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Smartphone Icon User Interface design for non-literate trackers and its implications for an inclusive citizen science

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ABSTRACT

In 1996 we developed an Icon User Interface design for handheld computers that enabled non-literate trackers to enter complex data. When employed in large numbers over extended periods of time, trackers can gather large quantities of complex, rich biodiversity data that cannot be gathered in any other way. One significant result in the Congo was that data collected by trackers made it possible to alert health authorities to outbreaks of Ebola in wild animal populations, weeks before they posed a risk to humans. Trackers can also play a critical role in preventing the decimation of large mammal fauna due to poaching. Collectively, the seven case studies reviewed in this paper demonstrate the richness and complexity of scientific data contributed by community-based citizen science. Furthermore, trackers can also make novel contributions to science, demonstrated by scientific papers co-authored by trackers. This may have far-reaching implications for the development of an inclusive citizen science. Community-based tracking can significantly contribute to large-scale, long-term monitoring of biodiversity on a worldwide basis. However, community-based citizen science in developing countries will require international support to be sustainable.

1. Introduction

With the advent of the Anthropocene the world is experiencing a period of rapid environmental change linked to human development (Corlett, 2015), such as habitat change, pollution, and climate change, which may affect ecosystem services gained from wildlife (Roy et al., 2015). Current rates of extinction are about 1000 times the background rate of extinction (Pimm et al., 2014). Monitoring biodiversity hotspots with high levels of diversity, as well as larger coldspots that are home to rare species (Kareiva and Marvier, 2003; Mouillot et al., 2013; Marchese, 2015) is therefore of increasing importance for informing conservation management (Sutherland et al., 2015).

There are too few professional ecologists to deal with the scale of environmental challenges. The development of citizen science has dramatically increased the extent and efficiency of data collection for studies in ecology and conservation (Dickinson et al., 2012; Pocock et al., 2015). Despite considerable differences in countries and cultures Danielsen et al. (2014a) found that community members and scientists produced similar results for the status of and trends in species and natural resources. Promoting community-based citizen science could therefore significantly enrich monitoring within global environmental conventions and enhanced decision making at all levels of resource management (Danielsen et al., 2014b).

However, global biodiversity conservation is seriously challenged by gaps in the geographical coverage of existing information. Wealth, language, geographical location and security each play an important role in explaining spatial variations in data availability. (Amano and Sutherland, 2013). Yet locally based monitoring is particularly relevant in developing countries, where it can lead to rapid decisions to solve the key threats affecting natural resources, and empower local communities to better manage their resources to improve local livelihoods (Danielsen et al., 2008; Danielsen et al., 2014c).

Large mammal fauna in Africa and Asia is being decimated by illegal hunting and loss of habitat. In the future trackers can play a critical role in preventing poaching of endangered species such as rhino, elephant and tigers.

The case studies discussed in this paper will demonstrate the value of employing trackers using smartphones in large-scale, long-term monitoring of ecosystems for conservation management, especially in

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areas in the developing world where there are gaps in the geographical coverage. In particular, trackers can be of great value for monitoring rare and endangered species.

2. The art of tracking and scientific reasoning

The art of tracking involves the creation of a working hypothesis on the basis of initial interpretation of signs, knowledge of the animal's behavior and knowledge of the terrain (Liebenberg, 1990). Since tracks may be partly obliterated or difficult to see, they may only exhibit partial evidence, so the reconstruction of the animal's activities must be based on creative hypotheses. To interpret the footprints, trackers must use their imagination to visualize what the animal was doing to create such markings. With a hypothetical reconstruction of the animal's activities in mind, trackers anticipate and predict the animal's movements and look for signs where they expect to find them. When their expectations are confirmed, their hypothetical reconstructions are reinforced. When their expectations prove to be incorrect, they must revise their working hypotheses and investigate other alternatives.

Tracking involves a continuous process of conjecture and refutation, a characteristic feature of a theoretical science (Popper, 1963), and uses hypothetico-deductive reasoning (Liebenberg, 1990). Some of the predictions made by trackers may result in novel discoveries about animal behavior (Liebenberg, 2013). A significant feature of science is that testable hypotheses enable scientists to predict novel facts that would not otherwise have been known (Lakatos et al., 1978a).

The various continuities between tracking and science seem to be sufficient to warrant the claim that anyone having a capacity for sophisticated tracking will also have the basic cognitive wherewithal to engage in science (Carruthers, 2006). Scientific reasoning may therefore be an innate ability of the human mind (Liebenberg, 2013). This may have far-reaching implications for the development of an inclusive citizen science.

2.1. An inclusive citizen science

Non-literate trackers, or "oralate trackers" (Sienaert, 2006), have made original contributions to science and have co-authored scientific papers (Berger et al., 1993; Berger et al., 1994; Liebenberg et al., 1998; Liebenberg et al., 1999; Stander et al., 1997a; Stander et al., 1997b; Elbroch et al., 2011; Pastoors et al., 2015; Pastoors et al., 2016).

Inclusion, however, should not only be understood from the point of view of professional scientists. It should also be seen from the point of view of communities who may include professional scientists into their traditional knowledge systems. For example, over the last 20 years we have been developing the CyberTracker tracker certification system to recognize traditional tracking skills (Liebenberg et al., 2010; Liebenberg et al., 2013). While the tracker certificates have been mostly awarded to African trackers, we have an increasing number of trackers in the USA and Europe receiving tracker certificates, including professional scientists. From an oralate African tracker perspective, "inclusion" means including professional scientists, among others, into traditional tracking.

In particular, Dr. Mark Elbroch, who received his PhD at the University of California, Davis, is the first tracker outside Africa to receive the Master Tracker certificate, the highest level recognized by CyberTracker. He came to Southern Africa to track with traditional African trackers and now uses his tracking skills to do research on mountain lions in the USA (in addition to using satellite telemetry collars and video camera traps).

Co-author Liebenberg finds himself mid-way between these opposite ends of the inclusive citizen science spectrum and has strived to act as a bridge between these two world views, or paradigms as Thomas Kuhn (1962) would have described them. Born in Africa, he is a self-taught tracker with no formal academic qualifications. As an independent citizen scientist he has published scientific papers in high impact peer-reviewed journals (for example Liebenberg, 2006, 2008, of which the first paper has been cited more than 120 times), and has been appointed as an Associate of Human Evolutionary Biology at Harvard University.

Two centuries ago, almost all scientists made their living in some other profession. The rise of science as a paid profession is a relatively recent phenomenon, dating from the later part of the 19th century. Today, most citizen scientists work with professional counterparts on projects that have been designed to give amateurs a role (Silvertown, 2009). In the future most citizen science projects will rely on standardized field protocols to collect and visualize data necessary to monitor socioecological systems at multiple spatial and temporal scales (Newman et al., 2012).

Shirk et al. (2012) divide "public participation in scientific research" (PPSR) projects into five models based on degree of participation: *Contractual* projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results; *Contributory* projects, which are generally designed by scientists and for which members of the public primarily contribute data; *Collaborative* projects, which are generally designed by scientists and for which members of the public contribute data but also help to refine project design, analyze data, and/or disseminate findings; *Co-Created* projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all aspects of the research process; and *Collegial* contributions, where non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals.

The contractual and collegial models lie at the far boundaries of the PPSR spectrum. Shirk et al. (2012) focus on the center three models, while acknowledging that programmatic innovation often occurs at the boundaries.

The Biological Records Centre, established in 1964 in the United Kingdom, is volunteer led and involves an estimated 70,000 people. Their datasets are long-term, have large geographic extent and are taxonomically diverse. Significantly, many recorders undertake 'individual research projects' on their own or with others or make observations on novel interactions or behavior. They publish these in various journals and newsletters. The aspiration to involve volunteers in all aspects of the scientific process (from design to outputs) has been fulfilled in natural history in the UK for well over a century (Pocock et al., 2015).

The collegial model is exemplified by amateur astronomers, archeologists, and taxonomists, who often work on their own to make important contributions to science (Stebbins, 1980; Hopkins and Freckleton, 2002). In this model, professional and amateur researchers may collaborate only when an amateur writes and submits findings for peer review and publication. Although often overlooked or highly critiqued, committed amateurs can make critical contributions that may not otherwise transpire owing to a lack of resources, time, skills, or inclinations in the professional scientific community. As such, their work demands a reconsideration of expertise as exclusive to traditionally credentialed scientists (Taylor, 1995; Ellis and Waterton, 2005). In these cases, the degree of amateur participation in the research process is so extensive and independent that expert amateurs arguably adopt the traditional role of scientist-as-knowledge-producer (Shirk et al., 2012).

Inclusive citizen science recognizes that there is continuity from professional science on the one end of the spectrum through traditional knowledge among oralate communities on the other end of the spectrum. It strives to break down the barriers between professional scientists and amateur citizen scientists, thereby extending the range and capacity of the scientific community. Charles Darwin, after all, was an amateur citizen scientist.

Developing an inclusive citizen science will enable participants, regardless of their level of education, whether or not they can read or write, regardless of their cultural background, to make original contributions to science.