Developing a Novel Citizen-Scientist Smartphone App for Collecting Behavioral and Affective Data from Children Populations

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Abstract. The paradigm of citizen-science, i.e., scientific research that is conducted in whole or in part by non-professional scientists, has gained popularity lately, e.g., for the purpose of crowdsourced data collection. Smartphones with their abundance and ubiquity are perfectly suited and have been widely used for crowdsourced data collection in real life settings. The ongoing, EC-funded research programme named BigO exploits the citizen-science paradigm to collect behavioral (eating, sleeping and physical activity) and affective (mood) data from children populations by means of a novel smartphone application with the intention of developing a decision support system to assist public health authorities in effective policy making against childhood obesity. This paper presents the development – in the context of BigO – of the myBigO app, one of the first citizen-scientist smartphone applications addressed to children for behavioral and affective data collection. This includes the design, implementation, and deployment of myBigO app in a number of data collection studies as well as its preliminary evaluation with respect to technical robustness and user experience in the context of these studies.

Keywords: mHealth · Citizen-science · Crowdsourced data collection · Behavioral informatics · Children behavior

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1 Introduction

Citizen-science, a relatively new scientific paradigm where the general public is actively engaged in scientific research [1], has gained popularity during the last decade. A popular application of citizen-science is the *crowdsourced collection of data* (for example in hydrology [2]) for a variety of research purposes, in cases where conventional data collection methods are impractical or even impossible. Nowadays, smartphones demonstrate an unprecedented abundance and, owing to their continuous presence in everyday life, are perfectly suited for *ecological momentary data collection* tasks [3]. For this reason, smartphones are commonly exploited by citizen-science initiatives when crowdsourced data collection is needed. However, designing smartphone applications (or apps) for citizen-science projects is a challenging task, since the user engagement and effectiveness need to be taken into account [4].

Focusing on crowdsourcing, there are several citizen-science studies that have employed smartphone apps for the collection of *behavioral data*. For example, the SMART study [5] has used the Ethica[1] smartphone app to collect (1) self-reported physical activity and sedentary behavior data, and (2) sensor-acquired data such as location, inertial measurement unit (IMU) recordings, image/audio files, etc. from 317 adult citizen-scientists. The objective of the SMART study has been to analyze the collected data so as to translate the gained knowledge about active living into policy interventions. The Ethica app itself has been employed in the past by citizen-science initiatives in epidemiology [6]. When it comes to children, there exist past studies where they have been engaged as data collecting citizen-scientists (e.g., [7]). However, to the best of our knowledge there are few – if any – citizen-science efforts that developed smartphone apps specifically designed for children.

Using a similar rationale to [5], the ongoing research programme named BigO[2] relies on the citizen-science paradigm to collect data concerning the *eating, sleeping and physical activity behavior* of children populations by means of a novel smartphone app. BigO undertakes extensive crowdsourced data collection in 6 European cities. The behavioral patterns of the local children populations that will be extracted from the collected data will then be associated with a number of local extrinsic conditions as well as the local prevalence of childhood obesity. These associations will be employed by the decision support system of BigO so as to inform public health authorities about promising policies against childhood obesity.

This paper presents the development of one of the first citizen-scientist smartphone apps that are addressed to children, namely the *myBigO app*. The myBigO app has been developed to support the crowdsourced data collection activities of the BigO programme. The behavioral and affective data that are collected by the app are intended for further analysis in the scope of the BigO programme. The current paper covers (1) the design and implementation of the app; (2) the deployment of the app in a series of data collection studies; and (3) the preliminary evaluation of the app through the aforementioned studies with respect to technical robustness and user experience.

[1] https://www.ethicadata.com/about.
[2] https://bigoprogram.eu/.

2 Methods

The design of the myBigO app has been guided by (1) its *intended usage*, i.e., the collection of behavioral and affective data that are associated with obesity, (2) its *intended user group*, i.e., school-aged children, and (3) its *intended research paradigm*, i.e., citizen-science. These three guides have majorly impacted the eventual functionalities (see Sect. 2.2) and user interfaces (see Sect. 2.3) of the app. For instance, the modern design of the screens and the included features of the app were considered to be appropriate for the age group of its users, while two extra tabs (Maps and Stats tab) were inserted in the Main Screen of the app for the purpose of providing feedback to the users. The data to be collected were carefully selected (see Sect. 2.1) on the basis of unobtrusiveness (e.g., keeping popping questions to a minimum and promoting data collection in the background). All aforementioned design decisions were made with the objective of maintaining the engagement of the users so as to eventually maximize their effectiveness in data collection [4].

2.1 Collected Data

The myBigO app is able to collect data concerning a variety of behaviors of its users (namely, sleeping, eating and physical activity behavior) as well as their emotional state (or mood). Table 1 provides the specification of the behavioral and affective data that are collected. Regarding the data collection process, a hybrid approach was adopted, which includes:

- **Passive data collection.** Collection of objective data from smartphone sensors in the background (e.g., accelerometry measurements).
- **Active data collection.** Collection of objective and subjective data that requires active input from the user; this is further classified as: (1) the user-initiated collection of sensory data such as meal and food advertisement photographs, and (2) the self-reporting of subjective data through ecological momentary assessment (e.g., user mood).

2.2 Functionality

The functionalities that are offered by the myBigO app can be organized into 3 categories based on the context of use and these are outlined in the following subsections.

Registration
This refers to initial, one time use of the app to register the user into the BigO platform. The users go through a typical registration procedure (e.g., reviewing and agreeing to the terms and conditions, entering their registration code and selecting their nickname). The registration functionality entails a certain amount of data collection as well through a series of self-assessment questions. For instance, the sleep and wake-up times for weekdays and weekends (see Table 1) are reported by the user as part of the present functionality.

Table 1. Specification of the behavioral and affective data collected by the myBigO app.

Target data	Collected data description	Collection mode	Collection frequency
Sleep duration	Sleep & wake-up times in weekdays, sleep & wake-up times in weekends	Active; self-reported	Once (at registration)
Mood	User rating in a revised 5-point Wong-Baker scale [8]	Active; self-reported	Once daily
Location	Latitude, longitude, altitude, accuracy, bearing, speed	Passive; sensory	Every minute
IMU data	Measurements from accelerometer & gyroscope	Passive; sensory	5–25 Hz
Annotated meal photos	Meal photo with meal type, temperature, preparation & main ingredients	Active; sensory & self-reported	User defined
Annotated food ad photos	Food ad photo with location, size and context	Active; sensory & self-reported	User defined

Main Usage

This functionality becomes available through the *Main Screen* of the myBigO app, as soon as the registration is completed. The Main Screen consists of 4 tabs:

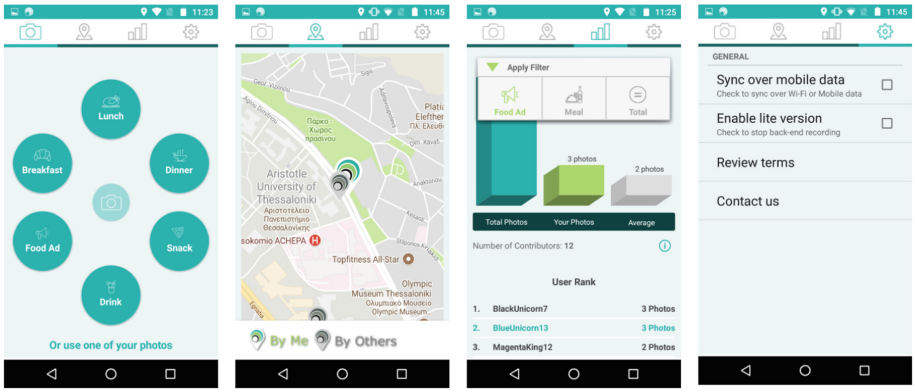
1. the *Action Tab* (default) initiates the process of meal and food advertisement photo acquisition and annotation (see Table 1)
2. the *Maps Tab* displays the locations where food advertisement photos have been captured
3. the *Stats Tab* presents statistics about the contribution of the user and her peers in photo collection, and
4. the *Settings Tab* allows the users to change their preferences and access app-related info.

Background Data Collection

This is a separate, non-interactive functionality of the myBigO app which transparently acquires measurements from the smartphone IMU and GPS receiver (see Table 1). This functionality covers the entirety of passive data collection by the myBigO app.

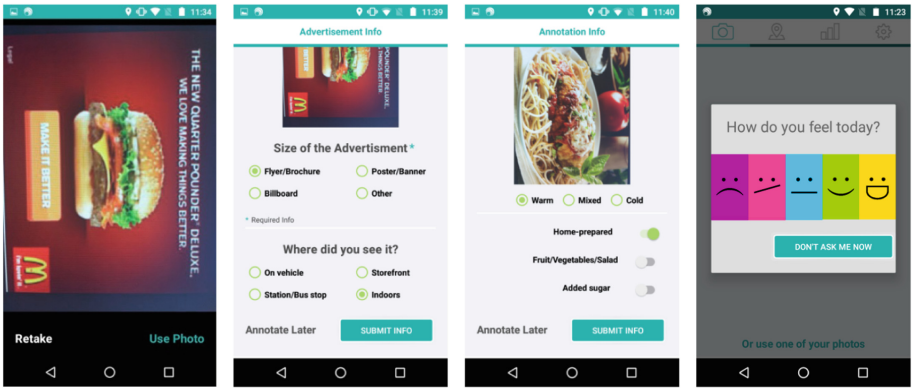
2.3 User Interfaces

The user interfaces (UI) of the myBigO app, i.e., the set of screens that implement the human-computer interaction within the app, have been carefully designed with the help of a professional usability expert. The screens that have been designed for the Main Usage functionality of the myBigO app are presented in the figures that follow with the help of screen captures from a running instance of the app. More specifically, Fig. 1 lists the tabs of the Main Screen, while Fig. 2 presents the screens that are associated with the active data collection in the myBigO app.



(a) (b) (c) (d)

Fig. 1. Tabs of the Main Screen of the myBigO app – (a) action tab, initiating the photo acquisition and annotation functionality; (b) maps tab, displaying the location of the contributed food advertisements; (c) stats tab, presenting statistics about photos contributions; (d) settings tab.



(a) (b) (c) (d)

Fig. 2. UI screens & dialogues associated with active data collection in the Main Usage functionality of the myBigO app – (a) photo preview screen; (b) food advertisement annotation screen; (c) meal annotation screen; (d) mood dialogue.

2.4 Implementation Details

The myBigO app has been developed for Android smartphones running on Android 5.0 to 9.0. Before being released, the app was thoroughly tested in a number of iterative test cycles simulating actual use and putting emphasis on app stability. During the testing phase, SonarQube[3] and Firebase[4] were leveraged for static code analysis and bug tracking, respectively.

3 Results

This section provides information about the deployment of the myBigO app so far for data collection in the context of the BigO programme, along with the preliminary evaluation of the app with respect to the technical robustness and user experience.

3.1 Deployment Studies

Up to this point, the data collection activities of the BigO programme revolved around 3 private schools, namely the *Internationella Engelska Gymnasiet* (IEGS) in Stockholm (Sweden), *Ellinogermaniki Agogi* (EA) in Athens (Greece), and *Ekpaideutiria Mpakogianni* (EKP) in Larissa (Greece). Each school organized and conducted a number of different data collection actions (8 in total) with the myBigO app being the main data collection instrument. Informed consent was acquired from all the participating students in the high school, while in the case of the primary school (EA) informed ascent and consent was acquired from the participating students and their parents, respectively. For the most part, an organized participation strategy relying on school projects (e.g., short-term projects as part of the Physical Activity class) was employed for student recruitment. The overview of the 3 participating schools and the corresponding data collection actions is provided in Table 2.

Table 2. Overview of the 3 participating schools and the corresponding data collection actions.

School	Level	Location	Dates	Nr. participants
IEGS	High school	Stockholm (SE)	11.2017–05.2018	84
EA	Primary school	Athens (GR)	03.2018–06.2018	83
EKP	High school	Larissa (GR)	03.2018–06.2018	38

[3] https://www.sonarqube.org/.
[4] https://firebase.google.com/.

3.2 Technical Robustness

From a technical standpoint, the myBigO app performed considerably well in the previously described deployment studies. No major issues (e.g., problems rendering the app unusable) were reported, while minor issues, such as occasional crashes, were constantly monitored with the help of Firebase and/or reported by the school personnel via Redmine[5]. The recorded issues were investigated, prioritized and then resolved through regular updates of the app. The performance of the myBigO app in its primary task is indicated by the volume of behavioral and affective data that were eventually collected during the deployment studies. Table 3 summarizes the volume of data collected from each school using an abstract categorization of the main types of collected data. In the particular case of the primary school (EA), the food advertisements and the accelerometry data were not part of the data collection actions that were organized by the school – thus the corresponding N/A entries in Table 3.

Table 3. Volume of the main categories of behavior data that were collected per school during the deployment studies.

	Students (#)	Ad photos (#)	Meals photos (#)	Accelerometry (days)
IEGS	84	1886	122	93.2
EA	83	N/A	411	N/A
EKP	38	9	472	196.1
Total	**205**	**1895**	**1005**	**289.3**

3.3 User Experience

User experience is a concept from the field of Human-Computer Interaction which refers to the attitude and emotions of a user towards a product or system. The User Experience Questionnaire (UEQ) is a validated instrument for evaluating user experience [9] and it consists of 26 questions which are rated on a 7-point Likert scale [10]. The questions are grouped in 6 scales associated with distinct aspects/dimensions of user experience. Concerning the standard interpretation of a scale, scores between -0.8 and 0.8 represent a neural evaluation, while scores >0.8 (< -0.8) represent a positive (negative) evaluation [11]. The high-school students participating in the previously described deployment studies were asked to fill in the UEQ after they have stopped using the myBigO app. In total, 30 students completed the questionnaire. The aggregated results along each scale of the UEQ are visualized in Fig. 3. One can observe that the myBigO app received a positive reaction for half of the scales and a neutral reaction for the other half. In brief, the app was considered to be adequately efficient in what it does, easy to use and attractive; however, it did not provide enough stimuli or novel features to the users. Surprisingly,

[5] https://www.redmine.org/.

given the small amount of logged and reported technical problems, the users were not convinced about the dependability of the app.

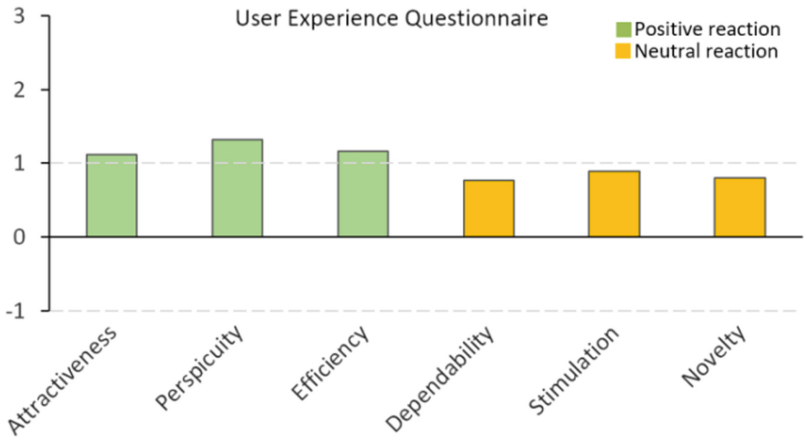


Fig. 3. Results from the evaluation of the user experience of the myBigO app along with 6 scales of the UEQ.

4 Conclusions

This paper has presented one of the first citizen-scientist smartphone apps that have been designed for children, namely the myBigO app. The app has been developed in the context of the BigO research programme with its primary goal being the collection of behavioral (eating, sleeping, and physical activity) as well as affective data from children populations. The myBigO app has already been successfully deployed in a series of data collection studies (in 3 European cities), providing the opportunity for the preliminary evaluation of the app with respect to technical robustness and user experience.

Additional evaluation covering other aspects of the myBigO app is still needed. This evaluation will be conducted in conjunction with the upcoming data collection actions of BigO, which will scale up the volume of collected behavioral and affective data. The successful utilization of the scale-up data for associating the behavioral patterns of the studied populations with local extrinsic conditions and local childhood obesity prevalence – to the aid of public health policy makers – will automatically validate the myBigO app. On top of that, our future plans include the enhancement of the app with features to support user engagement and more detailed logging of the collected data volume. Regarding user engagement, the need to improve user experience, especially with respect to stimulation and novelty, has been made evident from the conducted preliminary evaluation. To this direction, a gaming feature revolving around a data collection competition among citizen-scientists will be integrated in the myBigO app. The aforementioned detailed logging of the collected data will be also used for score calculations within the game.

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