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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.

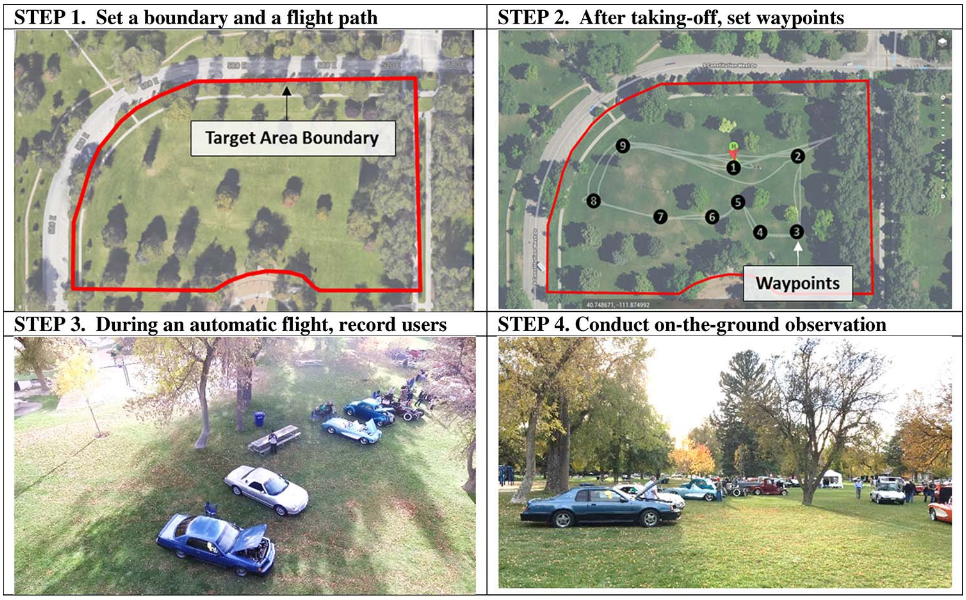

Fig. 1. A UAV observation process (Note that on-the-ground observation is conducted to check the validity of the UAV observation).

flight to determine an appropriate height for flying the UAV. Fig. 2 indicates that a height of no more than 30–40 feet may be the limit at which the UAV is able to identify the gender, age, and activity level of park users for SOPARC data collection. The flying height represents a tradeoff between data accuracy and flight safety because a too low height creates a greater risk of the UAV colliding with obstacles (e.g., large trees). Also, a low flying UAV might attract greater attention from park users, interfering with or altering their behaviors, which should be avoided in a direct observation study (Zeisel, 2006). Thus, this study set a height of 30 feet for flying the UAV but allowed for slight adjustments, depending on the presence of obstacles.

2.3. Analyses

To check for the inter-rater reliability of UAV observations, this study used intraclass correlation coefficients (ICCs) as a measure of agreement. Using ICCs, researchers analyze the consistency, or conformity, of measurements taken by multiple observers measuring the same quantity (Gwet, 2014; Shrout and Fleiss, 1979). The ICC method was also used in previous studies using SOPARC (Banda et al., 2014; Cohen et al., 2011, 2016; Han et al., 2016). This study calculated the ICCs between data from a primary observer and those from an additional observer watching the same video files taken by the UAV. Not only for the number of all park users, but the reliability was also computed by gender, age, and physical activity levels. In addition, by calculating the ICCs between data collected through UAV and human observations, this study was able to analyze concurrent validity, a type of criterion validity; that is, it compared the results of the new measurement tool (i.e., the UAV) to those of a criterion or well-established measurement tool (SOPARC, by human observers). Finally, from an analysis of field notes taken during each observation, this study suggests practical implications of the new method for studying park users and park-based physical activity. A similar method using the UAV for measuring park use has been tested in a preliminary study of urban parks in Busan, South Korea (Park & Park, 2016). Lastly, in order to assess the feasibility of the UAV observation, this study compares the cost and time spent on both methods.

3. Results

3.1. Summary of on-the-ground and UAV observations

In the 22 target areas of the five parks, 394 users (an average of 17.9 per target area) were counted from the on-the-ground observations (Table 2). The number of users per park ranged from 11 (Donner Trail Park) to 319 (Liberty Park). The largest number of observations of users took place in Liberty Park because of its sixteen target areas and regional-park status. The minimum number of observed users per target area was 1, and the maximum was 62, a huge variation. In the same areas, 379 users (an average of 17.2 per target area) were observed through the UAV observations (Table 2).

On-the-ground observations recorded slightly more male users (9.3 persons on average) than female users (8.6). The primary age group was adults (10.9 persons), followed by children (3.9), seniors (2.0), and teenagers (1.1). The most common activity was walking (8.6 persons), followed by sedentary activities (7.6), and vigorous activities (1.4).

Next, the time needed for two observation methods are compared in Table 3. On-the-ground observations required approximately 77 min in total for 22 target areas. Assuming that a SOPARC requires two observers for checking inter-rater reliability, the total time would be 154 min, or 7 min for two observers per target area. On the other hand, the UAV observations required 22 min for pre-flight setting, 55 min for actual flights, and 82.5 min for video counts by one observer, meaning 242 min in total for 22 target areas by two video assessors. This equals to 11 min for two observers per target area. This result shows that a UAV observation needs additional 4 min, or additional 36% of the time, per target area under the current research design.

However, as explored in the introduction and discussion sections, a UAV can cover larger areas in one observation than a human observer. If a target area of the UAV observation becomes doubled, the required time will become half − 5.5 min per target area, meaning 1.5 min (or 21%) of time saved compared to the on-the-ground observation. In terms of money spent on both methods, apart from the labor costs for direct observation (which are previously explained by the time spent), the UAV observation requires more as it includes the purchase of a UAV and necessary accessories (approximately $1400) and a test fee for a remote pilot certificate ($150), while the on-the-ground observation might need two tablet computers (approximately $800) if it involves two observers.

3.2. Reliability and validity of the UAV observations

To check the criterion validity of the UAV observation method, this study calculated the intraclass correlation coefficients (ICCs) of the results of the UAV and on-the-ground observations. Table 4 shows the similarity between the average number of users per target area

Fig. 2. UAV-recorded image examples by flight height, gender, age group, activity level, and circumstance.

observed by the UAV (17.2 persons) and observed on-the-ground (17.9). The two methods also exhibit similar numbers in the detailed user categories of gender, age group, and activity level.

From their ICC values, the UAV observations showed high criterion validity (ICC $>$ 0.8) for most user groups and moderate validity (0.8 $>$ ICC $>$ 0.6) for the walking and vigorous activity groups, except the teenager group (ICC = 0.33). The ICCs between the UAV and the on-the-ground observations were highly significant ($p < 0.001$),

Table 2
Summary of on-the-ground and UAV observation.

Category		On-the-ground observation Average (per target area)	Min.	Max.	S.D.	UAV observation Average (per target area)	Min.	Max.	S.D.
Total		17.9	1	62	16.5	17.2	3	60	15.2
Gender	Male	9.3	0	32	8.8	8.3	0	29	7.6
	Female	8.6	0	36	8.6	8.9	1	34	8.4
Age group	Children	3.9	0	26	6.7	4.5	0	35	8.7
	Teenager	1.1	0	8	1.9	0.9	0	3	1.2
	Adult	10.9	1	31	8.6	9.9	2	27	6.9
	Senior	2.0	0	19	4.2	2.0	0	30	6.4
Activity level	Sedentary	7.6	0	35	10.1	7.9	0	37	10.1
	Walking	8.6	0	22	6.0	7.0	0	23	5.2
	Vigorous	1.7	0	9	2.2	2.4	0	9	2.4

* Min.: minimum, Max.: maximum, S.D.: standard deviation.
*Number of target areas is 22.

Table 3
Comparison of total time spent for 22 target areas between two observation methods.

On-the-ground observation	Time spent (min.)	UAV observation	Time spent (min.)
Observation by observer 1	77	Pre-flight setting (e.g. waypoints)	22
		Flights	55
Observation by observer 2 (assumed)	77	Video observation by observer 1	82.5
		Video observation by observer 2	82.5
Total time (min.)	154	Total time (min.)	242
Average minutes per target area	7	Average minutes per target area	11

except in the teenager group. This finding shows that the results of UAV observations correspond well to those of on-the-ground observations.

To check the inter-rater reliability of the UAV observation method, this study calculated the ICCs between data from a primary observer and an additional observer watching the same video files taken by the UAV. Table 4 shows that the two observers saw a similar average number of users per target area (17.2 persons and 17.5 persons). The numbers of detailed user categories of gender, age groups, and activity levels were also similar; that is, the differences in all categories were not statistically significant. From their ICC values, the UAV observations demonstrated a high level of inter-rater reliability (ICC > 0.8) with some exceptions in the “Teenager” (ICC = 0.40) and “Vigorous” (ICC = 0.67) categories (Table 4).

4. Discussion

4.1. Comparison of the two observation methods

In this study, observations by the UAV yielded reliable and valid results. From the results of analysis, field notes, and the literature, we suggest several implications of the UAV observation method compared to traditional tools, as summarized in Table 5.

Table 4
Comparison of on-the-ground and UAV observation: Criterion Validity and Inter-rater Reliability.

Category		Average users per target area: On-the-ground (A)	UAV – observer (primary) (B)	UAV – observer (secondary) (C)	Criterion Validity (A:B) – ICCs [CI]	Inter-rater Reliability (B:C) - ICCs [CI]
Total		17.9	17.2	17.5	0.98 [0.94 – 0.99]***	0.99 [0.97 – 1.00]***
Gender	Male	9.3	8.3	9.5	0.95 [0.87 – 0.98]***	0.96 [0.90 – 0.98]***
	Female	8.6	8.9	8.1	0.95 [0.90 – 0.98]***	0.98 [0.95 – 0.99]***
Age group	Children	3.9	4.5	3.8	0.95 [0.89 – 0.98]***	0.98 [0.95 – 0.99]***
	Teenager	1.1	0.9	1.8	0.33 [−0.09-0.65]*	0.40 [0.00 – 0.70]**
	Adult	10.9	9.9	10.8	0.91 [0.80 – 0.95]***	0.94 [0.86 – 0.98]***
	Senior	2.0	2.0	1.2	0.87 [0.71 – 0.94]***	0.85 [0.68 – 0.94]***
Activity level	Sedentary	7.6	7.9	6.6	0.98 [0.95 – 0.99]***	0.94 [0.86 – 0.97]***
	Walking	8.6	7.0	7.4	0.78 [0.56 – 0.90]***	0.93 [0.84 – 0.97]***
	Vigorous	1.7	2.4	3.5	0.62 [0.29 – 0.82]***	0.67 [0.36 – 0.85]***

Note: 1. ICCs [CI]: Intraclass Correlation Coefficients [Confidence Interval].
* p-value < 0.1.
** p < 0.05.
*** p < 0.01.

Table 5
Comparison between two direct observation methods.

	on-the-ground observation	UAV observation
Advantages	• Easier to conduct • Better for gathering detailed user information	• Larger target area (~1000-foot radius) • Can be used in inaccessible or dangerous areas • Post data collection and checking are available
Disadvantages	• Smaller target area (~300-foot radius) • Blind spot: "behind" obstacles • Less accuracy in populated areas	• More training is needed • More subject to weather conditions • Blind spot: "under" obstacles • Additional time for video watching is needed

For one, a UAV can cover a larger observational area during each scan than a human observer. SOPARC, the on-the-ground observation tool used in this study, sets a target area of a manageable size in which an observer can scan without encountering visual obstructions (Cohen et al., 2014). In cases of high user density or a large number of obstacles such as trees or structures, the target areas are smaller. A UAV, however, can fly farther as long as a remote pilot can see the aircraft. Although this study sets the same size for the target areas (about a 300-foot radius) for direct comparison of the two methods, a UAV could fly as far as about 600–1,000 feet. In addition, a UAV could more easily observe a larger area extending beyond a park. Thus, a researcher could measure neighborhood conditions such as street trees, the number of pedestrians on nearby sidewalks, and automobile traffic. The UAV can also collect data in ways that a human observer cannot because of accessibility or practicality to users engaging in activities such as lake/stream use, rock climbing, or trekking on long, convoluted trails.

As their "blind spots" differ, UAV observation can also complement human or camera observation (Fig. 1). While eye-level observation complicates the identification of users behind visual obstacles such as trees or facilities, bird's-eye-level observation complicates the identification of users under obstacles. In addition, when many users are moving about at the same time, a human may not be able to observe the exact number of users or their activities accurately (Arnberger et al., 2005). By contrast, in UAV observation, a researcher can collect more accurate user data with the support of recorded video. Thus, for a more accurate survey, using both methods in a complementary way is desirable.

We also find that compared to on-the-ground observation, UAV observation is more suitable for surveying the total number of users and patterns of spatial park use than it is for collecting detailed user information such as age or activity levels. Because the UAV enables the observer to watch a video after a field observation, it is more advantageous for tallying an accurate number of users and mapping their behavioral patterns in a park. Although the results show that the UAV method is reliable in counting the number of users by gender, age, and physical activity levels, the assessors watching the UAV-recorded videos reported difficulty discerning detailed user information. Two less reliable categories − "teenager" and "vigorous" groups − are similar to the categories of previous studies utilizing SOPARC (Baran et al., 2014; Bocarro et al., 2009; Cohen et al., 2011; Han et al., 2016), which might be attributed to the following: 1) active users move quickly, so observations of these users at slightly different moments may differ (Cohen et al., 2014) and 2) at a great distance between a person and a UAV, a teenager may look like either an adult or a child. Thus, greater inter-rater reliability requires a more accurate survey protocol similar to that for SOPARC (McKenzie et al., 2006), and a researcher should implement sufficient observer training.

We also contend that UAV observation is more subject to survey conditions such as weather, topography, or surrounding buildings. On a rainy or windy day, flying a UAV is not recommended for safety reasons. Also, if an area contains many large trees, a UAV cannot capture people under the trees in its video well. In this case, the UAV might have to fly under the tree canopy, which requires great care. Fortunately, recently commercialized obstacle-avoidance technologies have reduced the risk of collision during UAV observation (Carloni et al., 2013; Stastny, Garcia, & Keshmiri, 2015).

4.2. Practical implications of UAV observations

When using a UAV to investigate park use, researchers must attend to the following. For one, they must ensure that the remote pilot follows UAV operational rules governed by an aviation administration. For example, on June 21, 2016, the U.S. Federal Aviation Administration (U.S. FAA, 2016) announced a rule called "Operation and Certification of Small Unmanned Aircraft Systems (Part 107)" for small UAVs of less than 55 lbs (25 kg). Part 107 requires that UAV be registered, remain within the visual line-of-sight of the remote pilot, not fly at night or above 400 feet (122 m) above ground level, and so on. A person operating a small UAV must hold (or be under the direct supervision of a person holding) a remote pilot certificate which costs $150 for a test in the U.S. One important rule of Part 107 regarding park observation is that a UAV must not fly directly above people. However, to observe park users, avoiding flying directly above people all the time is difficult. In this case, such as in dense urban parks, a UAV operator can request a waiver of specific regulations.

Researchers must bear in mind that the deployment of UAVs in civil applications raises safety, ethical, and privacy issues (Finn & Wright, 2012; Rapp, 2009). When a UAV crashes in a park, it could seriously injure people or damage vegetation, facilities, and/or the ground. UAVs operating at a lower level could be claimed as either a nuisance because of its noise or trespassing by nearby homeowners (Finn & Wright, 2012). The researchers contacted 21 municipalities in the Salt Lake region in Utah to check the legality of flying a UAV for research proposes and found that none had local ordinances regulating UAV flights. However, some refused the request for UAV flights in local parks because of concerns about the general safety of the public and the privacy of individuals. Therefore, UAV researchers need to assess these potential issues carefully. For instance, one legal review (Finn & Wright, 2012) found that while a UAV flight within or too close to a private property might lead to trespass or nuisance claims by homeowners, privacy claims are limited to wherever "a UAV captures images that could have been obtained from civilian aircraft travelling in a legally authorized manner" (p. 642), that is, data already available to the public. As the use of UAVs becomes more popular with the public, a survey using a UAV in a public space may raise fewer concerns.

For both safety and reliability, researchers must ensure the provision of sufficient training to UAV pilots in advance and conduct a preliminary survey of park sites. If the observation process involves too much variation in data among different observers, observation data will not be reliable. Thus, researchers need to prepare an observation protocol, including the observation process, flight waypoints, speed, and height, a camera shooting method, and so on. In a preliminary survey, researchers could finalize the target areas and set the flight paths accounting for visual obstacles and human gathering sites. They could also set the flight height according to a survey purpose. For an accurate count of the number of users, a UAV could fly high (e.g., 100 feet) with minimum movement. On the other hand, to collect detailed user information, it must fly lower and more slowly (e.g., 30–60 feet) and observe park users more carefully.

Researchers must also minimize the effects of a flying UAV on the behavior of park users. To record natural activities of individuals in direct observation, an observer should not intervene in human activities (Zeisel, 2006). To meet this goal, the UAV pilot in this study spent time pre-flying before the actual recording so that the users became accustomed to the presence of a UAV. As a result, the number of individuals that stopped their activities to watch the drone was only one or two in most target areas. However, when the target area was a playground with many children, more users watched or followed the flying UAV. In this case, longer pre-flights at higher and farther distances could reduce its intervention in children's activities.

4.3. Limitations

As a preliminary study examining the usability of a new observational method, this research involves several limitations. One was the limited size of the target area, which allowed for a direct comparison to the on-the-ground observation. However, as this study has found that a UAV could cover a larger area, a subsequent study could determine the practical use of UAVs in urban parks by examining larger target areas (e.g., a 600–1,000-foot radius). In addition, the parks in this study might not have been a representative sample of urban parks in the U.S. The average number of people per target area, which ranged from 3 to 60, was 17.2. These numbers are little higher than those of other park studies using SOPARC. In one review paper, Evenson, Jones, Holliday, Cohen, and McKenzie (2016) showed that the average number of people per target area ranged from 0.14 to 37.6. To ensure external validity, further research could include diverse samples. Third, the on-the-ground observation needed to be conducted simultaneously with the UAV flight, considering that SOPARC is a momentary assessment. While the authors acknowledge the necessity of simultaneous data collection between two methods, there was a small time-gap because the additional observer was not available at the time of observation. In spite of it, however, the result table provides high level of criterion validity, which supports the current approach (see Table 4). Finally, this study collected only quantifiable data from UAV observation. As suggested above, the recorded video files included information beyond numbers. For example, a study could analyze spatial use patterns in a park and create behavioral maps. That is, more qualitative or design-oriented usability of UAV observation is open to further research.

5. Conclusions

This study used a UAV to observe people in urban parks and tested the reliability and the validity of the new method by comparing it to an existing one entailing human observation. From a case study in Salt Lake City, Utah, we found that overflights by UAVs are a reliable and valid tool for counting and classifying park users and determining their physical activity levels. The use of UAVs could allow for the consistent and comprehensive monitoring of park use and enable comparative park studies. Then, the extensive park use data could help government officials from multiple departments plan more successful park programs and formulate policies that promote park utilization and park-based physical activities.

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