Ecological Momentary Assessments:
A Clinical Interface

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Abstract

This article focuses on a graphical user interface developed to facilitate the use of data for treatment review and planning. The interface was developed as a specific response to the Veterans Transition Project, a Pilot study conducted by Altarum Institute at the Pathway Home; an inpatient treatment facility focusing on acute PTSD military and veterans. Detailed systems design and outcomes from the Veterans Transition Project will be published under different covers. This article focuses on the graphical user interface developed in response to „lessons-learned". The interface operates as a stand-alone application portable to multiple applications, and is also integrated into the Life:WIRE communication system. The interface will be applied to future projects for maximum utilization of extensive EMA data used in treatment review and planning.

As service members transition from combat to non-warfare roles, medical and psychological teams require new techniques and tools to address multiple and inter-related psychological and physical health issues. Post-deployment responses to societal stressors vary greatly between individuals and sometimes trigger adverse responses (Krahn, D., Bohn, M., Henk, H., Grossman, J. & Gosnell, B., 2005). The number of available treatment providers who have the requisite skills, knowledge, and training to meet the psychological health needs of returning service members and their families is insufficient (National Council on Disability, 2009). Applied clinical research was used to identify four sets of data: 1) Patient Moods, 2) Patient Hassles, 3) Patient Uplifts, and 4) Patient coping strategies. PDA-based Ecological Momentary Assessments (EMA) were implemented as the vehicle to collect a set of questions derived from the initial patient intake assessments, from which we analyzed patient treatment outcomes.

A large amount of data was quickly amassed for each patient. It became obvious that clinicians required a simple and intuitive tool to effectively use these data for treatment decisions. The clinical interface tool was developed to filter and analyze data using standard statistical techniques providing clinicians and support staff with instant real-time patient data. This interface contains a series of unique scoring Indices which serve to „normalize" daily score reactivity into smoothed trend lines. Indices integrate multiple data elements into a common comparative score that can intuitively be used by the practitioner to recognize and track change; and crisis events. In addition to real-time data, the clinical interface tool tracks and charts change-over-time against intake and cohort reference lines. Graphical charts present detailed statistical data in an intuitive and non-technical interface easily usable by non-statisticians. These practical adaptations will empower clinicians to share outcomes with patients, and thus allow the patient to become more involved in their treatment. The interface will enhance therapeutic interventions and reduce provider burden.

Though specific to the Pathway Home, this interface is easily adaptable to multiple environments, questionnaires, or fields of study. Its utility suggests the need and opportunity for similar tools to be integrated into the treatment process.

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Introduction

Justification for Study

More than sixteen million men and women have volunteered for combat deployment in Iraq and Afghanistan since 2001 (National Council on Disability, 2009). Many service members returned with a variety of physical, emotional, and psychological injuries; both visible and hidden. Long tours and multiple deployments further exacerbated injuries, creating tremendous burdens on service members‟ families, treatment resources, and community services. As service members and veterans transition from combat to their homes injuries often contributed to increased suicidal ideation(RAND Corporation, 2009), increased substance misuse (ibid), marital dissatisfaction intimate partner violence (Bell, KM & Orcutt, HK., 2009), child abuse and neglect (Gibbs, DA, Martin, SL, Kupper, LL, & Johnson RE., 2007), and even homelessness (Iraq Veterans Project, 2007). Psychotherapeutic studies have shown that, post-deployment, individuals‟ responses to everyday stressors vary greatly and can trigger adverse responses. Research remains scarce on which stressors trigger individuals‟ responses, how individuals cope with these events, and how everyday stress responses relate to symptoms of veterans‟ occupational stress. This pilot study addresses how these patterns of stress response affect treatment, recovery, and transitions to prevent or ameliorate chronic conditions.

In a 2006 article in the *Journal of Psychiatry and Neuroscience* Ecological Momentary Assessment (EMA) was described as the *method of the future* (Moskowitz, D.S. & Young, S.N., 2005). Commonly used by social science researchers and increasingly by the medical and allied health community, EMA is used to collect real-time data on a broad range of behavioral responses associated with Observations of Daily Living (Cohen et al., 2008). By using electro-mechanical devices such a cellular phones and Personal Digital Assistants (PDAs) to collect data, client input can be collected and examined instantaneously increasing reliability, treatment compliance, patient motivation, treatment outcomes, and capacity (Hareva, Okada , Kitawaki & Oka, 2009). Particularly appropriate to documented symptomologies of Post-traumatic Stress Disorder (PTSD), Substance Use Disorder (SUD), Major Depressive Disorder (MDD), and mild Traumatic Brain Disorder (mTBI) such as short-term memory loss, EMA data collected using electro-mechanical devices allow patients to systematically record, and treatment staffs to monitor, a range of self-appraisals and patterns of behaviors.

Collecting real-time data about stressors such as interpersonal relationships, finances, health concerns as well as emotional responses to stressors and coping strategies inform treatment and encourage patients to become more involved in their recovery. Integration of simple technology solutions, such as two-way cell-phone text messaging improves treatment outcomes and eases transition from treatment to home and work. Integrated electro-mechanical intervention, analyses, and focused data that simultaneously assesses and monitor patients, promises to advance the delivery and efficacy of treatment interventions. Integrated electro-mechanical interventions can be implemented without the constraints of the clinician‟s office and extend beyond residential treatment to monitor and improve patient compliance with treatment goals. These innovations easily customize to the numerous clinical needs of individual Service members while lessening providers‟ clinical burdens.

Altarum‟s pilot-test was a simple straight-forward solution that integrated PDAs and cell-phones to collect real-time patient attitudinal data. Historically, EMA have been collected via paper and pen questionnaires or health diaries to capture retrospective information that relies on patient memory. PTSD, mTBI, SUDs, and MDD most often include some level of short-term memory loss. Integrated real-time data demonstrated potential to dramatically improve the accuracy of patient recall with more accurate data having potential impact in the recovery of service members, veterans, and their families. PDAs and cell-phones were used to capture EMAs and then to maintain contact reinforcing treatment goals with the client throughout their recovery regimen. The study sought to establish the effectiveness of electro-mechanical augmentation as an adjunct to treatment; and to explore the effectiveness of using these devices as a data collection methodology.

Research was conducted onsite at the Pathway Home, an intensive residential treatment program serving Operation Enduring Freedom / Operation Iraqi Freedom (OEF/OIF) veterans diagnosed with posttraumatic stress disorder (PTSD), substance use disorders (SUDs), major depressive disorder (MDD) and/or mild traumatic brain injury (mTBI). Two treatment cohorts were selected. Data was collected over the period of one year.

This project integrated readily available commercial technologies in a noninvasive treatment methodology. PDAs were issued to each participant. EMA loaded onto these PDAs were utilized as a way to capture patient status at random times throughout the day. EMA data, along with input from clinicians and patients, were used to develop customized treatment plans based on individual triggers and sensitivities. Treatment plans were continually updated based on summarized EMA data.

Real-time EMA data contained key questions extracted from patient intake assessments. The clinical treatment team determined the questions used in the EMA survey. Questions focused on emotional states, responses to events, self-appraisals, daily stress (e.g., interpersonal relationships, health, financial, goal achievement), perceived control over situations, coping, and cravings for alcohol and other substances. The pilot was comprised of forty current and former residents and five clinical providers. EMA data were collected one to three times daily from each patient. Research data was de-identified by a Pathway Home clinical research assistant, and transferred to Altarum‟s secure server for compilation and analysis. Data and feedback collected using EMA methods was analyzed and used by both patients and clinicians to monitor treatment progress, adjust treatment interventions, and improve outcomes.

Extensive data were collected. Clinicians participating in this study continued to be accountable for all responsibilities required before adding duties from this intervention. Therefore, additional time allocated to this study was extremely scarce. Additionally, pre-study provider focus groups indicated that clinicians were not likely to use these data unless they significantly saved time or eased the clinician‟s current workload. The clinicians interface was developed to address these issues.

Goals of the Clinical Interface

To best utilize and understand collected EMA data, a graphical clinical interface was developed. The interface delivered filtered concise data to the treatment team in an intuitive and easy to

comprehend format in order to facilitate the use of those compiled data in treatment planning and execution. The following criteria were determined to be critical in developing the clinical interface. It must be client specific. It must display actual data to allow the clinician to make the determination of treatment, rather than having the interface determine treatment. It must provide summarized data, with easy access to specific detailed data; if or when backup information was required. The interface must be intuitive and provide key information within seconds of accessing. It must dynamically adapt to changes in information collected by the patient EMAs. Finally, the interface was available in real-time, from any location the clinician was required to interact with clients. The pilot demonstrated potential for scalability to larger numbers of veterans transitioning to community life nationwide.

All data were collected using the highest standards for Federal Rights to Privacy. Clinical personnel developed a unique client identifier (UCI) for each patient. All data was de-identified by an automated process which removed all identifying information and added the appropriate UCI for each client. De-identified data were appended to a database located on a secure network meeting stringent VA Health Information Record protocols, through an encrypted FTP link. Researchers only had access to research data by using a secure virtual private network (VPN) to access a remote workstation located in a DMZ of the secure network. All data analyses were performed on the remote workstation.

EMA Data

Key initial intake assessments questions were selected by the clinical team and researchers during a pre-research focus group. These 28 questions were compiled into a survey which was ported to operate on personal digital assistants (PDA). PDAs were issued to each study participant. Each question was answered by clicking the appropriate 0-5 Likert-scale response on the PDA. Data from Ecological Momentary Assessments (EMA) were collected one to three times daily. Data from each PDA were collected into a centralized database located at the treatment facility each time the PDAs were docked. PDA data were then batch-loaded via FTP to the secure research server for analyses.

The Matrix

A matrix was created to analyze collected EMA values. Each category selected from the EMA questionnaire represents an individual question and is organized as a column in the matrix. Columns are identified by key words representing the question. Each set of EMA responses comprises a row of the matrix, or a research event. Rows are identified by the UCI and date the EMA was collected. The matrix is dynamically created to allow as few as 2 reporting events with no upper limit on the number of events that could be tracked.

		4607											
	Timestamp	Happy	Angry	Scared	Confident	Alone	Alert	Guilty	Effective	Valuable	Fulfilled	Secure	Influential
4607	5/4/10	4	2	2	2	2	2	2	1	1	1	1	1
4607	5/4/10	2	2	1	2	1	2	1	1	2	0	2	2
4607	7/12/10	3	2	2	3	3	3	1	3	3	2	2	3
4607	7/12/10	3	2	2	3	3	3	1	3	3	2	2	3

Individual daily reports compared to cumulative patient daily reports.

For use in the clinical interface, individual data is queried from the central secure database of de-identified data. In order to achieve various desired outcomes, data is charted in both raw and calculated formats. When data are analyzed for change-over-time, each individual response is compared to the running mean of that question. This process serves to make all observations relative to the individual rather than an external standard or value. More critically, comparison of individual to cumulative data allowed the clinical tool to be instantly adaptable to varying criteria without recoding or modification the core program logic. This tool is, therefore, agnostic to the survey, questions, or data values, and may be applied across a wide variety of implementations.

Corrected Data

To reduce the potential for automatic responses (e.g. answering 3 to every question), questions were mixed in the EMA survey. All answers are on a 5 point Likert scale with 0 being Not at All, and 4 being Most of the Time. For questions such as "How Angry do you feel right now?" a 0 was a positive. Conversely, for the question "How confident are you right now?" 0 was a non-positive response. Mixing required the participant to read and consider each question before responding. Data used for statistical analyses in the matrix was „corrected" so 0 was always a non-positive response, and 4 was a highly positive response.

Switching was performed in a non-displayed matrix used for calculation purposes. Raw data is always displayed in its native format. In this way all graphics can be analyzed with a simple metric – up is good. Clinicians and staff do not need to have a reference EMA questionnaire to review wording in order to analyze change-over-time.

Selective Data

Although hard coded for the initial development, current modifications are underway that will allow clinicians and researchers to dynamically select a data source, and the desired fields within that data source, and corrected scales, for analysis. This ability to dynamically configure the clinical interface will allow treatment teams to focus on only those data elements that prove over time to be indicative of long-term patient change; with the ability to dynamically add new items or remove non-critical elements.

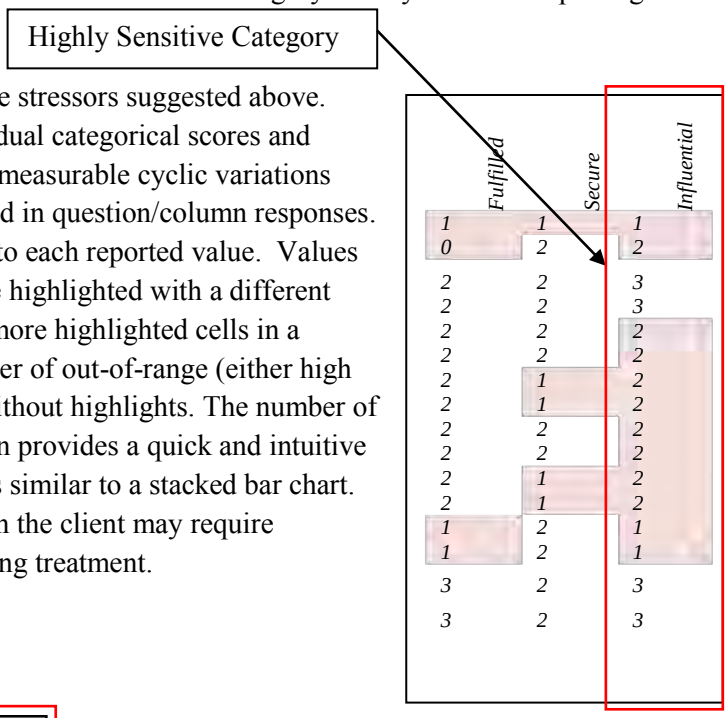
Out of Range Determinates

Patient responses varied significantly over time – often within a single day. A wide variety of external stressors motivated changes in individual daily responses, such as mood change, finances, interpersonal relationships, health, etc. In order to determine a „normal" standard for each individual, individual responses are compared to the cumulative mean of responses in the same category for that individual, from inception to the date being analyzed. Each value was then compared to the cumulative mean plus or minus 1 standard deviation for the cumulative values. Outliers above or below 1 standard deviation from the mean for the calculated value were determined to be out-of-range from the „normal" responses for that individual. Out-of-range

responses were highlighted in a different color. Cumulatively, fewer than 5 percent of all responses had 0 out-of-range responses in at least one category for any collected reporting event.

Sensitivity Scoring

Individual events reflected all of the stressors suggested above. Graphical representations of individual categorical scores and cumulative event scores contained measurable cyclic variations based on these stressors, as reflected in question/column responses. Out-of-range analysis was applied to each reported value. Values determined to be out-of-range were highlighted with a different background color. Columns with more highlighted cells in a column represented a greater number of out-of-range (either high or low) responses than a column without highlights. The number of highlighted cells in a matrix column provides a quick and intuitive representation of client sensitivities similar to a stacked bar chart. These may suggest an area in which the client may require additional or focused attention during treatment.



Index Scoring

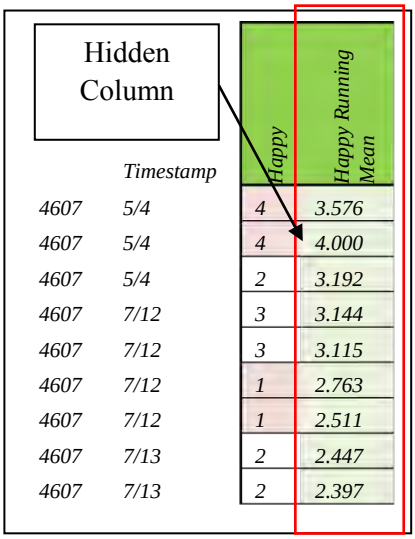
Valuable	Fulfilled	Secure	Influential	No. Crises
1	1	1	1	8
2	0	2	2	5
3	2	2	3	4
3	2	2	3	4
1	2	2	2	7
1	2	2	2	7

A series of index scores were developed to convert extensive data into simple scales that compare each reported event to those accumulated to-date. These indices provide a single number that can efficiently be used by technical and non-technical staff without significant interpretation, and with equal accuracy. Indices were calculated using a compilation of individual raw or calculated responses for each event. The column of index scores represents an estimated reactivity across all categories for each collected EMA event. Using index scores reduces the effect of individual out-of-range responses for each event, and provides a better representation of overall event response.

Due to its dependence on accumulated raw scores, index scoring while ameliorating the effect of one or two out-of-range responses continued to have strong cyclic variations representing „good" and „bad" days during treatment. Out-of-range scoring was again applied to highlight index scores that fell outside the client"s cumulative normal range. Out-of-range index scores were highlighted using a red background for responses falling above 1 standard deviation from the client"s calculated mean, and green for responses falling below 1 standard deviation from the client"s calculated mean. Current interface modifications will automatically generate a text message to a designated treatment team member indicating that this client is reporting abnormally high or low responses for that day. These messages will allow the treatment team to immediately respond to events before they escalate or the client decompensates.

Statistical Noise Reduction

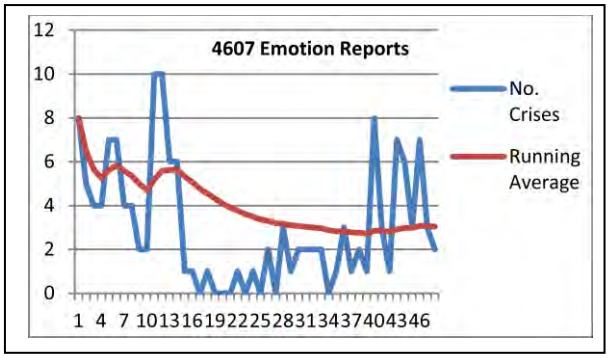
Hidden statistical noise reduction columns were added to the matrix to minimize the cyclic effect of any single out-of-range value. Noise reduction columns contain the calculated running mean for each cell in each column. Similar to other calculated means, these running means are calculated by including all responses for that question from the inception of data collection to the event being reported. Running means ameliorate the effect of an abnormally high or low reported value by averaging these values into the cumulative mean to-date, thus reducing the variability of individual reported values. Each value builds on the previous mean score and becomes the averaged expected, or normal, value for that category. By graphing the running mean for each event against the raw daily score, the clinician can instantly see the cumulative change to date, whether the daily reported value for that question is within range of the expected value, and the how far out-of-range each response is. Each out-of-range spike can be tracked to the date listed on the x-axis, or by referring to the matrix for specific details.



	Timestamp	Happy	Happy Running Mean
4607	5/4	4	3.576
4607	5/4	4	4.000
4607	5/4	2	3.192
4607	7/12	3	3.144
4607	7/12	3	3.115
4607	7/12	1	2.763
4607	7/12	1	2.511
4607	7/13	2	2.447
4607	7/13	2	2.397

Noise reduction was used in a several places throughout the clinical interface. Charts were developed for each question, so clinicians can evaluate change-over-time both by individual category or cumulatively.

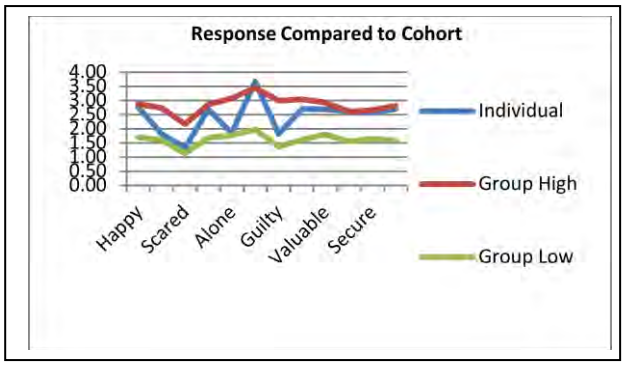
A similar process was applied to the calculated index score. Applying statistical noise reduction to the index scores creates a trend line representing the patient‟s cumulative change-over-time. When the noise-reduced index trend line is charted against the raw index scores it shows overall patient „good‟ or „bad‟ days; and the extent to which each of these events was out-of-range. During individual counseling these spikes allow the clinician to immediately focus on days, and events within each day, that elicited a strong response; thus reducing lost time during therapy searching for, rather than focusing on, specific issues.



Cohort ‘Norming’

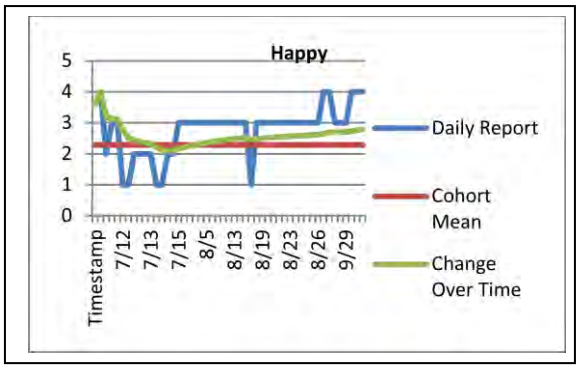
Cumulative cohort data provides reference scores to evaluate how each client‟s self-report compares to their treatment group. Cohorts consisted of all persons participating in the same treatment sequence, at the same facility, during the same period of time; all having similar or common diagnoses. The cumulative running mean value for each column was calculated using same values from all cohort members. Additionally, these data provided a standard deviation score for the cohort.

Best Fit



A line graph was developed to compare cohort scores, for each column. The mean plus one standard deviation – the upper range - and mean minus one standard deviation – the lower range were plotted for each column. The space between upper and lower ranges represents the cohort‟s normalized range of responses. Each patient‟s mean scores were overlaid on the cohort „normal‟ range to represent the individual‟s „fit‟ compared to their treatment cohort. Categories where patient‟s do not fit within the cohort „normal‟ range may indicate to the clinician that the client may respond better to individual therapy for the identified issue. Issues within the cohort normal range seemed to indicate a good fit for group therapies and activities for those issues.

Cohort Mean



The cohort mean score was also useful as a reference „relative‟ to each patient‟s reported scores. Graphs were augmented by two reference lines: one for the cohort norm to provide a measure of acuity relative to the cohort, and one for the individual‟s response to that issue at intake to represent gross change over treatment. Values seemed to provide a baseline comparison of the patient‟s relative acuity to that of the cohort. By charting the running mean for each question against the question‟s daily raw scores, charts displayed a dashboard of issue-specific change-over-time.

Sample Charts and Possible Clinical Implications

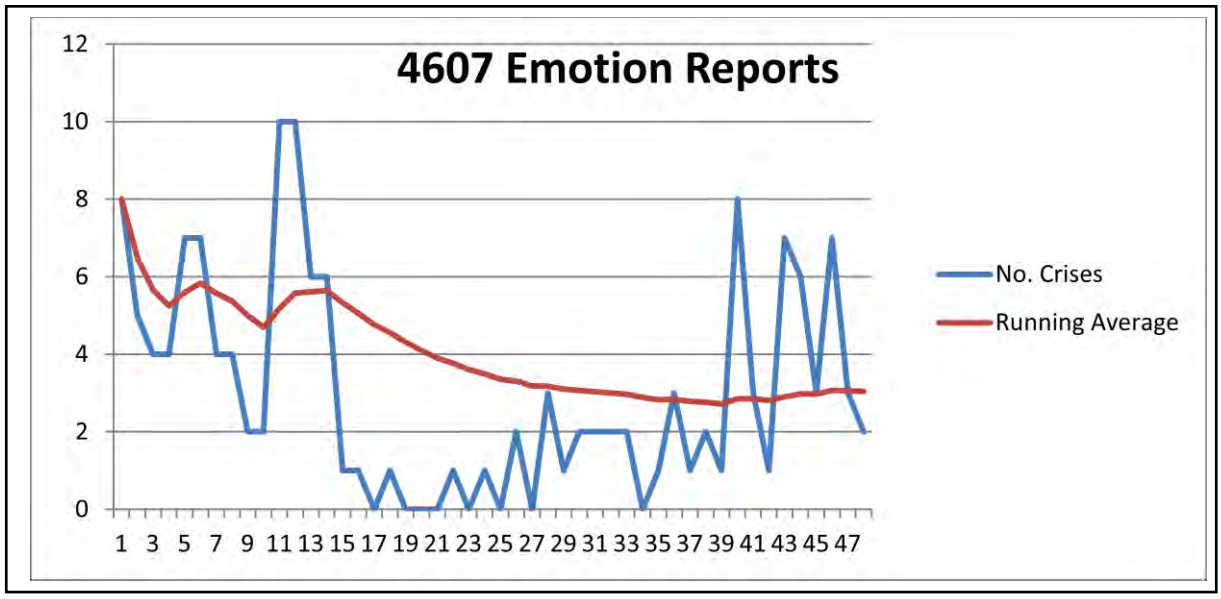
Matrix

4612

	Timestamp	Happy	Angry	Scared	Confident	Alone	Alert	Guilty	Effective	Valuable	Fulfilled	Secure	Influential	No. Crises	
4612	7/14/10	2	1	1	2	2	3	1	2	2	2	3	2	0	
4612	7/14/10	2	1	1	2	2	3	1	2	2	2	3	2	0	
4612	7/14/10	2	1	1	1	2	1	1	2	2	1	4	2	2	
4612	7/14/10	2	1	1	1	2	1	1	2	2	1	4	2	2	
4612	7/15/10	2	2	1	1	3	1	1	2	2	1	2	2	2	
4612	7/15/10	2	2	1	1	3	1	1	2	2	1	2	2	2	
4612	7/19/10	2	3	1	1	3	1	1	2	2	2	2	2	2	
4612	8/5/10	2	3	1	1	3	1	1	2	2	2	2	2	2	
4612	8/6/10	2	1	1	2	2	1	1	3	3	3	3	3	0	
4612	8/6/10	1	2	1	1	3	1	1	1	2	1	1	2	5	
4612	8/16/10	1	4	1	1	4	1	1	2	1	1	1	1	7	
4612	8/16/10	1	4	1	1	4	1	1	2	1	1	1	1	7	
4612	8/19/10	2	1	1	1	2	1	1	3	3	3	3	3	0	
4612	8/23/10	3	1	1	3	2	1	1	3	3	3	3	3	1	
4612	8/23/10	3	1	1	3	2	1	1	3	3	3	3	3	1	
4612	8/24/10	3	1	1	1	2	1	1	3	3	3	3	3	0	
4612	8/25/10	2	1	1	1	2	1	1	3	3	3	2	3	0	
4612	8/26/10	1	4	4	1	4	1	1	1	1	1	1	1	9	
4612	8/31/10	2	1	1	2	2	1	1	2	2	2	2	2	0	
4612	8/31/10	2	1	1	2	2	1	1	2	2	2	2	2	0	
4612	9/7/10	4	1	1	4	1	1	1	4	4	4	4	4	8	
4612	9/16/10	3	1	1	3	2	2	1	3	3	3	3	3	1	
4612	9/17/10	4	1	1	4	1	3	1	4	4	4	4	4	8	
4612	9/17/10	4	1	2	3	1	1	1	3	3	3	3	3	3	
4612	9/20/10	1	3	3	1	2	4	1	2	2	2	1	2	5	
	Mean +1 Stdev	3.042	2.891	2.534	2.694	2.986	3.235	2.013	3.090	3.090	3.075	3.280	3.085	6.040	
	Mean -1 Stdev	1.244	0.776	0.657	0.830	1.300	0.717	0.701	1.434	1.434	1.258	1.291	1.344	-0.088	
4612 Mean		2.143	1.833	1.595	1.762	2.143	1.976	1.357	2.262	2.262	2.167	2.286	2.214	2.976	

This matrix shows that client 4612 has more out-of-range responses in feeling Alone than any other category. The number of out-of-range responses initially indicate something outside of normal scoring. On closer examination, however, the clinician can see a fairly rapid decrease in reported loneliness during this period, with out-of-range indicators moving from high to low. In the index column on the right the clinician can see a major swing from very positive emotions on 8/26 to very negative emotions in the range of 9/7-9/17. Automated texts should have been triggered to the treatment team on 8/16, 8/26, 9/16 and 9/17 to alert them that this client was experiencing rapid and major mood swings. These may have otherwise gone unnoticed or undetected by clinical staff. If they were unreported during one-on-one therapy, the treatment team may not have addressed these rapid and distinct cyclic changes at all.

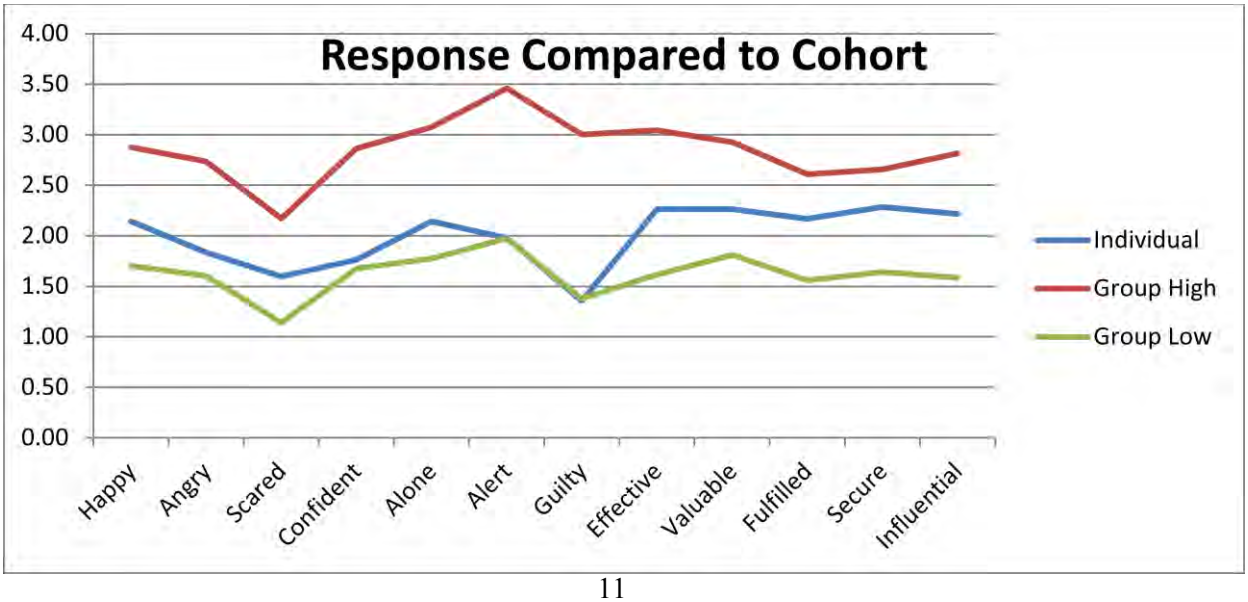
Emotional Event Change-Over-Time



Change-over-time charts the daily reported out-of-range events as reported by the Emotions Index and the running mean of the Emotions Index. The Running Average in the example demonstrates a trend reducing the average number of out-of-range items per EMA event from 8 to approximately 3 over 48 days of treatment. Days 12 and 13 report a major event driving the index into statistically high range, which would have been automatically reported to clinical staff by text message. The client progresses quite evenly with low events cycling over a small range until day 40, at which time something triggered 3 major episodes over a week. Clinicians would again have been automatically notified of these major fluctuations, and been able to directly address these issues immediately through direct intervention.

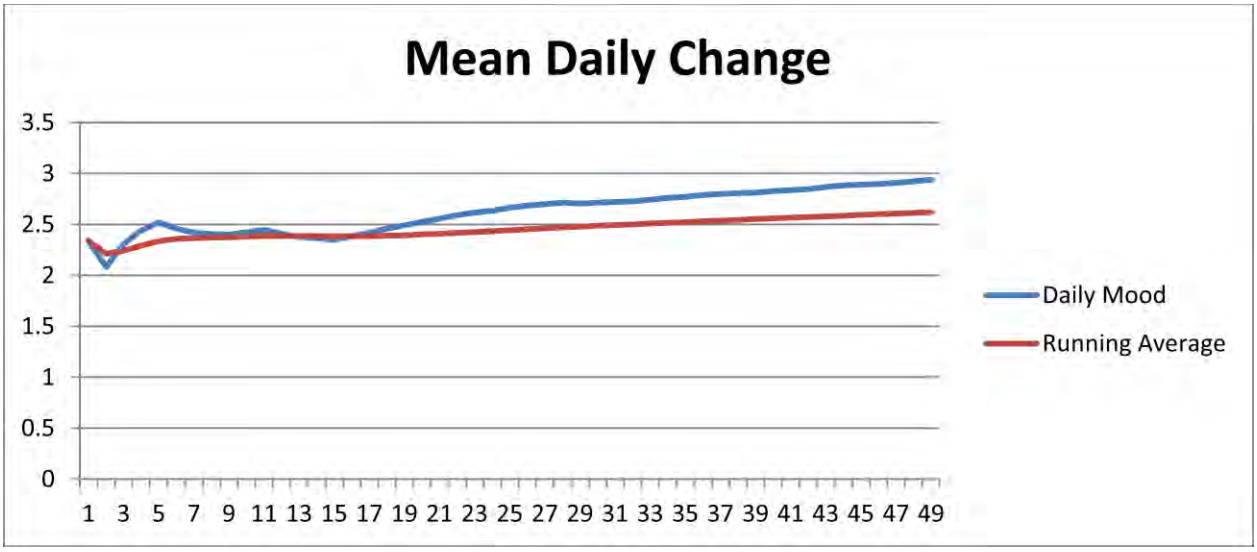
Fit with Cohort

Cohort fit represents the individual‟s mean scores for each question compared to those of the cohort. The treatment significance of this graphic may indicate the type of treatment that may best address the client



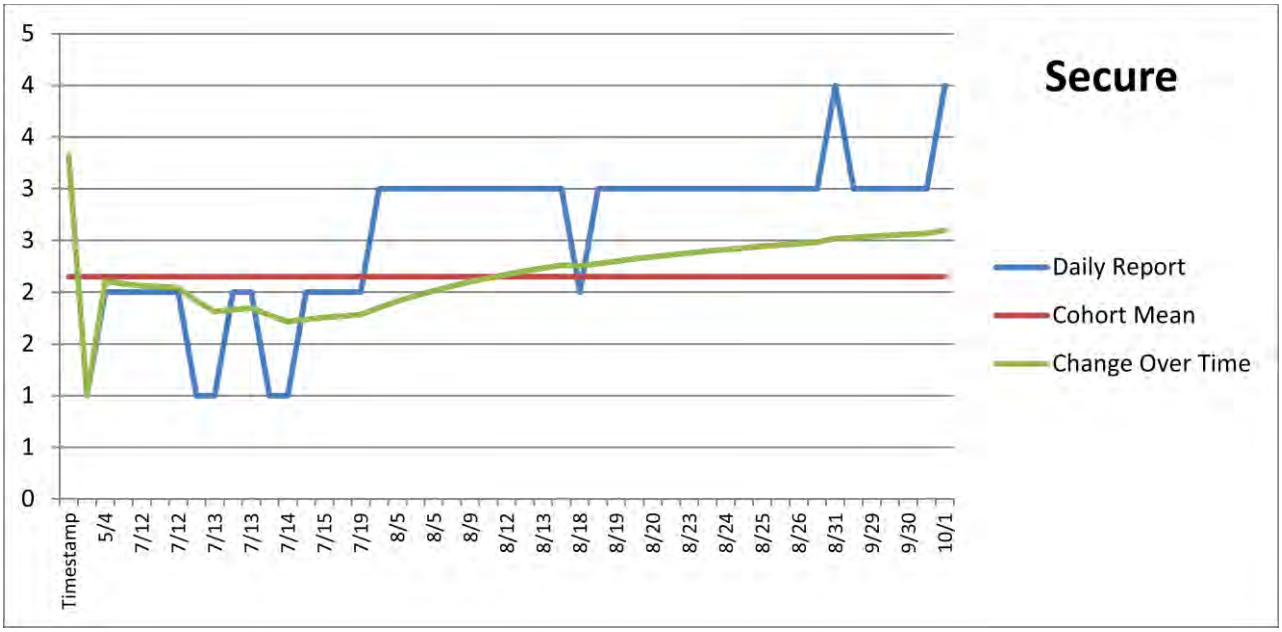
for each of the queried ranges. In this example the patient actually fits quite well with their cohort over the entire range of emotions. Possible caution could be applied for Alertness and Guilt. These areas may need to be initially explored in individual therapy before introducing this client to group treatment. Without individual attention, the individual may appear non-responsive or combative to the group when confronted with these issues.

Overall Change



Overall change-over-time is charted from an index score based on the sum of the running mean for each category at each reporting event. Using the running mean, this index is far less volatile to individual events or overall bad days than the episodic index score. While the episodic score represents a decrease in out-of-range episodes, this index indicates the cumulative improvement of responses over time. Charting the actual index against its calculated running average allows an accurate representation of client change-over-time.

Individual Change per Category



Individual graphics represent changes per category or question over time. In this 90-day graph the green bar charts the running mean of daily scores for security. The red line represents the average score of all cohorts to give the clinician an idea of where the client‟s responses score when compared to their cohort. The blue line charts individual daily scores. This graph represents the classic theoretical model of recovery where episodes become less acute and less frequent as the person adjusts to normal life cycles.

Implications and Applications

The final sample size of n=40, comprised of several cohorts of approximately 15 persons, is not statistically large enough to produce findings sufficient for generalization to any population, or to infer relationships beyond this pilot study. They do, however, provide some strong trends and provide multiple suggestions for future research. A detailed set of lessons learned has been compiled throughout this study which has informed the design, implementation, and tracking of future proposed projects. Extensive quantitative outcomes analyses and of lessons learned for future implementations have been, or are being, completed; but are beyond the scope of this paper. Additional papers addressing these areas will be published under separate titles.

The graphical clinical interface was designed late in this project, and in response to the demand of efficiently using collected data. Its refinements and enhanced descendants offer exciting potential as templates to assist end users in other venues use real-time data to inform and improve outcomes. This study was originally designed as proof of concept for integrating data collection into behavioral science decision making, maintaining patient compliance to treatment goals, and engaging patients in their treatment. The clinical interface tool is a significant unanticipated benefit of this pilot study, and is unique in its portability to multiple applications. Long-term viability will be demonstrated through its adaptability into multiple, diverse implementations currently being pursued.

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