usability. Study participants considered the tool of value for elderly people, as they are commonly pointed out as vulnerable to excessive heat, but several respondents commented that the tool's complexity and navigating functions would not be suitable for this group. This highlights the limitation for digital climate services in terms of inclusivity for a significant vulnerable group. Simplifying the tool could however present a trade-off as it would reduce the accuracy of the information, while some of the functionality might still be difficult to navigate for users that lack experience in similar type of digital tools. The high relevance that was indicated by participants implies however that the tool might instead be used by home care staff, friends, or companions to elderly persons. In particular, the results of this study outlined specific potential user groups and that the integration with other types of information, e.g., accessibility and steepness could increase the relevance for people in wheelchairs or with health problems. Similarly, the integration with other tools, e.g., featuring running or hiking trails, could increase the relevance among a greater diversity of users.

The temporal variability of the provided information was addressed by some respondents in terms of integrating data specific to different conditions depending on the time of day, as the urban landscape influences heat development both in terms of varying shade and intensity, but also for the integration of e.g., real time measurements, that could provide additional guidance to the users. The use of Land Surface Temperature (LST) data for the background measures, which only represents one point in time for the temperature measure represents a further limitation. For instance, Sheng et al. (2017)) compared Urban Heat Island intensity using Landsat LST and hourly measured air temperature and found that the resulting UHI intensity values were not comparable. Our study could thus be improved by inclusion of real time sensor measurements (Rød and Maarse, 2021) or high-resolution modelled data (e.g. Amorim et al., 2020). This involves however finding a balance between tailoring information to the needs of specific users, while sustaining reliability which might be compromised by coarse spatio-temporal resolution of the background information, and its inherent uncertainty (Brasseur and Gallardo, 2016).

The results of this study confirmed that a tool for supporting urban pedestrian navigation through heat prone areas was considered relevant and useful in both climatic contexts. While our participants did not test the app under heat conditions, the prioritization of routes and respondent's reasoning confirms the relevance of guiding pedestrians to avoid heat prone areas, but also raises the trade-off between selecting the route with less heat exposure versus the shorter route with short-term higher heat exposure.

5. Conclusions

Based on the analysis of the perspectives of practitioners and experts on the Wayfinder^{Heat} pedestrian routing tool we outline the following main conclusions. Firstly, an interactive climate service that fits in your pocket can increase accessibility of climate information and provides the opportunity to link to tools and activities that are already part of daily routines. While there is evident potential to guide behavioral change and hence everyday adaptation, digital tools also risk excluding particularly vulnerable groups, such as elderly citizens, that might not be part of the digital transition, hence requiring other modes of engagement. Secondly, our respondents emphasized the need for contextualizing and tailoring the application to match the specific demands and decision context of the user, which can be achieved by incorporating additional relevant information or direct integration with other tools to increase the relevance and usability of the tool. As such, this study points towards a variety of pathways for future endeavors to increase the potential of climate services to support the awareness and engagement of citizens in terms of climate adaptation in their everyday adaptation practice when navigating heat in urban areas.

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CRediT authorship contribution statement

T.-S. Neset: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Funding acquisition. **C. Navarra:** Conceptualization, Methodology, Software, Formal analysis, Writing – original draft. **M. Graça:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **T. Opach:** Conceptualization, Methodology, Software, Writing – review & editing. **J. Wilk:** Methodology, Formal analysis, Investigation, Writing – original draft. **P. Wallin:** Methodology, Investigation, Writing – review & editing. **L. Andersson:** Methodology, Investigation, Writing – review & editing. **S. Santos Cruz:** Methodology, Writing – review & editing, Funding acquisition. **A. Monteiro:** Conceptualization, Writing – review & editing. **J.K. Rød:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.uclim.2022.101333.

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