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Research Paper

The usability of unmanned aerial vehicles (UAVs) for measuring park-based physical activity

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ABSTRACT

While various observation techniques have been developed to measure park use or park-based physical activity, no study has used unmanned aerial vehicles (UAVs) to do so. Thus, this study develops a new observation method that uses UAVs to survey park-based physical activity. This study tests the inter-rater reliability and criterion validity of the UAV-using observation method in comparison to an existing on-the-ground observation tool in five diverse urban parks in Salt Lake City, Utah. With a systematic observation tool, SOPARC (System for Observing Play and Recreation in Communities), this study finds that the UAV observations show a high level of inter-rater reliability (ICC = 0.99 for a total number of users). In addition, compared to the results of on-the-ground observations using SOPARC, those of UAV observations demonstrate validity (ICC = 0.98 for a total number of users). Compared to existing methods, the UAV observation tool, covering larger target areas, is suitable for counting park users in a more reliable and efficient way and mapping their use patterns; however, the tool is weaker at collecting detailed user information and surveying under poor weather conditions. Thus, the UAV method could complement existing tools. Finally, this study suggests practical implications of the UAV observation method.

1. Introduction

More than half of adults and about a third of American children in the United States are overweight, and the percentages of both have more than tripled since the 1960s (Fryar, Carroll, & Ogdenet, 2014). Regular physical activity could provide significant health benefits for people of all ages, including reduced abdominal obesity (U.S. DHHS, 2008). An attractive, free (or low-cost) setting in which people can engage in such activity is urban parks (Bedimo-Rung, Mowen, & Cohen, 2005; Henderson and Ainsworth, 2001). Measuring park usage is a prerequisite to an understanding of which factors (e.g., park design, accessibility, neighborhood characteristics) are associated with park use and park-based physical activity (Akpinar, 2016; Baran et al., 2014; Cohen et al., 2010; Floyd, Spengler, Maddock, Gobster, & Suau, 2008; Giles-Corti et al., 2005; Grow et al., 2008; Kaczynski, Potwarka, & Saelens, 2008; Kemperman & Timmermans, 2006; Koohsari, 2013; Leslie, Cerin, & Kremer, 2010; Loukaitou-Sideris & Sideris, 2009; McCormack et al., 2010; Mowen, Orsega-smith, Payne, Ainsworth, & Godbey, 2007; Özgüner, 2011; Parra et al., 2010; Ries et al., 2009; Schipperijn et al., 2010; Wendel, Zarger, & Mihelcic, 2012; Westley et al., 2013).

Direct observation by human observers is a commonly-used objective tool for measuring park use (Cohen et al., 2011 Goličnik and Thompson, 2010 McKenzie, Cohen, Sehgal, Williamson, & Golinelli, 2006) while there are several subjective tools that rely on individual self-reporting such as questionnaires (Floyd et al., 2008; Giles-Corti et al., 2005; Grow et al., 2008; Kaczynski et al., 2008; Loukaitou-Sideris & Sideris, 2009; Parra et al., 2010) or interviews (Byrne, 2012 Gidlow & Ellis, 2011; Krenichyn, 2006; McDonald & Price, 2009; Tucker, Gilliland, & Irwin, 2007; Veitch, Salmon, & Ball, 2007; Wendel et al., 2012). In direct observation, a researcher observes the activities of humans rather than intervening in their behavior and asking questions and then documents, analyzes, and interprets the user behaviors to understand how they use space (Gehl and Svarre, 2013). The strength of direct observation is that it allows for the collection of data on a large number of people within a relatively short time period without placing a burden on participants (Cohen et al., 2011). Also, it allows for collecting environmental information in addition to the user data (McKenzie & van der Mars, 2015).

One of the most systematic and popular tools for human observation in a park setting is SOPARC (System for Observing Play and Recreation in Communities), developed by McKenzie et al. (2006). SOPARC uses "momentary time sampling techniques," in which researchers systematically and periodically scan individuals and contextual factors within

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pre-determined target areas (McKenzie et al., 2006). The reliability and validity of this method have been tested and confirmed in numerous studies (Baran et al., 2014; Chung-Do et al., 2011; Cohen et al., 2011; Rung, Mowen, Broyles, & Gustat, 2011). Other approaches for direct observation of park use include behavioral mapping (Cosco, Moore, & Islam, 2010; Project for Public Spaces, Inc, 2000; Marušić & Marušic, 2012) and the gate method (Zhai & Baran, 2016).

The observational methods of these studies, however, entail several limitations (Engelhard et al., 2001; McKenzie & van der Mars, 2015). One is that direct observation, requiring multiple trained observers and visitations to obtain valid estimates, incurs considerable cost in both time and money. In addition, because of the influence of observers on data collection, the collected data are not purely objective. Finally, an observer can scan only one area of a park at a time, not an entire park or its surrounding areas.

Some studies have used a time-lapse video camera for visitor monitoring, setting cameras in fixed spots (Arnberger, Haider, & Brandenburg, 2005; Guillén et al., 2008). However, such methods of video monitoring are more conducive to use in small plazas or trails rather than large urban parks having multiple entrances. In certain circumstances such as a high density of users, video recording has an advantage over counting by human observers. Arnberger et al. (2005) showed that while the two methods did not generally differ, the accuracy of observers' counting is lower at high use levels, so video recording is recommended for more accurate and lower cost observations.

To overcome some of the above limitations, this study explores the usability of unmanned aerial vehicles (UAVs), also known as drones, in park use studies. UAVs carrying a video camera combine the advantages of human observation and video recording. As UAVs cover a greater area in a shorter amount of time than other methods, they are expected to save time and money required for data collection. UAV-recorded video files allow for post- data processing and validation (Lenhart, Hinz, Leitloff, & Stilla, 2008). In addition, as they capture not only the number of people but also their activities, attributes, and spatial patterns in a more accurate way, they are also more informational.

This study develops a new observational method that uses UAVs in surveying park-based physical activity and tests its reliability and validity. The use of UAVs has become popular in environmental studies such as geology (Vasuki, Holden, Kovesi, & Micklethwaite, 2014), forestry (Getzin, Wiegand, & Schoning, 2012; Lin, Jiang, Yao, Zhang, & Lin, 2015), agriculture (Torres-Sanchez, Pena, de Castro, & Lopez-Granados, 2014), and transportation engineering (Coifman, McCord, Mishalani, Iswalt, & Ji, 2006), but to date, no study has tested UAVs in observations of park use. A more efficient and reliable observation tool could lead to savings in both cost and time for planners and designers.

2. Methods

2.1. Study sites

We selected five neighborhood parks—Laird Park, Reservoir Park, Wasatch Hollow Park, Donner Trail Park, and Liberty Park—in Salt Lake City, Utah, based on their diversity in size, park type, and facilities (Table 1). The parks, which range from 1.54 (a small neighborhood park) to 96.49 acres (a regional park), all have a playground and green space in common, and the largest also has a swimming pool, basketball/volleyball/tennis courts, and a greenhouse.

We conducted field observations during weekday afternoons (3 p.m. to 6 p.m.) in October 2016. Before the field survey, the researchers divided each park into several target areas that could "be scanned from left to right without encountering visual obstructions and that [were] of a manageable size so that all individuals [could] be counted accurately" (Cohen et al., 2014: 11) following the SOPARC tool. The target areas were the same for both UAV and human observations, which enabled direct comparison between the two tools. The number of target areas per park varied from 1 to 16 and the average target area was about 4 acres. The number of target areas was 25, but as three of them were empty at the time of observation, the analysis included only 22. This study entailed the use of a quadcopter, commonly referred to as a drone. The specific model was a DJI Phantom 3 Advanced, which carried a fully stabilized three-axis 2.7 K video camera.

2.2. Observation methods

Each UAV observation in a park was conducted in three steps: 1) An operator planned the flight path by considering boundaries, obstacles, and park users; 2) after flying the UAV up to an appropriate height (around 30 feet, see Fig. 2), the operator set flight waypoints on the pre-planned path; and 3) the UAV automatically flew through the waypoints and recorded the area (Fig. 1). After the on-site flights, an assessor collected data on park users from the recorded videos. To test inter-rater reliability, an additional assessor watched the same video. Every UAV operation followed safety regulations set forth by the Federal Aviation Administration, and the researcher obtained approval from both IRB (approved July 29, 2016) and the municipal park department.

To test the appropriateness and effectiveness of UAV as a method for collecting park use data, this study compares results of the UAV-using approach with those of on-the-ground observations. To be specific, for both types of observations, this study entailed the use of the systematic observation tool, SOPARC. As introduced in the previous section, SOPARC is a reliable and valid observation tool for assessing park use, including the physical activity levels, genders, and ages of park users (McKenzie et al., 2006). During an area scan (i.e., an observation sweeping from left to right), the activity of the individual was coded as sedentary, moderate, or vigorous. Summary counts describe the number of users by gender and age group. Because one observer collected data on the site, on-the-ground observations using SOPARC were conducted immediately after the UAV flight so that the time differences between the two measurements were minimized (Fig. 1). For the reliable utilization of the SOPARC tool, the observer was trained using multiple SOPARC materials such as protocols and training videos found at the Active Living Research website (http://activelivingresearch.org/soparc-system-observing-play-and-recreation-communities).

Before data collection, the researchers conducted a preliminary

Table 1
Study Sites.

Name	Size (Acre)	Target Areas	Facilities
Laird Park	1.54	1	Playground, Lawn
Reservoir Park	5.45	2	Playground, Lawn, Tennis courts
Wasatch Hollow Park	7.68	3[a]	Playground, Lawn, Creek trail
Donner Trail Park	11.95	3[a]	Playgrounds, Lawn, Trail
Liberty Park	96.49	16[a]	Playground, Lawn, Picnic Areas, Swimming Pool, Basketball/Volleyball/Tennis courts, Jogging path, Greenhouse, etc.
Total		**22**	

[a] This indicates that one target area in the park had no users at the time of observation, and thus, is excluded in the data collection. As a result, the total number of target areas included in the analysis is 22.