Positive and Negative Affect Balance Trajectories in the Treatment of Depression

Submitted March 10, 2010

Robert M. Schwartz
University of Pittsburgh School of Medicine

Jonathan Touboul
The Rockefeller University and University of Pittsburgh

Author Note

This study was supported in part by a grant from the National Science Foundation (DMS0817131).

Robert M. Schwartz, Department of Psychiatry, University of Pittsburgh School of Medicine; Jonathan Touboul, Department of Mathematical Physics, The Rockefeller University and Department of Mathematics, University of Pittsburgh.

The two authors contributed equally to this work.

Correspondence concerning this article should be addressed to Robert M. Schwartz, 155 North Craig Street, Suite 170, Pittsburgh, Pa 15213. E-mail: robsch@pitt.edu or Jonathan Touboul, Department of Mathematical Physics, The Rockefeller University, 1230 York
Ave, New York, NY 10065. E-mail: jonathan.touboul@rockefeller.edu.
Abstract

To account for the complex interplay between positive and negative dimensions of experience in a well-defined framework, psychology needs theoretical models associated with mathematical tools that integrate both dimensions. To this end, we drew upon the Balanced States of Mind Model, an information-processing model that relates quantitatively precise emotional balances of positive and negative affects to psychopathology and optimal functioning. Using an intra-individual design, we conducted a time series analysis on the emotional balance variable as it evolved during different types of psychotherapy administered sequentially to the same patient, and compared the results of this precise analysis with three other patients. We mathematically identified three different trajectories of change (Phases) that varied with the type of therapy and the stage of treatment: variability, stability and oscillation. In contrast to a coping focused therapy, a dynamic focused therapy presented a longer initial phase of variability and resulted in a prolonged end-state phase characterized by oscillations of the emotional balance between normal and optimal levels that were associated with psychological flourishing and sustained through one year follow-up. This result suggests that initial variability and end-term oscillation (rather than stability) represents a more resilient treatment outcome. The use of theoretically based mathematical tools within a dynamical systems model generated the first observation of a post-treatment oscillatory pattern in the emotional system and provides a quantitative framework to investigate the process of human change.

Keywords: depression, psychotherapy, relapse, dynamical systems, time series analysis, positive and negative affect, states of mind model, Lomb-Scargle transform
Positive and Negative Affect Balance Trajectories in the Treatment of Depression

Human functioning is regulated by a dialectical tension between both positive and negative states. Traditional psychology has focused primarily on negative states (e.g., Beck & Alford, 2009), whereas positive psychology has recently shifted the emphasis to positive experience (Snyder & Lopez, 2005). Rather than developing these two dimensions along independent lines, psychology needs theories that systematically integrate both dimensions concurrently. Describing the process of change during psychotherapy thus requires the development of theoretically based models that explicitly capture the dynamical interaction of positive and negative dimensions along with mathematical tools to analyze the evolution of these states.

The Balanced State of Mind model (BSOM; Schwartz, 1997), an integrative model of positive (P) and negative (N) cognition and affect, has demonstrated that distinct ratios differentiate psychopathological, normal and optimal states. Drawing on Lefebvre's mathematically based theory of consciousness (Lefebvre, 1992), the BSOM model uses a ratio computed as P/(P+N) to define emotional and cognitive balance. Numerous studies have shown that clients progress from pre-treatment low balances to the normal or optimal balances depending on the success of the therapy (Haaga, Davison, McDermut, Hillis & Twomey, 1993, Schwartz et al., 2002). The robustness of this phenomenon is demonstrated by the finding that balance ratios in the .70 to .80 range characterize normal and optimal functioning, whether applied to individuals (Schwartz et al., 2002), marital couples (Gottman, 1994) or business teams (Fredrickson & Losada, 2005).

Discovering a relationship between quantitative ratios and psychological functioning will advance diagnosis and treatment for the same reason that medicine progressed through the recognition that precise body temperature and blood pressure ranges were associated with physical health. This development brings to positive psychology quantitative benchmarks for
distinguishing between optimal and normal levels of functioning. It also enables psychotherapy researchers and clinicians to more precisely differentiate subnormal, average and optimal treatment outcomes, and to improve predictions about resistance to relapse.

This is especially important in the area of depression because of the documented high rates of relapse and recurrence (Paykel et al., 1999; Teasedale et al., 2000). Keller (2003) observed that whereas most medical conditions have a defined pathophysiology, the criteria for optimal outcomes in depression treatment have been limited to measuring symptoms and interpersonal functioning, with no universally accepted definition of remission. Keller concluded that continued work was needed to better describe the phenomenology and neurophysiology of the disease process that enables us to bring patients to “euthymia and a truly disease-free healthy state” (p. 3152). The purpose of this paper is to apply advanced data analysis tools within a dynamical systems theory framework to better understand the dynamics of positive and negative affect balance in depression as they relate to a more precise delineation of optimal treatment outcomes.

The BSOM model has thus far examined the emotional balance ratio as a static variable. Typical studies measured normal and dysfunctional populations at a single moment in time or assessed the client's ratio at pre- and post-treatment. As Hayes, Laurenceau, Feldman, Strauss & Cardaciotto (2007) aptly point out, this approach assumes that change is linear and gradual, whereas ample evidence suggests that the human growth process is better viewed as a nonlinear and dynamical system typically characterized by phases of variability, abrupt transitions and stability. Similarly, the BSOM model does not equate health with zero variability, but hypothesized that some degree of variability is acceptable in optimal functioning, depending on the type of construct, the stage of coping, and the individual personality style (Schwartz, 1997).

In this paper we thoroughly describe the evolution of the emotional balance of a recurrently depressed individual who was sequentially administered three types of therapies in order develop
mathematical and psychological methods to understand the structure of his healing. We also briefly analyzed data from three other clients to ascertain whether they revealed similar patterns of change. This approach avoids a drawback of nomothetic models that may sacrifice individual relevance by averaging data across individuals. We followed the growing trend that focuses on intra-individual structures and dynamics (cf. Grice, Jackson & Mc Daniel, 2006; Molenaar, 2004), what Cervone (2004, 2005) has termed “personality architecture”.

This work extends the BSOM model by investigating the evolution of the emotional balance during psychotherapy to mathematically identify distinct patterns in the trajectory of change. These trajectories and their phase transitions were examined in relation to the type of treatment, the stage of therapy and critical incidents in the patient's life in order to illuminate the dynamical process that yields an optimal treatment outcome.

**Method**

**Participants**

The study is based on archival data collected on four patients during different instances of therapy administered by the same practitioner.

**JR’s Three Consecutive Therapies.**

The primary focus of the study was an individual patient (JR) who was treated on three separate occasions over a ten-year period during which he twice relapsed. JR presented as a bright, over-ideational, 41-year-old man Caucasian male, married with two boys, and the son of a renowned scientist. He was moderately depressed and anxious, exhibited a sense of time urgency, tense facial expression, and strained interpersonal relationships because he was constantly competing to prove his superiority. His mother was chronically depressed and he lived under the shadow of his renowned father. Because intellectual efficiency was central to his self-esteem, he felt distressed by his ruminating and indecisive cognitive style. His productivity at work was
suffering, raising fears of failure and helplessness.

Treatment 1: Coping Focused Therapy. The first instance of cognitive-dynamic therapy administered to JR, described in Schwartz (1997), lasted five months and focused on developing cognitive and behavioral coping strategies with minimal emphasis on psychodynamic exploration. JR learned anxiety management techniques to deal with stress, cognitive strategies to reduce worry and self-punishing thoughts, and communication skills to enhance interpersonal functioning. To achieve a better thinking-feeling balance, emotive exercises were used, including music and vocalization. Later stages of therapy focused on the dynamic of JR being driven by futile competitive needs to surpass his unusually successful father. When his symptoms abated, JR prematurely terminated the therapy noting that he was used to a “dental checkup” model that involved brief treatment with follow-up if distress recurred.

Treatment 2: Mixed Coping and Dynamic Therapy. The second instance of therapy began 3 years after the previous treatment when JR experienced a recurrence of depression, anxiety and work inhibition. This instance of integrative therapy that lasted for 24 months expanded on the cognitive-behavioral coping strategies introduced previously and shifted the balance towards the psychodynamic spectrum. Dynamic issues focused on JR's extreme need to demonstrate his adequacy that was driven by his father complex. In addition, the treatment introduced new themes of anger at abusive peers and at his depressed mother because of her “grey moods” and her inability to protect him. Deeper dynamic issues surfaced occasionally with dream themes of deprivation, rage and mortality fears. Although JR was still struggling with these conflicts and exhibited dependency and interpersonal problems, he was no longer depressed or anxious. He somewhat abruptly terminated this instance of therapy, perhaps in flight from uncovering deeper layers of unmet dependency needs and accompanying rage.

Treatment 3: Dynamic Focused Therapy. The third instance of therapy began five
years later this time with JR experiencing the deepest level of anxiety and depression when he saw that his grandiose expectations wouldn't be realized. He more clearly recognized that he needed to fundamentally “re-invent himself both professionally and personally.” Although his previous treatments provided reasonably enduring symptomatic relief, they ended prematurely and did not fully address his underlying personality structures that predisposed him to mood disturbances. Thus, we agreed to use a more psychodynamic focus from the start, to penetrate to a deeper level and to work through these issues to a mutually agreed conclusion. This therapy began with a prolonged period of emotionally charged sessions of intense grieving about his mother's death and his not being as successful as he thought she expected. He became aware of his narcissistic personality structure and its role in his compulsive achievement striving and interpersonal conflicts. JR worked through more emotionally charged dreams with deeper, classical psychodynamic themes of oral deprivation, Oedipal content (killing father and flirting with mother), and raw, primitive images of dehumanization and helplessness. The end stage of therapy was different in that when JR became asymptomatic, he more patiently continued consolidating his treatment gains by working through personality issues and dream material. Termination was not hastened, occurring at a time considered ripe by both patient and therapist.

For the two last therapies a log was produced from the clinical notes to identify session content and critical events of the patient’s life.

**Other Patients Under Investigation: BF, TS & NA**

BF, a 44-year-old divorced Caucasian male, middle manager with severe depression and low self-esteem rooted in chronic physical abuse by his father, was treated for about 1 year with a mixed cognitive-dynamic therapy. He presented with a severely depressed mood and a subdued, serious demeanor that didn’t allow for any joy. He chose to conclude therapy after achieving a less than optimal emotional balance level because he was content with a relative degree of
improvement and doubted, given his history, that he would be able to elevate his mood much further.

TS, a 32-year-old single Caucasian male, librarian with longstanding depression, panic attacks and interpersonal anxiety, was treated for 4 years with mixed cognitive-dynamic therapy that included an early phase of graduated in vivo exposure therapy, followed by more psychodynamic exploration, including dream analysis. Emotional balance tracking was done only later in his therapy to obtain a more objective measure of his functioning to inform treatment decisions about medication effectiveness and termination.

NA, a 66-year-old married Caucasian male, retired engineer and volunteer worker, presented with recurrent episodes of deep depression and intermittent erectile dysfunction. Similar to JR, he terminated twice after brief periods of coping focused therapy that alleviated his erectile dysfunction and stabilized his mood. When he returned for the third instance of therapy, we gradually progressed into a deeper, dynamically focused treatment. Although his mood was labile with precipitous drops in response to conflicts with his wife or (volunteer) work stresses, an absence of hypomanic episodes ruled out cyclothymia or bipolar disorder. He is currently in the last stage of treatment.

**Measures**

Three main cognitive-affective domains consistently relate to well being, namely *emotion* (Fredrickson, 2001; Diener & Tov, 2007), *self-image* (Gough, 1983; Rosenberg, 1979) and *optimism* (Scheier, 1985; Seligman, 1991). Based on this research, we reasoned that an individual with high levels of emotional, self-image and optimism balance will be functioning well and therefore we monitored the evolution of these variables using different inventories.

Most existing measures of cognition and affect were not designed to assess balances. Therefore, they pose several problems when one wants to compute ratios. First, they don't include
an equal number of positive and negative items. Second, they use a Likert-scale anchored at 1 rather than 0, which creates a nonlinear, artificial ceiling and floor in the ratio, since the positive and negative scores are forced to a non-null minimum (i.e. 1 x the number of items in the inventory, cf. Amsel, 1998). And third, they contain only moderately positive and negative moods, such as “cheerful” or “scared” (e.g., PANAS: Watson & Clark, 1994). This prevents the evaluation of potentially dysfunctional extreme states such as excess positivity. To overcome these drawbacks, new measures were designed, as reported in detail in Schwartz (1997). These measures include an expanded version the Emotional Balance Inventory (EBI-E), constructed by adding to each sub-scale extreme affects such as passionate or infuriated, in order to capture intense states.

The resulting EBI-E is a 36-item inventory consisting of 18 positive and 18 negative mood terms of different intensity, categorized into 3 positive (Happy, Vital, Friendly) and 3 negative (Fearful, Sad, Angry) sub-scales. Participants indicate on a 5-point Likert scale how frequently they felt each emotion during the past week (0 = not at all to 4 = almost always). Clinical

1 Several studies that failed to find dysfunctional states associated with extremely high ratios (i.e., 0.90 or greater) are difficult to interpret because the measures used lacked items with extreme positive valance (Fichten, Amsel, Robillard & Tagalakio, 1991; Haaga, Davison, McDermut, Hillis & Twomey, 1992). Thus, we can only conclude from them that moderately positive states are not excessive or dysfunctional.

2 Along the same lines, a Self-Image Balance Inventory (SBI) and an Optimism Balance Inventory (OBI) were developed (Schwartz, 1997). These two additional measures vary slowly and are less correlated with the emotional state, and therefore were not described in the present paper.
symptoms were assessed pre-and post treatment and periodically as needed using the Beck Depression Inventory (BDI: Beck, 1961) and the Beck Anxiety Inventory (BAI: Beck, 1988).

**Balanced States of Mind (BSOM) Model**

Lefebvre and colleagues (Lefebvre, Lefebvre & Adams-Webber, 1986) developed a model of consciousness that employs a Boolean algebra formalism to derive ratios (r) representing the likelihood that individuals will make a positive response under five mood states (See Supplement A online for details):

- Positive evaluation of self in deep-positive mood (r=0.875),
- Positive evaluation of self in positive mood (r=0.813),
- Positive evaluation of self in neutral mood (r=0.719),
- Positive evaluation of self in negative mood (r=0.625), and
- Positive evaluation of self in deep-negative mood (r=0.500).

Symmetrical negative states were also derived and yield inverse ratios [1-r] that are associated with increasing levels of psychopathology. Drawing on this modeling, the BSOM model proposed that psychopathology is associated with P/(P+N) ratios of 0.50 and below (deep negative mood), subnormal but successfully coping states with 0.62 (negative mood), normal states with 0.72 (neutral mood) and optimal states with 0.81 (positive mood). These models were validated by several clinical studies. Schwartz and collaborators (Schwartz et al., 2002) tracked depressed men during cognitive and pharmacotherapy and found that at post-treatment a group of a priori defined “average” responders achieved an emotional balance of 0.70, close to predicted normal ratio of 0.72. The predefined group of “optimal” responders evinced an emotional balance exactly at the theoretically predicted optimal ratio of 0.81. Similarly, Oishi, Diener & Lucas (2007) reported that people who rated their happiness 80% were more successful on measures of income, education and political involvement than those that rated themselves either lower or higher.
In addition to the static BSOM *balance analysis* that relates individual ratios of the emotional balance to theoretically defined levels of psychological functioning, we introduce here a dynamic BSOM *trajectory analysis* that tracks the changes in emotional balance over time and identify distinct patterns of affect.

**Automatic Segmentation of Therapy Phases**

The trajectory of the emotional balance presents three main phases, described through three fundamental concepts: *emotional balance trend*, *local variability* and *presence of oscillations*. The patients were instructed to complete the balance inventories weekly and freely chose the day of the monitoring between sessions, which made the data unevenly sampled in time. Missed sessions and periodic extended vacations further increased the irregularity in the data collection. The time interval between two consecutive measurements for JR ranged from 3 to 27 days, with a mean of 8.6 days and a modal interval of 7 days.

In order to evaluate the three dimensions of interest (trend, variability and oscillations), we used the following data analysis tools (See Fig. 1):

- The emotional balance trend was evaluated using a sliding mean. Specifically, at time $t$, this quantity is equal to the local mean of the emotional balance in a time window centered on $t$, with a range of seven weeks.
- Random fluctuations were calculated using a sliding standard deviation.
- The presence of oscillations was assessed by the computation of a sliding local Lomb-Scargle transform on a neighboring window around the time point of interest. This transform is an extension of the classical discrete Fourier transform for unevenly spaced data, which reveals the frequencies that are present in a signal (See details in Supplement B online), and allows the evaluation of the statistical significance of the detected oscillation.

**Results**
We performed the dynamic affect balance trajectory analysis on the four subjects, and used JR’s clinical log to precisely relate the therapeutic content and critical incidents in the patient's life to his affect balance trajectory analysis and phase transitions. Note that the affect balance trajectory analysis of JR was done independently of the clinical log so that the results of the one would not bias the others.

**Phases of Therapy**

Throughout the separate instances of treatment, we analyzed the emotional balance data using sliding statistics and the Lomb-Scargle transform and empirically identified 3 generic phases:

*Phase 1. Variability* phase defined by a high degree of variability of the emotional balance (random fluctuations with a standard deviation around 0.17).

*Phase 2. Stability* phase defined by a very low degree of variability of the emotional balance (random fluctuations with a standard deviation around 0.05).

*Phase 3. Oscillating* phase defined by slow, non-random oscillations (statistical significance on Lomb-Scargle transform of $p = 0.05$ or less).

**Intensive Analysis of Treatments**

**Treatment 1: Coping focused therapy.**

*Balance trajectory analysis.* The time course of the coping-focused treatment presents two consecutive sequences of Phase 1 (Variability) and Phase 2 (Stability) (see Fig.3). The first Phase 1 (noted 1a) lasted five weeks, shows a rapid increase in emotional balance from a Negative Dialogue (.34) to a Successful Coping SOM (.65), and despite high variability achieves an overall mean SOM for the phase of .49, close to the Conflicted SOM ratio of .50, associated with mild psychopathology. This fast and clear initial increase of the emotional balance indicates the likelihood of success of cognitive therapy, as established by Tang & DeRubeis (1999). The
patient then stabilized at the Successful Coping SOM of .62 and sustained this SOM during four weeks of Phase 2 (noted 2a). Then another Phase 1 (noted 1b) started afresh with the patient dropping into a Conflicted SOM (.48), but rapidly rebounding to a Positive Dialogue ratio of .72, associated with normal (but not optimal) functioning. Finally, he stabilized at this level in another occurrence of phase 2 (noted 2b). From a mathematical point of view, the emotional balance reached a stationary state corresponding to a random variable with mean .72 and a standard deviation of .05.

**Therapeutic content and life events.**

*Phase 1a.* The rapid initial increase in emotional balance observed in the data is attributed to the process of “remoralization” that often characterizes the early stage of treatment (Howard, Lueger, Maling & Martinovich, 1993).

*Transition 1a-2a.* The transition from Phase 1a to 2a was not triggered by any identifiable critical events, but was correlated with a change in the patient's attitude. Specifically, the patient started to systematically analyze the source of his problems rather than ruminating about them.

*Phase 2a.* During this phase the patient stabilized his affect by learning anxiety management techniques, cognitive coping strategies to reduce worry and self-punitive attributions for failure, and communication skills training. No dreams were reported.

*Transition 2a-1b.* The transition from Phase 2a to 1b was triggered by mounting work pressures, interpersonal conflicts at work and the stress of the change process itself as he experimented with new modes of thinking and behaving.

*Phase 1b.* JR entered Phase 1b with his mood rebounding rapidly to the normal balance level of .72 where it stabilized, as opposed to Phase 1a that remained at a subnormal level.

*Transition 1b-2b.* This transition did not appear to be triggered by external life events *per se*, but by growing self-confidence resulting from cognitive restructuring of his attitudes towards his
critical father and teasing from peers. In what proved to be correct, JR expressed concern that these improvements might be transitory because he attributed them to situational factors (i.e., positive signs of work success), rather than to deep, fundamental changes.

*Phase 2b.* JR consolidated his newly developed coping strategies and improved mood, resulting in a steady, stable emotional balance at a normal (but not optimal) level (.72). At this point, he somewhat abruptly decided to terminate therapy.

Follow up assessments conducted at three, four and five months showed a sustained, normal emotional balance, but with an increasing standard deviation, probably linked with some destabilization of the state reached at the end of treatment.

**Treatment 2: Mixed coping and dynamic focused therapy.**

The second instance of therapy shows a different trajectory from Treatment 1. JR begins at a higher initial emotional balance and shows for the first time brief, unsustained periods of oscillation (See Fig. 4). Interestingly, the therapy contains two iterations of a progression through all three phases of variability, stability and oscillation, which we describe below.

**Balance trajectory analysis.** When JR returned after a three year hiatus, he began with an initial emotional balance of .64 placing him within the subnormal, but Successful Coping range. Although not clinically depressed from the BSOM theory viewpoint, he was struggling with negative mood, work inhibition, worry and sleep disturbance. His trajectory was moderately variable (Phase 1a), progressing gradually to the normal range at which point he entered a period of reduced variability and stabilization around the normal ratio of .72 (Phase 2a). As Phase 2a progressed, there was a slight increase in variability after which the client entered a single cycle of oscillation with a period of approximately six-weeks (Phase 3a). A peak in the Lomb-Scargle transform indicates a trend toward oscillation that did not achieve significance (p=0.34). The oscillating pattern involved lower emotional balance values that were outside the normal and
optimal range. These subnormal balances apparently disrupted the oscillation pattern and returned the patient to Phase 1b behavior of variability. This phase evinced the highest variability of the treatment and some of the lowest emotional balances that fluctuated mostly between Conflicted and Successful Coping ranges, with occasional peaks into the low Normal range. During this phase of about four months duration, he displayed no oscillation. After this phase, the variability dropped to its lowest level and the emotional balance stabilized in Phase 2b for a brief period of one and a half months. Finally, the client completed the iterative process by entering Phase 3b for the second time. During this phase of six and one half months duration, the variability increased to a moderate level and the emotional balance began oscillating between the Optimal (0.81) and Super-Optimal (0.88) levels with a seven-week period. The end of therapy interrupted the monitoring of these oscillations. Thus, the Lomb-Scargle transform, though presenting a clear peak compared to the rest of the signal, approached but did not achieve significance because it was not monitored for additional cycles (p = 0.17), (see Fig. 3).

**Therapeutic content and life events.**

*Phase 1a.* Therapy focused initially on a review of cognitive and behavioral coping strategies. After 3 months, the client explored interpersonal themes and engaged in emotional and dream expression (e.g., themes of food, need for unconditional approval and disturbing images of a primitive nature), but no deeper psychodynamic or dream analysis was done.

*Phase Transition 1a-2a.* This transition is marked by a stabilization in mood and self-image noted in the clinical log. Themes were emerging of oral deprivation and wishful thinking that others would “read his mind” so they could satisfy his needs.

*Phase 2a.* The client no longer reported dreams during most of this phase. Apparently picking up on the themes from the dreams during the transition period of oral (maternal) deprivation, the client worked on his sense of childhood loss because of his mother's depression and her current
serious illness, as well as the interpersonal conflicts within his marriage.

*Phase Transition 2a-3a.* At the phase transition, emotional and optimism balances were at the optimal level. The client started coping well with frustration and reduced compulsivity. A dream occurred with a theme of separation anxiety and not being protected as a child by parental figures.

*Phase 3a.* During the early part of this brief phase of oscillating affect, the client reported dreams in four successive sessions. The themes of these dreams involved two people dying, presumed to be his parents, childhood yearnings for more attention from his self-centered mother, and fear of world destruction. After this flurry of dream work ceased, JR shifted to more here and now issues of ambivalence in current peer relationships.

*Phase Transition 3a-1b.* Unlike the two prior phase transitions into more positive states, this transition regressed to an extended period of variability and low emotional balances and was not preceded by a dream. It appeared to be triggered instead by a verbal lashing from a colleague and the client's awareness of his own interpersonal insensitivity that provokes conflict.

*Phase 1b.* During this phase of high variability, the client worked on current interpersonal conflict issues and mounting anxiety, depression and sleep problems caused by his realization that his lifelong ambitions were unlikely to be realized.

*Phase Transition 1b-2b.* In the last week of Phase 1b, the client's mood reached the subnormal, but successful Coping level of .62 and he recalled a dream with conflicted feelings about his wife's increase in salary that made him feel diminished. Also, a critical external event occurred that the client experienced as transformational. His son had a significant accident, but his survival and recovery led the client to become more attuned to the needs of his family (especially his wife), to slowing down his hectic pace, and softening his competitiveness and interpersonal brusqueness.

*Phase 2b.* This stable phase of normal emotional balance (.72) finds the client engaging in less
“name calling” when he makes mistakes, enjoying family vacations more because he is less self-centered and more flexible, and communicating better with his wife.

**Phase Transition 2b-3b.** Two weeks prior to the last phase transition, the client reported successive weeks of dreams. The first is of two dogs dying which the clients relates to fears of the death of his aging parents and to conflicts with his mother as a “suffocating, amorphous and ill-defined problem.” The second dream is of a woman falling through a dam and his not being able to rescue her, reflecting his mother’s precarious moods and his inability to save her.

**Phase 3.** Dream recall and processing continued intermittently throughout this final phase of oscillating affect. The clinical log notes decreased self-focus, increased ability to be in the moment and better connection with his wife. Interestingly, these improvements are accompanied by dreams of disconnection from mother. He is able to express his emotions more directly regarding grief about his grandmother's death that occurred during this phase. At this point, his wife commented for the first time appreciatively about his progress.

JR requested a May termination that appeared influenced as much by the academic year as by his psychological state. Despite significant gains, the client had a dream revealing oral rage about maternal deprivation and parental inattention. Such recurrences of old themes when terminating therapy are not unusual, but the overall termination summary raised some questions about the need to continue working on his own on self-confidence, residual dependency issues and interpersonal style, as well as considering marital counseling. Interestingly, his final emotional balance of .74 was near the normal (not optimal) ratio of .72, but his Happiness sub-score was one-half lower than the other positive scales for Vitality and Friendliness.

**Treatment 3: Dynamic focused therapy.**

**Balance Trajectory Analysis.** The dynamic focused therapy resulted in a trajectory that was very different from the other treatments. The initial stage lasted considerably longer than
the previous treatments (5 months) and presented a highly variable but globally increasing emotional balance that gradually reached the normal ratio of .72 (See Figure 4). The emotional balance stabilized in Phase 2 (note the sharp decrease in variability) and smoothly climbed to a SOM of .79, close to the optimal ratio of .81. Phase 3 followed with a level of moderate variability intermediate between Phase 1 and 2. The emotional balance began oscillating smoothly between the normal (.72) and optimal (.81) ratios with a period cycle of seven weeks and a high statistical significance (p < 0.01). This pattern was sustained for seven months during treatment and later confirmed at the six-month and one-year follow-up assessments (see Fig. 4).

Therapeutic content and life events.

Phase 1. The client engaged in more emotional expression than earlier treatments, with intense sobbing about his mother's death and not succeeding at the level he thought she expected of him. A proliferation of emotionally charged dreams occurred with themes of maternal deprivation, Oedipal conflict with father and awareness of narcissistic strivings to succeed. As can be seen in Figure 4, this phase was characterized by extreme variability in emotional balance, with the sliding mean showing a gradual, steady increase.

Phase Transition 1 to 2. Several weeks prior to this transition into sustained stability, the client had worked through dreams, sometimes twice weekly, that progressed from female figures that were inconsistently present and associated with bad food to recovery themes of eating steak to get into good shape. JR made progress in shifting away from external and uncontrollable sources of self-esteem to becoming more self-validating, which provided a more stable sense of self. Several weeks prior to the phase transition, he experienced stressful events, including ambivalence about his father's re-marriage (which he did not attend) that led to a precipitous drop in emotional balance to .38. A dramatic surge in optimism to an optimal level (.81) triggered a recovery in mood which then stabilized at the normal ratio (.72).
Phase 2. JR engaged in increased positive activities and an increasing shift from dependence on validation from others to self-validation. Mourning losses continued but were diminished in intensity and JR focused less on mother and more on working through his dependence on his wife. He developed more insight into his narcissistic preoccupation with self-esteem management and achievement that diminished his sensitivity to others. Dreams revealed early concerns about loneliness as a child and throughout college, as well as peer rejection.

Phase Transition 2-3. The transition to the oscillation phase is marked by a startling experience: JR announced in the session prior to the transition that he had a transformative spiritual experience of increased God awareness following the inspiring story of a colleague who faced his death with tranquility and a positive attitude. He dreamt that his mother was still alive, and that he felt greater acceptance of his parents being in the process of dying. Immediately after this experience, his overall emotional balance began oscillating between the normal (.72) and optimal (.81) ratios (See Figure 4).

Phase 3. With his emotional balance oscillating, JR continued to work on resolving residual issues of narcissism, deprivation and childhood anger. He was less stressed by work and learned to maintain some joy even while engaged in the more thankless aspects of his job. Importantly, JR reported less envy, increased humility, social graciousness, acceptance of self and others, and spiritual transcendence. Although he continued to recall and process similar dream themes during this phase, his mood remained positive and his interpersonal functioning was vastly improved, with the exception of some residual tensions in his marriage. The Happiness sub-scale peaked at its highest level ever and he felt less constricted and more creative in his approach to work. With his Beck Depression and Anxiety Inventory scores at zero, we worked towards a planned termination with the recommendation that he monitor marital issues.

Follow-up at six months and one year showed a sustained pattern of oscillation between
the normal and optimal ratios with all measures remaining at the same levels. The patient has thus far demonstrated resilience as a result of this treatment.

**Succinct Trajectory Analysis of the Other Subjects**

Three additional patients that complied with the assessment procedure of computing their emotional balance at various stages of therapy (namely BF, TS and NA) are now analyzed. We provide here a complete SOM trajectory analysis, with no thorough analysis of the therapeutic content.

**Trajectory analysis of BF**

The first of these subjects (BF) started regularly monitoring his emotional balance several months after the beginning of therapy. At this point, the patient is exiting Phase 1 variability and soon enters Phase 2 (see Figure 5). This state of stable emotional balance with low sliding standard deviation lasts 15 weeks before turning to an oscillatory pattern corresponding to a Phase 3 behavior. The oscillation period is between 9 and 10 weeks, with an estimated trend toward significance (end-term significance of p = 0.14). Contrary to the third therapy of JR, these oscillations take place at very low emotional balance level, around the deep negative mood ratio of .50. This low level of emotional balance leads us to hypothesize that the pattern will not be sustained (similar to Phase 3a of the second therapy of JR), which is confirmed by the increased variability at the end of BF’s treatment. Because he was deeply depressed for most of his life, even this low emotional balance represented a breakthrough that oscillations might stabilize as a satisfactory end-state for this particular individual.

**Trajectory analysis of TS**

TS began systematic monitoring his emotional balance relatively late in the therapy (See Fig. 6A). We observe that the overall emotional balance is relatively high. The whole data set has an averaged SOM near the Normal ratio of .73, and never goes below the subnormal coping state
(0.62). The full signal presents statistically significant 10-week period oscillations (p < 0.01) as shown in the Lomb-Scargle transform of the full signal (See Fig 6B). The sliding Lomb-Scargle transform is characterized by a high peak at 10 weeks that is maintained all along the signal, does not provide further information, and is therefore not shown here. When thoroughly examining the emotional balance trajectory, one can further identify phases of reduced variability and amplitude that thus resemble Phase 2 stability. We interpret these phases as further consolidation of advances in the therapy, even if the patient is already in a resilient and flourishing state. Besides these intermediate Phase 2, the Lomb-Scargle transform presents in addition to the main highly significant peak, smaller peaks with statistical significance close to p = 0.2. These seem to correspond to nested rhythms, or to a natural variability of the oscillation frequency.

**Trajectory analysis of NA**

NA is still undergoing psychodynamic therapy, and presents clear signs of healing. The analysis of his emotional balance (see Fig. 7), similar to the dynamic therapy of JR, presents a prolonged Phase 1 with high variability and a progressive increase of sliding mean emotional balance, followed by a short phase of stability (Phase 2), and starts presenting oscillations that we interpret as the initiation of a sustainable oscillatory Phase 3 behavior. The significance of these oscillations is slightly above p = 0.20, but the clear increase of the amplitude of the peak in the Lomb-Scargle transform suggests that NA will soon reach higher significance levels.

Besides these common points with JR, NA displayed a more labile initial pattern of affect management. Note that Phase 1 is characterized by dramatic random jumps between high emotional balance values in the optimal zone (.81 at the second consultation) and extremely low values in the negative dialogue zone immediately after (.37 at the third consultation one week later, See Fig. 7). This personality trait is observed at the phase transition between Phase 2 and Phase 3 where the emotional balance presents an impressive drop at the very low level of .34.
Such negative spikes are also present in the third therapy of JR, but the amplitude of such jumps is substantially smaller. Besides these inter-personal differences, the common structure between the psychodynamic (third) therapy of JR and the psychodynamic therapy of NA strengthens our observation by showing that different patients administered the same therapies present the same process of change.

**Discussion**

This article employed a mathematical framework to investigate the dynamics of emotional balance. We studied the intra-individual change trajectories across three different therapies administered to the same recurrently depressed patient, and supported these results by comparing them to the trajectories of three additional patients. The results provided further confirmation of the mathematically derived BSOM model set-point ratios as they relate to pathological, normal and optimal functioning (cf. Calvete & Cardenoso, 2005; Calvete & Connor-Smith, 2005; Schwartz et al., 2002). More generally, the results of this article are consistent with the numerous studies relating positive/negative ratios to psychological and interpersonal functioning (Fredrickson & Losada, 2005; Gottman, 1994; Oishi, Diener & Lucas, 2007). However, as with any psychological measurement, these ratios are subject to statistical fluctuations and evolve in time, and these essential characteristics remained unexplored.

Extending beyond the previously static approach of the BSOM model, we used mathematical tools for trajectory analysis to explore patterns of change and identified three distinct phases: *variability, stability* and *oscillation*. The phases evidenced using these methods correlated in meaningful ways with the type of therapy, stage of treatment, critical external events and inner states of the client.

Specifically, we found that a brief, coping focused treatment administered to JR yielded two iterations consisting of a short Phase 1 variability with a rapid rise in affect balance to Phase 2
stabilization at the normal level. This therapy outcome never achieved Phase 3 oscillation, either because of the nature of the treatment or because it was too short in duration. In contrast, the longer term, purely dynamic therapy evinced a single, orderly progression through a prolonged Phase 1 variability, a brief Phase 2 stabilization and an extended Phase 3 oscillation with multiple cycles. Interestingly, the mixed coping-dynamic therapy showed two iterations that progressed through all three phases, producing oscillations of too short a time interval to achieve statistical significance. The analysis of three other successfully treated patients monitored at different stages of therapy supported these observations. All three patients presented slow oscillations with periods ranging between seven and ten weeks, and transitions between the three identified phases. One of these patients, NA, currently undergoing pure dynamic therapy presents the same overall pattern of change in emotional balance as the third, purely dynamic therapy of JR.

We infer from this data, taken together, an underlying dynamic within these patients that evolved progressively from variability to stability and finally to oscillation. Iteration is a process of achieving a desired result by repeating a sequence of steps and successively getting closer to that result, which aptly describes the evolution of JR's affect balance. Although engaged in long journey of emotional struggles, he apparently evolved through a sequence of therapeutic interventions and life events that brought him from variability to stability and finally to enduring oscillations between normal and optimal emotional balance ratios.

All therapies began with stages of Phase 1 variability (the initial state was not monitored for TS) that transitioned into Phase 2 stability close to the normal set point of .72. Note, however, that the duration of this phase is variable, from shorter durations in the coping therapy, through the first and second iterations of the mixed therapy of JR and finally to longer durations in the dynamic therapy. This finding has implications for the nature of interventions depending on the type and objectives of the treatment. A number of studies have shown that sudden gains early in
treatment are significant predictors of success and maintenance of gains during cognitive-behavioral treatments (Haas, Hill, Lambert & Morrell, 2002; Kelly, Roberts & Ciesla, 2005; Tang, DeRubeis, Beberman & Pham, 2005). In apparent contrast, Hayes and Strauss (1998) found superior treatment outcomes when the therapy included a stage of “destabilization” defined as variability in cognitive, affective, behavioral and physiological functioning, and high “affect intensity”, the latter defined as discomfort expressed by the client when addressing therapeutic issues.

The current data supports both findings, and suggests that the role of initial variability in predicting therapeutic outcome may vary depending on nature and specific goals of the therapy. This has implications for practicing therapists in defining whether their treatment objective is to pursue a rapid rise and stabilization of affect versus encouraging a longer phase of emotional expression and variability. This will depend on the needs, goals and resources of the client. When treating a mild and non-recurrent depression, it might be appropriate and cost-effective to use a brief coping focused therapy in which case the therapists would strive towards rapid improvement and stabilization of affect. However, given the high rate of relapse in depression (Fava et al., 2004; Thase, 2003), many clients will benefit from a longer term, dynamic treatment. Such treatment will initially destabilize the depressive personality structures before attempting to stabilize affect, in which case the optimal trajectory will include a longer initial variability phase. Indeed, Thase and collaborators proposed that because of the high relapse rate for short term cognitive therapy of depression, typically 12-16 weeks, models of long term therapy should be developed (Thase et al., 1992). These therapies should allow an extended initial phase of variability as well as a longer phase 3 to ensure that oscillations are well established before terminating treatment.

Regarding the final phase of treatment, a question that naturally arises is whether stability or
oscillations constitute the better outcome of therapy. Because instability is undesirable, one might presume that its opposite (viz., stability) represents the most adaptive state of mind. However, Rolls, Loh & Deco (2008) demonstrated that excess stability has negative consequences in the case of obsessive-compulsive disorder. They showed that too much stability in some neuronal attractors can cause difficulty in attentional and cognitive set switching, repetitive actions and difficulty in moving to new actions. This inflexibility sometimes leads people suffering from OCD to severely constrict their world because of their inability to handle novelty.

These considerations suggest that Phase 2, characterized by very high stability, is mainly a period when prior gains of the therapy are being consolidated, rather than a desirable final treatment outcome. This phase of low variability, which we designate as consolidation, was not maintained for very long in any of the therapies, and was terminated by the occurrence of either positive or negative internal states or life events. Although stability is a necessary phase in the therapy process during which the patient has positive feelings and a sense of security, it appears to have limitations as a final therapeutic outcome. When learning a new skill, a novice initially prefers to maintain a more rigid set of circumstances until acquiring the confidence and flexibility that allows engaging more varied and complex situations.

The oscillation phase, designated as resilience, is associated with well being and flourishing, as evidenced by the JR's heightened spiritual awareness, enhanced interpersonal sensitivity and complete absence of symptoms of depression and anxiety. The oscillations of the emotional balance are evinced by the measurement, but since these oscillations are bounded by the normal and optimal set points, no striking change is observed in the patient's state. This capability to oscillate allows one to handle good and bad times with flexibility. This adaptive property is similar to the capability of a reed to remain intact despite severe wind. Unlike the thicker but rigid branches of a tree that will snap, the thin and seemingly fragile reed will bend
and oscillate with the breeze. And it is this flexibility that enables it to smoothly survive life's vicissitudes. To the best of our knowledge, this is the first report of an oscillation in affect dynamics as a post-treatment outcome, which joins the widely observed phenomenon of oscillations in biological systems (cf. Strogatz, 2003), such as cardiovascular heart rate and brain rhythms.

Analysis of the therapeutic processes and critical life events that triggered transitions among the three phases revealed some surprising results. Tang et al. (2005) reported that “sudden gains", as measured by large drops in depression scores, were preceded by sessions in which the patient had significantly more “cognitive gains” than in sessions not followed by such improvements. The clinical log revealed that for all three instances of Phase 3 oscillation, the phase transition was triggered by dream recall and the phase itself contained ongoing dreaming. Transition into Phase 2 stability was generally not preceded by dream recall, nor was the single instance of regression into Phase 1 variability. We construe the presence of dream recall and the associated interpretations as representing “deep” cognitive gains that had a beneficial effect on emotional balance, strongly associated with oscillations at the normal to optimal levels. Although unexpected, this finding is consistent with research demonstrating the integrating, positive influence of dream sleep on daytime affect (Cartwright, Agargun, Kirkby & Friedman, 2006; Nofzinger et al., 1994). In developing more effective treatments of depression, cognitive therapy should pay more attention to the relationship of deeper cognitive processes and affect dynamics.

Not surprisingly, the clinical log showed that the two instances of regression to Phase 1 variability were preceded by either work or interpersonal stress. On the positive side, the phase transition during the dynamic focused therapy into the only sustained period of Phase 3 oscillation was triggered by the patient's spiritually transformative experience of a greater awareness of God that was inspired by a colleague's response to trauma. This phase was associated with enhanced
interpersonal sensitivity and the first “positivity spike” in his Happiness scores during any of the therapies. This finding is consistent with Tedeschi & Calhoun’s (2004) summary of the transformative potential of post-traumatic growth and suggests the need to further investigate the impact of such events on affect dynamics. It also suggests, consistent with positive psychology, that truly euthymic outcomes (cf. Keller, 2003) must not only reduce depression but also increase happiness.

The present study extends the understanding of treatment outcome by quantifying the fact that a high emotional balance alone is not a sufficient indicator that treatment has achieved a sustainable, optimal result. Psychological resilience and resistance to relapse depend on the ability to sustain this high level of positive mood and the presence of oscillations in the system provides the flexibility needed to accomplish this. The mathematical tools introduced here provide a more precise assessment of the levels and dynamics of affect that can be used clinically to better identify optimal treatment outcomes and to more precisely predict the likelihood of relapse.

The strength of this approach that allows a very detailed analysis of the complexity of the change process also brings corresponding limitations. The question that arises now is the universality of this discovery. Although the present findings statistically demonstrate an oscillatory phenomenon in the end-state functioning of several individuals, these observations need to be further investigated on larger groups of patients and with different therapists. Larger scale studies need to recruit more females and devise simpler, more accessible data recording systems\(^3\). The time scale of the oscillations (i.e., from 7 to 10 weeks) represents a practical

\(^3\) A web based system for tracking emotional, self-image and optimism balances is near completion and, together with handheld versions, should encourage greater use of self-monitoring.
limitation for large-scale experimentation that complicates further analysis of this “macro” oscillatory phenomenon. However, we believe that rhythms in psychological systems are to be found in a variety of phenomena. We conjecture that the human affective system, analogous to Russian dolls, contains multiple time scales and presents faster oscillations embedded within slower ones. This conjecture is supported by the different frequencies we observed in the long oscillatory periods in TS. We are currently exploring whether assessing emotional balance at shorter intervals (e.g., daily or every 90 minutes) will evidence such “micro” oscillations.

This study raises new questions with implications for positive and classical psychology about the dialectical effects of positive and negative affects considered separately: Are the oscillations driven by positive or negative affects or are they an emerging property of both? Are phase transitions induced more by positive versus negative states? Additional research is needed to ascertain whether oscillation, compared to stability, is universally related to psychological resilience and flourishing. More generally, we encourage further studies to delineate how variability, stability and oscillation in cognition and affect evolve during different stages of therapy with different disorders and personality types. The introduction of a dynamical and mathematical approach within a theoretical framework of positive-negative balance offers increased precision in the quest to illuminate the complex process of cognitive and affective change during psychotherapy.
References

Amsel, R., & Fichten, C. S. (1998). Recommendations for self-statement inventories: Use of valence, end points, frequency, and relative frequency. *Cognitive Therapy and Research, 22*, 255-277.

Barning, F. J. M. (1963). The numerical analysis of the light-curve of 12 lacertae. *Bulletin of the Astronomical Institutes of the Netherlands, 17*, 22-28.

Beck, A. T., & Alford, B. A. (2009). *Depression: Causes and Treatment*. Philadelphia: University of Pennsylvania Press.

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*, 893-897.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of general Psychiatry, 4*, 561-571.

Calvete, E., & Connor-Smith, J. K. (2005). Automatic thoughts and psychological symptoms: A cross-cultural comparison of american and spanish students. *Cognitive Therapy and Research, 29*, 201-217.

Cartwright, R., Agargun, M., Kirkby, J., & Friedman, J. (2006). Relation of dreams to waking concerns. *Psychiatry research, 141*, 261-270.

Cervone, D. (2004). The architecture of personality. *Psychological Review, 111*, 183-204.

Diener, E., & Tov, W. (2007). Subjective well-being and peace. *Journal of Social Issues, 63*, 421-440.

Fava, G. A., Ruini, C., Rafanelli, C., Finos, L., Conti, S., & Grandi, S. (2004). Six-year outcome of cognitive behavior therapy for prevention of recurrent depression. *American Journal of Psychiatry, 161*, 1872-1876.
Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American psychologist, 56*, 218-226.

Fredrickson, B. L., & Losada, M. F. (2005). Positive affect and the complex dynamics of human flourishing. *American psychologist, 60*, 678-686.

Gottman, J. M. (1979). Detecting cyclicity in social interaction. *Psychological Bulletin, 86*, 338-348.

Gottman, J. M. (1994). What predicts divorce?: *The relationship between marital processes and marital outcomes*. Hillsdale, NJ: Lawrence Erlbaum.

Gough, H. G., & Heilbrun, A. B. (1983). The adjective check list. *Consulting Psychologists Press, 237*, 57-63.

Grice, J. W., Jackson, B. J., & McDaniel, B. L. (2006). Bridging the ideographic-nomothetic divide: A follow up study. *Journal of Personality, 74*, 1191-1218.

Haaga, D. A. F., Davison, G. C., McDermut, W., Hillis, S. L., & Twomey, H. B. (1993). “States-Of-Mind” analysis of the articulated thoughts of exsmokers. *Cognitive Therapy and Research, 17*, 427-439.

Haas, E., Hill, R. D., Lambert, M. J., & Morrell, B. (2002). Do early responders to psychotherapy maintain treatment gains? *Journal of Clinical Psychology, 58*, 1157-1172.

Hayes, A. M., Laurenceau, J., Feldman, G., Strauss, J. L., & Cardaciotto, L. (2007). Change is not always linear: The study of nonlinear and discontinuous patterns of change in psychotherapy. *Clinical Psychology Review, 27*, 715-723.

Hayes, A. M., & Strauss, J. L. (1998). Dynamic systems theory as a paradigm for the study of change in psychotherapy: an application to cognitive therapy for depression. *Journal of Consulting and Clinical Psychology, 66*, 939-947.

Howard, K. I., Lueger, R. J., Maling, M. S., & Martinovich, Z. (1993). A phase model of
psychotherapy outcome: Causal mediation of change. *Journal of Consulting and Clinical Psychology, 61*, 678-685.

Keller, M. B. (2003). Past, present, and future directions in defining optimal treatment outcome in depression: Remission and beyond. *Journal of American Medical Association, 289*, 3152-1360.

Kelly, M. A. R., Roberts, J. E., & Ciesla, J. A. (2005). Sudden gains in cognitive behavioral treatment for depression: when do they occur and do they matter? *Behaviour Research and Therapy, 43*, 703-714.

Lefebvre, V. A. (1992). *A psychological theory of bipolarity and reflexivity*. Lewiston, NY: Edwin Mellen Press.

Lefebvre, V. A., Lefebvre, V. D., & Adams-Webber, J. (1986). Modeling an experiment on construing self and others. *Journal of Mathematical Psychology, 30*, 317-330.

Lomb, N. R. (1976). Least-squares frequency analysis of unequally spaced data. *Astrophysics and Space Science, 39*, 447-462.

Molenaar, P. C. M. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement: Interdisciplinary Research & Perspective, 2*, 201-218.

Nofzinger, E. A., Schwartz, R. M., Reynolds, C. F., Thase, M. F., Jennings, J. R., Frank, E., Fasiczka, A.L., Garamoni, G.L., & Kupfer, D.J. (1994). Affect intensity and phasic REM sleep in depressed men before and after treatment with cognitive-behavioral therapy. *Journal of consulting and clinical psychology, 62*, 83-91.

Oishi, S., Diener, E., & Lucas, R. E. (2007). The optimum level of well-being: Can people be too happy? *Perspectives on Psychological Science, 2*, 346-360.

Ong, A. D., & Van Dulmen, M. H. M. (2006). *Oxford handbook of methods in positive*
psychology. New York: Oxford University Press.

Paykel, E. S., Scott, J., Teasdale, J. D., Johnson, A. L., Garland, A., Moore, R., et al. (1999). Prevention of relapse in residual depression by cognitive therapy a controlled trial. *Archives of General Psychiatry, 56*, 829-835.

Rolls, E. T., Loh, M., & Deco, G. (2008). An attractor hypothesis of obsessive-compulsive disorder. *European Journal of Neuroscience, 28*, 782-793.

Rosenberg, M. (1979). *Conceiving the self*. New York: Basic Books.

Scargle, J. D. (1982). Studies in astronomical time series analysis. II- statistical aspects of spectral analysis of unevenly spaced data. *Astrophysical Journal, 263*, 835-853.

Scheier, M. F., & Carver, C. S. (1985). Optimism, coping, and health: assessment and implications of generalized outcome expectancies. *Health psychology, 4*, 219-227.

Schwartz, R. M. (1986). The internal dialogue: On the asymmetry between positive and negative coping thoughts. *Cognitive Therapy and Research, 10*, 591-605.

Schwartz, R. M. (1997). Consider the simple screw: cognitive science, quality improvement, and psychotherapy. *Journal of Consulting and Clinical Psychology, 65*, 970-983.

Schwartz, R., & Caramoni, G. (1989). Cognitive balance and psychopathology: Evaluation of an information processing model of positive and negative states of mind. *Clinical Psychology Review, 9*, 271-294.

Schwartz, R. M., Reynolds III, C. F., Thase, M. E., Frank, E., Fasiczka, A. L., & Haaga, D. A. F. (2002). Optimal and normal affect balance in psychotherapy of major depression: Evaluation of the balanced states of mind model. *Behavioural and Cognitive Psychotherapy, 30*, 439-450.

Seligman, M. (1991). *Learned optimism*. New York: Knopf.

Snyder, C., & Lopez, S. (2005). *Handbook of positive psychology*. New York: Oxford University Press.
Strogatz, S. H. (2003). *Sync: the emerging science of spontaneous order*. New York: Hyperion.

Tang, T. Z., & DeRubeis, R. J. (1999). Sudden gains and critical sessions in cognitive-behavioral therapy for depression. *Journal of Consulting and Clinical Psychology, 67*, 894-904.

Tang, T., DeRubeis, R., Hollon, S., Amsterdam, J., & Shelton, R. (2007). Sudden gains in cognitive therapy of depression and depression relapse/recurrence. *Journal of consulting and clinical psychology, 75*, 404-408.

Teasdale, J. D., Segal, Z. V., Williams, J. M., Ridgeway, V. A., Soulsby, J. M. & Lau, M. A. (2000). Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. *Journal of consulting and clinical psychology, 68*, 615-623.

Tedeschi, R. G., & Calhoun, L. G. (2004). Post-traumatic growth: Conceptual foundations and empirical evidence. *Psychological Inquiry, 15*, 1-18.

Thase, M. E. (2003). Effectiveness of antidepressants: comparative remission rates. *Journal of Clinical Psychiatry, 64*, 3-7.

Thase, M. E., Simons, A. D., McGeary, J. I., Cahalane, J. F., Hughes, C., Harden, T., et al. (1992). Relapse after cognitive behavior therapy of depression: potential implications for longer courses of treatment. *American Journal of Psychiatry, 149*, 1046-1052.

Vanicek, P. (1971). Further development and properties of the spectral analysis by least-squares. *Astrophysics and Space Science, 12*, 10-33.

Watson, D., & Clark, L. A. (1994). *The PANAS-X: Manual for the positive and negative affect schedule-expanded form*. Unpublished manuscript, University of Iowa.
**Figure 1.** Sliding statistics. The mean (star) and the standard deviation (polygon) correspond to the statistics computed from the emotional balance data (empty circles) on a 7 weeks window (box) around time $t$. 
**Figure 2.** Emotional balance trajectory for JR's first (Coping focused) therapy.

(A) Emotional Balance data present two iterations of Phase 1 and 2 sequences, and phase transitions are related to personal or therapeutic events. Red = raw emotional balance data; Black = sliding mean; Blue = standard deviation (multiplied by two for legibility).

(B) Sliding Lomb-Scargle (LS) transform show no significant oscillatory activity (the transform is less than 0.50 significance level) and (C) Presents two sample periodograms for Phase 1 and 2: purple for phase 1a and blue for phase 2b.
Figure 3. Emotional balance trajectory for JR’s second (Mixed Coping and Dynamic focused) therapy. (A) Depicts two iterations of Phase 1-Phase 2-Phase 3 sequences (B and C). Sliding Lomb-Scargle transform identifies two sequences of phases 1/2/3, but the short duration of the recorded oscillating phases implies that the Lombs Scargle transform approaches, but does not sustain significant levels (p = .17). (C): Phase 1: purple, Phase 2: blue, Phase 3: black.
Figure 4. Emotional balance trajectory for JR's third (Dynamic focused) therapy.

(A) Depicts a single sequence of Phase 1-Phase 2-Phase 3. (B) Lomb Scargle transform identifies a prolonged Phase 3 of oscillations with a six-week period sustained until the end of therapy. (C) Shows that the significance level is important (p < .01).
**Figure 5.** Emotional Balance Trajectory for BF. The patient presents a short Phase 1 variability before stabilizing in Phase 2 stability for few weeks before making a transition to Phase 3 (B) with peaked Lomb-Scargle transform that approached significance (p = 0.14).
Figure 6. Emotional Balance Trajectory for TS. (A) The trajectory presents a high emotional balance oscillating between the normal and sub-normal levels, with periods of increased stability that resemble to Phase 2 stability. (B) The ten-week period oscillation on the overall signal presents a very high statistical significance (p < 0.01).
Figure 7. Emotional Balance Trajectory for NA. (A) The trajectory presents a single sequence of Phase 1, 2 and 3. (B) The Lomb-Scargle transform presents a clearly increasing peak that approached, but did not yet reach statistical significance ($p = 0.21$ at the end of the monitoring, with a clear increasing trend).
Supplement A

Context Statement: Supplement A is a 3-page Microsoft Word document (file name SupplementA.doc) that provides additional details about the conceptual and mathematical background of Lefebvre’s model of self-reflexion upon which the Balanced States of Mind model is based.

The States-of-Mind Model

The States-of-Mind Model (Schwartz, 1997) draws upon a theory of self-awareness developed by Lefebvre (1992) in which he proposed that the human mind has an inner structure of awareness of the self and others at increasing levels of reflexivity. This structure regulates the ratio of positive and negative thoughts and feelings according to how individuals evaluate themselves and others within various social contexts. Lefebvre used a Boolean algebra (i.e., an algebra of binary situations) to model positive and negative states at three levels of reflexion. Reflexion is the capacity of a human to see himself (and others) and to observe himself seeing himself (and others). Consciousness is depicted as a reflexive hierarchy in which individuals have a mental representation (image) of themselves and an image of the other, with these images also having images. The first level of reflexion is the sensory experience without conscious awareness of the experience. In order to have conscious awareness, a second level of reflexion is needed so the individual has an image of the experience. A third level of reflexion provides an image of the image (i.e., a cognizant image) such that the individual knows that he or she has the particular experience.

This can be expressed in words as a person seated before a mirror (sensory level)
saying “I see myself in the mirror” (natural image) and “I know that I am seeing myself” (cognizant image). Both the sensory impression and the natural image are determined by physical reality; only the cognizant image can be freely changed through conscious acts of interpretation and choice. For example, imagine an artist who is painting a self-portrait sitting in front of a canvas and looking at her image in the mirror. The first (sensory existence) and second (mirror image) levels of reflexion are determined by the physical reality; the third level of the cognizant image is where she can exercise free will to paint herself on the canvas as either a princess or a frog. These reflexive levels are considered sufficient to model most interpersonal situations.

An individual's state of mind can be structurally represented by a formula that models his or her reflexive process in social situations. A ratio can be computed using rules of Boolean algebra by assigning 1s for positive (e.g., happy, calm) and 0s for negative (e.g., sad, tense) states of the individual at each level of self-reflexion. This ratio, which depends on situational demands and internal responses of the person, represents the outcome probability of the individual making a positive response to the environment. Using this formulation, stressful, neutral, or pleasant encounters can be modeled; 1s and 0s can be assigned on the basis of assumptions about the positive and negative inner states of the individual; and, through Boolean computations, a single ratio score from 0 to 100% can be calculated that represents the predicted positivity of responses to environmental demands. Theoretically derived predictions can then be compared to actual scores derived from cognitive-affective assessment instruments.
References

Lefebvre, V. A. (1992). *A psychological theory of bipolarity and reflexivity*. Lewiston, NY: Edwin Mellen Press.

Schwartz, R. M. (1997). Consider the simple screw: cognitive science, quality improvement, and psychotherapy. *Journal of Consulting and Clinical Psychology, 65*, 970-983.
Supplement B

Context: Supplement B is a 4-page Microsoft Word document (file name SupplementB.doc) that illustrates the mathematical derivations of the Lomb-Scargle transform, a variant of the Fourier transform which detects oscillations in data with irregular sampling. It includes two figures intended to illustrate how the graphical depiction of the data derived from the Lomb-Scargle transform can be interpreted.

The Lomb-Scargle Transform

Since the clinical protocol allowed patients to freely monitor their emotional balance between consultation sessions, the obtained assessments were not evenly spaced. In the case of irregularly sampled data, the classical Fourier transform (see e.g. Gottman, 1994 and Ong, van Dulmen, 2006) fails to provide the frequency content of the signal. To handle such cases, we used the Lomb-Scargle transform, a very efficient method that was developed for the study of astrophysical data (Barning, 1963, Vanicek, 1971, Lomb, 1976, Scargle 1982). This method is based on the following principles we now make explicit.

Consider that we observe a continuous phenomenon though a given scalar measurement $h$. The continuous time phenomenon produces a continuous time measure $h(t)$, but we only have access to a discrete set of, say $N$ values of this function sampled at unevenly spaced times $\{t_i, i=1\ldots N\}$. For this set of $N$ measurements $\{h_i = h(t_i), i=1\ldots N\}$, of mean denoted by $\overline{h}$ and of standard deviation denoted $\sigma$, the Lomb-Scargle transform performs a projection on sines and cosines evaluated only at times $t_i$ where data are actually measured. In detail, the Lomb normalized periodogram is defined by:
\[ P_N(\omega) = \frac{1}{\sigma^2} \left\{ \left( \sum_{j=1}^{N} (h_j - \bar{h}) \cos(\omega(t_j - t)) \right)^2 + \left( \sum_{j=1}^{N} (h_j - \bar{h}) \sin(\omega(t_j - t)) \right)^2 \right\} \]

where \( \tau \) is defined by the relation:

\[ \tau(\omega) : = \frac{1}{2\omega} \arctan \left( \frac{\sum_{j=1}^{N} \sin(2\omega t_j)}{\sum_{j=1}^{N} \cos(2\omega t_j)} \right). \]

The amplitude of the transform \( P_N(\omega) \) gives access to the oscillatory content of the signal. A peak in the transform at frequency \( \omega \) indicates that the signal presents oscillations at this frequency, and the bigger the amplitude of the peak, the more significant the oscillations. Oscillating signals present highly peaked transforms, whereas non-oscillating signals produce flat, generally noisy periodograms (see Figure B1).

Peaks are therefore related to oscillations and indicate the potential frequencies in a signal. The statistical significance of these oscillations can be rigorously evaluated under the assumption that the data are samples of a periodic signal perturbed by a Gaussian white noise. This estimator has a closed form, i.e. a formula provides levels of \( P_N(\omega) \) directly related to statistical significance levels of the observed oscillation. More precisely, the probability of a peak with amplitude \( z \) to be a false alarm of oscillation detection can be written \( P(>z) = 1 - (1 - e^{-z})^M \) where \( M \) is the number of independent frequencies considered, usually chosen to be equal to \( 2N \), i.e. twice the number of observations.
To evidence the appearance of oscillations in the course of treatment we performed a sliding Lomb-Scargle transform (instead of a Lomb-Scargle transform on the full time series). This means that for each time $t$, we compute the Lomb-Scargle transform of the recorded data in a time interval (window) around this time, providing for each time $t$ the related periodogram of the windowed signal. We will therefore represent this transform as a three dimensional graph. For each time $t$ and each frequency $\omega$ will correspond $P_x(\omega)$ the value of the Lombs-Scargle transform given by equation (1) of the signal in the time window around $t$. The onset of oscillations at time $t$ will produce a hill in the 3D surface of the transform that will persist for the whole oscillating phase, and that will be located around the oscillation frequency (see Fig. B2 for an artificial example).

Figure B1. Lomb-Scargle transforms. (A) On oscillating data, the Lomb-Scargle transform presents a peak, at a frequency $\omega$ related to the period of oscillations, and whose amplitude is related to the statistical significance of the observed oscillations (Data of JR, Phase 3, see Results). (B) Non-oscillating data present a shuffled Lomb-Scargle transform with small amplitude, corresponding to low levels of significance.
(Note that the scale of the two images is different, for the sake of legibility).

**Figure B2.** Sliding Lomb Scargle transform, 3D representation. Sliding Lomb-Scargle transform, on the function $f$ defined piecewise by: $f(t) = \sin(\phi t)$ with $\phi = \omega_1 = 2\pi$ for $t \leq t_1$ and $\phi = \omega_2 = 4\pi$ for $t > t_1$. We can clearly see the transition at time $t = t_1$, from oscillations with frequency $\omega_1$ to oscillations at frequency $\omega_2$. Note the imprecision in the observed frequencies and the decreased amplitude of the transform at the transition, linked with the presence of multiple frequencies in the signal.