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Mobile Behavioral Sensing in Outpatients and Inpatients with Schizophrenia

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Abstract

Objective—The purpose of this study was to examine the feasibility, acceptability, and utility of behavioral sensing in individuals with schizophrenia.

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Methods—Outpatients (N=9) and inpatients (N=11) carried smartphones for two or one week periods, respectively. Device-embedded sensors (i.e., accelerometers, microphone, GPS, WiFi, Bluetooth) collected behavioral and contextual data, as they went about their day. Participants completed usability/acceptability measures rating this approach.

Results—Sensing successfully captured individuals' activity, time spent proximal to human speech, and time spent in different locations. Usability and acceptability ratings showed participants felt comfortable using the sensing system (95%), and that most would be interested in receiving feedback (65%) and suggestions (65%). Approximately 20% reported that sensing made them upset. A third of inpatients were concerned about their privacy, but no outpatients expressed this concern.

Conclusions—Mobile behavioral sensing is a feasible, acceptable, and informative approach for data collection in outpatients and inpatients with schizophrenia.

Mobile phones are playing a growing role in the modernization of mental healthcare (1). Widely available mobile phones can be used to send and receive clinically-relevant text messages (2, 3), administer mental health screening and symptom assessment measures (4), and support illness management and treatment applications (apps) (5, 6). In addition to approaches that require individuals to actively engage with the device (e.g., go online, respond to prompts, launch an app, type and send text), mobile phones can also facilitate behavioral tracking techniques that require little to no action from the user.

Smartphones (i.e., mobile phones with significant computational and storage capacity) now come with multiple embedded sensors that measure movement, location, acoustics, and ambient light. Sensors can be harnessed to capture an abundance of information pertaining to their users' behaviors and environments passively, so long as individuals carry the device with them (7). Research conducted with non-psychiatric populations has demonstrated that mobile behavioral sensing can be used to draw inferences about how and where individuals spend their day (8), and to track behaviors that are associated with daily stress and changes in users' mental health over time (7, 9). A recent study showed that behavioral data captured with smartphone sensing techniques were associated with psychiatric symptoms in people with bipolar disorder (10).

Whether individuals with schizophrenia would be willing and able to engage in smartphone behavioral sensing is unclear. To examine the feasibility and acceptability of behavioral sensing in this group, we conducted two proof-of-concept studies with individuals with schizophrenia and schizoaffective disorder. The first was conducted with a clinically stable sample receiving outpatient care. The second was conducted with acutely-ill hospitalized inpatients. The combined findings have implications for the viability of smartphone sensing as a possible approach for behavioral and contextual tracking in people with schizophrenia spectrum disorders.

Methods

The research was approved by the Committees for the Protection of Human Subjects at Dartmouth College and the New Hampshire Department of Health & Human Services, and

Institutional Review Board at the Zucker Hillside Hospital. Participants provided informed consent. Nine individuals receiving outpatient care and 11 hospitalized inpatients participated. Patients were included in this study if they were 18 or older and had a chart diagnosis of schizophrenia spectrum disorder. Individuals were excluded if they had hearing, vision, or motor impairments that made it impossible for them to use a smartphone (assessed on-site by study staff) or had a legal guardian.

Research staff initially contacted candidates by phone (outpatient) or informational visit on the inpatient unit. Interested individuals met with research staff to get a complete description of the study. Interested individuals reviewed the consent form and were administered a competency screener verifying that they understood what is being asked of them. Following informed consent, enrolled participants were loaned a smartphone and received a tutorial on how to use the different functions (e.g., touchscreen, volume). Participants were asked to keep the smartphone on and to carry it with them as they go about their day. Due to hospital safety guidelines, inpatients handed in their device to staff at night, and received it fully charged the following day. Sensor data were collected continuously and did not require participant activation. Individuals in the outpatient group participated in two weeks of data collection and were compensated $80. Inpatients participated for one week (just short of the average length of hospitalization) and were compensated $50.

Smartphones came installed with study software that was developed by our research group. The data collection system enables both pre-timed and behaviorally-triggered sensor activation (i.e., microphone, multi-axial accelerometers, light sensors, GPS, Bluetooth receiver) (11). Human speech was captured by the microphone, which was activated every 2 minutes to capture ambient sound. If speech was detected, the microphone remained active. To protect privacy, the system did not record nor transmit audio recordings, but instead processed the data in real-time and stored features that are useful to infer the presence of human speech (i.e., energy, relative spectral entropy, autocorrelation peak values), but insufficient to reconstruct speech content (9, 11). Activity was captured by the smartphone accelerometers that detected movement. The system generated and stored an activity rating every 2 seconds (i.e., active vs. sedentary) (11). Location was captured differently for the two samples: for outpatients, we used Android location services which fuse information from the Global Positioning System (GPS), WiFi, and cellular networks to provide an optimized location estimate. Inpatients, however, were typically indoors on the same unit during their hospitalization. The few exceptions were when patients went off the unit for therapeutic groups which included walks outside, or when patients were able to use independent time inside the hospital, but off the unit. To get a more granular measure of their location, our team installed multiple Bluetooth beacons throughout the inpatient unit (e.g., halls, nurse station, kitchen, day room/lounge, group room). The smartphone's Bluetooth sensor received signals sent by the beacons, and our study software recorded participants' locations when they were on the unit, noting when they left.

The smartphones stored the data until it could be securely transmitted to a study server when internet connectivity was available (nightly for outpatients, at the end of the week for inpatients). All participants returned the smartphones and completed a questionnaire comprised of adapted items from several acceptability/usability measures (5) before receiving compensation.

Results

All 9 outpatients who were approached for the study agreed to participate and were successfully enrolled (67% male, 55% white, average age: 39). Twenty inpatients were approached for the study. Seven inpatients declined to participate; three stated that they were apprehensive about tracking technology. The remaining thirteen were interested in participating, but two were excluded because they failed the competency screener, leaving 11 participants (91% male, 55% white, average age: 38). The final overall sample consisted of 20 participants: 60% with schizophrenia and 40% with schizoaffective disorder (see online appendix for additional demographic and clinical information). All enrolled participants completed the study and filled out the usability/acceptability questionnaire. One outpatient did not charge the smartphone regularly and sensor data collected from his device indicated it rarely moved throughout the data collection period, suggesting poor adherence to the study protocol.

Sensor data showed that on average, outpatients were active (i.e. non sedentary) 2.5 hours and were proximal to human speech 4.4 hours a day. Speech and activity patterns varied across individuals; some were more engaged in the morning while others in the evenings. On average, they covered a daily distance of 9 miles and spent 16.7 hours a day in the same location. Outpatients used the smartphone to send an average 4.5 text messages and make 7.2 calls daily, averaging 16.8 minutes each (these functions were disabled for inpatients due to hospital regulations). Except for one individual, outpatients charged the phone on average twice daily, suggesting good adherence to the study protocol.

Inpatients picked up the smartphones in the morning and returned them at night at slightly different times. For consistency, we report on their sensor data from 8 AM to 8 PM. In general, inpatients were active (i.e. non sedentary) an average of 2.1 hours a day, and proximal to human speech 4.4 hours a day. On average, inpatients spent 5.5. hours in the men’s and women’s halls, where they were around human speech 0.8 hours and were active 25% of the time; 2.1 hours near the nurse station, where they were around human speech 0.7 hours and were active 32% of the time; 0.9 hours in the kitchen, where they were around human speech 0.4 hours and were active 30% of the time; 0.5 hours in the day room/ lounge, where they were around human speech 0.1 hours and were active 29% of the time; 0.68 hours in the group room, where they were around human speech 0.2 hours and were active 48% of the time. In summary, inpatients spent the most time in the halls, were most active in the group room, and were around human speech the most at the nurse station.

Averaging both groups, participant responses to the usability/acceptability measure (see Table 1) indicated they felt comfortable using the smartphone sensing system (95%), understood how it worked (70%), did not have difficulty keeping the device with them at all times (70%), and would be interested in receiving system-generated feedback (65%) and suggestions if they were distressed (65%). A total of 4 participants (20%) indicated that smartphone sensing made them upset. Four inpatients (36%) were concerned about their privacy but no outpatients expressed such concerns.

Discussion

To our knowledge, this is the first report describing the feasibility and acceptability of multi-modal smartphone sensing for behavioral and contextual tracking in outpatients and inpatients with schizophrenia. The majority of individuals approached for the study expressed interest in participating and adhered to the study protocol. Most participants reported feeling comfortable with this technique and did not experience distress or negative outcomes. Approximately two thirds indicated that they would be interested in receiving summary reports, feedback, and suggestions from the smartphone system.

Previous studies have shown that people with schizophrenia can use mobile technologies to self-report their behaviors and functioning (12, 13). The current research extends these findings by demonstrating that individuals with schizophrenia, including acutely-ill hospitalized patients, can engage in passive sensing facilitated by widely available smartphones. The methods used in this research are less vulnerable to many of the challenges associated with self-report paradigms, including problems with low literacy, self-presentation biases, poor insight or attention, and motivational difficulties (e.g. not responding to prompts). Excluding battery charging periods, the smartphone collected a wealth of objective information automatically and continuously, providing a multidimensional and vivid longitudinal depiction of users' behaviors and contexts.

The research had several limitations. Data collection was dependent on participants carrying the smartphone. If participants forgot the device or loaned it to others, the data captured for that period would not represent the intended user's activity and context. Additionally, location ratings could not be provided for periods when outpatients were indoors (i.e., no GPS data) and out of WiFi or cellular network range, and when inpatients left the unit that was fitted with Bluetooth beacons.

Conclusions

Individuals with schizophrenia are willing and able to engage in behavioral sensing using smartphones. More than fifty percent of the adult population in the United States already owns and uses smartphones regularly, and recent research suggests that individuals with psychiatric illnesses are not dramatically different in this regard (14). Wearable sensing technologies (e.g. bracelets, garments) require that users be motivated enough to want a specialized device, and that they be able to afford it (15). With the aid of software that can repurpose smartphone sensors, these ubiquitous devices can be leveraged as objective, affordable, and scalable behavioral measures. Used effectively and with appropriate protection of patient privacy, access to behavioral sensing data could potentially transform clinical decision making and practice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Usability and Acceptability Ratings

	Inpatients (n=11)						Outpatients (n=9)					
	Disagree		Neutral		Agree		Disagree		Neutral		Agree	
	N	%	N	%	N	%	N	%	N	%	N	%
Usability												
I found the system to be very complicated.	8	73	0	0	3	27	7	78	1	11	1	11
I thought the system was easy to use.	2	18	0	0	9	82	1	11	0	0	8	89
I think that I would need the support of a technical person to be able to use the system at home.	8	73	0	0	3	27	6	67	1	11	2	22
I found the system very awkward to use.	9	82	1	9	1	9	8	89	1	11	0	0
I felt very confident using the system.	1	9	1	9	9	82	1	11	0	0	8	89
I felt comfortable using system.	1	9	0	0	10	91	0	0	0	0	9	100
It was easy to learn to use the system.	1	9	1	9	9	82	2	22	1	11	6	67
I don't understand how the system works.	7	64	1	9	3	27	7	78	1	11	1	11
I found it easy to keep the device with me at all times.	2	18	1	9	8	73	1	11	2	22	6	67
Acceptability												
I was concerned about my privacy using the system.	4	36	3	27	4	36	9	100	0	0	0	0
I was comfortable with having my information collected by the system.	1	9	4	36	6	55	2	22	0	0	7	78
Using the system made me think about my condition more.	2	18	5	46	4	36	3	33	1	11	5	56
Using the system made me upset.	6	55	3	27	2	18	6	67	1	11	2	22
If the system could create a summary of my behavior, I would like to see it.	4	36	2	18	5	46	1	11	0	0	8	89
If the system could give me feedback about my behavior, I would want to hear it.	3	27	3	27	5	46	1	11	0	0	8	89
If the system could offer me suggestions when I am upset, I would use them.	2	18	3	27	6	55	0	0	2	22	7	78