

## Short-Form, Comedy Improv Affects the Functional Connectivity in the Brain of Adolescents with Complex Developmental Trauma as Measured by qEEG: A Single Group Pilot Study

Mary DeMichele\* and Scott Kuenze

Neuro Feedback Department, Calo Programs, Lake Ozark, Missouri, USA

### Abstract

Complex developmental trauma (CDT) is characterized by prolonged exposure to traumatic events in early life, resulting in the breakdown of neurobiological integration which impacts mental and physical health. The benefits of practicing short-form improvisation (improv), however, parallel the treatment needs of this population. To observe the neurobiological effect of improv, we used eyes-open quantitative electroencephalography (qEEG) to record the brains of 32 adolescents before and after participation in a 20-min intervention (One Rule Improv) consisting of short-form improv games. A paired *t*-test was used to evaluate coherence, phase, absolute amplitude, and low-resolution electromagnetic tomography (LORETA). Results indicated increases in coherence in delta, theta, alpha, and beta ( $p < .05$ ). Phase lag showed a statistical decrease ( $p < .05$ ) in delta, alpha, and beta. Absolute power showed significant increases in alpha frontally Fp1 ( $p = .004$ ), decreases in delta ( $p = .030$ ) at T4. LORETA analysis indicated significant changes in sensorimotor rhythm (SMR) at Brodmann area (BA) 6,  $t(27) = 6.1$ ,  $p < .05$ . Significant delta decreased at BA 6, BA 10,  $t(27) = 4.96$ ,  $p < .05$ ; and BA 24,  $t(27) = 3.90$ . Significant delta decreased at BA 4, BA 3, and BA 40,  $t(27) = 4.35$ ,  $p < .05$ . Results indicate preliminary evidence supporting improv as an intervention capable of affecting functional connectivity changes in adolescents with CDT. For developmental trauma, these results may indicate improved capacity to make meaningful connections with others and create opportunities for neuroplastic changes.

**Keywords:** functional connectivity; complex developmental trauma; improv; alternative therapies; adolescents with trauma; improvisational theater

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**\*Address correspondence to:** M. DeMichele, MSSc, P.O. Box 1941, Lake Ozark, MO 65049, USA. Email: <mailto:research@oneruleimprov.com>

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**Edited by:**  
Rex L. Cannon, PhD, SPESA Research Institute, Knoxville, Tennessee, USA

**Reviewed by:**  
Rex L. Cannon, PhD, SPESA Research Institute, Knoxville, Tennessee, USA  
Genomary Krigbaum, PsyD, Grand Canyon University, Phoenix, Arizona, USA

Complex developmental trauma (CDT) is a condition defined by exposure to multiple traumatic experiences most often of an interpersonal nature during early development, between the ages of zero and seven, resulting in an underdeveloped nervous system more inclined towards survival than healthy attachment (van der Kolk, 2005). The effects of this can result in poor neuronal development, and an overall inefficiency in the systems in the body and brain (Bower, 2016; van der Kolk, 2005). This

mental health state of dissociation, or a disconnection of neuronal connections, limits the functional connectivity of the brain (Schore, 2014). Functional connectivity refers to the integrated relationship between spatially separated brain regions.

In normative brain development, the functional connectivity of the three sections (brain stem, limbic system, and cortex) work together. Chronic

exposure to trauma moves the brain stem and limbic system into a state of hyper- or hypoarousal. Threat is perceived everywhere, triggering a fear-based survival response of flight/fight/freeze. The nervous system goes either below or above its window of tolerance and as a result of excessive stress, certain brain regions within the cortex become disorganized (Atzil, Hendler, & Feldman, 2011). This state negatively impacts emotional and behavioral regulation, motivation, cognitive function (De Bellis & Zisk, 2014) and sensorimotor integration (Stein, 2017). These deficits carry into adulthood, causing those who suffer from CDT to present with a comorbidity of emotional, behavioral, and cognitive diagnosis (Gunnar & Quevedo, 2007; Pechtel & Pizzagalli, 2011). Essentially, maltreatment during early life changes the trajectory of brain development that affects sensory systems, network architecture, and circuits involved in threat detection, emotional regulation, and reward anticipation (Teicher, Samson, Anderson, & Ohashi, 2016).

While many established therapies like cognitive behavior therapy (CBT) require higher cortical systems to be activated, like verbal acuity, those with CDT require an intervention that engages deeper centers of the brain before higher cortical systems can engage (Siegel, 2012). Successful treatment involves positive, healthy, repetitive, relational experiences in the context of safe, empathetic, and attuned relationships (Baylin & Hughes, 2016), which are all qualities developed through the practice of comedic/theatrical improvisation (improv; Ballon, Silver, & Fidler, 2007; Bermant, 2013; DeMichele, 2015; Gale, 2004).

Short-form comedic improvisation (improv) is an unscripted comedic art form that originated from the Theater Games of Viola Spolin (Spolin, 1963) and began its development into its own art form in the late 1950s in Chicago (Wasson, 2017) and early 1960s in England (Johnston, 1992). Today, short-form comedy improv is characterized by its short 30-second to 3-minute-long game structures, driven by audience suggestions and structured by the rule of saying “Yes, and....” This foundational rule of *Yes, and* (Halpern, Close, & Johnson, 1994) prompts players to unconditionally accept and add to the offers given by other players in every interaction. While performed professionally, improv with this frame of *Yes, and* is comparable to the improvisational, sociodramatic role-play of early childhood development when children develop cognitive and social skills (Sawyer, 1997).

Often misunderstood as being similar to stand-up comedy, improv, although comedic, is by contrast a positive and supportive relational activity. Its foundational rule of *Yes, and* frames the relationship between players, the audience, as well as the players to themselves. Halpern et al. (1994) describe improvisation as not merely an exchange of information between players. Instead, players share responsibility and “take care of each other” (p. 38). An interaction is not complete until a player “sees how it affects his partner” (p. 63). Spolin (1963) describes it as “communion” (p. 45), and Paul Sills, founder of Second City Improv explains that improv is the “finding of oneself in free space created through mutuality” (Sweet, 1986, p. 20). The requirement to unconditionally agree (*Yes*) and add to the offer of others (*and*), as well as oneself, encourages the practice of trust, acceptance, concentrated focus with all senses, and spontaneity (Gale, 2004). While improv has remained a comedic performing art form, parallels in several domains of applied psychology (body awareness and mindfulness, positive psychology interventions, and person-centered psychotherapy) have bolstered interest in the use of improv as an experiential therapeutic intervention (Bermant, 2013).

There is a growing body of research examining the use of improv as an intervention for a variety of clinical diagnosis or for self-identified mental health issues. Recent research exploring the effectiveness of improv has begun to report improv’s positive impact on those that suffer from anxiety and depression in adults (Krueger, Murphy, & Bink, 2017) and in teens (Felsman, Seifert, & Himle, 2019). Other studies report improvement in prosocial behavior (Corbett et al., 2019; Kisiel et al., 2006; Zucker et al., 2010) and social cognition (Corbett et al., 2019). Studies involving teenagers reveal improv’s ability to improve uncertainty tolerance (Felsman, Gunawardena, & Seifert, 2020; Hainselin, Aubry, & Bourdin, 2018) and affective well-being (Felsman et al., 2019; Schwenke, Dshemuchadse, Rasehorn, Klarhölter, & Scherbaum, 2020). Research involving children note a reduction in aggressive behaviors and an improvement in scholastic attention and engagement (Kisiel et al., 2006; Zucker et al., 2010).

Brain imaging technology is revealing improvisation’s ability to activate the frontocortical and sensorimotor regions of the brain of musicians and rappers, who also use a *Yes, and* frame as they repeatedly accept an offer without judgment and add to it. The activation of these brain regions may benefit those who suffer the neurobiological effects

of CDT (Schore, 2014). Findings, using fMRI technology, indicate that engagement in an improvisational activity increases the activation of the medial prefrontal cortex (MPFC; self-expression) and of the sensorimotor and language regions of the brain (Limb & Braun, 2008; Liu et al., 2012; McPherson, Barrett, Lopez-Gonzalez, Jiradejvong, & Limb, 2016). A 2019 study, using EEG brain mapping technology (Sasaki, Iverson, & Callan, 2019) revealed consistencies with the fMRI research (Donnay, Rankin, Lopez-Gonzalez, Jiradejvong, & Limb, 2014; Limb & Braun, 2008; Liu et al., 2012; McPherson et al., 2016) with greater power for scale in the frontal area comprising regions of the medial frontal cortex, anterior cingulate cortex, and the supplementary motor area (SMA). There are mixed results among these studies regarding activation of the dorsal lateral prefrontal cortex (DLPC). Some exhibiting its activation (Sasaki et al., 2019) and others its deactivation in relationship with the activation of the MPFC, suggesting the mental state of flow (Limb & Braun, 2008). There is, however, consensus that the different results may be due to the skill level of the subjects, as well as the level of constraint within the design of the study (Landau & Limb, 2017; Sasaki et al., 2019).

While the direction of research involving improv continues to expand, there have been no published articles looking at the nervous system of groups of adolescents with CDT before and after an intervention of improv was used. With existing research and the observation of positive emotional state changes during improv by adolescents with CDT, we hypothesized that improv changes the functional connectivity of the brain, moving individuals from a neurobiological state of survival to a state in which they are able to integrate higher cortical systems to better engage in connection with themselves and others.

## Methods

### Participant Characteristics

In this quasi-experimental pretest–posttest design, the experimental group consisted of 32 subjects between the ages of 15 and 18. Participants reside at a residential treatment center for adolescents, meeting the criteria for CDT. Thirty-two preassessment and postassessment qEEGs were recorded; however, four participants were excluded because of distortion in the recordings, resulting in the total number of  $N = 28$ . Participants included 14 female participants, 13 male participants, and 1 transgender male (female-to-male) participant (59% White, 15% Latino, 10% African-American, 10%

mixed race, 6% American Indian and Asian). Races were indicated in the records of the participants as determined by their parents. All 28 participants were adopted, and all were right-handed.

Participants had a co-occurring (average of five) of clinical diagnosis as listed in the DSM-5 (APA, 2013). The most common, listed in order of prevalence: attention-deficit/hyperactivity disorder (ADHD) (65%); major depressive disorder (50%); reactive attachment disorder, (25%) parent–child relational problem (16%); anxiety disorder (31%)/Social anxiety disorder (6%); posttraumatic stress disorder (PTSD; 31%); oppositional defiance (22%); disruptive mood dysregulation disorder (16%); specific learning disorder (16%); cannabis use disorder (16%).

### Assignment Method

Participants were selected from a voluntarily attended, on-site, 25- to 50-minute, weekly improv class. Experience and ability playing improv varied from 1 week to 16 months and was not a prerequisite for selection. Participants were selected based upon availability and simply asked if they would take part in what was called “Neuro Improv” (NI). One participant declined. Participants were informed they would have a qEEG, play improv while still wearing the qEEG cap, and have a postscan done after the improv session. Participants understood that their brain scans would be evaluated before and after improv and that their data was confidential. There was no further discussion or detail given about the hypothesis or purpose of the scans. An independent institutional review board (IRB), IntegReview, approved this study. All participants provided verbal consent, while written consent was provided by parents or legal guardians.

Immediately prior to the preassessment, participants were involved in unstructured social activities with peers and staff for a minimum of 15 to 45 minutes during the end of their routine day for baseline recording. The study was conducted over an 8-month period, with four participants being recorded each session for a total of eight sessions. After their prescan, each participant walked with the neuro technician approximately 2 minutes to the improv class where they began class with one to three other participants. To avoid self-consciousness due to the wearing of qEEG caps, the selection of the other one to three players in the session was based on having a neutral or positive relationship with the other participants.

### EEG Data Collection

Quantitative electroencephalography (qEEG) was used to record the nervous system of 32 adolescents with developmental trauma before and after the improv intervention (ORI) to evaluate changes in the brainwave frequencies. Scalp voltages were recorded using a 19 Sn electrode cap (Electro-Cap International, Eaton, OH) according to the 10–20 international system: Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2. The ground electrode was placed on the scalp between Fpz and Fz. Electrical signals were amplified with the BrainMaster's Discovery 24 and 20 EEG systems (BrainMaster Technologies, Bedford, OH) and all electrode impedances were kept under 5 k $\Omega$ . Electrodes were referenced to linked earlobes. The EEG was recorded continuously, digitized at a sampling rate of 256 Hz, and then spectral analyzed using the fast Fourier transform (FFT). EEG data was filtered with a 0.5–40 Hz bandpass filter. Participants recorded 5–6 minutes eyes-open recordings for the preassessment, and 5–6 minutes eyes open for the postassessment.

### EEG Data Processing

Using NeuroGuide 3.0.2, qEEG data was analyzed (Applied Neuroscience, 2008). Thirty-second minimum samples were collected. Elimination of artifacts were done visually by a trained professional. Coherence, Phase, and LORETA computations from NeuroStat and NeuroBatch 3.0.2 were used to analyze coherence, phase, and low-resolution electromagnetic tomography (LORETA). Coherence, which is a measurement of functional association between two brain regions (Nunez, 1981, 1995), was calculated by looking at the variability of time differences between two time series in a specific frequency band including delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), and beta (12–25 Hz). Phase lag is calculated by evaluating two waves at a specific frequency at the same point in time. The difference between the waves is measured in radians, and if a difference exists the waves are considered out of phase. If the difference is  $\pi$  radians, then the waves are in antiphase. LORETA was used to provide insight into the dynamic functioning of the brain. LORETA utilizes a 19-channel EEG cap and three-dimensional (3-D) source imaging to determine the specific source of an electric dipole (Pascual-Marqui, Michel, & Lehmann, 1994).

### Intervention

All participants experienced a 20-min improv intervention, Neuro Improv (NI), consisting of short-

form improv games and using the One Rule Improv (ORI) approach (DeMichele, 2019) to learning and playing improv developed and facilitated by a co-author of this study (DeMichele). The ORI approach to learning improv explicitly focuses on the rule of *Yes, and* when teaching, playing, and facilitating improv games. While many games, including theater games and some commonly performed improv games, are improvisational as they are unscripted, experiential, and learner centered, they are not necessarily collaborative or lack the frame of *Yes, and* (DeMichele, 2015), as are the games used in this study. Initially developed to help adolescents improve learning experiences and outcomes (DeMichele, 2015), this current intervention NI uses ORI to help students with CDT to attain a better mental state as well as the essential skills to enable them to better communicate and form healthy relationships.

During each 20-min NI session, participants practiced games for the entire duration of time without any debrief or discussion. Feedback and side-coaching were limited to *Yes, and* reminders. Each session began with a 7- to 10-minute full group warm-up which opened with the theater game *1–20*, in which participants stand in a circle, looking at each other and counting consecutively from 1 to 20, randomly offering one number at a time. If two players say the same number at the same time, all must start again at one. Although considered a theater game and not an improv game by the author because it is not based upon an audience suggestion or framed by *Yes, and*, as each player's offer is prescribed to be consecutive numbers between 1 and 20, players must still listen and add, creating an attunement to each other.

Next, a series of *Yes, and*-style games in which players must say "Yes, and" before each offer were played. *One Word at a Time* games followed, in which players create sentences speaking only one word at a time. Participants then played games in accordance with an appropriate challenge level for interest and enjoyment as chosen by the facilitator and the student. Games included the *Yes, and*-style and *One Word at a Time* games listed above, as well as the following: Expert-style games including Interview games whereby player(s) interview another player; Story games in which players create well-formed narratives either simultaneously as in *Mirror Story*, or by alternatively offering one word at a time or phrases and sentences at a time; Scene-based games in which players create scene like in *Alphabet*, where they must begin each line of dialogue with the next letter

of the alphabet, or like in *Freeze Tag*, where players start a scene, are frozen in a position, and a new player must tag in and start a whole new scene.

## Results

To assess the hypothesis and qualify if improv would change the functional connectivity of the brain, the metrics of coherence, phase lag, absolute amplitude, and LORETA were evaluated. Coherence is the measurement of the stability of phase, or the efficiency in communication between paired sites. Too much coherence at paired sites may contribute to rigidity, whereas if there is not enough coherence it may contribute to difficulty with task completion and neurological integration. Phase lag is a measurement of the speed and timing of communication between paired sites. If phase lag is too fast or too slow it impacts the usefulness of the information being communicated. Absolute amplitude is a measurement of the power of the frequencies, or  $\mu\text{V}$  squared. LORETA is a measurement that looks at the deeper centers of the brain related to the surface EEG. A paired *t*-test was applied to each one to look at the difference between preassessment and postassessment. The results of the averages of all participants showed noticeable changes in all the metrics.

### Coherence Outcomes

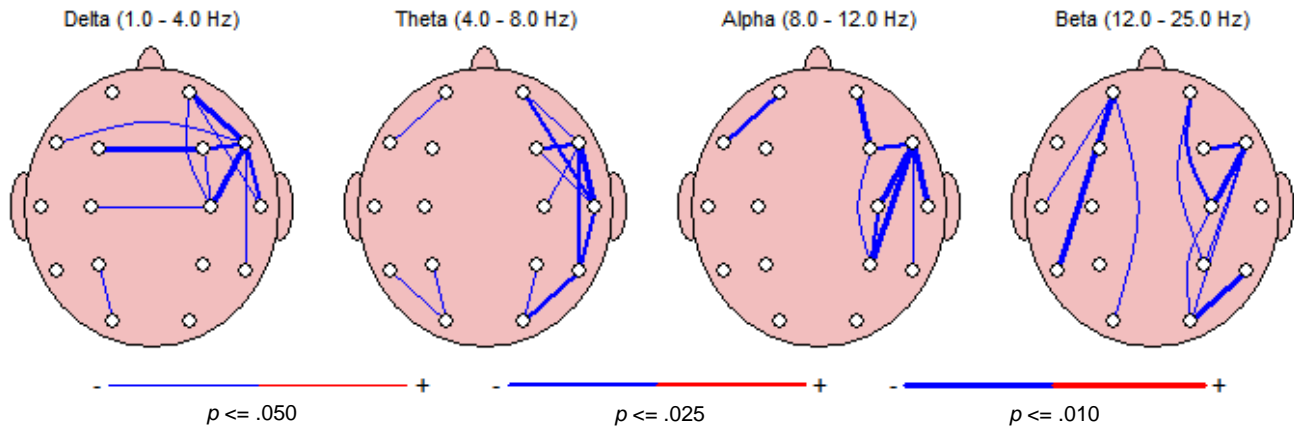
Using the 10–20 international system, all 361 paired sites were evaluated. The coherence results showed a statistically significant increase in coherence both interhemispherically and intrahemispherically in many different paired sites and across all frequencies with more increases in coherence in the right hemisphere than the left, except in beta where there is almost an equal amount of change difference (see Table 1).

As shown in Figure 1, the colors of the lines represent the statistical *p*-value: the blue color represents statistically significant *p*-value in the direction of more coherence from preassessment to postassessment.

**Table 1**

*Difference in Coherence for EEG frequency variables (delta, theta, alpha, and beta) before and after improv*

Placement	Frequency	<i>p</i> -value
F7, T3	Delta	.030
Fp2, F8	Delta	.002
Fp3, T4	Delta	.032
F4, C4	Delta	.046
F4, F8	Delta	.012
C4, F8	Delta	.007
F8, T4	Delta	.016
F3, F4	Delta	.007
P3, O1	Theta	.009
O1, T5	Theta	.023
Fp2, T4	Theta	.041
F4, F8	Theta	.017
F4, T4	Theta	.028
P4, O2	Theta	.027
O2, T6	Theta	.017
F8, T4	Theta	.002
F8, T6	Theta	.031
T4, T6	Theta	.034
T5, T6	Theta	.034
Fp1, F7	Alpha	.016
Fp2, F4	Alpha	.006
F4, F8	Alpha	.007
C4, F8	Alpha	.003
P4, F8	Alpha	.001
F8, T4	Alpha	.003
Fp1, P3	Beta	.033
Fp1, o1	Beta	.030
Fp1, T3	Beta	.022
Fp1, T5	Beta	.008
Fp2, C4	Beta	.023
Fp2, P4	Beta	.043
F4, F8	Beta	.017
C4, f8	Beta	.003
P4, F8	Beta	.040
O2, F8	Beta	.036
O2, T6	Beta	.006



**Figure 1.** 10–20 results from preassessment to postassessment ( $N = 28$ ). Any line indicates significant changes ( $p < .05$ ) in the coherence between paired sites. Red indicates decreases, while blue indicates increases. Colored lines indicate significant changes, while the thickness of the line denotes the associated probability value ( $p \leq .050$ ,  $p \leq .025$ ,  $p \leq .010$ ).

### Phase Lag

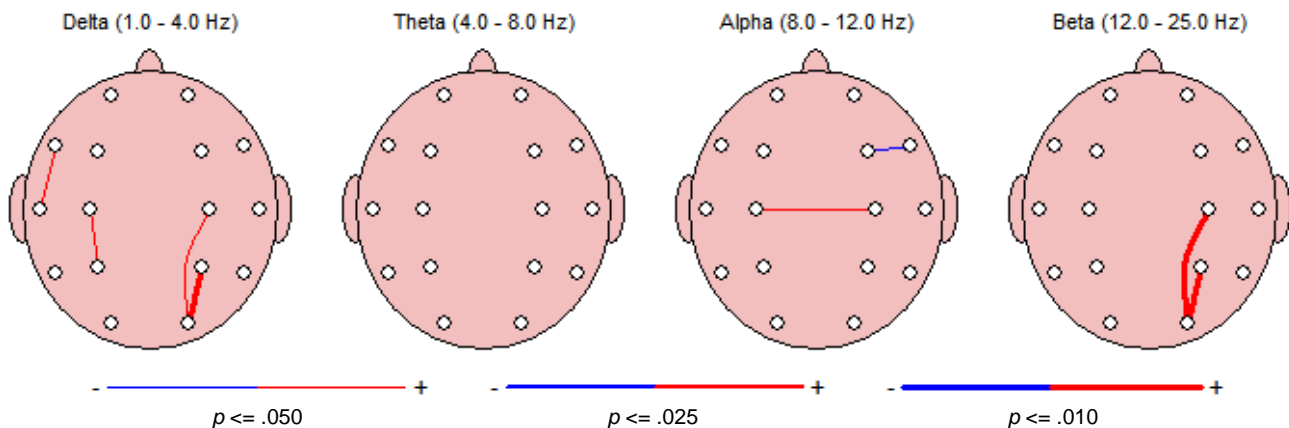
Using the 10–20 international system all 361 paired sites were evaluated. The phase lag analysis found significant change in phase lag from preassessment to postassessment, with more changes in the right hemisphere than the left. This shift indicated that after an improv session phase lag slowed down.

As shown in Figure 2, the colors of the lines represent the statistical  $p$ -value: the red and blue colors represent statistically significant  $p$ -values, where red shows a decrease in phase lag from preassessment to postassessment and blue indicates an increase in phase lag from preassessment to postassessment.

**Table 2**

*Difference in Phase Lag for EEG frequency variables (delta, theta, alpha, and beta)*

Placement	Frequency	$p$ -value
C3, P3	Delta	0.034
F7, T3	Delta	0.037
C4, O2	Delta	0.050
P4, O2	Delta	0.005
C3, C4	Alpha	0.028
F4, F8	Alpha	0.032
C4, O2	Beta	0.006
P4, O2	Beta	0.001



**Figure 2.** From preassessment to postassessment ( $N = 28$ ). Colored lines indicate significant changes ( $p < .05$ ) in the phase lag between paired sites. Red indicates decreases, while blue indicates increases. Colored lines indicate significant changes, while the thickness of the line denotes the associated probability value ( $p \leq .050$ ,  $p \leq .025$ ,  $p \leq .010$ ).

### Absolute Power Evaluation

To investigate the difference between qEEG absolute power preassessments and postassessments, a paired *t*-test was used. It revealed a significant increase in alpha frontal at Fp1 ( $p = .0043$ ), and a decrease in Delta at T4 ( $p = .030$ ).

T3 showed a decrease in high beta; however, in the raw data, despite using many different methods of muscle relaxation, some participants exhibited an unconscious or chronic tension at the T3 location. It was difficult to remove all muscle artifact from the EEG at T3. It was interesting that the postassessments revealed that improv affected the participants' ability to release chronic muscle tension.

As shown in Table 3, the colors indicate statistical *p*-values and direction of change: red indicates a decrease in amplitude, while blue indicates an increase in amplitude.

**Table 3**

*Amplitude Absolute Power maps for EEG frequency variables (delta, theta, alpha, beta, beta 1, beta 2, beta 3 and high beta)*

Placement	Frequency	<i>p</i> -value
FP1-LE	Alpha	.043
T3-LE	High Beta	.042
T4-LE	Delta	.030

**Note.** Blue and red coloration of *p*-value indicate significance increases or decreases, where blue indicates an increase while red indicates a decrease in power.

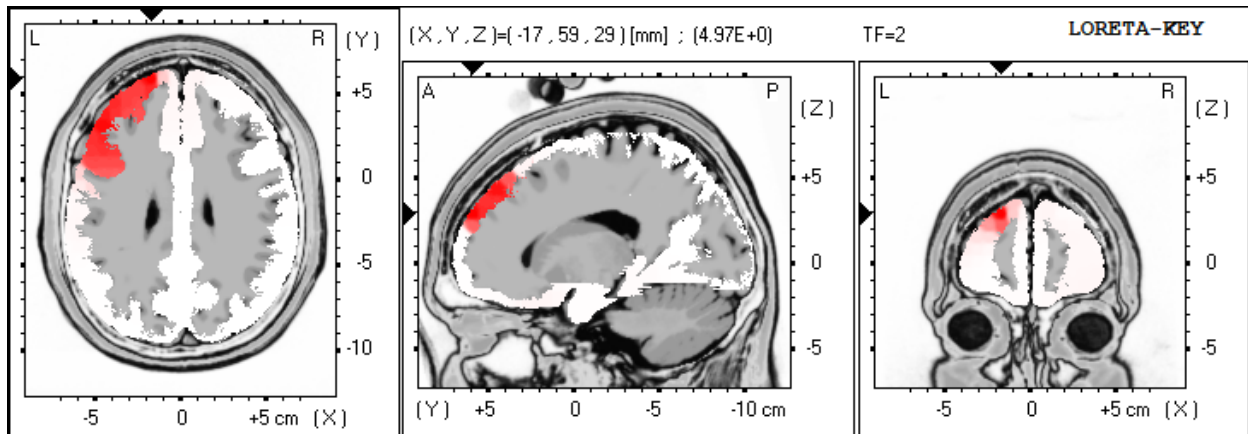
### LORETA Power

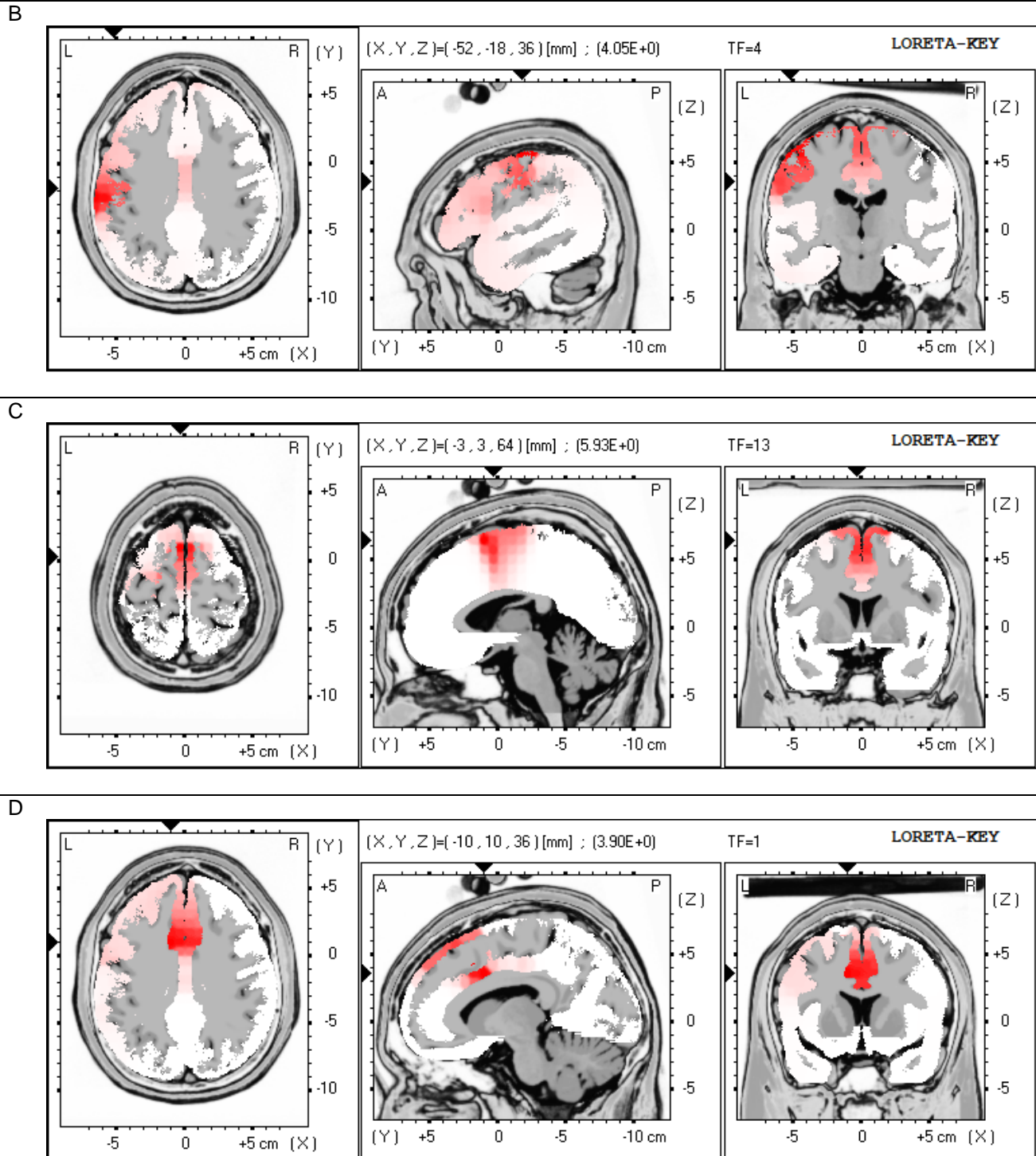
LORETA analysis indicated significant changes in Alpha level ( $p \leq .05$ ). Delta decreased in Brodmann areas (BA) 6, 10, and 24, which are medial frontal gyrus (MFG); superior frontal gyrus (SFG),  $t(27) = 4.96$ ; and anterior cingulate cortex (ACC),  $t(27) = 3.90$ . Delta decreased from preassessment to postassessment in BA 4, BA 3, and BA 40, which are the precentral gyrus (PCG) and inferior temporal gyrus (ITG),  $t(27) = 4.35$ ;  $df = 27$ ;  $p < .05$ . Sensorimotor rhythm (SMR) decreased in BA 6 which is the SFG,  $t(27) = 6.1$ .

**Figure 3**

*LORETA brain images: Red coloration indicated a significant decrease in activation*

A





**Figure 3.** (A) EEG frequency 2 Hz. BA 6, BA 10 medial frontal gyrus, superior frontal gyrus:  $t(27) = 4.96$ ;  $df = 27$ ;  $p < .05$ . (B) EEG frequency 13 Hz. Red coloration indicated a significant decrease in activation. BA 6 superior frontal gyrus:  $t(27) = 6.1$ ;  $df = 27$ ;  $p < .05$ . (C) EEG frequency 4 Hz. Red coloration indicated a significant decrease in activation. BA 4, BA 3, BA 40 precentral gyrus, inferior parietal lobule:  $t(27) = 4.35$ ;  $df = 27$ ;  $p < .05$ . (D) EEG Frequency 1 Hz. BA 24 anterior cingulate:  $t(27) = 3.90$ ;  $df = 27$ ;  $p < .05$ .



## Discussion

This is the first qEEG study to evaluate CDT and improv, and how it affects functional connectivity in the brain. Results indicate that improv affects the functional connectivity of the brain, activating higher cortical systems and moving individuals from a neurobiological state of survival to a state in which they are able to integrate complex problem-solving skills, to better engage in connection with themselves and others. Differing from the observation of ongoing events as seen in the existing studies involving musicians (Limb & Braun, 2008; Liu et al., 2012; McPherson et al., 2016; Sasaki et al., 2019) and those with autism (Corbett et al., 2019), a qEEG recorded before and after an improv intervention revealed results related to sustained effects of improvisation.

After one 20-min session of practicing short-form improv games framed by *Yes, and*, and participants having varying degrees of experience, results showed a change in the nervous system. While use of play to encourage epigenetic changes in the brain (Panksepp & Panksepp, 2013) may help to correct some of the effects of early life adversity when used in attachment-focused therapies (Baylin & Hughes, 2016), improv's foundational rule of *Yes, and* may be the catalyst for the observed neurobiological changes.

### Coherence Discussion

The results showed an increase in coherence from preassessment to postassessment with more changes in the right hemisphere than the left. Coherence is the stability of the phase relationship between two paired sites. Too much coherence may cause the brain to become too simple and undifferentiated, impeding variation of function. Lack of coherence results in too much differentiation leading to disconnection and dissociation. While CDT impacts the right hemisphere most profoundly, promoting dissociative states, which are indicative of neuronal disconnection (Schore, 2012), increases in coherence may influence the building new neural connections (Warner, 2013), thus helping to restore normative brain function.

Since improv is setting a frame for a positive experience with the opportunity for connection, the increase in right hemisphere activation may be a shift out of disassociation and towards interpersonal connection. Improv's structure of *Yes, and* may increase coherence by creating the conditions for safety needed to shift from the survival brain to a more integrated nervous system. *Yes, and* frames

each interpersonal interaction in a reciprocity of unconditional positive regard (Bermant, 2013). This positive energy and information can influence reactions of acceptance and impact coregulation. In every interaction, trust is built in oneself and with others. Additionally, *Yes, and* limits uncertainty in social interaction, thus limiting personal fear. With the conditions set for emotional safety, a shift from the survival brain to the activation of communication between other regions is possible (Baylin & Hughes, 2016). In other words, improv increases coherence and connectivity, shifting the nervous system from a predisposition of dissociation to improved stress tolerance, effectively increasing the span of the window of tolerance, and bringing arousal levels within it.

### Phase Lag Discussion

Results indicated that phase decreased from preassessment to postassessment, indicating that the timing of neuronal connections decreased. Phase lag is related to the timing of communication between areas of the brain. When timing is too fast and information gets to its destination too quickly, information becomes difficult to interpret or understand. This inefficient processing may result in rumination, and obsessive thinking without clarity or understanding. This may be the reason that there is so much mental perseveration with participants with CDT. A decrease means that the brain's timing has slowed down, increasing the effectiveness of the nervous system to coordinate movement, meaning, and decisions (Warner, 2013).

*Yes, and* may foster the condition for the decrease in phase lag because it encourages focused attention. Focused attention is created by the spontaneity or novelty (Kagan, 2002) instigated by *Yes, and* in every interaction. With attention focused on receiving and understanding an offer, along with the increase in coherence, information becomes more efficiently timed, complex, and thus effective for personal/self-connection and social engagement.

### LORETA: Sensorimotor System

Consistent with the improvisational studies involving musical and lyrical improvisation, significant activation of the sensorimotor system was observed (BA 40, BA 4, BA 6; Limb & Braun, 2008; Liu et al., 2012; McPherson et al., 2016; Sasaki et al., 2019). When underdeveloped, a sensorimotor system will negatively impact the emotional and cognitive systems; however, neuroplastic development can be experienced through play (Berghänel, Schülke, & Ostner, 2015) and improv is a form of play.

The activation of BA 6 indicates the potential for improved cognition and improved executive control (Stein, 2017) and is related to motor planning and premotor movement. This same region showed a decrease in SMR, suggesting the priming of motor cortex, essentially moving the brain to a state where movement was readily accessible. The activation of BA 40, 3, and 4 (PCG, ITG) involve the perception of space and limb location and may influence the ability to create meaning around posture and gestures, as well as access to the mirror neuron system (Carlson, 2012, p. 273–275; Reed & Caselli, 1994) and somatosensory processing (Stein, 2017). The results also indicated that improv affected the right temporal lobe, which is related to the function of auditory processing, personality, categorization, and organization (Soutar & Longo, 2011). Complex development trauma is typically characterized by a dissociation and impairment with affect regulation (Schore, 2014). The activation of these observational mechanisms within the sensorimotor system seems to be necessary conditions for attunement to oneself and others, which is essential for the formation of healthy relationships.

*Yes, and* may set the condition for this activation as it provides the opportunity to practice consistent and reciprocal attunement, prompting the mirror neuron system. It is plausible that with *Yes, and* the participants' brains attuned to internal and external sensory information to be better able to respond. This shift in the sensorimotor region allows for an easier experience understanding and making meaning out of verbal and nonverbal communication. Improv's effect on the sensorimotor system suggests that by participating in improv, the development of sensorimotor systems would become more refined over time.

#### LORETA: Medial Frontal Gyrus

Data showed the activation of the medial frontal gyrus (BA 10) which plays a critical role in human attachment neurobiology. Deficits in this region due to early adversity (Teicher et al., 2016) heighten the risk for psychiatric disorders (Schore, 2012). The activation of BA 10 is consistent with the findings of the fMRI and EEG studies of musical improvisation. This brain region is associated with higher-cognitive abilities that facilitate extraction of meaning from ongoing experiences, the organization of mental contents that control creative thinking and language, and the artistic expression and planning of future actions (Damasio, 1985; Semendeferi, Armstrong, Schleicher, Zilles, & Van Hoesen, 2001). Activation at the Fp1 location is related to the function of cognitive emotional valence, irritability, social

awareness, and approach behavior (Soutar & Longo, 2011) and is important for impulse control, attention, and self-regulation. The activation of BA 10 suggests improv's ability to influence the healthy development of the brain and the orbital frontal cortex, which Schore (2012) deems essential for healthy attachment and affect regulation.

#### LORETA: Anterior Cingulate

Data showed an activation of the anterior cingulate. This region is implicated in motor control and emotional regulation (Etkin, Egner, & Kalisch, 2011; Landau & Limb, 2017; Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002; Paus, 2001). Landau and Limb (2017) described that it "has been strongly implicated in the selection and sequencing of musical plans during improvisation" (p. 29).

While it was not determined if the DLPC quieted creating the neural signature of flow state (López-González, & Limb, 2012), the activation of MPFC (BA 10) was present. With the safety, risk, focused attention, full embodiment, and reciprocating co-creation created by *Yes, and* (Landau & Limb, 2017), improv may set the condition to exist in the span of arousal as described by Siegel (2012), which in turn triggers group flow (Sawyer, 2017) and integration. Interacting in a way where groups can exist within the span of arousal with a valence towards positive energy and information may be the pinnacle of desired human interaction and connection.

#### Strengths/Limitations

Neurobiological changes to the brain due to early childhood adversity are specific, depending upon the type and timing of exposure (Atzil et al., 2011; Teicher et al., 2016); therefore, those who suffer the substantial medical and psychiatric disadvantages of developmental trauma present with a comorbidity of diagnosis (Anda et al., 2006). The trauma experienced by this study's participants varied in type, timing, and origin in various domestic and international locations. While an adequate sample size of the represented individual diagnosis was not available to determine significant change specific to that diagnosis, the neurobiological changes recorded do suggest that improv may serve as a broad-based intervention to a variety of diagnosis that continue to impact health, education, correctional, societal systems, and individuals.

The main limitation to this quasi-experimental, single-group pretest–posttest study is the lack of a control. However, it can be said that based on the qEEG reliability and validity, if a participant was

to receive a qEEG, spend 15 min waiting, and then receive another qEEG, that the results would look very similar, and no change would occur (Thatcher, 2010). With this in mind, it is possible to conclude that improv did change the functional connectivity of the brain. The second limitation is that there were no reliable and validated subjective surveys or cognitive assessments used. This limits the qualitative evaluation of perceived decrease in symptoms.

## Conclusion

Data suggests that improv affected the functional connectivity of the brain. This impact may help the brains of adolescents with CDT, restoring their course for normal development and their ability to form healthy, connected relationships. Improv's rule of Yes, and is the access point to the brain as it creates the safety, attunement, and flexibility needed to achieve these neurobiological changes. Whether one's trauma has created a state of hyperarousal or hypoarousal, the conditions created by Yes, and drives the nervous system to self-organize towards integration and balance, thus shifting the individual from the mental state they are in to one better able to function cognitively, physically, behaviorally, and psychologically. Future research may focus on improv's effectiveness on specific diagnoses, as well as the use of longitudinal studies to determine if improv can create lasting neural change.

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