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Infection tracking in travellers using a mobile app (ITIT): The pilot study

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ABSTRACT

Background: Current surveillance of travellers' health captures only a small proportion of illness events. We aimed to evaluate the usability and feasibility of using an app to enable travellers to self-report illness.
Method: This pilot study assesses a novel mobile application called Infection Tracking in Travellers (ITIT) that records travel-related symptoms with associated geolocation and weather data. Participants were recruited in three Swiss travel clinics between December 2021 and March 2022. A feedback survey was used to examine app ease of use, and data from the app was used to examine travel and illness patterns as a proof-of-concept for the larger ITIT study.
Results: Participants were recruited from Zürich, Basel, and Geneva, with 37 individuals completing a total of 394 questionnaires in 116 locations in Asia, Africa, the Americas, and Europe. Illness symptoms were reported by 41% of participants, 67% of which were respiratory. The post travel questionnaire showed that all participants found the app easy to use and 63% said they would recommend it to others. Several users provided suggestions for improved usability.
Conclusion: The app fulfilled its function as a research tool linking infection symptoms with geolocation and climate data.

1. Introduction

As the COVID-19 pandemic has shown, illnesses contracted and spread through travellers can have wide reaching impact not only on the health of the individual traveller, but also on society as a whole. Travellers have long been exposed to a wide variety of infections ranging from arboviruses such as dengue, to diarrheal diseases, and parasites such as malaria [1]. When bringing these infections back into their home country, travellers can also cause local outbreaks, as recent dengue outbreaks in France and Spain have shown [2]. The tracking and reporting of these infections is important for travellers' health, and to identify and curtail outbreaks. However, much of current surveillance is top down, and relies on travellers seeking medical attention back in their home country, and on health care professionals and institutions reporting these infections to their respective public health authorities. This is time-consuming and misses many travellers with less severe symptoms, making timely outbreak detection more difficult. Therefore, it is of paramount importance to improve and supplement existing surveillance with bottom-up, participant-based surveillance, to identify outbreaks more quickly, and allow for more accurate prevalence predictions.

A promising area to achieve this is through mobile device-based applications. The number, and type of apps for health have exploded in recent years, with developments including apps for leprosy screening [3], tuberculosis treatment [4], HIV prophylaxis adherence [5], and a host of COVID tracking and reporting apps [6,7]. There are also apps dedicated to outbreak surveillance, however, most of these focus only on a single disease, notably influenza or only cater to health care providers

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[8]. Other apps focus on traveller risks and behaviour with respect to non-infectious disease [9]. In contrast, the Infection Tracking in Travellers (ITIT) project is concerned only with infection acquired during travel. Mobile apps can also provide a breakthrough in low resources settings, making acquisition of data easier, and more complete [10]. However, with this technology also comes an increased need to focus on participant privacy and data protection in the digital sphere [11]. Keeping all of this in mind, we conceptualised and developed the ITIT app, a symptom-based surveillance app that will collect bottom-up, real-time information from travellers on a wide range of travel-related infections, keeping data protection and privacy and public health at the forefront.

The ITIT project combines self-reported symptoms from the ITIT app with GPS location and weather data to create a system of bottom-up real-time illness surveillance. This paper outlines the pilot project of the ITIT study, looking at a first cohort of 38 participants to examine the feasibility of the larger ITIT study, evaluate app functionality and user-interface, and data that will be collected in the larger study.

2. Materials and methods

This is the pilot project of a prospective, non-interventional, cohort study called Infection Tracking In Travelers (ITIT). The project is funded by the Swiss National Science Foundation. This study has been approved by the Swiss ethical committees (BASEC number 2020–02292) and has been registered in the database "ClinicalTrials.gov" (identifier NCT04672577) [12].

As incentives the app provides vetted travel health information from the WHO including Disease Outbreak News bulletins (DONs), and an e-library of travel health topics, as well as vaccination recommendations and requirements for each country [13].

2.1. Participant recruitment

Study participants were recruited between December 8, 2021, and March 31, 2022, at three different Swiss travel clinics in Zürich, Basel, and Geneva. The recruitment period ended when the sample size reached 50 pilot participants. Individuals were eligible for the study if

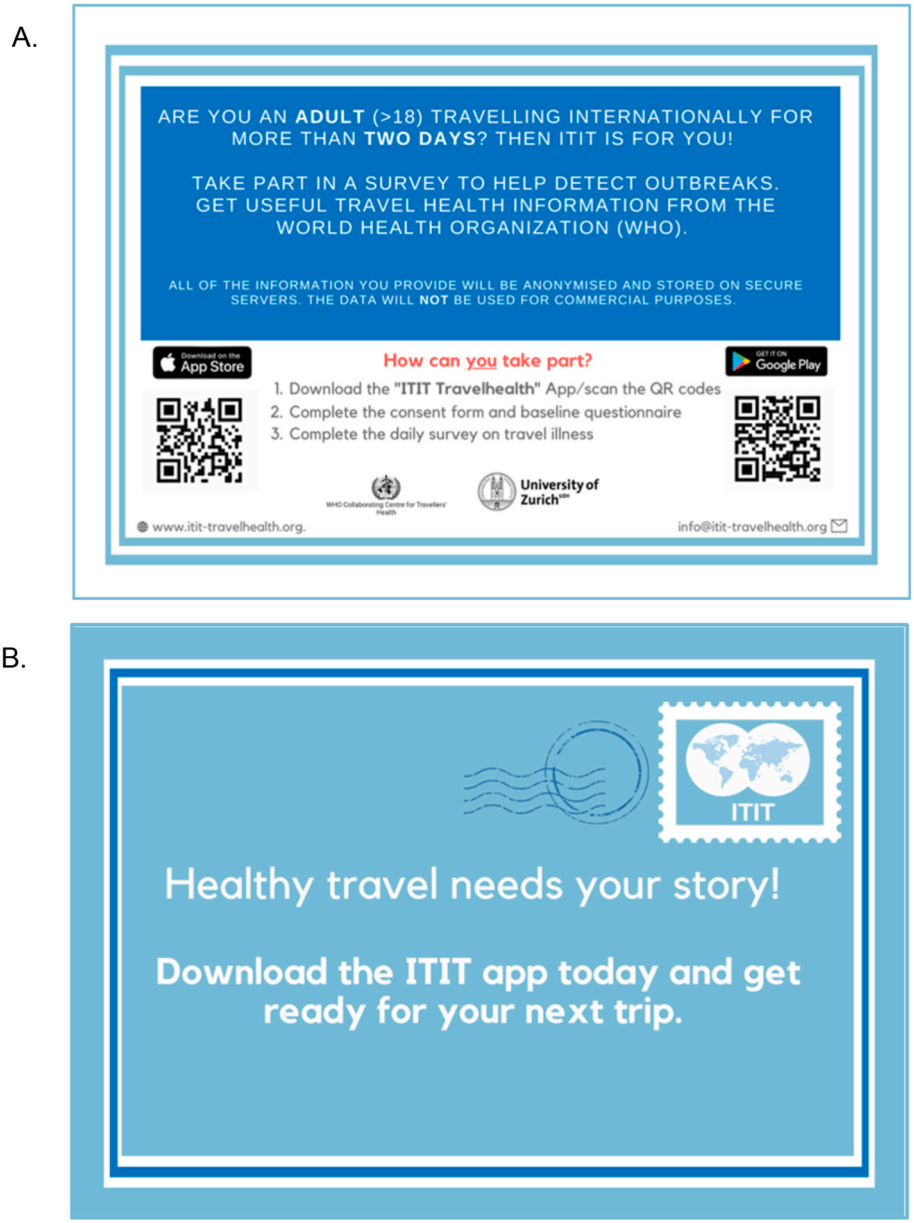

Fig. 1. Recruitment flyer developed for the ITIT project. Printed as a 'postcard'. A. Front B. Back.

they were over 18 years of age, travelled internationally for at least two days before the end of April 2022, and provided electronic informed consent.

Health care professionals at the various travel clinics were asked to introduce the study to eligible travellers during their pre-travel consultations. If interested, participants were informed of the study procedure and their contact information was recorded, along with the destination and dates of travel. Flyers with QR codes to download the ITIT application and describing the main study objectives were provided to interested participants and were freely available in the travel clinics (Fig. 1).

2.2. Survey and mobile application

The ITIT app could be downloaded free of charge by participants from the Apple App Store and the Google Play Store. The content of this application is available in 9 different languages. When the application was first launched, participants were guided through the electronic consent form and asked to digitally sign it. Only participants who had given consent could access and respond to the daily survey. Consent to provide location data was optional and could be adjusted at any time in the app.

To actively participate in the study, participants were asked to complete a demographic questionnaire prior to their departure that included questions about age, sex, travel characteristics and health information. Then, during their trip, travelers were sent pop-up questionnaires at a specific time each day (6 p.m.) reminding them to complete the daily survey.

The daily survey consisted of self-reported, 5-point Likert scales describing the intensity of symptoms ranging from “none” to “medical attention”. Symptom types were grouped into 4 different categories (gastrointestinal, respiratory, skin and rashes, and general symptoms) and could be skipped by participants as needed. Two additional questions about the impact of symptoms on daily activities and general mood were asked of all participants who reported at least one symptom event.

Responses were stored locally in the internal memory of the participant’s smartphone and sent periodically via an SSL-secured http request to the ITIT platform hosted by a Google server in Zürich when Internet connectivity was available. The data were then enriched with climate data through programmatic queries based on collected parameters such as longitude, latitude, and time recorded during the survey.

All collected data were anonymized and could only be accessed through a dedicated dashboard restricted to the principal investigator and core team. ETHZ Health Ethics and Policy lab were closely involved in all aspects of the project that involved digital ethics [14]. Additionally, a systematic review was conducted prior to the study to better understand the ethical implications in developing an application for travel medicine [11].

2.3. Feedback questionnaire

Once all pilot study participants returned from their travels, a feedback form was emailed with the collected contact information. All participants who did not respond were called at least twice before their contact information was deleted.

2.4. Analyses

Descriptive analyses were used to analyze the baseline questionnaire and the daily survey. Geolocation data were mapped to symptom categories and their intensity. Feedback results were displayed graphically. All statistical analyses were performed with the statistical software R version 4.0.4, R Foundation for statistical computing, Vienna, Austria [15].

3. Results

Sixty-four participants were recruited for the ITIT pilot study, of whom 38 (60%) completed the baseline questionnaire and 32 (50%) completed at least one daily symptom questionnaire, and 18 (28%) completed the feedback questionnaire.

3.1. Demographics

The majority (20/38, 53%) of the participants were traveling for leisure or tourism, with only 2 traveling for business. and 3 for visiting friends and relatives (VFR) (Table 2). Five participants were attending the Shanghai Olympics, and 8 were traveling for their medical studies. Overall, 45% were male, and the average age was 35 years old. 87% of participants did not smoke, and only one had a chronic disease (high blood pressure). The trips were between 2 and 68 days long, with a mean of 28 days, and the most highly visited region was Sub-Saharan Africa (58%) (Table 1).

Of the 38 participants who filled out the demographic questionnaire, 32 filled out at least one daily survey, and when accounting for each day of travel, the overall survey response rate was 31%, ranging from 0 to 95% (Table 2).

A total of 1070 daily surveys were completed by the participants, and 43 symptoms were reported, ranging in intensity from mild to very severe (Table 3). The most commonly reported symptoms were gastrointestinal (9 travellers), notably diarrhea (7 travellers) and stomach pain (8 travellers). No travellers reported any skin conditions or rashes. Several travellers reported multiple symptoms, notably a traveller to Senegal who had seven symptoms including a very severe sore throat and severe runny nose. For most travellers, their symptoms did not have a large impact on their daily activities, but 4 participants could not perform their daily activities due to their symptoms.

Fig. 2 shows a map of all daily questionnaires, and all reported symptoms by symptom group and intensity. Here again the spread of participants can be visualized, and the range and intensity of symptoms. The most symptoms were reported by participants traveling the African continent.

3.2. Feedback form

The responses of the feedback questionnaire can be seen in Fig. 3. The majority of participants found the app easy to find, install and use and felt comfortable using mobile applications, and found it easy to answer the daily surveys. However, some found it difficult to answer the surveys, due to not receiving notifications every day of the trip. Some participants received no notifications, and others received them before and after the trip. This was discussed with the app developer and the issue resolved in the future app versions. Over 60% of participants found all app functionalities useful, with 68% finding the specific country information useful, and 63% finding the DONS and travel health topics useful. 79% of participants would recommend the app to others. Specific feedback on questionnaires and pop-up notifications was also collected and relayed to the developer. Several participants reached over the phone disclosed that they had forgotten to download the app at all.

4. Discussion

Using the ITIT app, a total of 38 participants resulted in over 1000 data points outlining illness symptoms encountered by travellers globally. This method of data collection is fast, real-time, less labour intensive than traditional methods, and has the potential to give more accurate data, without recall bias.

59% of recruited participants downloaded the app and filled out the demographic questionnaire, but of these, 84% then filled out at least one daily symptom survey. These results were relayed back to the development team, and some changes were made to the app to increase user

Table 1
Demographic table of ITIT pilot participants (N = 38).

	Leisure/Tourism	Business/Corporate Travel	VFR	Mass Gathering Events	Other	Overall
	(N = 20)	(N = 2)	(N = sss3)	(N = 5)	(N = 8)	(N = 38)
Sex						
Male	9 (45.0%)	0 (0%)	1 (33.3%)	3 (60.0%)	4 (50.0%)	17 (44.7%)
Female	11 (55.0%)	2 (100%)	2 (66.7%)	2 (40.0%)	4 (50.0%)	21 (55.3%)
Age (years)						
Mean (SD)	37.0 (13.8)	31.0 (9.90)	36.7 (20.3)	44.6 (11.5)	25.4 (1.30)	35.2 (13.1)
Median [Min, Max]	32.0 [23.0, 72.0]	31.0 [24.0, 38.0]	27.0 [23.0, 60.0]	40.0 [34.0, 63.0]	26.0 [23.0, 27.0]	30.0 [23.0, 72.0]
Travel Duration (days)						
Mean (SD)	18.6 (14.5)	33.0 (31.1)	14.7 (10.4)	21.8 (6.98)	58.9 (5.30)	27.9 (20.6)
Median [Min, Max]	14.0 [5.00, 60.0]	33.0 [11.0, 55.0]	18.0 [3.00, 23.0]	22.0 [11.0, 30.0]	59.0 [50.0, 68.0]	21.0 [3.00, 68.0]
Smoking						
Not smoking	17 (85.0%)	2 (100%)	1 (33.3%)	5 (100%)	8 (100%)	33 (86.8%)
Daily	1 (5.0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	2 (5.3%)
Weekly	2 (10.0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	3 (7.9%)
Monthly	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Former Smoker	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Chronic Disease						
High BP	1 (5.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (2.6%)
None	19 (95.0%)	2 (100%)	3 (100%)	5 (100%)	8 (100%)	37 (97.4%)
Region						
Eastern Asia	1 (5.0%)	0 (0%)	0 (0%)	5 (100%)	1 (12.5%)	7 (18.4%)
Latin America and the Caribbean	2 (10.0%)	0 (0%)	1 (33.3%)	0 (0%)	1 (12.5%)	4 (10.5%)
Southern Europe	5 (25.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (13.2%)
Sub-Saharan Africa	12 (60.0%)	2 (100%)	0 (0%)	0 (0%)	6 (75.0%)	20 (52.6%)
Northern America	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	1 (2.6%)
Northern Europe	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	1 (2.6%)

Note: VFR: Visiting friends and relatives, SD: Standard Deviation, BP: Blood pressure.

Table 2
Follow-up time and response rates of ITIT pilot participants.

Questionnaire	N = 38[a]
Over all follow-up time (days)	
1–7	*3 (7.9%)*
7–14	*7 (18%)*
14–31	*8 (21%)*
>31	*14 (37%)*
No questionnaire completed	*6 (16%)*
Number of missed surveys (n)	
Mean (SD)	*20 (16)*
Range	*2, 56*
Survey Response rate (%)	
Mean (SD)	*0.31 (0.28)*
Range	*0.00, 0.95*

[a] n (%).

retention and use, including ensuring that the participants get pop-up notifications on their phone during their trip that lead directly to the survey screen, and a reminder pop-up if the first is ignored. Most participants, when contacted for feedback, stated that they had simply forgotten to download the app between the time of their travel clinic visit and their trip, or forgotten to fill the survey during their trip. Therefore, when training and on-boarding new centres for the ITIT project, there is also now emphasis on getting participants to download and fill the demographic questionnaire directly at the clinic, to reduce chances of travellers forgetting to download the app at a later date. Once the demographic questionnaire is filled out, the pop-ups will remind travellers of the app, which is essential for travellers who visit clinics far in advance of their travel dates. In addition, clear recruitment materials were created to gather interest and to simplify the recruitment process. Other additions to the app are planned, including a personalised 'my trip' screen, where participants will be able to see their entered data, in order to provide feedback, and be a valuable tool for travellers who develop symptoms, to record when, where and which symptoms occurred.

Overall, the app was successfully able to collect illness symptom data and the linked location and climate information in real-time. A variety of locations around the world were included in the initial pilot participants, and a range of symptoms and symptom intensities were seen. The wealth of information, including participant demographics, dates of symptoms, and climate information can lead to interesting analyses when more data points are collected in the larger ITIT study. This is promising for the larger study, and more data points will also allow for more sophisticated statistical analyses and visualisations and infectious disease predictions. Some proposed future work includes making profiles of expected symptoms by type of traveller and travel demographics through CART analysis and making maps showing hotspots of illness symptoms over time. Eventually the app could be used for real-time outbreak detection to supplement existing surveillance programs.

A limitation of this study is that there was no follow-up of participants, to see if anyone had developed symptoms after the last day of the trip, or to see if those participants with symptoms had any official diagnosis from a health practitioner, however, a follow-up, electronic questionnaire exploring these questions will be included in the larger ITIT project. This questionnaire will be sent to all participants post travel, and will include questions on persisting symptoms, diagnoses, and any treatment obtained. In addition, the small number of data points were not conducive for most statistical tests, so this pilot was primarily descriptive, again, an issue that will be resolved in the larger study. A further limitation is the fact that the recruitment of participants has the potential to be biased, as only travellers who visit a travel centre for pre-travel advice were asked to participate, and only travellers who have and can operate a mobile phone and download the app and who consent to having their location recorded would take part. This results in, on average, younger, more tech-savvy people with a higher socio-economic status that allows for travel clinic visits and international travel in the ITIT population. However, as compared to most infection surveillance in health care systems, this method will still cast a wider net. The goal of the larger ITIT project is to reach 10,000 participants, a number much larger than typical travel health studies, and from more diverse areas, as recruitment will not only be done through travel clinics, but also through universities, online through social media, and through the news, reaching a much broader population than only those who attend pre-travel consultations. The completely digital eConsent form also ensures that recruitment is less labour intensive, and that participants who

Table 3
Symptoms reported by ITIT pilot participants, coloured by symptom intensity and grouped by traveller.

Participant	Demographics	Travel Location, Duration (days)	Nausea	Vomiting	Stomach Pain	Diarrheoa	Constipation	Cough	Sore throat	Stuffed or runny nose	Out of breath - resting	Out of breath - running	Fever	Dizziness	Ear ache	Headache	Pain behind the eyes	Muscle pain	Aching limbs	Other	Pain in the joints	Swelling of the joints	Impact on Activities	Day Overall
1	26 f	Cameroon (55)				1																	1	3
						2																	1	3
						1																	0	3
						1																	0	3
						1																	0	3
			3	2		3																	2	2
2	26 m	Korea (62)											2			2				1			1	1
													2	1		1	1			1			1	1
3	24 m	Cameroon (58)	1		3	3										2		2					4	1
			1		2	2										1							4	1
					1	2																	0	3
						2																	1	2
																							1	2
									1	2		1											0	3
																							1	2
																							0	3
4	26 f	Bolivia (63)						1	1	4	1	2		1		1				1			1	2
								1		3		1											1	3
			2		1	3		1		2		1											2	2
										1													1	3
									1	1		1											0	2
5	25 m	Cameroon (61)	2		1	3																	2	2
			1		1	2																	1	3
					1	2																	0	3
						1																	1	3
6	28 f	Spain (10)														2							1	4
																				1			1	3
7	28 m	South Africa (41)	3	1	4	4					3	1											4	2
					1	2																	0	3
8	23 f	Senegal (57)						2	4	3		1		1		1		1					1	2
9	25 f	Cameroon (50)			1	1																	0	2
10	30 f	South Africa (34)														3							2	2
																							2	2
11	27 m	Cameroon (60)			3								1			3		3	2				4	1
12	38 m	China (11)			1	2																	2	2
13	38 f	Burkina Faso (5)																			4	2	1	3
14	26 f	South Africa (41)	1																				0	3
					2																		1	4
																							0	4

have no in-person contact with the study team can also easily take part in the study across the globe.

The ITIT project shows great promise in not only the number and variety of participants, but also the amount of real-time data that will be gathered, infection symptom data linked to real-time GPS and climate data, as well as information on travel type and traveller demographics. This, as well as the WHO vetted travel health information and timely disease outbreak news makes ITIT a trustworthy, valuable tool for travellers and travel health research alike. Using the ITIT app and shortening information flows to create a loop of travellers being data consumers and providers will enable many new use cases in illness monitoring such as early warnings and more accurate risk and symptom map data. And through being distributed as a mobile app we aim to reach an unprecedented number of participants for studies, with all the benefits of more data, coverage, and significance.

5. Conclusions

These results show great promise for the launch of the main ITIT project, and for app-based infection surveillance r. The data produced in the study are rich and will be even more valuable when there are more data points from the larger project. With some modifications to the app based on feedback from pilot participants, and what was seen in the data, the ITIT app has the potential to revolutionise modern illness surveillance.

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CRediT authorship contribution statement

Nadja Hedrich: ConceptualizationConcept, Methodology, Data curation, Formal analysis, Writing – original draft. **Thibault Lovey:** ConceptualizationConcept, Methodology, Data curation, Formal analysis, Writing – review & editing. **Esther Kuenzli:** Data acquisition, Writing – review & editing. **Gilles Epéron:** Data acquisition, Writing –

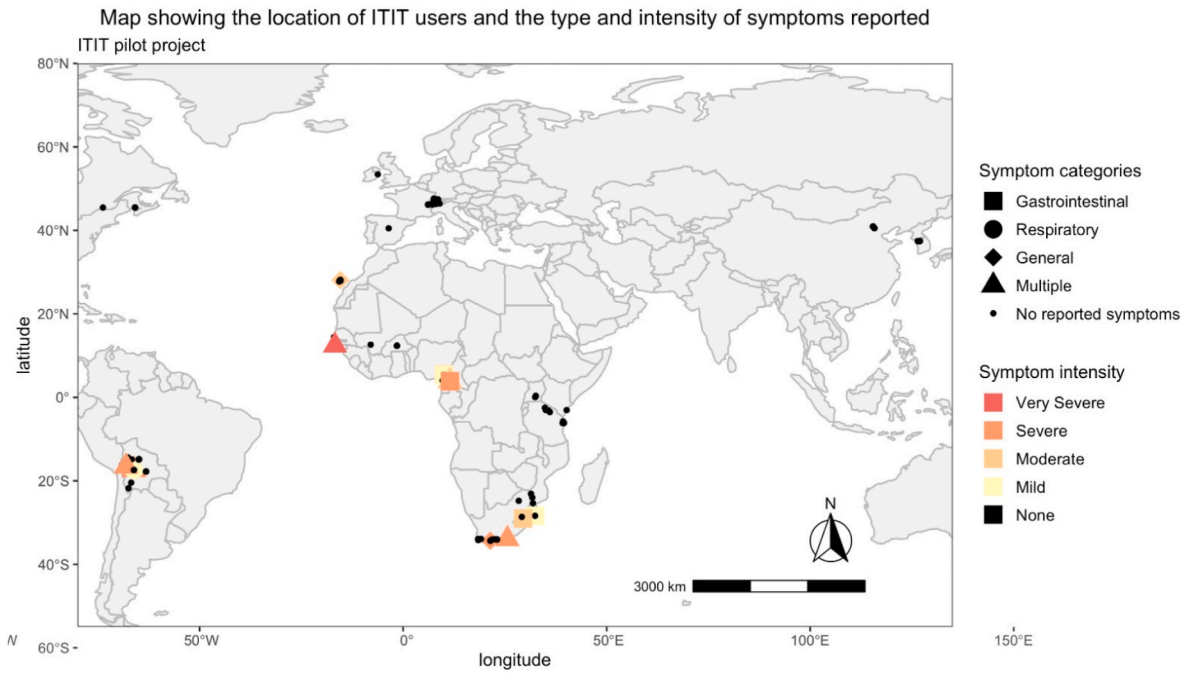

Fig. 2. Map of daily surveys filled out by ITIT pilot participants with location, symptom category and intensity (n = 43).

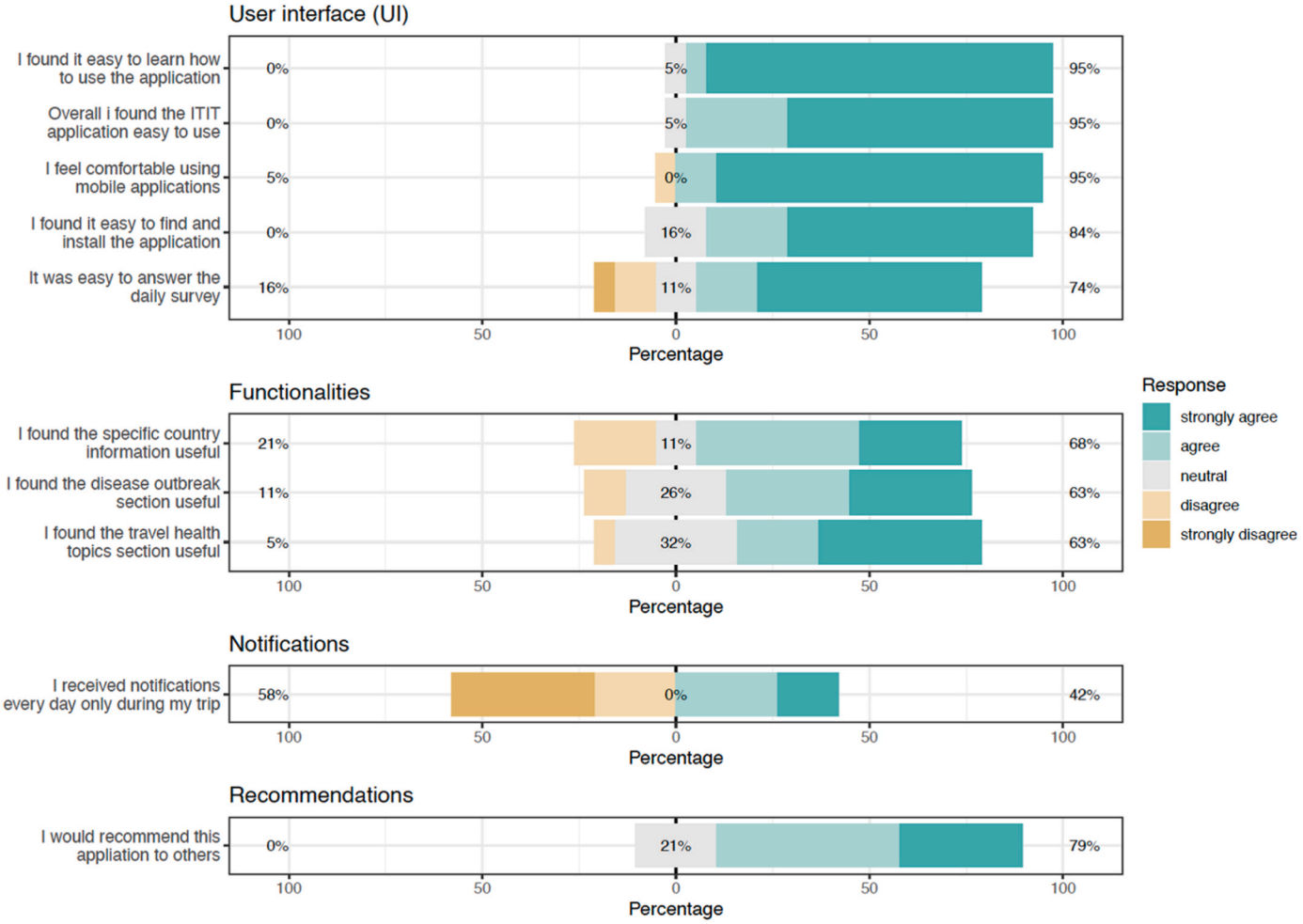

Fig. 3. Pilot participant responses to the ITIT app feedback form (n = 18).

review & editing. **Ulf Blanke:** Methodology, Data curation, Writing – review & editing. **Patricia Schlagenhauf:** Grant, and, Funding acquisition, ConceptualizationConcept, Methodology, Supervision, Data curation, Writing – review & editing.

Declaration of competing interest

The authors declare no competing interests.

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