Research project Fieldlab Evenementen phase II

Data collection and monitoring of group dynamics between visitors of the Fieldlab Evenementen pilot events using the Flockey app

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1. Introduction

By conducting applied practical research into visitor behaviour, the Fieldlab Evenementen research program aims to explore how mass gathering events could return safely at different risk levels during a pandemic. As part of the research team, Breda University of Applied Sciences (BUas) was tasked with collecting data on visitor behaviour in different experimental settings during the pilot events. Data on contact duration and distance needed to be gathered.

Prior to the pilot events, several suitable research instruments were identified and compared in order to collect this data[1]. Due to its accuracy and granular level of detail, Ultra-Wide Band (UWB) technology was chosen as the main technology of choice. As a result of this, every visitor for one of the pilot events in the first phase was handed a wearable that operates on UWB. These UWB tags have provided the research team with a very detailed overview of the number and types of contacts a visitor had. However, the UWB tags also had their shortcomings. During the ingress phase of the event, each visitor had to receive a tag to participate in the experiment. Consequently, each visitor also must hand in his tag during egress. The cost for the crew and the logistics behind this process was not scalable for the next series of events in phase two. Additionally, the operational cost to keep the system up and running would increase significantly.

During the second phase of the Fieldlab Evenementen research program, a new research instrument was adopted to cope with the increased number of visitors during the pilot events. Flockey, developed by Forkbeard Technologies in conjunction with EY Consulting, is a Bluetooth-based contact tracking application. The application is available for both Android and IOS and is based on the 'bring your own device' principles. This app would enable the research team to – without any logistical implications – collect the same type of data during the events at scale.

1.1. Flockey

Flockey uses patented technology, created by Forkbeard Technologies and EY Consulting, which logs and measures the proximity between visitors using anonymized Bluetooth Low Energy (BLE) data from mobile devices. This enables organizers to control the flow of visitors and creates a safer environment.

The app is downloadable via the Google Play Store and Apple App Store. Visitors of the pilot events had to download an app that includes their tickets and that was used as a communication channel; the Close app. Before the pilot events, visitors were asked to download the Flockey app through the dedicated link sent in the Close app. After downloading Flockey, visitors received a second link that activated the app and assigned them to a specific visitor group.

[1] Pas, J., Kamphorst, I., Coolen, J., van Rijn, M. (October 30th, 2020) *LCB-BUAS Onderzoeksresultaten.*

2. Results

Multiple pilot events were held during the second phase of the research program, of which four used the Flockey app to collect the contact tracking data;

- Racoon at Mainstage, Den Bosch
- The Residence Orchestra at the Zuiderstrandtheater, the Hague
- EventSummit at Jaarbeurs, Utrecht
- Eurovision Song Contest at Ahoy, Rotterdam.

During three of these events, the previously utilized research instrument (UWB tag) is used in conjunction with the Flockey app as a validation tool. Firstly, the data analysis steps will be explained. In the second part, the findings of the four events held will be discussed. Finally, user experiences will be briefly discussed.

2.1. Data analysis

The data analysis process aimed to answer the main research question: "How many unique contacts does a visitor have on average, lasting more than 15 minutes within 1.5 meters?". Data management and analysis were performed using Python and networkX.

Flockey provided the research team with data about the contact duration over several distance buckets of 0.25 meters wide. For the purpose of scalability, the mobile device aggregates the data from a contact between two individuals over a 10-minute time window. Thus, giving the total contact duration time in 0.25 meter intervals over a 10-minute time window (see Figure 1). By summing the total time two individuals saw each other in all buckets below 2 meters, to account for any measuring error, the total contact duration of these two individuals is known.

Time		**Contact between**		**Distance buckets (in meters)**							
start	end	Person A	Person B	0.0-0.25	0.25-0.5	0.5-0.75	0.75-1.0	1.0-1.25	1.25-1.5	1.5-1.75	1.75-2.0
12.00	12.10	12345	67890	60 sec	53 sec	125 sec	235 sec	47 sec	18 sec	55 sec	7 sec

Total contact duration time in distance bucket over a 10-minute time window

Figure 1. Example aggregated data from a contact between two individuals over a 10-minute time window

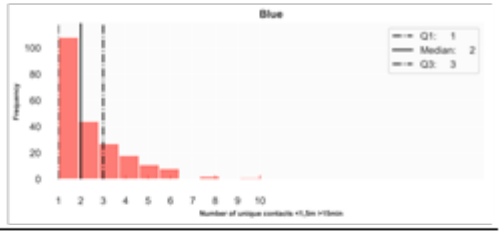
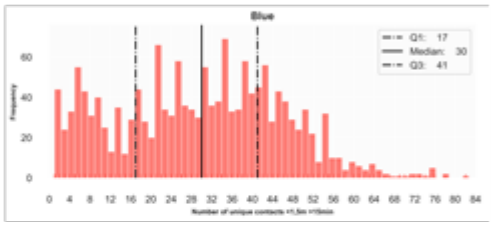
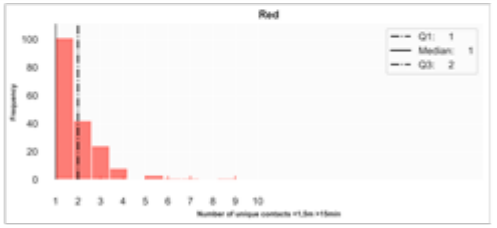
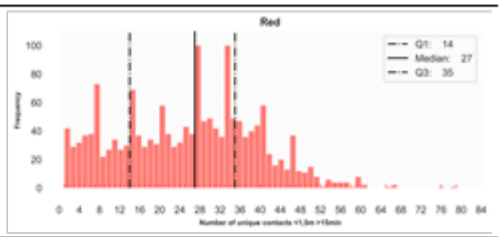
Based on these contact durations, a contact network can be constructed to calculate the average degree. The average degree is the average number of edges per node in the contact network, hence the average number of contacts per visitor. As the data provided by Flockey is not symmetrical, meaning that only one side of the connection reports, an undirected graph is used.

A similar analysis pipeline is performed on the UWB tags.

2.2. Racoon, Mainstage

The first event at which the Flockey app was deployed was the Racoon concert in Mainstage, an indoor venue. The total duration of the event was about 5 hours and 3.252 visitors attended. The total visitor group was divided into two separate 'bubbles', red and blue, to answer several research questions. The differences between the Flockey app and the UWB tags are highlighted in Table 1. What stands out in the table is the significant difference in the number of participants (N), as well as the average amount of contacts a visitor has. In total 3.252 people received an UWB tag during the ingress phase whereas the Flockey app was adopted by 1.269 people (40% adoption rate). Prior to the event, visitors received a message through the Close app with the request to download the Flockey app. However, the subsequent activation link was sent incorrectly to one of the bubbles, which received both the activation link for the blue and the red bubble. Due to a lack of human resources capacity, there was no possibility to actively check whether visitors had downloaded the app and correctly activated it.

Table 1. Results Racoon

Bubble	Research instrument	N	Average amount of contacts (IQR)	Distribution
Blue	Flockey	668	2.18 (1-3)	
	UWB tag	1574	29.6 (17-41)	
Red	Flockey	601	1.8 (1-2)	
	UWB tag	1678	25.49 (14-35)	

A probable explanation for the lower average amount of contacts is the lower adoption rate. For every 10 people around a visitor, on average only four will have the Flockey app installed. Another possible contributor to the lower number of contacts registered is the average time a user was active. Figure 2 gives an overview of the total number of users reporting over time. The most interesting aspect of this graph is the steep dive in reporting users around 20:40, coincidental with the changeover and start of the main show.

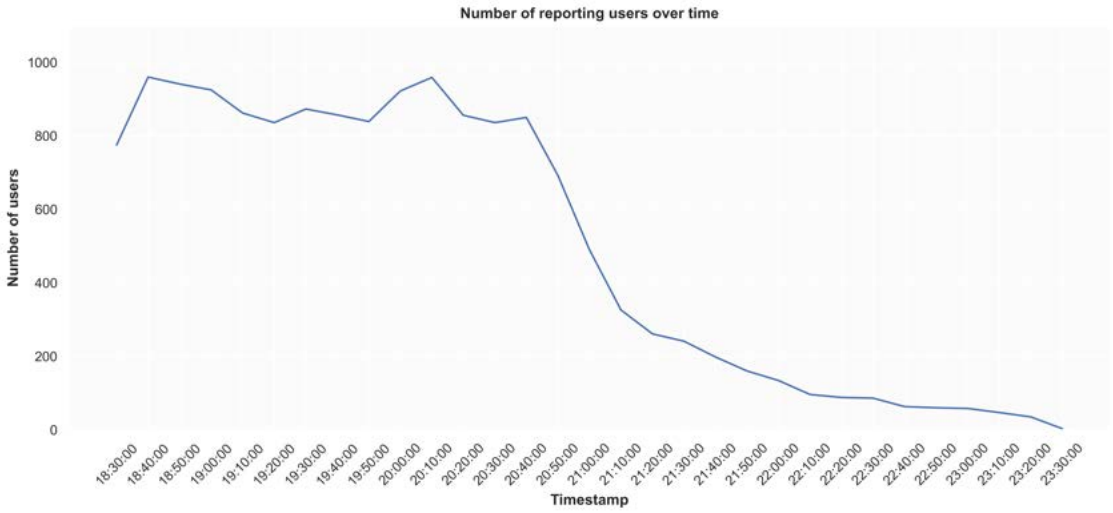
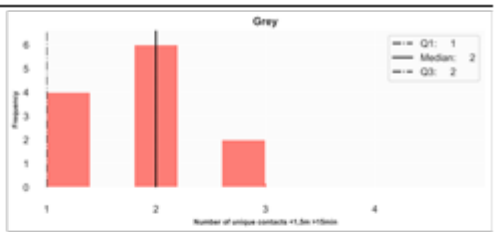
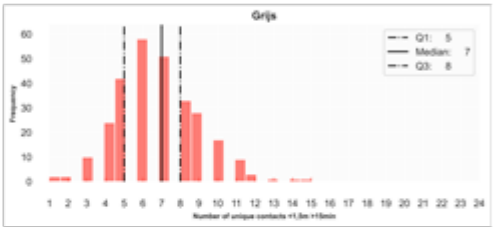
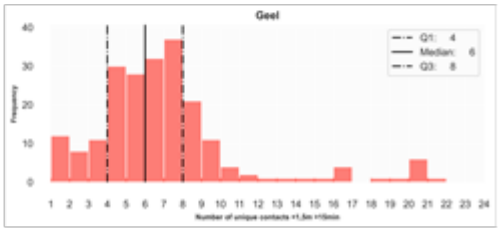


Figure 2. Reporting users Racoon over time

2.3. Residence Orchestra, Zuiderstrandtheater

The second event at which the Flockey app was deployed was the Residence Orchestra concert at Zuiderstrandtheater, an indoor theatre. The total duration of the event was about 3 hours and 516 visitors attended. The total visitor group was divided into two separate 'bubbles', grey and yellow, to answer several research questions. The differences between the Flockey app and the UWB tags are highlighted in Table 2. A similar pattern as the previously discussed event can be noticed. In total 516 people received a Kinexon tag during the ingress phase whereas the Flockey app was adopted by 155 people (30% adoption rate). The target audience of the Residence Orchestra mostly consists of seniors who are less familiar with using their mobile phones. In addition, most of the target audience relies on the local WiFi rather than 4G/5G, increasing the difficulty to increase the adoption rate.

Table 2. Results Residence Orchestra

Bubbel	Research instrument	N	Average amount of contacts (IQR)	Distribution
Grey	Flockey	96	1,83 (1-2)	
	UWB tag	288	6,7 (5-8)	
Yellow	Flockey	59	No relevant data (n=1)	
	UWB tag	228	6,6 (4-8)	

The same applies to the number of actives users over time (see Figure 3). Once again a steep drop in reporting users is seen around show start (19:30).

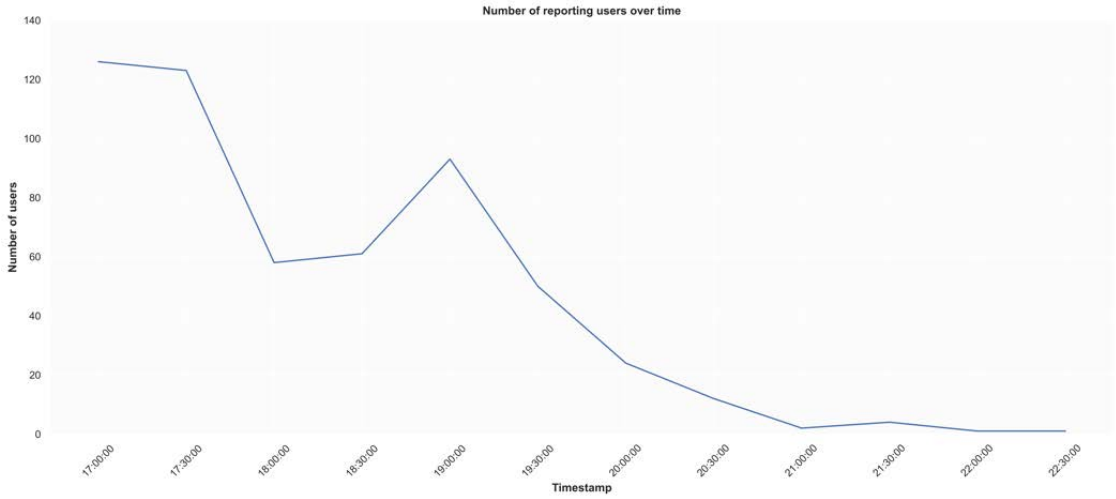


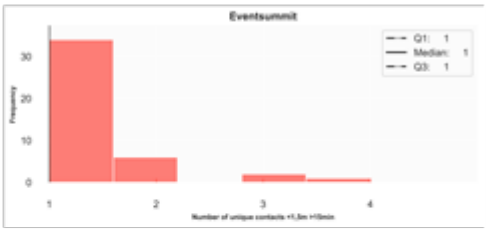
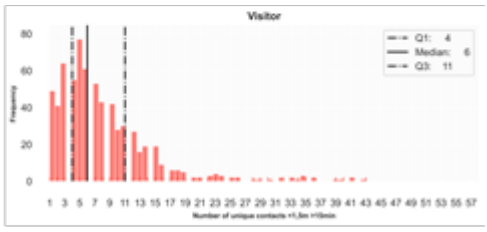
Figure 3. Reporting users Residence Orchestra over time

2.4. EventSummit, Jaarbeurs

The third event was a trade exhibition show aimed at the event industry. Visitors were able to freely walk around the exhibition floor and no specific bubbles were formed. Both visitors and exhibitors received a tag during ingress. Table 3 shows the results of the data analysis as performed. In total 1.263 people – including both visitors and exhibitioners – received an UWB tag. Flockey was adopted by 728 people (57%). At the entrance, all visitors have been actively checked for having downloaded and activated the Flockey app. Due to unexpected events, the exhibitors were not actively checked at the entrance, however, they have all been checked during the event.

Table 3. Results EventSummit

General statistics

Bubbel	Research instrument	N	Average amount of contacts (IQR)	Distribution
eventsummit	Flockey app	728	1 (1-1)	
	UWB tag	1263	8,88 (4-12)	

Because of the gradual inflow of visitors, the total amount of reporting users over time are not of interest for this comparison. Still, total active time defined as the total duration between the first registered and last registered contact can be compared as a measure for app usage. Flockey users were active – on average – for a duration of 2 hours and 45 minutes. In comparison, an UWB tag user had an average active time of 4 hours and 46 minutes.

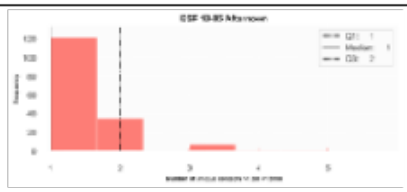
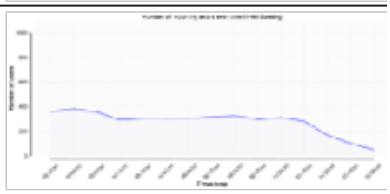
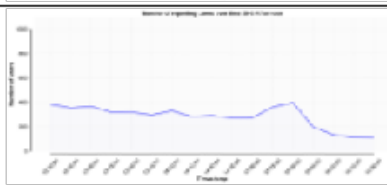
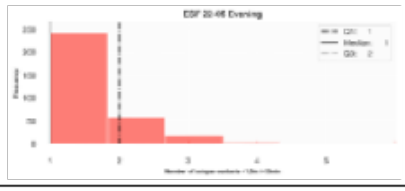
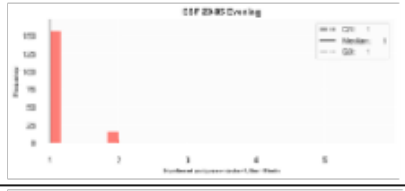
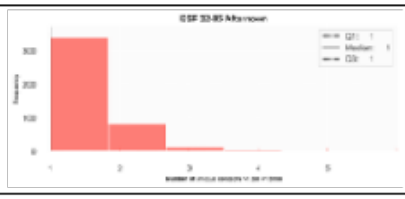
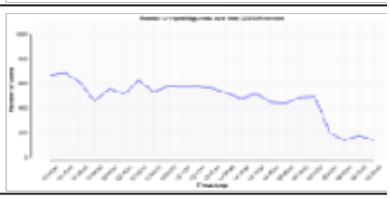
2.5. Eurovision Song Contest, Ahoy

Finally, the Flockey app was deployed at the Eurovision Song Contest. Over the course of one week 9 shows with a total of approximately 31.500 visitors were held (3.500 visitors per show). Due to the scale and level of production the use of the UWB tags was not possible. Therefore, in this section only a comparison will be made between the event days itself.

Table 4 shows per show the total amount of active users, the average amount of contacts each user had and its distribution as well as the total amount of users active during a specific timeframe. The adoption rate lays between 14% and 35% based on 3.500 visitors per show. Since the adoption rate during the first three shows was very low (18%, 18%, 15%, respectively), visitors were actively checked upon downloading and activating the app upon arrival by a crew of 15 people. This resulted in a higher uptake (35%, 22%, 33%, 37%, 26%). The show on May 20th in the afternoon was not actively monitored, since this show was specifically focused on primary school classes, which are not expected to have mobile phones. During the last three shows, push notifications were sent to alert visitors to keep the app active, which did seem to affect the duration a user is active.

Table 4. Results Eurovision Song Contest

General statistics

Day	N	Average amount of contacts (IQR)	Distribution	Active users
May 17th evening	628	1.25 (1-1)		
May 18th afternoon	637	1.34 (1-2)		
May 18th evening	509	5 (1-1)		
May 19th evening	1239	1.28 (1-1)		
May 20th afternoon	838	1.16 (1-1)		
May 20th evening	761	1.09 (1-1)		
May 21th evening	1143	1.3 (1-1)		
May 22th afternoon	1312	1,29 (1-1)		
May 22th evening	924	1.35 (1-2)		

2.6. User experiences

Throughout the attempts to increase the adoption rate by actively approaching visitors at their arrival, quite some interesting feedback was collected. The main points may be useful for the further development of the app and thus are listed below;

- Battery consumption is deemed high
- Multiple applications were required to be downloaded to gain access to a pilot event
- GPS permission is deemed unnecessary or privacy-violating
- Downloaded the app but did not activate it
- Download and activation procedure is deemed complex (mostly Android users)

3. Conclusion

In conclusion: Bluetooth Low Energy-based contact tracking applications based on 'bring your own device' principles have provided limited use as a research instrument during these experiments. External factors like adoption rate and activity time have a significant impact on the usability of the collected data.

The main premise for adopting the Flockey app as a research instrument during phase 2 of the research program was to collect the same type of data as in phase 1 and answer the main research question: "*How many unique contacts does a visitor have on average, lasting more than 15 minutes within 1.5 meters?*", without any logistical implications.

Unfortunately, throughout all pilot events as discussed in this paper, the adaption rate was rather low. An attempt was made to increase the adoption rate by actively checking the visitors at their arrival at the EventSummit and the Eurovision Song Contest. Nonetheless, the adoption rate never got higher than 57%. In addition, actively checking whether visitors have downloaded and activated the app defeats the main premise that the instrument has no logistical impact on the ingress process.

Due to restrictions on an operating system level, 3rd party developers face technical limitations on how their app can collect data when the app is running in the background. Users switching off the app for various reasons – for instance, because battery consumption was deemed high by visitors - during the event, had a significant impact on the usability of the tool as a research instrument. Government-issued apps like the CoronaMelder are embedded at an operations system level and do not face these technical challenges.

In order to effectively use a BLE-based contact tracking application, a high adoption rate is of crucial importance. Despite several efforts, the research team has not been able to succeed at achieving this. In addition, the application is often deactivated by the users throughout the event, causing the data collection to stop. Therefore, the research team has concluded that such an application in this development phase is unsuitable for the aim of the research. The challenge now is to make a continued effort to make Flockey more accessible by:

- Achieving a higher adoption rate by creating an easier onboarding and checking process
  - For example; activating the app by locating NFC chips or beacons
- Improving battery performance

Some of the issues emerging from these findings relate specifically to how the research team has attempted to integrate the Flockey app as a research instrument. Issues encountered by the research team may not be the same for other cases.