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Participatory mapping in low-resource settings: Three novel methods used to engage Kenyan youth and other community members in community-based HIV prevention research

Eric P. Green, Ph.D.^{a,*}, Virginia Rieck Warren, B.A.^a, Sherryl Broverman, Ph.D.^{a,b,c}, Benson Ogwang^b, and Eve S. Puffer^{a,d}

^aDuke Global Health Institute, Box 90519, Durham, NC, USA

^bWomen's Institute for Secondary Education and Research, Muhuru Bay, Kenya

^cDuke University, Department of Biology, Box 90338 Durham, NC, USA

^dDuke University, Department of Psychology and Neuroscience, Box 90086, Durham, NC, USA

Abstract

Understanding the link between health and place can strengthen the design of health interventions, particularly in the context of HIV prevention. Individuals who might one day participate in such interventions—including youth—may further improve the design if engaged in a meaningful way in the formative research process. Increasingly, participatory mapping methods are being used to achieve both aims. We describe the development of three innovative mapping methods for engaging youth in formative community-based research: ‘dot map’ focus groups, geocaching games, and satellite imagery assisted daily activity logs. We demonstrate that these methods are feasible and acceptable in a low-resource, rural African setting. The discussion outlines the merits of each method and considers possible limitations.

Keywords

participatory mapping; youth; methods; CBPR; Kenya

Introduction

Characteristics of the social and physical environment—the social ecology—can positively or negatively influence the health and well-being of adolescents, including their ability to avoid contracting HIV and other sexually transmitted diseases (Sumartojo, 2000). This environmental/structural view suggests that risk for HIV cannot be solely explained by characteristics of individuals, such as knowledge of HIV transmission or attitudes towards risky sexual behaviour (Blankenship, Friedman, Dworkin, & Mantell, 2006; Coates, Richter, & Caceres, 2008; Gupta, Parkhurst, Ogden, Aggleton, & Mahal, 2008; Latkin & Knowlton, 2005; O'Reilly & Piot, 1996; Sumartojo, 2000; Sumartojo, Doll, Holtgrave, Gayle, & Merson, 2000). The broader social ecology—from micro-level influences such as household

*Corresponding author. eric.green@duke.edu.

resources, neighbourhood disorder (Latkin, Williams, Wang, & Curry, 2005) and social networks (Latkin, Hua, & Forman, 2003) to macro-level factors such as laws and policies (Rojanapithayakorn & Hanenberg, 1996)—can restrict or enhance individual agency to avoid risk (Blankenship et al., 2006). Thus in developing HIV prevention interventions, it is necessary to understand and address social-ecological factors that influence HIV transmission in a particular context.

Various frameworks have been offered to classify these extra-individual factors that influence HIV risk and also serve as points of intervention (Barnett & Whiteside, 2002; Sumartojo et al., 2000; Sweat & Denison, 1995), yet our knowledge of where and how to best intervene throughout the social ecology remains limited. In large part, prevention efforts have focused on the individual while research on the social determinants of risk has concentrated on the structural (or societal) level, such as poverty—the two extremes of the social ecology.

In the HIV prevention intervention literature, for instance, most interventions have attempted to change characteristics of individuals, not environments or social structures (DiClemente, Salazar, & Crosby, 2007). Though individual-level approaches have proven to be efficacious in the short-term, effects typically diminish over time. There is some indication that multilevel interventions increase the likelihood of reducing risk behaviours (Coates et al., 2008), though there is limited empirical evidence on the effectiveness of ‘structural’ approaches to HIV prevention (Gupta et al., 2008).

On the other hand, and with a few notable exceptions (Campbell, 1997, 2003), research on the social determinants of HIV risk has too often been silent on the local mechanisms of disease transmission—finding, for instance, that poverty is an important risk factor for HIV without articulating *how* poverty increases risk in a particular setting. Thus the conclusion of this research is often limited to general prescriptions for change (Blankenship et al., 2006) rather than specific targets for intervention.

Concordant with the growing recognition of the role of social-ecological factors in disease transmission and the benefits of intervening at multiple levels, there is a specific need for knowledge of how the immediate physical and social environments increase behavioural risk factors for HIV and are amenable to sustainable change. Social settings represent important proximal targets for intervention that would complement individual- and structural-level approaches.

The systematic study of social settings, however, has been frustrated by measurement challenges (Blankenship et al., 2006; Gupta et al., 2008; Poundstone, Strathdee, & Celentano, 2004) and an emphasis on individuals as the unit of analysis (Tseng & Seidman, 2007). We lack critical information on setting development, functioning, and outcomes. This study directly addresses these limitations by developing and evaluating new methods for collaborating with local communities to understand social settings.

Frameworks for studying social settings

The social-ecological perspective (Bronfenbrenner, 1979; Moos, 1974; Moos & Bromet, 1986) offers a useful framework for conceptualizing the transactional relationships between individuals and their environments that increase or decrease HIV risk. In Bronfenbrenner's concentric circle model, the individual is placed at the centre of an expanding system of inter-related environmental influences—from the immediate family to the neighbourhood to the broader context of culture, time, laws, and policies. Poundstone and colleagues presented a similar model specific to HIV transmission dynamics that diagrams individual, social, and structural factors (Poundstone et al., 2004). The current study draws upon two publications that advanced the study of social settings: (a) Tseng and Seidman's systems framework (Tseng & Seidman, 2007) for understanding youths' social settings; and (b) Latkin and Knowlton's (2005) application of Barker's concept of behaviour settings (Barker, 1963, 1978; Barker & Gump, 1964; Barker & Wright, 1954) to HIV prevention.

Social settings

Tseng and Seidman (2007) made a major contribution to the field by advancing a systems framework for understanding youths' social settings. Interested primarily in the end goal of setting-level interventions, the authors described social settings as consisting of several systems that are amenable to change, including resources (e.g., human, economic, physical, temporal), the organization of resources, and proximal social processes—the interactions between people and their everyday environments. This conceptualization of youths' social settings can inform our understanding of the context of HIV prevention and ultimately identify targets for intervention. How are resources physically organised in communities, and how does this organisation impact daily social processes? Where do youths spend their time? Are there certain geographic locations that are associated with risky behaviours like transactional sex? If so, what are the social norms and relationships that characterize these locations? How could resources (e.g., parental monitoring) be rearranged to alter these social processes? Broadly speaking, what is the immediate social ecology of the risky behaviours that could be targets for interventions?

Behaviour settings

Another useful conceptual framework for studying the role of social settings in HIV transmission is Barker's notion of behaviour settings that describes how particular settings are associated with defined patterns of behaviour (Barker, 1963, 1978; Barker & Gump, 1964; Barker & Wright, 1954). Applying this theory to HIV prevention, Latkin and Knowlton (2005) described a behaviour setting as '...a venue in which individuals may be linked by various forms of social interaction and meaning-imbued physical space and attendant behaviour norms' (p. xx). The authors cited research on drug users in American cities to explain how certain settings are governed by routine behaviours that are associated with increased risk—for example, sharing needles in shooting galleries. HIV risk is further elevated in these environments by the clustering of high-risk people who adhere to the norms of the setting.

Developing innovative methods for studying social settings

In designing this study, we set out to address the measurement challenges that limit progress in developing interventions and evaluating social settings. As part of a broader mixed-methods approach that included surveys, interviews, and focus groups with a broad range of community stakeholders (Puffer et al., 2011; Puffer, Watt, Sikkema, Ogwang-Odhiambo, & Broverman, 2012), we developed and tested several innovative participatory mapping methods for collecting data on social settings and involving youth in the process.

Participatory mapping

In the past decade, geospatial technologies—which include geographic information systems (GIS), remote sensing (e.g., satellite imagery), and global positioning systems (GPS)—have emerged as useful tools for studying contextual and social-ecological aspects of communities across the social and behavioural sciences (Luke, 2005). This is particularly true in quantitative domain (Goodchild, Anselin, Appelbaum, & Harthorn, 2000), but there have also been interesting applications to qualitative research (Elwood, 2006; Knigge & Cope, 2006).

GIS technology itself dates back to the 1960s, but early work was limited to technical audiences. As GIS became more integrated in planning and policy over the years, a new approach called ‘Public Participation GIS’ (PPGIS) grew out of a concern that the non-technical public would be excluded from the policy-making process (Obermeyer, 1998). Different variations on this approach have since emerged, and PPGIS has been classified more generally as a subtype of ‘Participatory GIS’ (PGIS; Dunn, 2007). In general, PGIS models seek to incorporate local knowledge through public participation. In public health, community psychology, and other health-focused disciplines, the same concerns about integrating local knowledge and pursuing wider public participation have been addressed under the framework of community-based participatory research (CBPR; Israel et al., 2008; Jason, Keys, Suarez-Balcazar, Taylor, & Davis, 2004). Proponents of these participatory methods assume that the knowledge derived from CBPR, like PGIS, will be more representative, will gain access to data not available with standard methods, and will be more useful in addressing health concerns of research participants (Jason et al., 2004; Townley, Kloos, & Wright, 2009), including children and youth (Jacquez, Vaughn, & Wagner, 2013; Vaughn, Wagner, & Jacquez, 2013) and populations affected by HIV and AIDS (Puffer, Pian, Sikkema, Ogwang-Odhiambo, & Broverman, 2013).

The literature on participatory mapping approaches with young people is small but growing. Youth have been active participants in community mapping (Lundine, Kovacic, & Poggiali, 2012) and spatially-informed public health evaluation (Amsden & VanWynsberghe, 2005), as well as key informants about community life and local context (Literat, 2013; Pearce et al., 2009; Robinson & Oreskovic, 2013). Innovative methods for exploring how youth interact with their environment have been developed, including Participatory Photo Mapping (Dennis, Gaulocher, Carpiano, & Brown, 2009), Ecological Interviews (Mason, Cheung, & Walker, 2004), and GPS tracking (Oreskovic et al., 2012). The current study adds to this literature by introducing methods suitable for low-resource settings: ‘dot map’ focus groups; geocaching games; and satellite-imagery assisted daily activity logs. Our focus in this article

is the implementation of these methods, rather than the specific results of using the methods to study the ecological nature of HIV risk in this particular setting. We focus on the latter only to the extent necessary to explain how the information gathered could be useful to researchers and program planners.

Methods

Setting and participants

This study took place in 2009 in Muhuru Bay, a small fishing town located in Kenya's (former) Nyanza Province and situated on the shores of Lake Victoria and the country's northernmost border with Tanzania. Two factors influenced the decision to work in Muhuru Bay: (i) this region of Kenya has the highest prevalence rate of HIV in the country—14.9% at the time of the study; (ii) our study was part of a larger HIV prevention intervention development effort based in this community (Puffer et al., 2013).

At the time of fieldwork, Kenya had five administrative levels: provinces (8), districts (46), divisions (262), locations (2,427), and sub-locations (6,612). Muhuru Bay Division had 4 locations and 8 sub-locations. Following enactment of the new constitution that voters approved in 2010 and the elections in 2013, a system of devolved government took effect and counties and sub-counties became the new administrative levels, replacing the existing structure. Muhuru Bay is located in the newly formed Migori County (population 1,028,579).

As described below, activities involved youth ages 10 to 18, their parents, their teachers, community leaders, and health workers from local medical facilities. Recruitment strategies are described in (Puffer et al., 2011) as this study was part of a larger effort.

Procedures

This study was conducted in four stages. In the first stage, the research team worked with the local community to develop a digital basemap, a basic map of the community depicting boundaries, main roads, and points of interest such as schools. The research team then conducted mapping activities and focus groups with youth, parents, and teachers and used the results to design a participatory mapping game for youth. In the final stage, youth participated in individual mapping interviews to document daily activities.

Community mapping

The goal of the first stage was to create the basemap of the community. A team of three young adults, including author BO, were recruited from the community and trained to use consumer grade, handheld GPS devices to identify and locate community features that would be used to create the map. This step was necessary because the community did not have accurate paper or digital maps. The only paper map of the community that we found was a hand-drawn poster (not to scale) that was several years old and in poor condition. We were able to locate a shapefile—a common spatial data format for depicting points (e.g., villages), lines (e.g., roads), and polygons (e.g., administrative boundaries)—that outlined

the division, and we used this as the extent of our basemap; the metadata for this file could not be located.

The mapping team created all of the other features by traveling throughout the division over the course of two weeks to capture waypoints (coordinates of latitude and longitude depicting specific locations) and routes (strings of coordinates depicting the path traversed). To complete this work, the team talked with dozens of residents they encountered and crosschecked information about location and sub-location boundaries with these informants. There were no paved roads in the division, so most of the work was done on foot or by motorbike. High-resolution satellite imagery (less than 0.5 meters) captured a few months prior by the GeoEye-1 satellite was used to guide the team's efforts (Chen, 2008). With imagery of this resolution, it was possible to identify ground structures and distinguish between buildings and dwellings. We used the imagery to plan daily mapping activities and resolve discrepancies in field-mapped waypoints and routes. All spatial data were compiled into basemap layers using the free, open-source desktop GIS program *QGIS* (version 1.1; QGIS Development Team, n.d.).

Dot map focus groups

Once the basemap was finalized, 'dot map' focus groups followed to identify important places within the community with an emphasis on locations of positive and negative youth activity. Paper copies of the basemap were printed and presented to focus group participants (see Figure A1 in the Online Appendix). A total of 15 focus groups involving 82 individuals were conducted: 1 with health workers ($n=5$); 1 with traditional male chiefs ($n=7$); 1 with women leaders ($n=4$); and 12 with parents ($n=26$), teachers ($n=16$), and youth ($n=24$) across the 4 locations (segmented by school and parent/teacher/youth). Each participant was provided with one paper copy of the map and a sheet of coloured sticker dots (1/8 inch diameter). Two members of the research team (one American and one Kenyan) facilitated the group activities and discussion. The Kenyan team member translated English to Dholuo and vice versa for youth and parent focus groups (other groups preferred to conduct the session in English).

Following a brief orientation to the map, basic map reading knowledge was tested by asking participants to use a sticker to indicate the location of four commonly known points of interest in the community (e.g., the health clinic, a particular beach, a cultural landmark). Participants were then asked a series of questions (e.g., What are places where youth can get into trouble?) and instructed to place certain coloured dots on the map that corresponded to that specific question (see Table A1 in the Online Appendix). Once participants completed the activity, the facilitators asked individuals to explain their maps to the group as a way of initiating discussion about associations between the locations certain types of youth behaviour (e.g., alcohol use).

The resulting paper dot maps (see Figure A2 in the Online Appendix as an example) were scanned and saved in the portable document format (PDF). The PDF of each map was then imported into another desktop GIS program called *ArcGIS* (version 9.3) and georectified (ESRI, 2008). In this process, the digital scans of the paper maps were aligned with the

original digital shapefiles. Once aligned, the centre of each colour sticker was converted into a map waypoint. Each waypoint was linked to the original participant's unique identifier.

Since the map was drawn at a scale of 1:50,000, it was only useful for discussions about the larger community and did not allow participants to pinpoint specific neighbourhood locations. Thus, following the paper map exercise, facilitators used a projector running on generator power (as focus group locations were not on the power grid) to show participants recently captured high-resolution satellite imagery of their local neighbourhoods. The activity began with volunteers locating their homes on the screen as a way of orienting participants to the imagery. Facilitators then continued the discussion from the previous exercise and focused on local community features. The facilitator operating the laptop created digital waypoints that corresponded to locations participants discussed. The activities and discussions lasted 45–75 minutes.

Geocaching games

Stage 3 then aimed to gather more detailed information from youths' perspectives about the locations identified during the focus groups as important to understanding positive youth development and risky behaviour. To do this, the research team designed four photo 'scavenger hunt' games for youth, one for each school participating in the focus group discussions. The games were inspired by the popular outdoor activity called geocaching and the Participatory Photo Mapping method (Dennis et al., 2009). Geocaching is an activity in which participants hide small objects in public places and post the coordinates, or clues to the coordinates, on geocaching websites. Other geocachers then use GPS devices to navigate to the coordinates and find the hidden object. Anyone who locates a geocache may take the object in exchange for another object of similar value.

A different game was organized at each school, and 2 teams of 4 youth from the school participated ($n=32$ overall). Teams were provided with hand-held GPS units (with built-in two-way radios) for navigation, and smartphones with a built-in camera and GPS to geotag locations of photos. They were given list of 5 geocache coordinates to locate that required them to travel a 3 to 5 kilometre route. As they travelled between geocaches along the route, they were instructed to find and photograph locations that fit a list of seven scavenger hunt categories related to youth behaviour, such as places 'where you have seen people having sex' or 'places to have fun'. The research team identified the coordinates and scavenger hunt categories based on the focus group discussions. When teams completed the activities, the youth and the facilitators reviewed the photographs to label them with the appropriate categories and to discuss why the student teams captured the images and what could be learned about the community. The games and review sessions lasted about 90 minutes.

Satellite imagery-assisted activity logs

In the final activity, 325 youth ages 10 to 18 years taking part in a cross-sectional survey of psychosocial correlates of HIV risk behaviour (Puffer et al., 2011) were invited to participate in individual interviews about their daily activities. This sample of youth was randomly selected from student rosters collected from 14 area schools (grade standards 5–8). Pairs of the research team (one American, one Kenyan) interviewed each youth in a private setting.

One member of the team asked questions (see Table A2 in the Online Appendix) and operated a laptop that displayed the high-resolution satellite imagery while the other member of the team recorded the youth's answers on a paper form. Interviews lasted about 20 minutes.

At the start of the interview, the participant described where she lives and the research team navigated to this location on the satellite image. When the participant and the team located the participant's home, the facilitators would mark a digital waypoint (latitude and longitude coordinates) in a shapefile created for the interviewee. The participant then recounted all of her activities on a specific day within the past week, starting with the time and place she woke up. As the participant described where she went throughout the day, the facilitators helped her to identify locations using the satellite imagery. The facilitators created waypoints for each location and recorded the ID numbers on a paper form. The result was a personalized log documenting times, spatial locations, and typical frequency of the participant's activities. As shown in Table A2, the facilitators also asked participants to identify other places where they go (and how often they go there) when they have free time.

Process surveys

Following each study activity, all participants were invited to complete a brief, anonymous survey about their experience. Survey items were translated from English to Dholuo and presented in writing. Kenyan facilitators were available to help any participants who struggled to read the items. Participants responded to each item on a 4 point scale: Strongly Disagree (1); Disagree (2); Agree (3); Strongly Agree (4). Higher numbers represent greater satisfaction.

Analysis

Focus group transcripts were analysed by the research team to identify salient themes and community locations for follow-up investigation during the geocaching games. The georectified dot maps were aggregated in *QGIS* and heat maps were generated using the 'Heatmap' plugin. Heat maps plot the geographic clustering of spatial features, in this case the density of participants' sticker placements. For instance, in Figure 1, part A, darker red patches show locations most commonly identified as places where youth get into trouble. This analysis tool functions by applying kernel density estimation to a set of input points and interpolates a density raster. To create the heat maps shown in Figure 1, the search radius was set to 500 meters and the 'triweight' kernel function was selected to give more weight to closer points. Photographs captured during the geocaching games were labelled by students and summarized. The standard deviational ellipse method of calculating activity spaces (Sherman, Spencer, Preisser, Gesler, & Arcury, 2005) was used to analyse daily activity logs, though those results are not reported here. Summary statistics of dot map placements and counts of photographs by domain were calculated in Stata 12MP (StataCorp, 2011).

Ethical review

The research protocol was reviewed and approved by ethical review boards at Duke University and the Kenya Medical Research Institute.

Results

A total of 316 youth participated in the spatial activity logs, and a subset played the geocaching games ($n=32$) and took part in focus group discussions ($n=24$). Participant demographics are listed in Table 1.

Community mapping

With significant community support, the research team mapped the majority of community features over the course of two weeks. Features included the locations of 72 villages, 65 churches, 32 businesses, 30 primary and secondary schools, 10 beaches, and 1 public medical facility. The team also traced numerous tertiary roads (all unpaved), major footpaths, and the boundaries for all 4 locations and 8 sub-locations within Muhuru Bay Division. A paper map depicting the locations of schools and beaches is shown in Figure A1. A large version of the map was printed for the division's administrative offices and was their first formal map of the community.

Dot map focus groups

Across the 15 focus groups, 81 participants (1 missing) used a total of 1,374 stickers to respond to facilitator questions. An example map from one youth participant is shown in Figure A2. Table 2 reports counts, means, and standard deviations of the number of sticker dots used by each type of participant to identify overall differences in patterns of responding. On average, the traditional chiefs identified 3.1 more 'bad' (red) places for young people to spend time compared to the youth participants. On average, parents and teachers also identified more 'bad' places than the youth.

Figure 1 displays the heat maps of 'bad' and 'good' places pooled across participants. There is no notable overlap in 'bad' and 'good' hotspots, suggesting that participants believe there are defined areas youth should avoid. Figure 2 shows the result of a hotspot analysis of 'bad' places according to adults and youth separately. Adults identified more beaches and a business district known as 'customs' compared to youth. Youth highlighted the dangers of fishing, a common income-generating activity for boys, by placing red stickers in Lake Victoria.

In describing the dangers of local beaches where fishermen disembark and sell their catch to female traders, a 50 year-old participant in the group of women's leaders explained:

It is a bad place because the youth get spoiled in that place...They are getting 'bhang' which they smoke. They get music and they dance, and they even watch videos. These things are bad, and they are spoiled by these things.

A 45 year-old mother of one of the youth participants added:

At the beaches there are different people, especially women who are not having their husbands. They are staying at the beaches, so if the youths go there, these women attract them and engage in sex, so it is a bad place.

The adult participants—and the youth to a large extent—frequently endorsed these sentiments. Health workers made the link between sexual behaviour at beaches and the increased risk of contracting HIV.

Geocaching games

The 8 student teams captured a total of 263 geotagged photos during the geocaching activity (see Table 3). Students classified two-fifths of the photos as locations associated with ‘risky’ behaviours or behaviours that adults labelled detrimental to youth. A total of 40% of the photos were identified as places to have fun.

Process surveys

The results of the process surveys are presented in Table 4. Scores on every item show a high level of satisfaction with little variability. This could reflect excitement over new techniques and technologies that participants had not encountered previously.

Discussion

In this paper we demonstrate three simple participatory mapping methods for engaging youth in research: focus group discussions with a dot map activity and review of high-resolution satellite imagery; geocaching ‘games’, and daily activity geologs. Participants found each activity to be fun, easy, and informative. The ‘hands-on’ nature of the mapping exercises enabled information to flow both ways—from the community to the external members of the research team and from the research team to the community. Through the use of recent, high-resolution satellite imagery, participants gained a new perspective on their community—in a both literal and figurative sense. By anchoring this new perspective in engaging activities, participants and researchers were able to work together to create new knowledge about the community context.

Each method described here offers the researcher or program planner something unique in terms of community engagement and information gathering. Community mapping is an established, but underused methodology. Community members can be involved in a number of ways, from leading the actual mapping to providing input and context. What we call ‘dot map’ focus groups are an easy way to get community input about broad issues that are linked to place. The activity is interactive, and can be used to involve any community member regardless of educational background or literacy. The maps produced represent data about individuals’ perceptions as well as focus group content for further discussion and debate. Geocaching games are particularly well-suited for engaging youth as the activity is designed to make data collection fun. Unlike the focus groups, these games have a hyper-local focus as teams have to walk (or run) a set course. For this reason, the games can be a good follow-up exercise to the broad and introductory focus group exercises. Finally, the satellite imagery-assisted activity logs can elicit individual-level data on youth (or adult) activity spaces without the need to physically visit the home of every participant. Geospatial data can also be linked to more traditional survey data to examine potential associations between place and behaviour.

An essential consideration in technology-based CBPR methods is whether methods match specific contexts. Results of this study suggest that these participatory mapping activities were particularly well-suited for a rural, low-resource environment. The youth who collaborated on this research come from a very poor community located in one of the poorest regions of a low-income country. At the time of the study, few residents had access to reliable electricity. Most adults have not completed secondary school. Food insecurity and health challenges like malaria and HIV steal time, money, and energy from just about every household. Yet none of these traditional ‘barriers’ limited the success of the study.

In fact, the rural backdrop of this work likely increased the probability of success. The community welcomed the research team, and local leaders found value in the ability to use modern technology to create a new community map. Residents guided the mapping team through fields and homesteads in search of a common understanding of boundaries. The absence of land conflict in this community meant that such an exercise did not run the risk of sparking or inflaming local disputes. Furthermore, without many vehicles on the road, it was safe to let youth race through the bush and over green hills, guided by GPS devices as they documented their journey. With relatively few huts dotting the landscape, it was also possible to sit with youth and pan through high-resolution satellite imagery to locate their homes, the places where they fetch water, the routes they travel to school, the areas they avoid, and the spots where they spend time with friends. Other initiatives like *MapKibera* have shown that such work is possible in Kenya's urban slums (Hagen, 2011), but the rural setting makes some aspects of the work easier to manage.

The feasibility of using technology-based participatory mapping tools in very low-resource settings is ever increasing. This makes it a promising approach for future studies in which understanding a community's geography and learning about specific locations can shed light on youths' behaviours and well-being. New tools and technologies are continuing to reduce the cost and difficulty of what was already a relatively inexpensive and easy endeavour in 2009. Smartphone prices are falling as the capability of the most basic models is expanding. When we conducted this work, we determined we needed two devices: a smartphone with a camera and a separate GPS unit for geocaching. If we had conducted the same study 3 to 5 years earlier, we would have needed to exchange the smartphone for a point-and-shoot camera. Today, a single smartphone device would suffice. Increasingly these devices can be found in the pockets of Africa's youth. Mobile subscriptions on the continent will hit 1 billion by 2015 on the way to 1.2 billion by 2018 (Informa, 2013). Smartphone ownership is projected to increase more than 5-fold in the next 4 years, from 79 million to 412 million.

In addition to advances in hardware, there are new software platforms that are lowering barriers to entry. Possibly the most impressive of them is the free, open-source mapping platform OpenStreetMap (Neis & Zipf, 2012; OpenStreetMap, n.d.). Since its founding in 2004, more than 1.5 million registered users have uploaded almost 4 billion GPS points and edited billions of nodes (OpenStreetMap, 2014b). Several browser-based editors make it easy for non-technical users to create free accounts and contribute to the world map (OpenStreetMap, 2014a). We have done this for Muhuru Bay; using the high-resolution satellite imagery provided through OpenStreetMap's license agreements with companies like Bing, we have traced all of the major roads and footpaths in the community (OpenStreetMap

Contributors, 2014). If conducting the study today, we would be able to rely almost completely on this freely available resource and give youth the ability to contribute directly to OpenStreetMap via laptops and smartphone applications. There are also new ‘low-tech’ paper options like Walking Papers that enable citizens to contribute to OpenStreetMap without having access to a computer or smartphone (Migurski & Stamen Design, n.d.).

There is still a need for separate analysis tools, but this space has grown substantially over the past few years as well. We used two propriety software programs over the course of this study—*Stata* and *ArcGIS*—but neither is essential. *ArcGIS* remains the industry leader in GIS, but the free, open-source alternative *QGIS* is capable of most tasks. The R statistical programming package, also free, open-source, and cross-platform, is also capable of carrying out many spatial analyses once only available in *ArcGIS* (R Development Core Team, n.d.).

Especially given this increasing feasibility, these methods also have a secondary community service dimension. First, they include training local community members, including youth, to learn to use new technologies, building both technical and analytical skills. Beyond training in the use of the equipment, which can be valuable, participants and local research team members also learn about the integration of data from different sources (e.g., data from GPS units and satellite imagery) and are exposed to data visualization techniques. As young adults are often the primary demographic serving as local staff for research in such settings, this type of exposure and experience can be motivating and valuable when seeking out future employment and education opportunities. In addition, as these technologies are becoming more accessible, the training equips community members to replicate the methods to answer new questions about their community in the future.

Despite these positives, there are challenges to implementing these methods and limitations to the approach. No amount of technology will ever replace the process of relationship-building with host communities. In this study, even strong endorsements from community leaders and an established presence in the community via a non-governmental organization did not inoculate us to challenges of fieldwork. It is well-known that photodocumentary approaches can make bystanders uncomfortable if photographs are recorded without permission (Wang & Redwood-Jones, 2001). We experienced two occasions in which additional sensitization of the community might have proved helpful. First, as students were racing to document their community during the geocaching games, a few shop owners expressed frustration to the facilitators that they were unaware of the nature of the activity and concerned about the implications. It was easy enough to address their concerns after the fact, but the experience taught us that we should have travelled the route first to introduce the activity to local residents. A similar situation occurred when a member of our research team was detained briefly by the local police for taking a photograph of the police station. The misunderstanding was also easily corrected, but better advance planning might have avoided the encounter altogether. Approval at the highest levels does not always flow quickly or completely to all segments of the community.

Nevertheless, with cheaper, more widely available hardware, easy to use platforms like *OpenStreetMap* with current high-resolution satellite imagery, and free and robust analysis

tools like *QGIS* and *R*, it is possible for participants in low-income communities to participate in every aspect of this research. There will still be barriers to accessing computers and building computer literacy and technical skills for analysis, but barriers to this type of CBPR have never been lower.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Hotspot analysis of "bad" (A) and "good" (B) places for youth to spend time, pooled analysis.

Figure 2.
Hotspot analysis of "bad" places for youth to spend time according to adults (A) and youth (B).

Table 1

Participant demographics.

Participants	Female		Age		Education (years)		Married (%)	
	n	(%)	mean	sd	mean	sd		
<i>Focus groups</i>								
Parents	26	38	40.5	16.6	8.2	3.4		96
Teachers	15	20	35.5	12.3	12.7	0.4		80
Youth	24	50	14.0	1.3	7.3	0.8		0
Chiefs	7	0	50.1	3.7	11.1	1.8		100
Women leaders	5	100	54.3	6.5	9.5	2.6		100
Health workers	4	40	34.2	12.5	12.2	1.3		60
<i>Geocaching</i>								
Youth	32	50						
<i>Activity logs</i>								
Youth	316	51	14.0	1.6	5.6	1.2		0

Note. Age, education, and marital status not documented for youth participants in geocaching game.

Table 2

Count, mean, and standard deviation in the number of stickers used by sticker colour and participant type.

Group	n	Red			Blue			Green		
		count	mean	sd	count	mean	sd	count	mean	sd
Parents	26	134	5.2	2.3	76	7.6	3.5	155	17.9	6.6
Teachers	15	90	6.0	1.9	97	12.9	3.0	89	19.1	4.9
Youth	24	111	4.6	1.6	105	8.8	2.9	96	12.0	5.8
Chiefs	7	54	7.7	0.5	54	15.4	1.5	56	24.0	0.0
Women leaders	5	15	3.8	1.0	32	16.0	0.0	28	21.0	4.2
Health workers	4	10	2.0	1.0	31	12.4	5.0	12	7.2	3.4

Note. Chiefs were not asked the question about parental supervision, thus they used zero yellow stickers. See Table A1 for the link between sticker colour and focus group questions.

Table 3

Photo descriptives.

Photo Tags	Tagged photos	% of Tags	% of photos (263)
Places where alcohol can be purchased	27	9.3	10.3
Places where you have seen people doing drugs	34	11.7	12.9
Places where you have seen people having sex	34	11.7	12.9
Places where you buy items for your family	57	19.7	21.7
Places to have fun	38	13.1	14.4
Places to watch videos	15	5.2	5.7
Important places	83	28.6	31.6
Other	2	0.7	0.8
<i>Total</i>	<i>290</i>	<i>100.0</i>	<i>110.3</i>

Note. Photos could be tagged with more than category, so the final column (percentage of photos) exceeds 100%.

Table 4

Process survey results.

Process questions	Youth (n=24)		Parents (n=26)		Teacher (n=15)		Chiefs (n=7)		Women leaders (n=5)		Health workers (n=5)		All (n=82)	
	m	sd	m	sd	m	sd	m	sd	m	sd	m	sd	m	sd
<i>Focus groups: Sticker dots and satellite imagery</i>														
I liked putting stickers on the maps to share my views about Muhuru Bay.	4.0	0.0	3.9	0.3	3.6	0.8	4.0	0.0	4.0	0.0	3.6	0.6	3.9	0.4
I thought it was easy to use stickers to share my views about Muhuru Bay.	4.0	0.2	3.8	0.4	3.7	0.8	3.9	0.4	3.8	0.5	3.6	0.6	3.8	0.5
The sticker map I made helped me to explain things about life in Muhuru Bay.	3.8	0.4	3.9	0.4	3.9	0.4	4.0	0.0	3.6	0.6	3.6	0.6	3.8	0.4
I learned something new from discussing everyone's sticker maps.	3.8	0.4	3.9	0.3	3.7	0.5	3.9	0.4	4.0	0.0	3.8	0.5	3.8	0.4
I liked looking at the picture of Muhuru Bay.	3.8	0.5	3.9	0.3	4.0	0.0	3.9	0.4	3.8	0.5	3.4	0.9	3.9	0.4
I thought it was easy to recognize places on the picture of Muhuru Bay.	3.6	0.5	3.9	0.4	3.7	0.5	3.4	1.1	3.4	0.6	3.6	0.6	3.7	0.6
I learned something new from discussing the picture of Muhuru Bay.	3.9	0.3	3.9	0.3	3.8	0.4	4.0	0.0	4.0	0.0	3.8	0.5	3.9	0.3
<i>Geocaching games: Youth only (n=41)</i>														
I liked using the GPS units.	4.0	0.2												
I liked using the camera phones.	4.0	0.0												
I thought it was easy to find places using the GPS units.	4.0	0.2												
I thought it was easy to use the camera phones.	4.0	0.2												
I thought the game was fun.	4.0	0.2												
I liked seeing my team's photos on the computer.	4.0	0.0												
<i>Activity logs: Youth only (n=323)</i>														
I liked looking at the picture of Muhuru Bay.	3.9	0.3												
I thought it was easy to recognize places on the picture of Muhuru Bay.	3.8	0.5												
I could recognize my home and places around my home.	3.9	0.4												
I learned something new from discussing the picture of Muhuru Bay.	3.9	0.4												

Note. Participants were invited to complete anonymous surveys following each study activity. Response options: Strongly Disagree (1); Disagree (2); Agree (3); Strongly Agree (4). The number of youth completing process surveys for the activity log exercise exceeded the number of youth who actually completed the exercise by 7.