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Public Interest in Microclimate Data in Knoxville, Tennessee, USA

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Abstract: New technologies can sense urban environmental conditions at finer scales than previously possible. This has paved the way for monitoring microclimates between and within neighborhoods. Equally vital, though much less studied, is stakeholder engagement in understanding and using such data. This study examines interests and preferences for accessing neighborhood-scale microclimate data among residents of Knoxville, Tennessee, USA. Data are from randomly sampled phone surveys (N = 200) and purposively sampled focus group participants (N = 25). Survey participants expressed high interest in neighborhood air quality, temperature, and rainfall. Focus groups revealed four themes for designing smartphone applications or websites for neighborhood-scale data: easy access to integrated data, clear and intuitive design, information for everyday living and healthy behavior, and tools for civic engagement. Results support the value of creating meaningful, usable science interfaces with which the public can readily engage.

Keywords: urban; neighborhood; weather; air quality; community; communication

1. Introduction

Environmental sustainability is a critical issue for cities. As urbanization increases, so do resource consumption, generation of greenhouse gasses, and disruption of human-environmental cycles with consequences for human health and well-being [1–3]. The impacts of urbanization on local humidity [4], air temperature [5], air quality [6], and water quality [7] are substantial. These effects have high spatial and temporal variability due to the complexity and patchiness of the urban landscape. New technologies can sense urban environmental conditions at finer scales than previously possible by monitoring neighborhood microclimates, instead of relying on low-spatial-resolution data for a city or county [8–11]. Smart, sustainable, and connected communities can benefit from such technologies to collect data and understand urban environmental conditions at highly localized scales.

Equally vital, though much less studied, are processes for engaging diverse stakeholders in understanding and using such data. Such knowledge could help influence human behavior in the social environment in ways that improve urban sustainability, whereby an active, engaged public both receives data and generates feedback for sustainability-related systems. With access to downscaled and real-time or forecast data, urban residents may become more informed about local environmental conditions and more engaged in addressing urban sustainability problems through community-driven efforts [12,13]. While the drivers of pro-environmental attitudes and behavior are complex, knowledge about the problem and place attachment are two drivers upon which stakeholder engagement with sustainability data could build [14]. Examples of making downscaled environmental data available to and meaningful for the public, however, are few.

Recent syntheses in science communication [15–18] recommend new approaches that (1) create usable science by incorporating stakeholder input from members of the public and official decision-makers; (2) use a variety of information and communication technology strategies that are targeted to different consumers; and (3) provide local, context-specific information that matters to people's everyday lives and resonates with their lived experience. In lieu of assuming what citizens and decision-makers would benefit from or prefer, multidisciplinary teams are encouraged to ask people's preferences, conduct analyses, and integrate results into the design of science communication systems. Such engagement should begin early in the planning stages, to generate meaningful and inclusive public input on planned science communication efforts [19]. In addition, new approaches should consider ways to empower the public to act, moving beyond the perceived helplessness often felt in the face of complex sustainability problems [20].

To advance this emerging area, this study examines interests and preferences for accessing microclimate data at the neighborhood scale among a sample of residents in Knoxville, Tennessee, USA. A multidisciplinary effort, this study advances new knowledge at the innovative nexus of urban sustainability, emerging technologies, and public engagement. As part of a larger project on urban microclimate monitoring [10,11], this study represents the next stage of an effort to make high-resolution sustainability data meaningful for a wide range of stakeholders—from everyday citizens of diverse backgrounds at the household or neighborhood scale (who may want localized data to inform their own behaviors and environmental actions) to city planners and officials charged with sustainability decision-making that must account for distinct needs of different groups—by examining people's interests and preferences for receiving and interacting with microclimate data. This kind of inclusive, engaged process is rarely seen in sustainability science but is vital if social and technical solutions for critical urban issues are to be integrated effectively and carried out jointly by scientists, policy-makers, and the public [21,22].

2. Materials and Methods

2.1. Study Setting

Data were collected in Knoxville, Tennessee, a medium-sized city in the southeastern USA. As of 1 July 2015, Knoxville's estimated population was 185,291 and consisted primarily of White or Caucasian (76.1%) and African American (17.1%) residents [23]. Located in a valley between the Cumberland Plateau and the Great Smoky Mountains, Knoxville has a humid subtropical climate with warm summers (average maximum temperature in July: 31.2 °C) and cool winters (average maximum temperature in January: 8.5 °C) [24]. Prior studies in Knoxville suggest that microclimates can vary among and within urban neighborhoods [10,11] and that residents of different neighborhoods may perceive and experience environmental problems in different ways [25].

2.2. Data Collection and Analysis

Data are from randomly sampled phone surveys (N = 200) and purposively sampled focus groups (five groups; N = 25 total participants) with Knoxville residents, using a concurrent mixed methods design [26] with quantitative methods to assess data interest and qualitative methods to explore communication preferences. Survey participants were recruited from a randomly-sampled list of Knoxville-based landline and cell phone numbers. Inclusion criteria were that participants reside within Knoxville city limits and be at least 18 years old. After providing informed consent, participants completed a 5 min survey, administered using standard computer-assisted telephone interviewing software. Survey items measured public interest in neighborhood-scale air quality, temperature, rainfall, and noise information, each on a five-point, Likert-like scale (1 = Not at all interested; 5 = Extremely interested), and participant demographic characteristics. The survey was constructed and reviewed for content and face validity by the research team. Survey data were analyzed with descriptive statistics and logistic regression. Four regression models were built;

each model regressed high interest in one of the neighborhood parameters on participant gender, age, race/ethnicity, education, marital status, children in the home, and annual household income. Household access to technology resources was measured in the survey but omitted from final models for parsimony and model fit.

Focus group participants were recruited from the Knoxville regions with which residents typically identify: North, South, East, West, and Central/Downtown. One focus group was organized for each region. Prospective participants were recruited via telephone by research staff, either through random digit dial or direct dial if the person had previously expressed interest in joining a focus group. An experienced focus group facilitator used open-ended questions with participants to explore their perceptions of sustainability, interest in localized data, and reactions to basic features of select environmental applications already available for smartphones or through websites (apps/sites). Participants explored up to four existing apps/sites, each focused on different parameters such as air quality (American Lung Association State of the Air app), ultraviolet light exposure (Environmental Protection Agency (EPA) UV Index app), environmental toxin release (EPA My Right to Know website), or general urban conditions (Urban Observatory website). While these apps/sites did not necessarily provide participants with neighborhood-scale data, they did provide ways to explore current and, in some cases, forecast conditions for Knoxville or other cities of interest, and to probe for participant preferences about environmental app/site design and usability. Each focus group lasted 90 minutes and was audiorecorded and transcribed with participant permission. Multiple members of the research team analyzed transcripts with descriptive and interpretive coding techniques to identify qualitative themes [27].

3. Results

3.1. Survey Results

3.1.1. Participants

Survey participants had a range of gender, age, and other background characteristics (Table 1). Compared to the city of Knoxville's general population, the sample had a higher percentage of female (58.5% vs. 52.0%), White or Caucasian (81.4% vs. 76.1%), and bachelor's degree or higher educated (51.5% vs. 29.9%) participants [23]. Given the local median household income of approximately $33,500, the survey sample also had a higher income, with over half (54.2%) reporting an annual household income of $50,000 or more. Although gender, education, and income have been linked to more pro-environmental attitudes and behaviors [14], a bivariate analysis of the association between these variables and a high interest in neighborhood-scale data yielded non-statistically significant results in this study.

3.1.2. Interest in Neighborhood-Scale Data

As shown in Table 2, participants expressed the most interest in receiving neighborhood-specific air quality data (83.0% chose "3" or higher on a five-point scale), followed by temperature (81.5%) and rainfall (77.5%). About half of the participants (54.5%) were as interested in neighborhood-specific noise.

Among participants who expressed a high level of interest in at least one of the four neighborhood parameters (response of "4" or "5"; 80% or N = 160), 19.6% preferred monthly or less frequent access to such information, 30.6% preferred weekly, 43.1% preferred daily, and 6.3% preferred two or more times per day. The most preferred ways of receiving information were smartphone applications (64.6%), email updates (27.8%), cell phone text messages (25.9%), and online websites (21.5%). Other possible communication methods were tablet applications (16.5%), mailed brochures or newsletters (7.0%), and presentations at neighborhood meetings (2.5%).

Table 1. Survey participant characteristics (N = 200).

Characteristic	% or Mean (SD)
Gender, female	58.5
Age, years	49.3 (15.6)
Race/ethnicity	
White or Caucasian	81.4
Black or African American	13.6
Other, including more than one	5.0
Education	
High school diploma or less	23.5
Associate's or vocational	25.0
Bachelor's degree	35.0
Graduate degree or higher	16.5
Marital status	
Single, never married	24.5
Married or partnership	55.0
Separated or divorced	17.0
Widowed	3.5
Children < 18 in the home, yes	30.5
Household income [1]	
Less than $30,000	23.9
$30,000 to less than $50,000	21.8
$50,000 to less than $75,000	21.8
$75,000 or more	32.4
Household technology resources, yes	
Smartphone	89.5
Computer with internet	85.0
iPad or tablet	72.5

[1] N = 188; data missing for 6.0%

Table 2. Level of interest in neighborhood-scale data (N = 200).

Variable	1 = Not at all Interested (%)	2 (%)	3 (%)	4 (%)	5 = Extremely Interested (%)	Mean (SD)
Air quality	13.5	3.5	20.5	18.0	44.5	3.8 (1.4)
Temperature	13.0	5.5	22.0	20.5	39.0	3.7 (1.4)
Rainfall	14.5	8.0	23.5	22.5	31.5	3.5 (1.4)
Noise level	34.5	11.0	17.5	12.5	24.5	2.8 (1.6)

Logistic regression found that participants with children under the age of 18 in the home were 2.48 times as likely (95% CI: 1.12–5.16, $p = 0.02$) to have a high interest in air quality and 4.06 times as likely (95% CI: 1.88–8.78, $p = 0.00$) to have a high interest in temperature, compared to participants without children under the age of 18 in the home (Table 3). While the specified model for air quality fit the data no better than a model with no predictors at a 95% confidence level, bivariate analysis of the association between a high interest in neighborhood-scale air quality and having children under the age of 18 in the home also suggests a positive relationship between these variables, X^2 (1) = 6.24, $p = 0.01$.

Table 3. Logistic regression models of high interest in neighborhood-scale data (N = 196) [1].

Predictor	Air Quality				Temperature				Rainfall				Noise			
	OR	**95L**	**95U**	***p***	**OR**	**95L**	**95U**	***p***	**OR**	**95L**	**95U**	***p***	**OR**	**95L**	**95U**	***p***
Gender, female	0.88	0.48	1.62	0.69	0.88	0.48	1.63	0.69	0.77	0.43	1.38	0.38	1.06	0.58	1.94	0.84
Age, years	1.01	0.99	1.03	0.33	1.00	0.98	1.02	0.99	1.00	0.98	1.02	0.61	1.02	0.99	1.04	0.07
Race/ethnicity, white	1.08	0.50	2.34	0.85	1.23	0.56	2.70	0.61	0.80	0.38	1.70	0.56	0.89	0.42	1.91	0.77
Bachelor's degree+	1.16	0.62	2.17	0.65	1.24	0.66	2.35	0.50	1.13	0.62	2.06	0.70	1.07	0.57	1.99	0.84
Married/partner	1.39	0.74	2.61	0.31	1.19	0.63	2.24	0.60	1.37	0.74	2.53	0.32	0.73	0.39	1.37	0.32
Children < 18 in the home	2.48	1.12	5.16	0.02	4.06	1.88	8.78	0.00	1.32	0.68	2.59	0.42	1.56	0.78	3.12	0.21
Income, $30,000 or more [2]	1.12	0.53	2.38	0.76	0.58	0.26	1.26	0.17	0.55	0.26	1.18	0.13	0.55	0.26	1.18	0.12
Model statistics	X^2 (7) = 9.24, p = 0.24				X^2 (7) = 17.62, p = 0.01				X^2 (7) = 5.18, p = 0.64				X^2 (7) = 7.90, p = 0.34			

[1] DVs modeled as 1 = 4 or 5 level of interest, 0 = 1, 2, or 3 level of interest; OR = odds ratio; 95L = lower bound of the 95% OR confidence interval; 95U = upper bound of the 95% OR confidence interval; [2] Missing values imputed at 1 = $30,000 or more.

3.2. Focus Group Results

About half of the focus group participants expressed interest in accessing smartphone applications or websites with neighborhood-specific data. Participants with less interest tended to be older or generally did not use smartphone applications. Qualitative analysis identified four themes regarding information communication preferences: easy access to integrated data, clear and intuitive design, information for everyday living and healthy behavior, and tools for civic engagement.

3.2.1. Easy Access to Integrated Data

Many participants observed a need for an app/site with integrated data. Instead of accessing multiple apps/sites, participants wanted a single virtual destination for neighborhood-scale temperature, air quality, environmental pollutants, and more, as long as each data source is identified on the app/site and credible. Also, while participants appreciated apps/sites with current or historical data, many expressed interest in forecast data for multiple parameters.

3.2.2. Clear and Intuitive Design

Participants preferred apps/sites with clear and intuitive design features such as red-to-green color schemes ("...it's like a traffic light—green means go, yellow caution..."), scales that make sense to the everyday public user ("...they take measurements and convert them...it's very good for the beginner..."), and maps and charts as effective ways to display information. Participants also liked features that provide an option to obtain detailed information about the data, such as tapping on a score to learn more about that condition or pollutant. For example, while exploring an air quality app, a participant remarked, "I like how you can tap on the ozone level, and it gives you info about what it means, especially for people with health problems."

3.2.3. Information for Everyday Living and Healthy Behavior

Participants described how they would use a neighborhood-scale app/site in their everyday lives, especially for taking action on their or their families' health. They tended to appreciate apps/sites that gave succinct, clear messages about how current or forecast conditions could affect health and that provided protective steps that people should take using clear language. Participant examples of how they might use neighborhood-scale data to inform action included planning daily exercise, yardwork, or children's outdoor play times around temperature and air quality forecasts; knowing which local waterways to avoid for recreation due to pollution; and identifying the best times for using or conserving energy for cooling homes. Some participants also suggested that apps/websites should provide general sustainability tips such as how to increase green space at home or in your neighborhood and encourage reduced automobile use.

3.2.4. Tools for Civic Engagement

Participants responded positively to apps/websites with built-in tools for civic engagement such as one-click features that send advocacy messages to elected officials about environmental concerns or easy ways to sign up for e-newsletters about environmental issues. As one participant described, "I like the Speak Up feature because you don't have to look any of that info up. It's already there for you." Other civic-related suggestions from participants included providing information about neighborhood or other local environmental events, contact information for local agencies and officials (not just U.S. Congress members), and editable emails or letters for participants to send.

3.3. Study Limitations

While the strengths of this study include its mixed methods approach, its use of random sampling for phone surveys, and its purposive recruitment of focus group participants from each Knoxville region, results should be considered in light of the study's limitations. Due to non-response bias, survey participants are not necessarily representative of the general Knoxville population, a limitation which future research might overcome through multi-mode survey administration and quota sampling. Also, three of four logistic regression models had poor model fit, suggesting that non-observed variables may drive significant variation in the study outcome measures. Finally, the study is cross-sectional and non-experimental, given that it is in the early phase of a multi-stage effort to understand, implement, and test public engagement with neighborhood-scale environmental data.

4. Discussion and Conclusions

Results suggest that interest in localized air quality, temperature, and rainfall data is high among study participants. Among those with a high interest, many would like to access information at least once per day and via smartphone applications. These findings may be used to support additional research into environmental monitoring efforts at the neighborhood scale and testing of innovative technology development for making information available to the public. Given high access to technology resources such as smartphones in the study sample, future research should explore whether people with fewer technology resources also want this information, and if so, through what means. Families with children under the age of 18 in the home may be another group to target for additional research, based on regression results for air quality and temperature interest. Focus group findings shed some light on this finding, as participants discussed wanting to ensure their children's health or be thoughtful about what times children play outside, an example of an environment-related attitude that may stem from a non-environmental goal [14]. Study designs that obtain more representative samples for understanding stakeholder interests and preferences should also be considered.

For communicating neighborhood environmental data to the public, the results from this study suggest that smartphone applications and websites may want to consider integrating data, having clear design features, and focusing on useable and compelling behavioral and civic engagement messages. For behavioral messages, in particular, clear and effective communication may need to explore strategies that encourage both small, specific actions and critical thinking about larger change [28]. Public desire for integrated data may require novel partnerships among data providers such as the National Weather Service, the Environmental Protection Agency, municipal governments, and university researchers. In general, study findings support previous recommendations to create meaningful, usable science with which the public can readily engage [15–18], as specifically applied here to problems of urban environmental sustainability. As residents become more informed about their immediate environments and empowered with information and messaging, they may be more likely to invest in and support community-driven sustainability initiatives [12,13,22].

Building from this study's results, one unanswered but compelling next step is to partner with communities to design, disseminate, and test data communications for urban environmental sustainability with user feedback integrated into every stage of the design process. Multidisciplinary teams that bring together engineering, geography, social work, public health, computer science, and other disciplines will be critical to these kinds of innovative, community-engaged, and applied research efforts.

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