Use of Multimodal Technology to Identify Digital Correlates of Violence Among Inpatients With Serious Mental Illness: A Pilot Study

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Objective: The study examined multimodal technologies to identify correlates of violence among inpatients with serious mental illness.

Methods: Twenty-eight high-risk inpatients were provided with smartphones adapted for data collection. Participants recorded their thoughts and behaviors by using self-report software. Sensors embedded in each device (microphone and accelerometers) and throughout the inpatient unit (Bluetooth beacons) captured patients' activity and location.

Results: Self-reported delusions were associated with violent ideation (odds ratio [OR]=3.08), damaging property (OR=8.24), and physical aggression (OR=12.39). Alcohol and cigarette cravings were associated with violent ideation (OR=5.20 and OR=6.08, respectively), damaging property (OR=3.71 and OR=4.26, respectively), threatening others (OR=3.62 and OR=3.04, respectively), and physical aggression (OR=6.26, and OR=8.02, respectively). Drug cravings were associated with violent ideation (OR=2.76) and damaging property (OR=5.09). Decreased variability in physical activity and noisy ward conditions were associated with violent ideation (OR=.71 and OR=2.82, respectively).

Conclusions: Identifiable digital correlates may serve as indicators of increased risk of violence.

Psychiatric Services in Advance (doi: 10.1176/appi.ps.201700077)

Whether a serious mental illness increases one's propensity for violence has been the topic of much debate (1,2). It is clear, however, that psychiatric conditions such as schizophrenia increase individuals' risk of substance use (3), and evidence suggests that the combination of serious mental illness and co-occurring substance use disorder is associated with increased risk of violence (4,5).

Prediction or prevention of violence depends primarily on the use of traditional assessments, such as questionnaires, interviews, and review of archival information. These approaches rely on individuals' recollections of weeks, months, or even years, a process that is affected by confounding factors. In addition, such approaches lead to identification of risk factors that are relatively stable (for example, age, gender, and diagnosis) and thus more difficult to modify, and they produce broad risk categories that have limited specificity, sensitivity, and utility (6,7). Recent advances in mobile health (mHealth) technology offer us opportunities to better understand the relationships between internal states, external conditions, and violent behavior. Smartphones have sensors that can facilitate detection of users' behavior and context (8). Smartphones can also facilitate ecological momentary assessment (EMA), a data collection technique in which individuals complete self-report questionnaires delivered by the device (9). Participants report their current state and context without having to retrospectively summarize feelings or reconstruct events.

We provided psychiatric inpatients at high risk of violence with a smartphone that enabled behavioral sensing and EMA. We integrated the data to identify digital correlates of violent ideation and behavior in this high-risk group.

METHODS

This study was approved by the institutional review boards of Dartmouth College and the New Hampshire Department of Health and Human Services. Data collection was conducted between 2014 and 2016 at a state hospital where most patients are admitted because they are dangerous to themselves or others. Participants completed baseline assessment, which included the Psychotic Symptom Rating Scales, Beck Depression Inventory–Second Edition (BDI-II), and Green-Paranoid Thoughts Scale (G-PTS).

Participants were provided a customized Android smartphone to engage in data collection for a maximum of seven days or until discharge. Smartphones were adapted to fit

the needs of a secure hospital: cameras, audio recording, and programs that could save typed content were disabled. To prevent strangulation, participants were not given chargers with cords. Data plans and Wi-Fi were inaccessible; participants could not make calls, send text messages, or use the Internet.

Data collection software combined pretimed and behaviorally triggered sensor activation (8,10,11). The microphone was activated every two minutes to capture sound. If the software detected human speech it remained active. Speech duration was calculated as the total minutes that participants were proximal to human speech daily. Device-embedded accelerometers continuously detected movement. An activity rating was generated every two seconds. For each ten-minute period, the system calculated moving versus stationary time. If the ratio was greater than .5 the period was labeled "active."

Stationary Bluetooth beacons were installed throughout the inpatient units. The smartphone received signals from the beacons. The location in which a participant spent the longest amount of time in the two minutes prior to completion of the questionnaire was used as the location for that period. [A map showing placement of beacons on the unit is included in an online supplement to this report.]

Participants were prompted to complete EMA questionnaires six times daily. Questionnaires focused on internal and contextual states that are dynamic and potentially modifiable. These included affect, environmental conditions, delusions, substance cravings, withdrawal symptoms, suicidal ideation, and violent ideation and behavior. Response options ranged from 0, not at all, to 4, extremely. [A list of questionnaire items is included in the online supplement.]

We anticipated that violent behavior would be fleeting and that participants would not respond to an EMA prompt in the midst of a violent event. Therefore, the items evaluating violent behavior inquired about the interval since the last EMA prompt. On completion of data collection, participants returned the smartphone and received $50.

Because of the relatively low prevalence of violence among individuals with psychiatric conditions, we recruited a subgroup of patients who were considered at high risk of violence. Inclusion criteria were chart diagnosis of schizophrenia, schizoaffective disorder, or bipolar disorder; co-occurring substance use disorder; violence-related circumstances six months prior to hospitalization or while on the unit; sixth-grade reading level or higher; and hearing and vision functioning that enables use of the smartphone (verified using a demonstration device).

Nonlinear mixed-effects models were fit for each violence outcome and for each sensor and EMA predictor. EMA items were dichotomized to indicate whether the symptom was endorsed (0 versus 1–4). These models accommodated the dichotomous outcome and the nonindependence of observations from the same individual. Multivariate models were then fit for each violence outcome, including features found to be significant in bivariate models. In this study, we focus on the bivariate results because of the exploratory nature of the analyses; the goal was to identify all correlates of violence. For the same reason, adjustment for multiple comparisons was not performed.

RESULTS

A total of 603 patient charts were reviewed. Sixty-four inpatients were approached about the study, and 32 expressed interest. One failed the competency screener; one's diagnosis was updated, rendering the patient ineligible; and another scored below the required reading level. Two participants were dropped from the study: one became symptomatic during baseline and could not continue, and the other told research staff to leave him alone after enrollment. Twenty-seven participants completed the study.

Participants had a mean±SD age of 33±11.13, and 15 (86%) were men. Three participants did not report their race. Of the remaining participants, 18 (76%) were Caucasian. Approximately half the sample (N=12, 46%) had more than six lifetime psychiatric hospitalizations. Diagnoses were as follows: schizophrenia, N=14, 54%; schizoaffective disorder, N=4, 14%; and bipolar disorder, N=9, 32%. Participants had mild depressive symptoms (BDI-2 mean total score=18.8±12.2; range 4–52) and moderately severe persecutory ideation (G-PTS mean total score=90.6±37.6; range 32–155).

The mean length of data collection was 6.32 days. Participants responded to a mean of 23 EMA prompts, yielding 588 questionnaires in total. Participants were active an average of 2.10 hours a day and proximal to human speech 4.15 hours a day. They spent a mean of 4.34 hours in the hallways, 2.11 hours near the nurses' station, .94 hours in the kitchen, 1.24 hours in the lounge, and .61 hours in the group room. On average, participants left the inpatient unit for .79 hours over the course of the study.

Fourteen participants (52%) reported at least one event of violent ideation or behavior, for a total of 110 events (19% of questionnaires). In this subgroup, 12 participants reported thinking of harming someone at least once (mean=6.8±8.2 times, range 1–33), six participants reported damaging property at least once (7.0±11.8 times, range 1–31), 11 participants reported threatening someone at least once (4.7±9.1 times, range 1–32), and nine participants reported being physically aggressive toward someone on the unit at least once (5.3±10.4 times, range 1–33).

Self-reported delusional beliefs were significantly associated with violence (Table 1). Endorsing any type of delusion was associated with violent ideation, damaging property, and being physically aggressive toward someone on the unit. That is, questionnaires on which individuals self-reported delusional beliefs were more likely to indicate violent ideation or behavior than questionnaires on which no delusional beliefs were reported. Results were similar for individual delusion items. In the multivariate models, the relationship between thought insertion and violent ideation remained significant. [A table in the online supplement presents results from the multivariate models.]

TABLE 1. Predictors of violent ideation and behaviors among inpatients with serious mental illness, by passively sensed and self-reported variables

	Ideation		Behavior					
	Thinking of harming		Damaged property		Threatened someone		Physically aggressive	
Variable	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Passively sensed feature								
Smartphone detection								
Speech duration	.98	.72–1.58	.97	.55–2.33	.97	.64–1.48	.87	.53–1.43
Physical activity								
Mean	1.26	.92–1.62	.80	.47–1.36	1.17	.76–1.81	.91	.57–1.44
Minimum	1.52*	1.10–1.61	.83	.48–1.36	1.04	.69–1.58	.77	.48–1.24
Maximum	.95	.65–1.77	.83	.44–1.57	1.24	.70–2.21	1.30	.67–2.55
Variability	.71*	.51–1.64	1.19	.69–2.05	.78	.51–1.22	1.26	.80–1.98
Bluetooth location (reference: outside unit)								
Nurses station	1.27	.23–13.27	.49	.00–52.64	2.26	.10–50.33	2.89	.10–85.10
Private areas (women's and men's hall)	.86	.17–11.42	.99	.01–108.56	3.29	.15–71.43	3.44	.12–99.02
Group room	.70	.10–17.78	2.46	.02–392.17	5.74	.22–146.72	11.29	.35–368.11
Public areas (day room, recreational area, and kitchen)	.65	.13–12.12	1.79	.02–195.17	2.45	.11–54.50	2.19	.08–63.50
Self-report (reference: not endorsed)								
Suicidal ideation	6.84***	2.70–4.08	3.43*	.69–17.00	3.48	.96–12.60	11.59***	2.95–45.58
Being spied upon	3.37**	1.68–3.34	5.21**	1.42–19.15	2.39	.88–6.46	4.27*	1.34–13.61
Thought insertion	4.76 ***	1.97–3.78	7.15*	1.82–28.13	2.02	.72–5.66	5.06**	1.51–16.96
Special powers	1.04	.41–4.06	4.89*	1.20–19.90	1.64	.58–4.62	4.30*	1.12–16.52
Delusional thoughts[a]	3.08*	1.29–3.74	8.24*	1.57–43.42	1.89	.62–5.74	12.39**	2.47–62.04
Cravings								
Drugs	2.76*	1.21–3.47	5.09*	1.31–19.70	2.49	.86–7.16	3.14	.87–11.38
Alcohol	5.20***	2.19–3.69	3.71*	1.01–13.64	3.62*	1.34–9.77	6.26**	1.82–21.46
Cigarettes	6.08***	2.30–4.35	4.26*	1.01–18.01	3.04*	1.06–8.73	8.02**	1.67–38.43
Withdrawal symptoms								
Stomach upset	1.31	.63–3.07	3.89	.91–16.54	2.04	.76–5.53	2.40	.75–7.60
Hot and cold flashes	1.92	.89–3.21	6.18**	1.76–21.69	3.68**	1.43–9.49	11.05***	3.16–38.65
Pain	1.50	.67–3.38	1.89	.46–7.75	2.09	.70–6.23	2.82	.72–10.98
Negative affect								
Angry	3.19***	1.63–2.76	4.84*	1.40–16.78	5.30***	2.01–13.95	3.64*	1.23–10.77
Sad	3.95***	1.76–3.38	1.68	.51–5.54	4.87**	1.66–14.27	11.96**	2.67–53.51
Bored	.92	.41–3.40	1.19	.33–4.25	1.53	.58–4.02	.91	.29–2.87
Restless	5.16***	2.29–3.40	4.87*	1.21–19.64	1.51	.61–3.73	3.41*	1.04–11.17
Ward conditions								
Crowded	1.73	.88–2.75	3.24	.99–10.56	1.39	.57–3.41	1.81	.66–5.02
Noisy	2.82**	1.42–2.81	1.74	.46–6.61	1.84	.72–4.69	2.47	.81–7.54

[a] Combines endorsement of any delusional belief (being spied upon, thought insertion, and special powers)
*p<.05, **p<.01, ***p<.001

Suicidal ideation was associated with violent ideation and with being physically aggressive toward someone, and the relationship with violent ideation remained significant in multivariate models. Cravings for alcohol and cigarettes were significantly associated with violent ideation, damaging property, threatening someone, and being physically aggressive toward someone, and cravings for drugs were associated with increased odds of violent ideation and damaging property. In multivariate models, cravings were no longer significantly associated with violent thoughts or behaviors. Hot and cold flashes (symptoms of withdrawal) were associated with damaging property, threatening someone, and being physically aggressive, and the associations with damaging property and being physically aggressive remained significant in multivariate models.

Negative affect was associated with violent ideation and behaviors in bivariate models. Self-reported anger was associated with increased odds of violent ideation, damaging property, threatening someone, and being physically aggressive. Self-reported sadness was associated with violent ideation, threatening someone, and being physically aggressive. Restlessness was associated with increased odds of violent ideation, damaging property, and being physically aggressive. In multivariate models, only the association between restlessness and violent ideation remained significant.

Periods with higher variability in physical activity were associated with decreased odds of violent ideation, and periods with higher minimum activity were associated with increased odds of violent ideation. However, these associations were not significant in multivariate models. Noisy ward

conditions were associated with increased odds of violent ideation, and this association remained significant in multivariate models. Location on the inpatient unit and speech duration, captured via the smartphone microphone, were not associated with violence.

Sensitivity analyses (excluding one participant who reported 30 incidents of violent ideation, 42 incidents of damage to property, 32 incidents of threatening, and 33 incidents of physical aggression) showed similar patterns of results.

DISCUSSION

Identification of proximal correlates of violence among people with serious mental illness may improve risk assessment and prevention (7,12). This study was the first to use multimodal mHealth and location-aware technology to identify behavioral and psychosocial correlates of violent ideation and behavior. The findings contribute to the study of violence and advance our understanding of the potential for sophisticated technological data collection approaches in clinical populations with complex conditions. Participants demonstrated good adherence to the study protocol and very low dropout, suggesting that multimodal mobile data collection focusing on highly sensitive topics is feasible among acutely ill hospitalized individuals.

Previous research has linked delusions with violence. This study found that delusional beliefs were associated with violent behavior and that the relationship was quite time sensitive over a timeframe of several hours. Delusional beliefs are neither constant nor static (13). Any risk of violence that is related to experiencing delusions may be similarly dynamic.

Suicidal ideation was associated with thinking about and acting aggressively toward others. People who act violently often also report self-directed violent ideation (14). On one hand, the literature suggests that social isolation increases the risk of suicidal behavior and that social support has preventive value. On the other, placing suicidal individuals with others on an inpatient unit may increase the risk of victimization. Whether they are alone or not, individuals who have suicidal ideation require close monitoring to prevent self- and other-directed violence.

Cravings for alcohol, cigarettes, and drugs were associated with violent ideation and behavior. Hot and cold flashes, which are a common manifestation of substance withdrawal, were associated with all types of violent behavior, whereas other physical symptoms of withdrawal were not. It is possible that other withdrawal symptoms cause people to focus their attention inward on rest and recuperation. Additional research is required to examine whether cravings and withdrawal increase the likelihood of violence among individuals with serious mental illness in a manner that differs for people without serious mental illness.

Our data collection period was brief and the sample was relatively small. Future studies with longer periods of engagement and larger samples will enable greater breadth of evaluation of violent ideation and behavior. The study was exploratory in nature and no adjustment was made for multiple comparisons, which may have introduced the possibility that the significant results did not represent true associations. Data collection from larger samples is needed to confirm factors identified in this initial analysis. The setting of a structured inpatient unit is not a typical environment, limiting generalizability. Hospital staffing and patient turnover may have affected the likelihood of violent ideation and action (15).

CONCLUSIONS

Delusional beliefs, suicidal ideation, loud ward conditions, negative affect, lack of variability in physical activity, substance-related cravings, and some symptoms of withdrawal were found to be linked with violence among individuals with serious mental illness and a history of co-occurring substance use disorders. If these relationships are causal, the underling mechanisms are not yet clear. Digital correlates of violence, which may be more easily identifiable by hospital staff or more openly endorsed by patients, may serve as risk indicators. Studies are needed that examine whether modification of these internal states (for example, cognitive restructuring of beliefs and relaxation) and external conditions (for example, quieter environments for high-risk patients) may help mitigate the occurrence of violent events in inpatient settings.

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The study was supported by an award granted through the Dartmouth Center for Technology and Behavioral Health (P30DA02992), which is funded by the National Institute on Drug Abuse. The funder was not involved in study design, data collection or analysis, report writing, interpretation of findings, or decision to submit the paper for publication.

Dr. Ben-Zeev has a content licensing and consultation agreement with Pear Therapeutics. The other authors report no financial relationships with commercial interests.

Received February 15, 2017; revision received April 3, 2017; accepted May 12, 2017; published online July 1, 2017.

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