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RESEARCH ARTICLE

Dampening versus amplification: Intrapersonal and interpersonal vocal affect dynamics during psychotherapy for depression

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Abstract
Objective: Major depressive disorder (MDD) is associated with ineffective affect regulation. Vocal data can shed light on communication and expression during psychotherapy and provide high-resolution data for the study of affective arousal dynamics. Computerized vocal analyses were used to examine the extent to which intrapersonal and interpersonal vocal-arousal dynamics were linked to session outcomes and whether a session's dampening as compared to an amplification arousal trajectory would moderate this association.
Method: Data from 30 clients treated for MDD by nine therapists were analyzed. A total of 9,324 vocal arousal data points were extracted from the working phases of 137 therapy sessions. The clients reported their well-being levels before and after each session on the Outcome Rating Scale.
Results: Vocal-analysis revealed both intrapersonal regulation (towards one's baseline) and interpersonal regulation (towards the partner's arousal level). Only clients' interpersonal regulation towards their therapist's arousal level was linked to better session outcomes. Notably, this positive link occurred more in sessions where the client's overall arousal decreased (dampening); no such link was observed when arousal increased (amplification).
Conclusions: These results suggest that interpersonal (i.e., therapist-client) affect regulation may contribute to therapeutic change in sessions characterized by overall dampening in patients diagnosed with MDD.

Keywords: affect dynamics; coregulation; vocal arousal; major depressive disorder; psychotherapy

Clinical or methodological significance of this article: The current findings highlight the potential of computerized vocal analyses to capture moment-by-moment processes during psychotherapy sessions. Analysis of a sample of clients treated for major depressive disorder showed that both clients and therapists tended to return to their own affective arousal baseline (intrapersonal pull). Similarly, they tended to be "pulled" by their partner toward this baseline arousal level (interpersonal pull). Furthermore, we found that greater interpersonal regulation (being pulled towards the partner's arousal level) was associated with better session outcomes. Interestingly, this tie was evident only when the sessions were characterized by reduced arousal. These findings support the importance of interpersonal affect regulation in psychotherapy treatment for depression.

Affect, specifically affective arousal, is a dynamic and oscillating phenomenon (see Boker & Nesselroade, 2002; Helm et al., 2012; Reed et al., 2015). Ineffective affect regulation and, consequently, deficits in experiential engagement are related to several forms of psychopathology (e.g., Fonagy & Luyten, 2009), most prominently, depression (Hayes et al., 2015).

To better understand these affective dynamics, it is important to differentiate two separate processes: affect dampening and affect amplification.

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Dampening refers to a decrease in the amplitude of affective arousal that culminates in a return to one's homeostatic baseline. In contrast, amplification refers to an increase in amplitude and a further departure from the baseline (Reed et al., 2015). Laboratory and clinical studies have shown that individuals suffering from depression often present characteristic affective dynamics consisting of either inertia (i.e., "getting stuck") or excessive variability (i.e., lability) in their negative affect (e.g., Koval et al., 2013; for a review, see Houben et al., 2015). These individuals often struggle to reestablish emotional homeostasis after experiencing distress, facing challenges in both dampening their maladaptive affect (Nolen-Hoeksema et al., 2008) and recruiting adaptive emotional experiences (Joormann & Gotlib, 2010; Shahar & Herr, 2011).

Studies examining affect dynamics and affect regulation in psychopathology have mostly focused on *intrapersonal* processes; namely, the dampening or amplifying of an individual's affect (e.g., Kuppens et al., 2010; Rocke & Brose, 2013, and specifically in depression, Werner-Seidler et al., 2013). The recent decade has witnessed the rise of a dyadic perspective on affect dynamics (Helm et al., 2012; Reed et al., 2015) and the emergence of prominent research on the *interpersonal* dynamics of affect (for a review, see Dixon-Gordon et al., 2015), and the *coregulation* of affect (Butler & Randall, 2013). In interpersonal coregulation, dampening involves one party pulling the other's arousal toward their baseline, and amplification involves one party pulling the other's arousal away from their baseline (see Reed et al., 2015).

As developmental theorists and researchers have argued (e.g., Beebe & Lachmann, 2015; Feldman, 2012, 2015) intrapersonal and interpersonal regulation are intricately related. Indeed, acquiring adaptive intrapersonal affect regulation capabilities often involves delicate, complex interpersonal processes. These capabilities can be traced back to the parent-infant relationship, in which adaptive affective states are co-constructed dyadically during interactions, with the adult helping the infant internalize regulatory skills. Infants' emotions can be painfully intense or too overwhelming to manage independently. In such instances, dyadic processes of coregulation with a sensitive and responsive adult (e.g., a parent) can help downregulate (i.e., dampen) children's intense affect, thus enabling them to maintain or regain adaptive emotional states. Conversely, infants sometimes benefit from increasing their affective arousal (e.g., pleasant feelings emerging in loving or play states) or expanding their capacity to tolerate and withstand negative emotions without necessarily escaping them. In such instances, dyadic processes with an attentive and responsive adult can help upregulate (i.e., amplify) children's affect. Throughout development, dyadic emotional coregulation processes enable individuals to become better able to do for themselves what was initially accomplished through the relationship with a caregiver; that is, gradually develop more productive emotional regulation abilities, which in turn may lead to enhanced well-being (see Schore & Schore, 2014).

Opportunities to experience one's feelings with an authentic and emotionally present caregiver usually arise as part of the infant's primary attachment bond early in life. Later in life, this process may occur within other attachment relationships—most prominently, through intimate bonds (Bodenmann, 2005) and psychotherapy (Aron & Harris, 2014; Castonguay & Hill, 2012; Fosha, 2001; Schore & Schore, 2014). Indeed, many models of psychotherapy (e.g., Bromberg, 2003; Fosha, 2001; McCullough, 2003; Mitchell, 1993; Summers & Barber, 2009; Winnicott, 1971; Young et al., 2003) have incorporated developmental concepts and highlight the role of interpersonal regulation (or coregulation) dynamics as part of the therapeutic relationship. These models highlight how these dynamics can enhance clients' intrapersonal regulation abilities.

Psychotherapy and Affect Regulation Dynamics

The role of psychotherapy vis-à-vis affect dynamics and regulation has received considerable empirical attention. The literature on intrapersonal and interpersonal dynamics is reviewed below, and a model linking the two is described.

Intrapersonal Affect Regulation

An increased capacity for affect regulation capabilities can be therapeutic (e.g., Berking & Lukas, 2015; specifically for clients suffering from depression, see Berking et al., 2019). However, to date, most studies addressing intrapersonal affect regulation in psychotherapy have relied on self-reports (e.g., Fisher et al., 2019). These studies draw heavily on clients' capacity and willingness to identify their affect dynamics, regulation skills, or difficulties in self-regulation (Cummins et al., 2015), but cannot provide data on moment-to-moment fluctuations within sessions. This has prompted researchers to employ observer ratings of clients' in-session emotional or affective arousal (e.g., Carryer & Greenberg, 2010; Pos et al., 2017). These observational studies provide rich and detailed views of affective dynamics and processes but are labor-intensive,

expensive to implement, and thus have typically been restricted to relatively small samples with a small number of sessions (e.g., Pos et al., 2017). More importantly, observational methods cannot uncover or model high-resolution affective arousal dynamics.

Interpersonal Affect Regulation

A growing number of recent studies have explored interpersonal affect regulation in psychotherapy. Many have focused on the key dynamic of synchrony. Studies examining client-therapist synchrony are often premised on the idea that such therapeutic relationships involve ongoing mutual coordination or influence (Koole & Tschacher, 2016). Indeed, several studies using objective measures to study client-therapist synchrony (e.g., physiology: Marci et al., 2007; Tschacher & Meier, 2019; body movement: Tschacher et al., 2014) have found it to be an indicator of therapeutic progress. However, other studies have reported mixed effects on therapeutic outcomes for synchrony (e.g., with body movement: Altmann et al., 2020; Ramseyer, 2019).

One possible explanation for these inconsistent findings on affect synchrony may be due to the overly broad scope of the term. Specifically, synchrony refers to any covariation between two parties. It may reflect attunement, coregulation, and thus *dampening*, but may also reflect mutual escalation or *amplification* (Butler, 2015). To date, few psychotherapy studies have contrasted dampening as compared to amplification in client and therapist affect. In addition, most studies exploring interpersonal dynamics have only used data drawn from one (Bryan et al., 2018; Imel et al., 2014; Marci et al., 2007; Soma et al., 2020; Tschacher et al., 2014) or two (Ramseyer & Tschacher, 2014) representative sessions. By contrast, Paz et al. (2021) analyzed multiple dyads from multisession data and found an association between interpersonal dynamic pulls and positive session outcomes.

Jointly Considering Affect Intrapersonal (Self-Regulation) and Interpersonal (Coregulation) in Psychotherapy

The current study draws on watershed work by Butler (2015) and Butler and Randall (2013) on pull forces in affect self-regulation and coregulation. Figure 1 illustrates common patterns emerging from the interplay between these forces, based on dynamic systems principles adapted to affect regulation. We conceptualize the **intrapersonal force (a)** as reflecting self-regulation. While this force often acts homeostatically, pulling arousal back towards the individual's session-specific baseline (mean = 0), affect dynamics are complex. Indeed, prior work using this type of data has shown that while the *average* intrapersonal tendency is towards the baseline (Paz et al., 2021), pulls *away* from baseline are also evident. The **interpersonal force (b)** represents the coregulatory influence of the partner. Panel A (dampening) depicts a common dampening scenario where both forces align, pulling arousal towards the baseline. Panel B (amplification) illustrates one specific pattern of amplification resulting from this dynamic interplay where the forces are opposed: the net intrapersonal pull towards baseline is counteracted by the interpersonal coregulatory force pulling *away* from baseline. This highlights

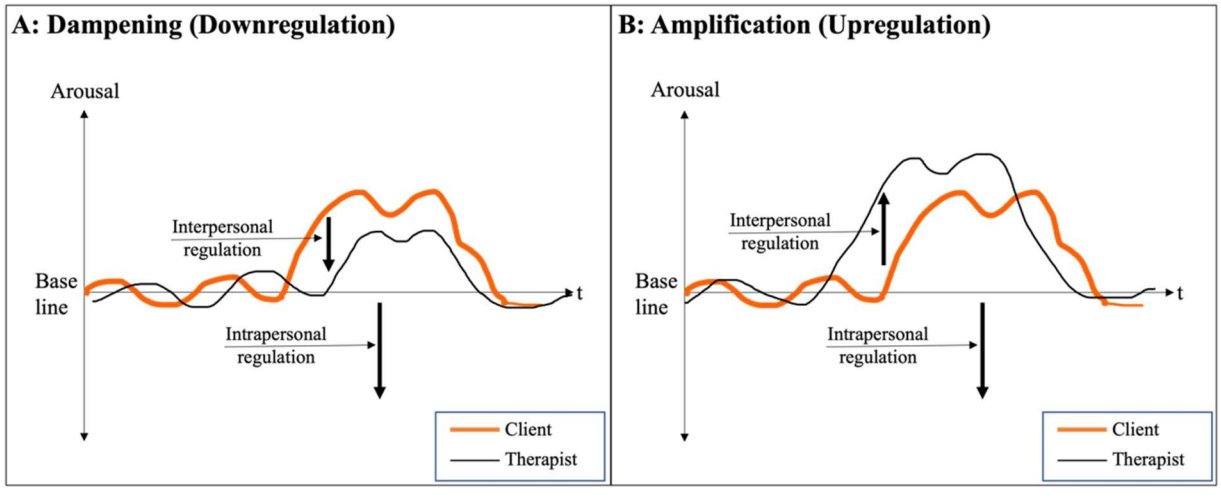

Figure 1. Illustration of Dampening and Amplification Models of Arousal Regulation.
Note. Panel A depicts the Dampening model in which both the intrapersonal and interpersonal regulatory "pull forces" conjoin to dampen arousal towards the affective baseline. Panel B depicts the Amplification model in which the intrapersonal regulatory force pulls towards the baseline while the interpersonal regulatory force pulls away from the affective baseline.

the dynamic tension modeled, showing how interpersonal dynamics can interact with self-regulatory tendencies, but does not exclude other potential pathways to increased arousal.

Therapeutic interactions can involve both dampening and amplification dynamics, since each can serve different functions when addressing affective difficulties. Thus, the meaning and impact of specific moment-to-moment regulatory processes such as the interpersonal pull are likely to be highly dependent on the broader affective context of the session. Coregulation theories consider that the nature of dyadic coordination contributes significantly to relational and individual outcomes, and suggest that patterns of mutual influence unfold differently in contexts of shared de-escalation as compared to shared escalation (Butler & Randall, 2013; Reed et al., 2015). For instance, the implications of an interpersonal pull towards baseline might differ considerably if it occurs within a session characterized by a dampening trend versus one characterized by an amplification trend. Therefore, to gain a more nuanced understanding of affect regulation in therapy, it is crucial to investigate whether the association between interpersonal regulation dynamics and session outcomes is indeed moderated by the session's overall dampening versus amplification trajectory. In the present study, we set out to test this joint model using non-obtrusive measures of both client and therapist affect – namely, using indices of vocal arousal.

Voice as an Index of Affective Arousal in Psychotherapy

The study of affective arousal dynamics requires high-resolution sampling. Advances in technology make it possible to obtain high-resolution data from the vocal channel (and other non-verbal channels including physiology: Kleinbub, 2017; and body movement: Tschacher et al., 2014), which is considered the primary channel of emotional expression and communication (Juslin & Laukka, 2003; Schuller et al., 2011). This makes vocal analysis particularly well-suited to examining intrapersonal and interpersonal affect dynamics, in particular since voice lends itself easily to non-obtrusive measurements.

Rice and Wagstaff (1967) pioneered the use of speech- and voice-related measures to study psychotherapy processes. Recent advancements have led to a surge in the implementation of these measures in recent years (e.g., Tomicic et al., 2015). Several vocal features have been explored in psychotherapy studies (e.g., vocal pitch [the fundamental frequency; f_0], level, and variability: Alpert et al., 2001; Yang et al., 2012; f_0 range: Breznitz, 1992; speech-rate and pause variability: Mundt et al., 2012). Baseline f_0 and deviations from baseline were shown to correlate strongly with self-reported and physiological indicators of affective arousal such as heart rate, blood pressure, and cortisol secretion (Juslin & Scherer, 2005).

The most widely used vocal index in psychotherapy research is f_0. For example, Imel et al. (2014) found that client-therapist f_0 synchrony was linked to therapist empathy as assessed by external raters (although Gaume et al. [2019] failed to replicate these findings in two large samples). Moving to more complex patterns of coregulation, Bryan et al. (2018) found that mutual dampening of affective arousal was associated with a stronger client-reported emotional bond. Soma et al. (2020) demonstrated that clients and therapists modulated each other's affect; when clients became more emotionally labile over the course of a session, therapists became less so, and vice-versa.

These studies are all based on one vocal feature (f_0) obtained in a single session. However, more recent work on vocal arousal suggests that a combination of several features, rather than f_0 alone, may more accurately reflect human affective arousal (Bone et al., 2014a; Chaspari et al., 2017). In particular, an index combining intensity and pitch was more strongly associated with subjectively reported arousal than separate indices of intensity and pitch (Bone et al., 2014a; Chaspari et al., 2017).

Applying these ideas, Paz et al. (2021) utilized a multi-feature index of arousal (Bone et al., 2014) to measure intrapersonal and interpersonal affect regulation dynamics. Their findings delineated the presence of intrapersonal and interpersonal affective "pull forces" towards affective baselines. They used data collected from 277 sessions from 30 client-therapist dyads who engaged in various forms of psychotherapy within a community mental health clinic. Although the clients' intrapersonal pull (self-regulation) grew stronger on average over the course of treatment, the interpersonal pull (coregulation) alone was associated with session outcome. The findings also showed that interpersonal dampening was much more frequent than interpersonal amplification.

The Current Study

The current study aims to further the understanding of intrapersonal and interpersonal affect dynamics and their association with session outcomes in psychotherapy while distinguishing between affective dampening and amplification dynamics. This distinction allows us to investigate whether the association between specific regulatory dynamics

(intrapersonal and interpersonal pulls) and session outcomes differs depending on the overall affective context of the session – specifically, whether the session is characterized by a general trend of dampening versus amplification of vocal arousal. Specifically, we pursued two primary aims:

Aim 1: To examine the presence of intrapersonal and interpersonal vocal arousal pulls and their direct association with session outcomes in a new, homogenous sample of clients treated for depression, seeking to replicate previous findings (Paz et al., 2021).

Aim 2: To extend previous work by investigating whether the association between these regulatory dynamics and session outcomes would be moderated by the continuous session-level vocal arousal trajectory slope (reflecting the extent of the overall dampening or amplification trend within a session).

Method

Participants and Treatment

Clients. The sample was composed of participants engaged in short term (16 session) supportive expressive psychodynamic therapy (SET; Luborsky et al., 1995) In total, 178 candidates were screened on the Beck Depression Inventory-II (BDI-II; Beck et al., 1996). Of these, 64 individuals with BDI-II scores ≥17 were asked to come for an intake interview, during which the Mini-International Neuropsychiatric Interview version 5.0 (MINI; Sheehan et al., 1998) was administered. The inclusion criteria for the study were as follows: (a) a primary diagnosis of Major Depression Disorder (MDD) as indicated by the MINI and (b) aged 18–67. The exclusion criteria were: (a) active suicidality, (b) substance abuse or dependence, (c) current or past bipolar disorder, (d) presence of psychotic tendencies, (e) past severe head injury, (f) pending legal proceedings, and (g) current pregnancy or a medical condition warranting hormonal treatment. Thirty-five clients started treatment; two clients withdrew before the 12th session were considered dropouts and were excluded from the analyses for insufficient length of therapy. Three other clients opted to take psychiatric medication during the treatment period and were excluded from the analysis to avoid confounding medication effects with the effects of psychotherapy. The final cohort thus comprised N = 30 (19 male) clients diagnosed with MDD, with a mean age of 34.63 years (standard deviation [*SD*] = 9.27; range: 21–59 years). Fourteen participants were single, 16 were married or in a permanent relationship, 23 had at least a bachelor's degree, and all but two were fully or partially employed. The clients' mean BDI-II score at intake was 22.5 (*SD* = 7.75), indicating moderate depression levels (Beck et al., 1996).

Therapists. Nine therapists (five females) participated in this study (age: mean = 33.1; range: 30-41); four therapists treated three or four clients each, and the five others treated one or two clients each. The therapists were advanced trainees in a university clinic with three to seven years of clinical experience.

Treatment. The clients underwent brief (16 sessions) supportive-expressive psychodynamic therapy adapted for the treatment of depression (SET; Luborsky et al., 1995). The key treatment features included supportive techniques, such as affirmation and empathic validation, as well as expressive techniques, such as interpretation and confrontation. SET had been found to be effective in treating depression (Beck et al., 1996; Sheehan et al., 1998). The therapists were trained and supervised by senior clinicians with extensive expertise in SET and underwent weekly individual and group supervision.

Measures

Outcome Rating Scale

The Outcome Rating Scale (ORS; Miller et al., 2003) is a four-item scale developed as a brief alternative to longer outcome measures. It gauges three areas that are widely considered valid indicators of progress in treatment: client functioning, interpersonal relationships, and social role performance. Respondents complete the ORS by rating the items on a visual analog scale anchored at each end by the words "low" and "high." The sum of the items ranges from 0 to 40, with higher scores indicating better functioning. In the current study the ORS was completed immediately before and after each session. The pre-to-post ORS change (ORS diff) was calculated as the pre-session ORS subtracted from the post-session ORS.

Vocal Arousal (VA)

The original audio recordings were segmented into speech turns using an automatic diarization algorithm explicitly developed for psychotherapy conversations, since clients often speak for longer periods, whereas therapists frequently respond with shorter utterances. To address these unbalanced activity patterns, we used an algorithm based on previous work

on speech diarization and separation (Laufer-Goldshtein et al., 2018a, 2018b).[1]

Subsequently, following Bone et al. (2014), VA was computed as the weighted average index of three speech features: (1) intensity, (2) pitch, and (3) HF500 (the ratio of energy above 500 Hz to the energy between 80 and 500 Hz). This approach aligns with research demonstrating that composite acoustic indices are more strongly associated with human-perceived arousal than single features are (e.g., Bone et al., 2014; Chaspari et al., 2017). To account for individual and session-specific differences in vocal characteristics, these features were then normalized within each participant for each session by setting the mean vocal arousal level for that specific participant during that session to zero, thus creating a relative, session-specific baseline rather than an absolute zero arousal state. The final VA score was calculated from the weighted average of these session-specific normalized scores for the three features. Studies have reported state-of-the-art performance in cross-corpus automatic arousal recognition for this method (Valstar et al., 2016). Across the N = 30 therapy dyads and the 137 available sessions, a total of n = 9,324 VA data points were obtained from the extracted speech signals (M = 68.1 observations per session [SD = 30.74]).[2] These VA data points constituted the basis for the dynamic systems modeling described below.

Procedure and Ethics

This study was conducted at Bar-Ilan University and was approved by the university institutional review board. Clients participated voluntarily. The participants were told they could terminate their participation at any time with no repercussions on their treatment and that their therapists would not be informed of their responses. The clients completed the ORS electronically (using computers in the clinic rooms), before and after each therapy session. Of the 16-sessions in the SET, 5 sessions were chosen for vocal analysis (primarily sessions 2, 5, 8, 11, and 14). Due to technical problems (e.g., low-quality audio recordings), 137 sessions were analyzed out of the 150 collected measurements. The current study analyzed data collected during the working phase of each session, which was defined based on Auszra et al. (2013) as the 15 minutes before the last 5 minutes of the session. This phase is considered the part of the session in which clients are the most likely to be engaged in therapeutic work.

Data Analysis

To capture the interpersonal affect dynamics unfolding between speakers, we followed Levitan and Hirschberg (2011) who found that the vocal features surrounding *turn-switches* (defined as the transition points at the end of one speaker's turn and the beginning of the partner's subsequent turn, see Figure 2 for illustration) carried more information about the affective interaction between the speakers than average vocal scores from entire speech turns. They recommended concentrating on interpausal units (IPUs), the parts of speech turns demarcated by pauses lasting at least 50 ms and that are pause-free (i.e., interrupted, at most, by pauses lasting less than 50 ms).

In the following equations, the indices denote the turn-switch time point (i), session (s), dyad (d), client (c), and psychotherapist (p). The notation c/p indicates that the variable applies to either the client or the therapist as the focal individual. Changes in vocal arousal between turn-switches were operationalized as the first-order difference approximation of the first derivative, calculated as the change between the

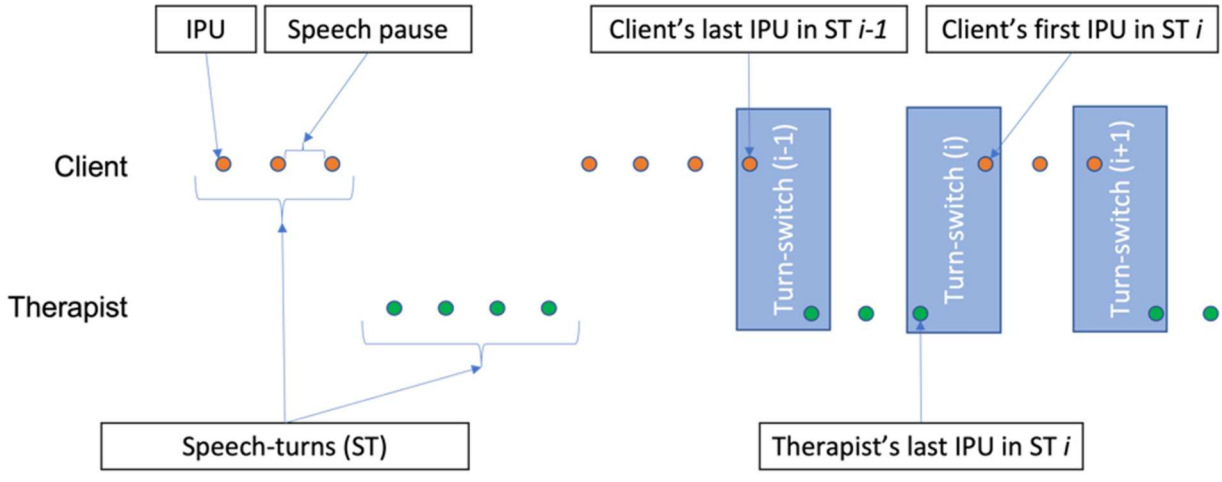

Figure 2. Speech Turns, Pauses, IPUs, and Turn Switches

two vocal arousal data points divided by the elapsed time (Δt; i.e., the time elapsed between consecutive turn-switches), as follows:

$$V.A.Change_{isd}^{c/p} = \left(\frac{VA_{(i)sd}^{c/p} - VA_{(i-1)sd}^{c/p}}{\Delta t}\right) \quad (1)$$

Here, $VA_{(i-1)sd}^{c/p}$ represents the vocal arousal of the speaker (client c or psychotherapist p) in their last interpausal unit (IPU) *before* their partner begins speaking (i.e., the VA associated with turn-switch i-1), and $VA_{(i)sd}^{c/p}$ represents the vocal arousal of the *same* speaker in their first IPU *after* their partner has finished speaking (i.e., the VA associated with turn-switch i). The calculation $V.A.Change_{isd}^{c/p}$ thus specifically quantified the change in the speaker's arousal over the entire course of the partner's speech turn.

Dyadic affect dynamics were modeled based on the method proposed by Butner et al. (2017, 2018), who estimated these dynamics in romantic couples using a first-order dynamic systems model. Specifically, in the current study, client/therapist vocal arousal change (see Equation 1) was predicted by their own previous VA level (*intrapersonal pull; see* Equation 2*)* as well as the difference between their partner's penultimate and ultimate VA levels (*interpersonal pull; see* Equation 3), adjusted for elapsed time to account for variation in the duration of speech turns.

$$IntraPersonalPull_{isd}^{c/p} = VA_{(i-1)sd}^{c/p} \quad (2)$$

$$InterPersonalPull_{isd}^{c/p} = \left(\frac{VA_{(i-1)sd}^{c/p} - VA_{(i)sd}^{p/c}}{\Delta t}\right) \quad (3)$$

Note that the second VA term in Equation 3 used the *p/c* index to calculate the arousal level of the focal individual's partner (psychotherapist if the focal individual was the client; the client if the focal individual was the psychotherapist) associated with the current turn-switch *i*. Because the data were nested (speech turn-switches nested within sessions, themselves nested within dyads), a multivariate multilevel framework (Baldwin et al., 2014) was used in which client and therapist VA changes were modeled simultaneously. Their residuals were allowed to vary within sessions (Level 1), between sessions (Level 2), and between dyads (Level 3).

Model 1 [Aim 1]: Average Intra and Interpersonal Pulls and their Associations with Session Outcome

The first model (see Equation 4) estimated VA change for turn-switch i for client c (or psychotherapist p) in client-therapist dyad d's session s, as predicted by the client's (or psychotherapist's) intercept (γ_{000}^{c} *or* γ_{000}^{p}), as well as by the client's (or therapist's) intrapersonal pull (γ_{100}^{c} *or* γ_{100}^{p}) and interpersonal pull (γ_{200}^{c} *or* γ_{200}^{p}). In this model, the intrapersonal pull parameters are negative when the speaker's VA is "attracted" to the baseline (e.g., when the VA of a speaker in one IPU is above his or her baseline, a negative parameter suggests a decrease in VA in the following IPU). The interpersonal pull parameters are negative when the speaker's VA is "attracted" toward the partner's VA (e.g., when the partner's VA is higher than the speaker's, the speaker will tend to show an increase in VA in the following IPU), such that that a more negative coefficient indicates a stronger pull or attunement towards the partner's arousal level.

At Level 2 (see Equations 5, 6 & 7), the change from pre-session to post-session ORS was included as a moderator of the intrapersonal or interpersonal slopes at Level 1. These cross-level interactions (γ_{110}^{c} *or* γ_{110}^{p} ; γ_{210}^{c} *or* γ_{210}^{p}) tested whether sessions characterized by stronger intrapersonal or interpersonal pulls were marked by greater improvement in well-being.

The model also included random effects at the dyad (u_{00d}^{c} *or* u_{00d}^{p}), session (r_{osd}^{c} *or* r_{osd}^{p}), and turn switch (e_{isd}^{c} *or* e_{isd}^{p}) levels (see Equations 8) to account for data nesting.

Notably, these two equations were run simultaneously to allow clients' and therapists' Level 2 and Level 3 residual terms to covary (to account for dyad interdependence).

Level 1

$$V.A.Change_{isd}^{c/p} = \beta_{0sd}^{c/p} + \beta_{1sd}^{c/p} * IntraPersonalPull_{isd}^{c/p} + \beta_{2sd}^{c/p} * InterPersonalPull_{isd}^{c/p} + e_{(i)sd}^{c/p} \quad (4)$$

Level 2

$$\beta_{0sd}^{c/p} = \pi_{00d}^{c/p} + \pi_{01d}^{c/p} * ORSDiff_{sd}^{c/p} + r_{00d}^{c/p} \quad (5)$$

$$\beta_{1sd}^{c/p} = \pi_{10d}^{c/p} + \pi_{11d}^{c/p} * ORSDiff_{sd}^{c/p} \quad (6)$$

$$\beta_{2sd}^{c/p} = \pi_{20d}^{c/p} + \pi_{21d}^{c/p} * ORSDiff_{sd}^{c/p} \quad (7)$$

Level 3

$$\pi_{00d}^{c/p} = \gamma_{000}^{c/p} + u_{000}^{c/p};\ \pi_{01d}^{c/p} = \gamma_{010}^{c/p};\ \pi_{10d}^{c/p} = \gamma_{100}^{c/p};\ \pi_{11d}^{c/p} = \gamma_{110}^{c/p};\ \pi_{20d}^{c/p} = \gamma_{200}^{c/p};\ \pi_{21d}^{c/p} = \gamma_{210}^{c/p} \quad (8)$$

$(r^{c}_{00d}) \sim N[(0,\ \tau^{c}{}_{00d}{}^{2})]$; $(r^{p}_{00d}) \sim N[(0,\ \tau^{p}{}_{00d}{}^{2})]$; $(u^{c}_{000}) \sim N[(0,\ \tau^{c}{}_{000}{}^{2})]$; $(u^{p}_{000}) \sim N[(0,\ \tau^{p}{}_{000}{}^{2})]$

Model 2 [Aim 2]: Intra and Interpersonal Pull and the Associations with Session Outcome moderated by Session-Level Vocal Arousal Trajectory

The second model focused solely on clients' VA change and tested whether the association between the client's intra- or inter-personal pulls and session outcome was moderated by the overall affective context of the session's working phase. Specifically, it tested whether this trajectory moderated the association between intra- or inter-personal pulls and reported ORS improvement from pre- to post-session.

To operationalize this affective context, a session-level vocal arousal trajectory was calculated for each session's working phase. This trajectory was defined as the continuous linear slope derived from momentary arousal levels (calculated as the standard deviation of the VA within a moving 60-second window) across the 15-minute working phase, as estimated by linear regression. This operationalization stems from the assumption that affective arousal is a dynamic, oscillating phenomenon (e.g., Boker & Nesselroade, 2002) where higher momentary arousal was conceptualized as involving higher-amplitude oscillations from baseline reflected as a larger standard deviation within a short temporal window.

Across the 137 sessions analyzed, the mean session arousal trajectory slope was 0.00 (SD = 0.04, Range = −0.11–0.12), indicating that the overall session trajectories were varied and roughly balanced between the dampening (negative slope) and amplification (positive slope) trends in this sample. Note that this continuous, session-level slope, where negative values indicate an overall session's dampening trend and positive values an overall session's amplification trend, captured the broader session context and was distinct from the micro-level (turn-switch) dampening/amplification dynamics resulting from the interplay of pull forces. This continuous session-level vocal arousal trajectory slope was then added as a moderator to Model 1 (interacting with the pull terms and ORS difference) to examine its influence on the pull-outcome relationship.

Results

Model 1: Intrapersonal and Interpersonal Vocal Arousal Pulls and their Associations with Session Outcome

Table I presents the fixed effects estimated in Model 1. In line with Paz et al. (2021), the effect of the intrapersonal pull was negative and significant for both clients and therapists. In other words, client and therapist VA levels were pulled toward their baseline. In addition, the effect of interpersonal pull was negative and significant for both clients and therapists suggesting that both the client's and therapist's VA levels were pulled toward the other party's VA. However, the session outcomes were not positively associated with the clients' or the therapists' intrapersonal or interpersonal pulls; rather, in sessions marked by greater ORS improvement, therapists' intrapersonal pull was significantly weaker.

Model 2: Vocal Arousal Trajectory as a Moderator of the Associations Between Intrapersonal/Interpersonal Pull and Session Outcome

The vocal arousal trajectory for each session's working phase was entered into Model 2 as a possible moderator of the association between intrapersonal or interpersonal pulls and session outcomes. Table II presents the fixed effects estimated in this model, including the 3-way interactions that served as the test of moderation effects. As in Model 1, the main effects for intrapersonal and interpersonal pulls were significant, while the 2-way interactions with changes in ORS were not. Importantly, though the 3-way

Table I. Model 1: Fixed Effect Predictors for the Speakers' VA Change: interpersonal and intrapersonal pulls and their interaction with session outcomes

	Client			Therapist		
Variable	*Est.* (*SE*)	*CI (95%)*	*p*	*Est.* (*SE*)	*CI (95%)*	*p*
Intercept	0.01(0.02)	[−0.02, 0.05]	0.415	−0.01 (0.01)	[−0.04, 0.02]	0.413
Intrapersonal pull	−0.34 (0.01)	[−0.37, −0.31]	<0.001***	−0.33 (0.01)	[−0.36, −0.31]	<0.001***
Interpersonal pull	−0.35 (0.01)	[−0.38, −0.32]	<0.001***	−0.27 (0.01)	[−0.30, −0.25]	<0.001***
ORS diff.	0.02 (0.01)	[−0.01, 0.04]	0.145	−0.01 (0.01)	[−0.03, 0.01]	0.530
Intrapersonal pull X ORS diff.	0.01 (0.01)	[−0.01, 0.04]	0.253	0.03 (0.01)	[0.00, 0.05]	0.017*
Interpersonal pull X ORS diff.	−0.01 (0.01)	[−0.03, 0.01]	0.187	0.00 (0.01)	[−0.02, 0.03]	0.872

Note. *$p < .05$. **$p < .01$. ***$p < .001$. ORS diff. = Outcome Rating Scale measuring pre-to-post session difference.

Table II. Model 2: Fixed Effect Predictors for the Speakers' VA Change: interpersonal and intrapersonal pulls and their interaction with session outcome as moderated by the sessions' arousal trajectories

	Client		
Variable	*Est. (SE)*	*CI (95%)*	*p*
Intercept	0.012 (0.02)	[−0.02, 0.04]	0.481
Intrapersonal pull	−0.338 (0.01)	[−0.37, −0.31]	<0.001***
Interpersonal pull	−0.345 (0.01)	[−0.37, −0.32]	<0.001***
ORS diff.	0.017 (0.01)	[−0.01, 0.04]	0.141
Session arousal trend	−0.001 (0.35)	[−0.69, 0.69]	0.998
Intrapersonal pull X ORS diff.	0.015 (0.01)	[−0.01, 0.04]	0.255
Interpersonal pull X ORS diff.	−0.014 (0.01)	[−0.03, 0.01]	0.177
Intrapersonal pull X Session arousal trend	−0.010 (0.36)	[−0.72, 0.70]	0.979
Interpersonal pull X Session arousal trend	0.128 (0.39)	[−0.63,0.88]	0.741
ORS diff. X Session arousal trend	−0.449 (0.38)	[−1.20,0.30]	0.238
Intrapersonal pull X ORS diff. X Session arousal trend	−0.298 (0.41)	[−1.10,0.50]	0.465
Interpersonal pull X ORS diff. X Session arousal trend	1.357 (0.38)	[0.62,2.09]	<0.001***

Note. *$p < .05$. **$p < .01$. ***$p < .001$. ORS diff. = Outcome Rating Scale measuring pre-to-post session differences.

interaction between intrapersonal pull, session outcome, and vocal arousal trajectory was not significant; the counterpart 3-way interaction between interpersonal pull, session outcome, and vocal arousal trajectory reached significance. To probe this significant 3-way interaction involving the continuous session arousal trajectory moderator, a simple slopes analysis (Preacher et al., 2006) was conducted. Figure 3 plots the estimated simple association between interpersonal pull slopes (Panel B) and changes in ORS at three representative values of the session arousal trajectory slope depicting no slope (representing "no change"), one standard deviation above (representing "amplification"), and one standard deviation below (representing "dampening")[3] the mean. Panel A, using an identical approach on the intrapersonal pulls, shows the non-significant interaction with intrapersonal pull. These results indicated that sessions characterized by dampening and a strong interpersonal pull resulted in better session

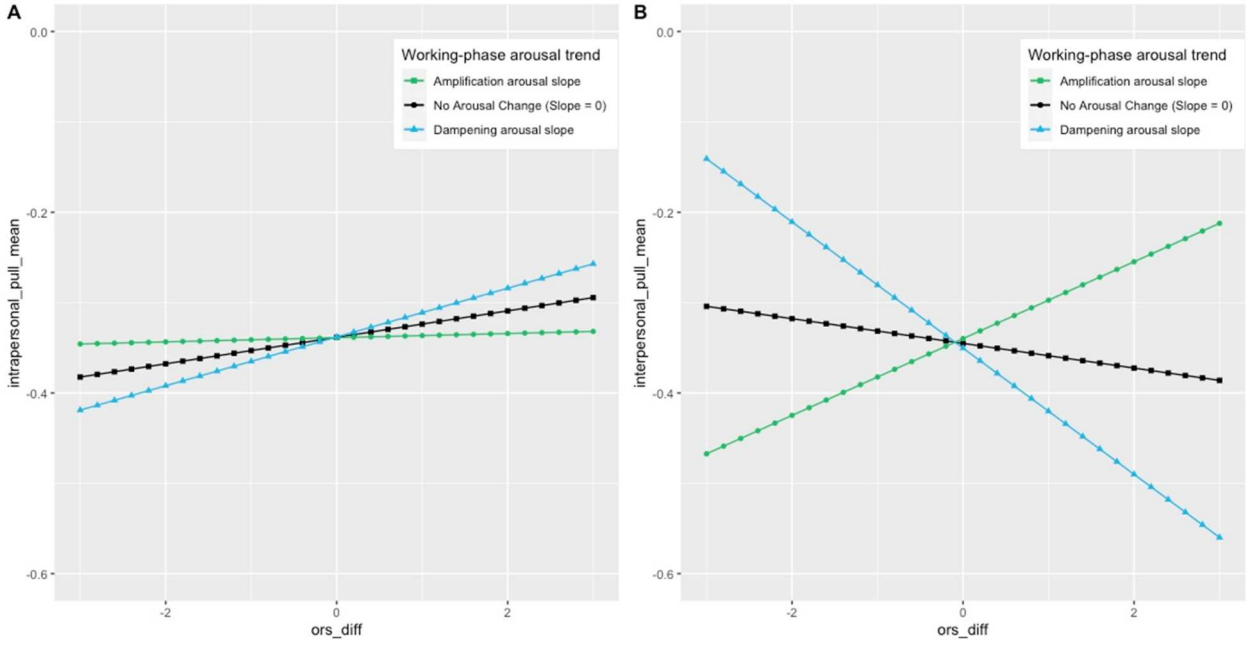

Figure 3. Association between Intrapersonal and Interpersonal Pulls and Session Outcomes (ORS Diff.) moderated by Sessions' Working Phase Arousal Trajectories.

Note. The simple slopes represent the association between ORS difference (x-axis) and the interpersonal pull effect slope (y-axis; Panel B) or intrapersonal pull effect slope (y-axis; Panel A) at representative levels of the session arousal trajectory moderator (slope = 0, +/- 1 SD). For Panel B, consistent with the model's parameterization (see Data Analysis section), a more negative value on the y-axis indicates a stronger interpersonal pull towards the partner's arousal baseline.

outcomes when the interpersonal pull towards the partner's baseline was stronger (i.e., represented by a more negative simple slope coefficient for the interpersonal pull effect; *Est.* = −0.070, $p < 0.001$). In contrast, sessions marked by amplification and strong interpersonal pull showed a trend-level association towards poorer session outcomes (*Est.* = 0.043, $p = 0.06$).

Discussion

In this study, vocal measures and dynamic system models were used to examine intrapersonal and interpersonal affective arousal pulls in psychotherapy sessions. The first goal was to replicate Paz et al. (2021) by examining whether the two intrapersonal and interpersonal pull forces were present in the current sample of clients treated for depression with short-term dynamic SET. The results replicated Paz et al. by showing that both intrapersonal and interpersonal dynamics were present.

In line with predictions, the intrapersonal pulls toward the clients' baselines were unrelated to the session outcomes. By contrast, and unlike in Paz et al., the interpersonal pulls of the therapists toward the clients' baselines were also unrelated to the session outcomes. One possible explanation for this null association is that therapists' pull on their clients' vocal arousal does not necessarily contribute to improved outcomes. Alternatively, not all clients suffering from depression need downregulation in the first place. Instead, clients who suffer from depression and experience emotional flatness may benefit more from amplifying their emotional arousal than dampening it (e.g., Joormann & Stanton, 2016).

To test the latter hypothesis, a second set of analyses was conducted to examine whether the trajectory, distinguishing between sessions characterized by amplification and dampening, would moderate the association between interpersonal pull and session outcomes. In line with this hypothesis, the results showed that the association between interpersonal pull and session outcome depended on the session's arousal trajectory. Specifically, interpersonal pull towards the partner's baseline was only positively associated with outcomes (i.e., greater pull was linked to greater improvement) in sessions characterized by an overall dampening of the client's arousal. Conversely, in sessions characterized by amplification, there was a trend towards the opposite pattern: stronger interpersonal pull (i.e., a more negative coefficient) was associated with poorer session outcomes. While this pattern of findings underscores the importance of interpersonal downregulation in certain contexts, it contrasts somewhat with the literature suggesting that there are potential benefits to emotional amplification in clients treated for depression (e.g., Joormann & Stanton, 2016). This point is dealt with in more detail in the limitations section on the null findings for amplification trajectories and issues related to measurement.

Overall, the results are consistent with theoretical approaches to psychotherapy that view interpersonal downregulation between clients and therapists as one of the central mechanisms of change in psychotherapy for depression (Bromberg, 2003; McCullough, 2003). These approaches suggest that depressed clients need therapists' help to tolerate and regulate emotions that are too intense or painful to manage alone (Fosha, 2001; Luborsky et al., 1995). The current findings are consistent with models pointing to the adaptive nature of interpersonal dynamics characterized by coregulation (e.g., Butler & Randall, 2013), where synchronized elevation followed by a joint return to an affective baseline (i.e., dampening) characterize effective coregulation, and where morphogenic processes of continuous mutual affective escalation without a return to baseline (i.e., amplification) characterize maladaptive processes.

This beneficial effect of dampening is consistent with other studies that have reported this pattern in other interpersonal relationships and modalities, such as analyses of voice (Hilpert et al., 2022), physiology (Coutinho et al., 2021), and hormonal responses (Provenzi et al., 2019). These findings are also congruent with the small but growing literature on vocal analyses that has reported the beneficial effect of coregulation in psychotherapy (e.g., Bryan et al., 2018; Soma et al., 2020).

The lack of a positive association between amplification dynamics and outcomes may indicate that the therapists intuitively attempted to calm the clients' emotional arousal and shied away from interpersonal upregulation. However, in some contexts, emotional arousal may benefit the client, especially when it involves productive emotions such as assertive anger, grief, or positive emotions (Greenberg, 2012). Several emotion theorists and researchers have suggested that in such situations some clients should be helped to amplify avoided or flattened emotions (e.g., Benjamin & Atlas, 2015; Greenberg, 2012). To do so interpersonally, however, therapists may themselves experience high levels of emotional arousal. This may be challenging, especially for novice therapists, such as those in this study. Future work could investigate whether variables such as therapist experience, emotional regulation abilities of the therapist or client, or particular features of the emotional context moderate the associations between interpersonal amplification and treatment outcomes.

Another explanation for the lack of a positive association between amplification and outcomes may be rooted in the design. Specifically, even if the amplification of painful emotions has positive long-term therapeutic effects, it is likely that short-term outcomes (e.g., the post-session ORS used here) would not show them and would be directly influenced by the painful emotion itself. Future work could examine the long-term consequences of amplification to test this idea, which would require larger samples that would allow testing amplification as a therapy-level construct.[4]

Limitations and Future Direction

This study has several limitations. Voice is an unobtrusive window to emotional information but is limited by being non-continuous (i.e., it only generates data when a person speaks and not during pauses or silences) and non-simultaneous (i.e., it involves turn-taking, so that speakers typically do not speak at the same time). In addition, although vocal arousal taps into arousal, which is one dimension of affect it neglects another key dimension of valence. Further, in this study, computationally derived vocal arousal served as the behavioral proxy for the internal affective/physiological state. While the literature supports associations between these acoustic features and perceived arousal (e.g., Bone et al., 2014a; Juslin & Scherer, 2005), the correspondence is partial; therefore, careful interpretations should focus on the observed dynamic patterns rather than interpret precise momentary internal states.

Second, this study focused on the working phase of each session, a decision that was motivated to a large extent by pragmatic considerations. This may be problematic, since other phases within each session (e.g., the initial minutes or those close to the end) may also play important roles in affect regulation.

The current sample only included clients diagnosed with depression who were receiving short-term dynamic therapy thus making the extent to which these findings can be generalized to different clinical populations unclear. It is possible that for clients suffering from other diagnoses such as an avoidant personality, amplification would be more productive.

While the sample size was sufficient to detect the main moderation effect, the statistical power may not have been sufficient to detect effects within specific moderator conditions (e.g., amplification trajectories). Future research with larger samples would provide greater power for additional specific simple slope analyses.

Finally, the analytical approach, particularly the within-participant, within-session normalization of vocal arousal, meant that the dynamic models captured fluctuations relative to a session-specific baseline. Thus, the findings pertain specifically to these relative, within-session regulatory dynamics and do not directly address potentially important factors such as the absolute level of arousal (e.g., whether a client is consistently "low") or systematic changes in baseline levels across the course of therapy.

Future research could build on the current findings by incorporating methodologies that address the limitations inherent to using vocal arousal alone and within the scope of the current study. To mitigate the ambiguity of arousal valence, future studies could integrate a linguistic analysis of verbal content or automated analysis of facial expressions along with vocal dynamics, that could potentially distinguish between positively and negatively valenced arousal states (see Paz et al., 2021 for an example). Furthermore, to better understand the complex links between vocal parameters (as behavioral proxies) and internal states, concurrent measurement of physiological signals (e.g., electrodermal activity, heart rate variability) would be valuable. Finally, explicitly integrating an analysis of the specific verbal content or conversational context could help disentangle the meaning of arousal fluctuations (e.g., stress vs. excitement) and clarify its interplay with linguistic expression.

Overall however, these results highlight the importance of interpersonal regulation, and particularly the downregulation of affective arousal, as a key therapeutic process in treating depression. These findings are consistent with clinical theories that underscore the role of therapist emotional engagement, and point to one particularly fruitful avenue for this engagement, where the therapist's own activation and regulation serve as a guide for the client.

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Notes

[1] Additional information and details on the diarization method can be found in the Online Supplementary Materials (OSM): https://osf.io/k8wj9/?view_only=94d0bbf335c44c1ea1bfa02604f04764

[2] The diarization algorithm and VA extraction implemented using MATLAB (Version 2019a). The vocal features were extracted using the Praat computer program (Boersma & Weenink, 2017). For additional information, see https://osf.io/5xr8c?view_only=94d0bbf335c44c1ea1bfa02604f04764).

[3] The session trajectory slopes were roughly balanced in the sample; approximately half of the 137 sessions evidenced

amplification trends (positive slopes, N ≈ 67) and half evidenced dampening trends (negative slopes, N ≈ 70).

[4] The sample size did not make it possible to examine questions pertaining to client effects (e.g., whether clients with higher capacities for intrapersonal regulation would benefit more from amplification) or therapist effects (e.g., whether certain therapists are better at helping their clients interpersonally regulate their affective arousal).

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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