A Case Study of two Adolescent-Parent pairs describing the association between vagal tone and social-emotional adjustment during a Positive-Cognitive- Behaviour-Therapy-Program

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Abstract

Objective: A case study describing the association between RMSSD and social-emotional adaptation in two distressed Adolescent-Parent (A-P) pairs during a Positive Cognitive Behaviour Therapy Program (P-CBTP).

Methods: Two A-P pairs completed a P-CBTP with pre-and post-intervention bio-social-emotional assessments; weekly training sessions over 7 weeks to develop individual strengths, new adaptive cognitions, positive discipline skills, optimism and knowledge on age-appropriate developmental expressions; augmented by moderate physical activity. Resting vagal tone and vagal reactivity were assessed by RMSSD.

Results: Social-emotional adjustment improved in all A-P pairs. Resting RMSSD increased over the intervention period, from low-to-low-normal towards average-for-normal in three subjects. The fourth individual had excessive pre-intervention resting RMSSD that declined in the direction of normal over the intervention period. RMSSD reactivity in response to orthostatic stress remained the same pre- to post-intervention.

Conclusions: Changes in resting vagal tone demonstrated improvements in psychological functioning in all four subjects over the period of intervention. Results supported the view of the association between vagal tone and mental health not being an absolute positive relationship, but that low, as well as excessive vagal tone may be maladaptive. More studies need to examine the association between resting vagal tone and emotion regulation in A-P relationships during P-CBTP, keeping in mind that a linear relationship cannot summarily be expected in population studies.

Introduction

Adolescence is a critical period to establish either lifelong positive health-related behaviours or negative risky behaviours. It is also a highly susceptible phase for effective intervention and parental psycho-education on normative adolescent development tasks and to assist with improving Adolescent-Parent (A-P) relationships (Holmbeck, 2002).

Emotions reflect the quality of child-parent relationship, caregiving environment and attachment (Dix, 1991). Attachment creates the view that a child has of himself and the world; for integration with that of his mother (Bowlby, 1973; Stern, 1985). Various stressors such as early negative parenting emotions in first-time unplanned pregnancies may trigger a cascade of long-term child-parent attachment/relationship problems (Hart & McMahon, 2006; Lederman & Weiss, 2009; Nelson & O'Brien, 2012; Webster-Stratton, 1990). Limited research has been done on the effect of parental emotional regulation, emotion expression and the development of adaptive child and adolescent emotion regulation (Bariola, Gullone & Hughes, 2011).

Successful Parenting programs are supported in the research literature as those integrating both cognitive (P-CBT) and behavioural (positive rewards) components (David, 2004; Gavita, Joyce & David, 2011). Cognitive Behavioural Therapy (CBT) is predominantly centred on the psychological suffering of patients, proven to be an effective approach for a variety of psychological problems in children, adolescents and adults. In contrast, Positive Cognitive Behaviour Therapy focuses mainly on the strength and abilities of patients by merging CBT with Positive Psychology and Solution Focused Brief Therapy to increase psychological well-being by building personal resilience (Bannink, 2012; Padesky & Mooney, 2012; Prasko, Hruby, Holubova, Latalova, Vyskocilova, Slepecky, … Grambal, 2016). Moderate exercise is postulated to benefit mental health through mechanisms such as distraction, improvement of self-efficacy, self-esteem, social interaction and cognitive function and by alleviating social withdrawal (Sharma, Madaan, & Petty, 2006; Raglin, 1990), and has on occasion been introduced into CBT therapy programs (Heiden, Lyskov, Nakata, Sahlin, Sahlin, & Barnekow-Bergkvist, 2007). Emotional experiences are boosted by moderate exercise; which in turn will precipitate positive emotions and build psycho-social resources that inspire mental health. (Hogana, Catalinob, Mataa & Frederickson, 2015).

Finding appropriate physiological correlates of psychological health is, in general, problematic. Heart rate variability (HRV), which is largely determined by the autonomic nervous system (ANS) and related to emotional arousal has, with variable degrees of success, been used to gauge the outcome of therapeutic interventions in individuals with stress-related psychological dysfunction. HRV is a measure of the oscillations in the interval between consecutive heart beats that result from complex, non-linear interactions. It is considered a measure of neuro-cardiac function that represents heart-brain interactions, as well as autonomic nervous system dynamics (Shaffer *et al*., 2014). Structures within the central nervous system, including the central autonomic network, coordinate autonomic and behavioural responses to environmental challenges (Porges, 2007; Thomas, 2017). The vagal component of the ANS indexes this central nervous system ANS integration (Porges, 2007; Thomas, 2017) and is thus seen as a psychophysiological measure of adaptive emotional regulation. HRV is detected using electrocardiogram or photoplethysmograph sensors to determine the cardiac inter-beat-

interval (IBI). The resultant IBI signal can then further be analysed by either linear algorithm (e.g., time domain and frequency domain) or non-linear algorithm (e.g., Poincaré and entropy-based) analyses. An optimal level of variability in the heart rate signal is critical to the flexibility and resilience that characterizes health. While too much instability is detrimental to efficient functioning, too little variation may similarly indicate pathology (Shaffer *et al*., 2014). HRV methods have in the past been used to assess both sympathetic and vagal (parasympathetic) status. However, in view of the present uncertainty about the validity of HRV measures of sympathetic nervous system activity (Reyes del Paso, Langewitz, Mulder, van Roon, & Duschek, 2013; Thomas, 2017), vagal indicators are generally the HRV measures of choice.

Vagal-mediated HRV is believed to index the capacity of an individual to allocate psychophysiological resources to meet environmental demands and various studies have shown a link between vagal tone and emotion regulation. Greater vagal tone and flexibility have, for instance, been reported with psychological well-being indices such as positive emotionality, prosocial behaviour, sympathy, empathy, self-regulation, decreased maladaptive coping, cheerfulness, kindness, the ability to deal with stress and positive social-emotional outcomes (Beauchaine, 2001; Geisler, Kubiak, Siewert,& Weber, 2013; Kogan, Gruber, Shallcross, Ford & Mauss, 2013; Kok & Fredrickson, 2010; Miller, Kahle & Hastings, 2015; Muhtadie, Koslov, Akinola, & Mendes, 2015; Porges, 2011). In contrast, low vagal tone have been reported in a wide range of maladaptive conditions; stress, anxiety and depressive disorders, trait hostility, deficient behavioural inhibition, as well as in a host of metabolic and cardiovascular disorders (Gross, 1999; Chambers & Allen, 2002; Friedman, 2007; Rodebaugh & Heimberg, 2008; McLaughlin, Rith-Najari, Dirks, & Sheridan, (2015); Viljoen, Claassen, & Mare, 2013). A large spectrum of psychopathologies, many of them out of tune with the social context, has been described in association with poor vagal flexibility (Muhtadie *et al*., 2015). Vagal flexibility or reactivity, i.e., vagal withdrawal in response to a stressor, is considered adaptive in the sense that it facilitates coping with physiological or behavioural demands posed by stressors and is said to reflect social sensitivity in a context-dependent manner (Porges, 1995; Muhtadie *et al.,* 2015) This is in line with Porges' polyvagal theory that implies vagal status to be related to more adaptive regulatory behaviour and vagal withdrawal to be a physiological strategy that allows sustained attention and behaviours indicative of active coping (Calkins, Graziano, & Keane, 2007; Porges, 1995). Relevant to the present study are indications of parent's capacity for A-P emotional regulation (ER), specifically interpersonal functioning, to be related to individual differences in vagal regulation (Gyurak & Ayduk, 2008; Porges, 2003); permitting adjustment to parenting demands in response to recognizing the child's behaviour; while facing challenges in relationships- and work (Cheron, Ehrenreich & Pincus, 2009). Although a positive relationship between mental health and vagal status has repeatedly been reported, indications for an association between excessively high vagal tone, generally as implied by low resting heart rates, and a decline in aspects of psychological health have also been found to exist (Calkins et al., 2007; Calkins, Propper, & Mills-Koonce, 2013; Kogan *et al*., 2013; Sturge-Apple, Suor, Davies, Cicchetti, Skibo & Rogosch, 2016). In fact, low resting heart rates, and by implication (i.e. high vagal tone), has been described as physiological correlates of aggressive and antisocial behaviour in adolescents and low resting heart rates in late adolescent males is said to be associated with an increased risk for criminality in

adulthood (Latvala, Kuja-Halkola, Almqvist, Larsson &, Lichtenstein, 2015, Ortiz & Raine, 2004; Portnoy & Farrington, 2015).

In view of published associations between vagal tone and vagal reactivity on the one hand, and psychological well-being on the other, it seems feasible to hypothesise that the difference between pre- and post-P-CBTP vagal status may reflect the success of therapeutic intervention. The aim of this case study was therefore to investigate the potential use of vagal tone and/or vagal reactivity as physiological indices of social-emotional adjustment during a Positive-Cognitive-Behaviour-Therapy-Program.

Methods:

Two Adolescent-Parent (A-P) pairs, each consisting of mother and son, hence referred to as adolescent-parent pair A and adolescent-parent pair B, completed a Positive Cognitive Behaviour Therapy Program (P-CBTP). Recruitment was done by the principal investigator and involved referrals from the Child and Adolescent Out Patient Department, followed by initial telephonic screening and subsequent interviews to confirm suitability and informed consent/assent to become part of the study.

Ethical clearance, in accordance with the declaration of Helsinki, the National Health Act and the policy of the University, was received from the Faculty of Health Sciences Research and Ethics Committee of the University of Pretoria (Number: 264/2014) and the required informed consent documents were signed before initiation of the study. All four research patients provided informed consent for the publication of this research report, documented as case studies.

Detailed case study presentation of two A-P pairs (Table 1 and Table 2)

Diagnostic focus:
No official diagnoses were made.

Therapeutic focus (Tailored P-CBTP): See appendix for detail.
Exercise (15 min mother-and-son walk, 4 times a week) was introduced in an attempt to improve social interaction and alleviate withdrawal from each other.

Methodology:

See Appendix A: Social–emotion assessment tools for A-P pairs, Appendix B: P-CBTP (behaviour and cognitive components to improve parenting skills, changing parents' and child's interpretations of each other's behaviour, augmented with exercise).

Table 1: Demographics, main complaints and functioning.

Mother A	Unemployed, female recently divorced, in her early thirties with distress due to irregular maintenance payments and poor financial situation; developed recent relationship problems with her two teenage children. She would air her frustration by shouting at the children when unable to cope, displaying symptoms of irritability, insomnia and worrying. Her youngest child who had been diagnosed with bipolar disorder presented with ongoing symptoms of an unstable mood, apprehension, insomnia, low self-esteem, suicidal thoughts and aggressive outbursts.
Adolescent A	Since his parents' recent divorce the 18 year old male matric adolescent developed worries about the welfare of his mother and sister, feelings of hopelessness, irritability, low energy, checking doors at night, relationship problems and poor communication, quarrelling with both his parents and sister, poor academic achievement: his marks dropped and he failed one subject,
Mother B	30 year old unmarried mother, working long hours as domestic worker, poor relationship with her two primary school children; different fathers, financial constraints (shack dwelling), ongoing conflict with her own parents (who were never married). Recent multiple stressors triggered development of anger, anxiety, hopelessness, worries, sadness and depression, inability to cope with her frustration, subsequently yelling at the children. Her youngest child with intellectual disability-, medical- and psychiatric conditions, recently relapsed with unstable mood and -behaviour at home and at school.
Adolescent B	13 year old adolescent male with an absent father figure, staying with his mother and half-brother; overwhelmed by responsibilities (caregiving of brother and household chores). Bullying at school had worsened over past months; feelings of anger, low self-image, depression, hopelessness, thoughts of leaving school, disobedient at times, not completing household chores. Increased fighting between him and his younger intellectually disabled brother, strained A-P relationship, lack of communication with a loss of emotional A-P intimacy.

Table 2: Developmental history and stressors.

Mother A	She had recently divorced her alcoholic husband, relationship strain had led her to experience the visits of ex-husband and new wife as traumatic, financial constraints, maintenance defaults, worried that ex-husband could claim children.
Adolescent A	Concerns about recent parental divorce; -relationship discord; failed one subject, pending matric exam, responsible for supervising his sister who suffered a relapse in bipolar disorder with mood swings. He withdrew from his father and new wife, worried that his mom would not cope alone and anxious about poor finances.
Mother B	Unstable childhood with a poor mother-child relationship: teenage pregnancy during her school years, schooling was not completed; forced by her mother to leave school and home early; still blaming both parents for not supporting her. Relationship problems with both parents and both her children, anger, frustration and hopelessness, ongoing negative

	thoughts about her mother.
Adolescent B	Premature birth with prolonged hospital stay, breastfeeding failed, delayed speech development, repeat grade R once and grade 1 twice. Responsible for supervising his intellectually disabled brother, too many household chores, ongoing school bullying, poor relationship with brother and mother.

Intervention methodology overview

The therapy was performed weekly over 7 weeks with meetings between investigator and A-P pairs to encourage and monitor progress. Baseline (Pre-) and post-intervention assessments included: physical examinations, physiological measurements of autonomic nervous system status and psycho-social assessments. Psycho-social Assessments (Barkley, 2013), DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure-Adults (APA, 2017). DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure -Child Age 11–17 (APA, 2017); World Health Organization Disability Assessment Schedule 2.0. (WHODAS) (World Health Organization, 2012) (WHO) and Children's Global Assessment Scale (C-GAS) (Shaffer, Gould, Brasic, Fisher, Aluwahlia & Bird, 1983). P-CBTP and homework for A-P (Bannink, 2012; Barkley, 2013).

Methodology for HRV assessments

In order to avoid circadian influences, HRV assessments were performed between 08:00 and 10:00, on Saturday mornings to circumvent stress induced by absence from school and work. Baseline measurements were carried out in a quiet, temperature controlled, room before the psychological interviews. Tachogram recordings for the calculation of HRV consisted of 5 min stabilization in the supine position, followed by 5 min supine baseline (resting) recordings, followed by getting up into the standing position and remain standing for 5 min (orthostatic stressor) recordings. The Actiheart chest-worn heart rate monitor (CamNtech Ltd, Cambridge, UK) was used to record IBI by digitising the ECG signal from the R-R interval with a 1 ms resolution. Error correction was performed by means of Polar Precision Performance Software, version 4.03.040 (Polar Electro Oy, Kempele, Finland). HRV analysis was carried out using the advanced HRV Analysis 2.2 software for windows - Biomedical Signal Analysis Group, University of Kuopio, Finland (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014). The time-domain measure of vagal tone, i.e., the root mean square of differences between successive R-R intervals (RMSSD), was calculated from the error-corrected R-R interval series (Task force of the European society of cardiology and the North American society of pacing and electrophysiology, 1996). RMSSD was reported as indicator of vagal activity, in preference to the high frequency (HF) indicator obtained by frequency domain analysis, as HF is influenced by respiratory rates and depths, while the time domain measure RMSSD appears to be relatively free of respiratory influences (Laborde, Mosley & Thayer, 2017; Hill & Siebenbrock, 2009; Thomas, 2017). In line with majority recommendations for psychophysiological studies (Laborde *et al*., 2017; Thomas, 2017), recordings in the present study were done under conditions of non-paced breathing.

Normal values for vagal tone vary over wide ranges, even in homogenous healthy groups, and the reactivity to stressors is influenced by the baseline values. For this reason the actual values are given, but reactivity values

are then also calculated as percentage change from baseline. For the purpose of this writing we refer to the normal values derived from a quantitative review of normal values for approved Task Force measures of short-term heart rate variability (Nunan, Sandercock & Brodie, 2010; Task force of the European society of cardiology and the North American society of pacing and electrophysiology, 1996)

Results:

HRV outcome adolescent-parent pair A and adolescent-parent pair B.

Mean normal short-term absolute vagal values in terms of RMSSD are 42 ± 15 (range 19 - 75) ms. ((Nunan *et al.*, 2010; Task force, 1996). Vagal tone is said to increase up to an age of 10 and overall variability up to 15 years of age (Silvetti, Drago, & Ragonese, 2001). HRV results are summarised in Table 4.

Adolescent-parent pair A (AP & AA).

Mother (AP): Time domain analysis of AP showed a pre-intervention resting value for RMSSD, as marker of vagal tone, well below the lowest value for the normal range with a RMSSD value of 9.4 ms. She demonstrated a RMSSD decline (vagal withdrawal) of 42% from her resting RMSSD when confronted with an orthostatic stressor. Post-intervention assessment of her resting RMSSD showed a 25% increase (RMSSD: 9.4 - 11.7 ms) above pre-intervention levels. While that is indeed a remarkable improvement in vagal tone it still did not bring her resting vagal tone into the normal range. Post-intervention, her RMSSD decline in response to orthostatic stress remained virtually the same (42% vs 44%).

Adolescent (AA): AA showed a pre-intervention resting RMSSD within the normal range, marginally below the mean of normal values (RMSSD 37.1 ms). He demonstrated a RMSSD decline of 50% from his resting value when confronted with orthostatic stress. Post-intervention assessment showed a 21% increase (37.1 - 45 ms) in his resting RMSSD. This post-intervention RMSSD of 45 ms compares well with the Task Force mean value for normal. Post-intervention, his RMSSD decline in response to orthostatic stress showed a relatively small decline of 15%. .

Table 3: Self-report psychiatric symptoms and functioning: Pre-intervention and post-intervention.

Assessments intensity levels: Pre-& Post intervention	***DSM-5 Self report symptoms-**Adult (APA, 2017)	****DSM-5 Self report symptoms-** Child (APA, 2017)	*****WHODAS** (World Health Organization, 2012)	******C-GAS** (Shaffer et.al., 1983)
Mother A	**DSM-5 Self-rating level:** improved from moderate to slight or rare (less than a day or two).		**WHODAS self-rating level:** enhanced from moderate to mild difficulties.	
Adolescent A		**DSM-5 Self-rating level was enhanced from** moderate to slight.		**C-GAS:** Enhanced from sporadic noticeable difficulties to doing well (mild anxiety before exam)
Mother B	**DSM-5 Self-rating level:** enhanced from moderate to rare**.**		**WHODAS self-rating level:** improved from moderate to mild impairment.	
Adolescent B	.	**DSM-5 Self-rating level:** improved from moderate (more than half the days) to less than a day or two.		**C-GAS report**: Improved from obvious problems (impairment in functioning school- bullies) to doing all right (minor impairment)

*DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure-Adults (APA, 2017); ** DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure -Child Age 11–17 (APA, 2017); ***WHODAS: World Health Organization Disability Assessment Schedule 2.0. (World Health Organization, 2012) (WHO); ****C-GAS Children's Global Assessment Scale (Shaffer, Gould, Brasic, Fisher, Aluwahlia & Bird, 1983).

Adolescent-parent pair B (BP & BA).

Mother (BP): Time domain analysis of BP showed a low normal pre-intervention resting RMSSD of 23 ms. She demonstrated a RMSSD decline of 27% of her resting value when confronted with orthostatic stress. Post-intervention HRV assessments of BP demonstrated a favourable change in resting vagal tone by a 53% increase in RMSSD over the period of intervention. Her post-intervention RMSSD decline in response to orthostatic stress increased by a negligible 8%.

Adolescent (BA).

BA showed an excessively high pre-intervention resting RMSSD value of 98.2 ms. He also demonstrated an excessive pre-intervention RMSSD decline of 78% of his resting vagal tone when confronted with orthostatic stress. Post-intervention assessment of BA showed a 25% decline in his resting RMSSD which brought his resting vagal tone, while still high, close to the upper limits of normal. Post-intervention, his RMSSD in response to orthostatic stress remained virtually the same (78% vs 80%).

Table 4: RMSSD as a time domain HRV measure of vagal tone (VT).

Subject	Period	*VT Resting RMSSD (ms)	*VT OS RMSSD (ms)	% VT Withdrawal to OS	%Pre-post Change in VT	% Pre-post Change in withdrawal to OS
AP	Pre-intervention	9.4	5.5	42	↑25	↑2
	Post-intervention	11.7	6.5	44		
AA	Pre-intervention	37.1	18.7	50	↑21	↓15
	Post intervention	45	29.1	35		
BP	Pre-intervention	23	16.7	27	↑53	↑8
	Post-intervention	35.3	23.1	35		
BA	Pre-intervention	98.2	21.7	78	↓25	↑2
	Post-intervention	72.8	15	80		

VT: Vagal tone; OS: Orthostatic stress; *: Indicate absolute value, Normal short-term absolute values for RMSSD: 42 ± 15 (range 19 - 75) ms

Discussion:

As discussed in the introduction, positive associations have widely been described between vagal tone and vagal reactivity on the one hand, and favourable social-emotional adjustment on the other. However, inconsistencies exist.

In the present study psycho-social observations demonstrated a favourable outcome of the Positive-Cognitive-Behaviour-Therapy-Program (Table 3). These clinical observations coincided with changes in resting RMSSD, a marker of vagal tone. In three of the four subjects (AP, AA, BP) resting RMSSD increased over the period of intervention, from low-to-low-normal, towards the average for normal. This increase in RMSSD in the face of improvements in mental health is in line with consensus of a positive association between resting vagal tone and psychological well-being (Geisler *et al*., 2013; Kogan *et al*., 2013; Kok & Fredrickson, 2010; . The fourth individual (BA), i.e., the adolescent with arguably the most problems with anger, had an excessive RMSSD pre-intervention. In contrast to the RMSSD of AP, AA and BP that increased form low-to-low-normal towards moderate over the period of intervention, the excessive resting RMSSD of BA declined by 25% over the intervention period – that is, also in the direction of normal or moderate. Although at variance with the erstwhile majority view of a positive association between vagal tone and emotional well-being, excessive vagal tone has also elsewhere been reported in association with a decline in aspects of psychological health (Calkins *et al*., 2007; Calkins, *et al*.,2013; Kogan *et al*., 2013; Ortiz and Raine 2004, Portnoy and Farrington 2015. Specifically relevant to the values obtained for BA is the excessively high vagal tone previously reported in children living in resource-poor environments where it was associated with reduced delay of gratification. (Sturge-Apple, *et al*., 2016). BA was, similarly, living in a resource limited environment where he was resentfully responsible for the household chores and caring for an intellectually disabled, disruptive half-brother, while the mother figure was trying to cater for their financial needs. In addition to his stressful home environment he was also a victim of school bullying, a factor known to have serious consequences for adolescent mental well-being (Lardier, Barrios, Garcia-Reid, & Reid, 2016).

Indirect evidence for an association between high vagal tone and antisocial behaviour has been described in large cohorts of subjects. Low resting heart rate, and by implication high vagal tone, is said to be associated with antisocial behaviour (Ortiz & Raine, 2004; Latvala *et al*., 2015). According to the writing by Ortiz and Raine (Ortiz & Raine, 2004) the low resting heart rate appears to be diagnostically specific to antisocial behaviour and not replicated in conditions such as anxiety, depression, schizophrenia, hyperactivity, and post-traumatic stress disorder. Of interest is a study on a large cohort of men that suggested low resting heart rates in late adolescent males to be associated with an increased risk for criminality in adulthood (Latvala *et al*., 2015). However interesting the above findings may be, it is important to remember that many environmental, genetic, physiological and psychological factors could be at the root of low resting heart rates and that antisocial behaviour or the risk for future criminality should not summarily be suspected.

Vagal flexibility, as inferred by vagal withdrawal in response to a physical stressor, i.e., to orthostatic stress, was subsequently assessed. The expected vagal withdrawal in response to orthostatic stress occurred in all four subjects. However, the vagal withdrawal in BA, the same adolescent with the high resting vagal tone, appeared to be excessive (78%). Excessive vagal withdrawal in response to a challenge has elsewhere been reported in children with a combination of externalizing and internalizing problems (Calkins *et al*., 2007). Vagal flexibility as inferred by vagal withdrawal in response to the physical stressor remained virtually the same from pre- to post-intervention, but for one subject (AA) who showed a moderate decline of 15%. It seems feasible

to suggest that the reactivity (flexibility) in response to the orthostatic stressor might have changed over a longer intervention period.

In summary: Resting vagal tone has been positively associated with a wide spectrum of emotion regulation processes and behaviours. However, inconsistencies varying from a positive, to a negative, to no relationship between resting vagal tone and aspects of psychological health exist in literature. A major contributor to this may be that statistical analyses are generally based on the presumption that a linear relation invariable exists between vagal tone and aspects of mental health. Some recent studies refuted this previously assumed absolute linear relationship (Kogan, *et al*., 2013; Miller, Kahle &Hastings, 2017). Evidence exists that both low and excessive vagal tone may be maladaptive (Kogan, *et al*., 2013; Miller *et al*., 2017) and that a quadratic association between aspects of mental health and resting vagal tone may exist, in adults (Kogan, et al., 2013), as well as in children (Miller, *et al*.; 2017). It is obvious how the distribution of individuals with low, normal and excessively high vagal tone in the same study cohort could result in conclusions of positive, negative or no relationship. The results of the present study are in agreement with the concept of the link between resting vagal tone and psychological health not being an absolute linear association. Low as well as excessive resting vagal tone changed in the direction of moderate over the period of the successful Positive Cognitive Behaviour Therapy Program.

Conclusions

Changes in RMSSD, a marker of vagal tone, concurred with improvements in mental health in all four subjects over the period of a successful therapeutic intervention. The results support the view of vagal tone and mental health not being an absolute linear relationship, but that low, as well as excessive, vagal tone may be maladaptive and that moderate resting vagal tone may be best associated with positive emotion regulation. It is necessary to emphasise that correct statistical procedures be followed for population studies as linearity between vagal tone and psychological well-being cannot summarily be assumed. It is also necessary that the vagal profile of each subject be individually assessed when evaluating the effectiveness of therapeutic interventions.

Limitations:

As this was a case study; the sample size was too small for statistical analysis and should be repeated on a larger cohort.. Furthermore, the relevant process measures were assessed at the level of pre- and post-intervention only; but allowing for measures to be taken multiple times across the treatment period may contribute additional information.

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Appendix A:

A. The assessment methodology:

A-P pairs Baseline (pre-intervention)- and post-intervention assessments included:

Type of Assessment	Description
1. Screening:	Psychiatric history, physical- and mental status examinations, vital signs
2. Physiological measurements	Physiological measurements of autonomic nervous system responses to orthostatic challenge.
3. DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure-Adults	Self-rated measure to assess important mental health domains across psychiatric diagnoses; 23 questions that assess 13 psychiatric domains, including depression, anger, mania, anxiety, somatic symptoms, suicidal ideation, psychosis, sleep problems, memory, repetitive thoughts and behaviours, dissociation, personality functioning, and substance use. Specific symptom(s) during the past 2 weeks. Each item is rated on a 5-point scale (0=none or not at all; 1=slight or rare, less than a day or two; 2=mild or several days; 3=moderate or more than half the days; and 4=severe or nearly every day). Simple scoring: scores from each of the items are simply added/summed.
4. DSM-5 Self-rated level 1 Cross-Cutting Symptom Measure -Child Age 11–17	Self-rated measure; 25 questions to assess 12 psychiatric mental health domains across psychiatric diagnoses. To identify additional areas of inquiry that may have significant impact on the child's treatment and prognosis; to track changes in the child's symptom presentation over time. Each item: how much (or how often) he or she has been bothered by the specific symptom during the past 2 weeks. Simple scoring: the scores from each of the items are simply added/summed. Nineteen of the 25 items on the measure are each rated on a 5-point scale (0=none or not at all; 1=slight or rare, less than a day or two; 2=mild or several days; 3=moderate or more than half the days; and 4=severe or nearly every day). The suicidal ideation, suicide attempt, and substance abuse items are each rated on a "Yes or No" scale. Measure: to track change in the child's symptom presentation over time.
5. World Health Organization Disability Assessment Schedule 2.0. (WHODAS) for adult Self-report scale for completion by the adult	Rate how much difficulty he or she has had in specific areas of functioning during the past 30 days; WHODAS36-item measure asking how much difficulty he or she has had in specific areas of functioning during the past 30 days. Assesses disability in adults age 18 years and older. It assesses disability across six domains, including understanding and communicating, getting around, self-care, getting along with people, life activities (i.e.,

	household, work, and/or school activities), and participation in society. Scores assigned to each of the items—"none" (1), "mild" (2), "moderate" (3), "severe" (4), and "extreme" (5). Simple scoring: the scores from each of the items are simply added/summed.
6. Clinician report: The Children's Global Assessment Scale (CGAS)	Mental health clinician rates on a numeric scale the general functioning under the age of 18. Coding of the CGAS: patient's worst level of emotional and behavioural functioning in the past three months; selecting the lowest level which describes his/her functioning on a hypothetical continuum of health-illness. Scores can range from 1, which is the very worst, to 100, which is the very best. Use intermediary levels (e.g. 35, 58, 62). Account patient functions in four major areas: at home with family; at school; with friends; during leisure time.

B. The intervention methodology:

Duration of P-CBTP: The intervention was performed over 7 weeks with weekly meetings, homework assignments and WhatsApp's messages between investigator and subjects to encourage and monitor progress.

Psycho-education on developmental tasks: knowledge to monitor progress, impairments of and manage parent expectations as children grow; includes tasks for a specific age within each domain of competence (social, behaviour, emotional, academics/executive function, self-regulation).

Successful transition to high school; academic achievement; involvement in extracurricular activities; forming close friendships within cross gender; forming a cohesive sense of self-identity (Masten & Coatsworth, 1998).

A-P P-CBTP: intervention techniques: P-CBTP: Integrated strategies reinforcing positive behaviours, while at the same time reducing unwanted inappropriate child behaviours; in combination with changing parental attitudes and emotions in changing parenting practices (Gavita et al. 2014; Ben-Porath 2010). Teaching A-P cognitive, behavioural and emotion regulation skills in interventions. Behavioural learning theory a (operant and respondent learning), social learning theory (e.g. modelling, behavioural rehearsal), (Barkley, 2013); and ii) cognitive theories of learning (e.g., challenging misattributions about parenting) (David et.al. 2014) (Webster-Stratton, 1990); rational emotive behaviour therapy for identifying, understanding and changing unhealthy and negative A-P ideas and beliefs; enhancing positive emotional functioning; increasing A-P 's ability to make effective behaviour management decisions (Gonzalez, et.al. (2004)).Parental dysregulated emotions have been associated with maternal distress, psychopathology, both externalizing and internalizing problems in early childhood through to adolescence (Buckner et al. 2003).

P-CBT is a "strengths perspective," where patient motivation is improved by a consistent focus on strengths as the patient defines them, discovering strengths, believing that most environments contain resources (Saleebey, 2006). The key to thriving emotionally is having a high positive-to negative emotion ratio; either

increasing positive or decreasing negative emotions. P-CBT focus on: strengths, building hope; focus on helpful cognitions and beliefs by identifying and reality-test unhelpful cognitions which underlie repeated negative patterns of emotion and behaviour; to develop and test new, more adaptive cognitions that can assist to develop more positive experience of the self, others and the world. Using positive imagery to imagine future success; weekly homework assignments according to the topics (Bannink, 2012; Barkley, 2013; Frederickson, 2009). Emotional regulation strategies: using positive emotions and cognitive change such as rational emotive therapy (REBT) to help parents and their child to manage their own negative and unhealthy behaviours and alter child-parent behaviours by teaching the child and parent the ABC's of emotions (Gonzalez, Nelson, Gutkin, Saunders, Galloway, & Shwery 2004; Gross, John, 2003; Lyons & Woods, 1991).

Augmented by moderate exercise: moderate exercise (30 minutes of brisk walking), (Raglin, 1990). Emotional experiences are boosted by exercise; precipitate positive emotions and build psycho-social resources that inspire mental health. (Hogana, et al., 2015).

Appendix B: Positive Parenting Program for adolescent-parent (mother) pairs- included intervention and training with both; tailored individual therapy implemented- see table

Weeks	1 Visit one **Baseline assessments**	2 Visit two **Training & Therapy**
A-**P Pairs A &A-P Pairs B**	1.Psych history and mental status exam 2.Physical exam & vitals & weight: AP: 70 kg, BP=150/95 AA:77kg, BP=120/80 BP: 57 kg, BP= 140/90 BA: 44kg, BP=115/75 3.. Physiological Assessment 4. Overview of program discussed 5. Consent & assent completed	**-Explain why Exercise is an excellent mood stabilizer & discuss benefits.** Homework: Both AP pairs undertook to do daily moderate exercise (30 minute brisk walk or run) for next 7 weeks. **Strengths perspective** (Saleeby, 2006): respect-, improve motivation, discover- and focus on strengths. Exercise: "I have a problem vs -opportunity". P-CBT approach: Colours for Problem focused/negative (-) vs Solution focused/positive (+); Where are A-P pairs? Both pairs describe (-). **- Counteract depressive thoughts with +interventions:** **1. A-P pairs to Identify own strengths and positive qualities** **From 1st session onwards requests for weekly positive (+) data. What positive things happened since last visit** **2. Use therapeutic alliance to demonstrate pair is seen as valuable human beings.** 3. Patients to identify own strengths & what **positive evidence** to counteract negative (-) beliefs. 4.Being alert for **instances of +coping** (good idea to ask friend to help

	6.Preliminary Bookings finalized 7. Overview of program:Training & psycho-education content: homework & exercise, weekly follow-up & weekly WhatsApp's. 8. **Discuss age and developmental level tasks:** Note previous developmental milestones and give Information on what the parental expectations should be for the adolescent phase: both parent A and B had unrealistic expectations of their sons: Mother A expected her son in final year (matric) to do his school work and to supervise his younger sister's home work while her mood was unstable. Mother B who worked long hours as a domestic expected her oldest son to do all the household chores and to look after his disabled brother. Both AP & BP failed to adapt adequately: AP: Withdrawal from peer group; failed one subject, academics dropped 70%-40%; conflict relationship with mother, sister and father BP: withdrawal from his mother; contemplated to leave	you or discuss your problem) 5. Collaboratively setting **homework** assignments to be listed daily to facilitate experience of **pleasure & achievement.** **6. + Communication:** include positive reinforcement techniques for positive discipline 7. Discuss concept of **empathy**: 'to put yourself in another person's shoes'. Initially A-P pairs needed assistance to list the 10 life positives.

	school because he was scared of the bullies, School marks was poor; falling behind; 13 years old grade 7 in primary school; limited communication with his mother;	
Mother A	**Pre-intervention: DSM-5 self-rated** level 1 cross-cutting symptom measure-adult: Pre-Therapy: 27/92. Self-report symptoms of more intense; level of mild-moderate intensity of perceived self-reported symptoms: depression, lost interest in doing things, irritability, hopelessness, anger, worries, feelings of panic, sleep problems, with poor quality of sleep and excessive smoking; as experienced over the past 2 weeks **WHODAS**: The degree of functional limitations:	Both pairs: The rule: Focus on strengths Having a high positive an low negative emotional ratio Solution focused vs problem focused -Processes to build positives and processes to take-away negatives
Adolescent A	**DSM-5 Self-rated** Symptom-Child: Pre-therapy: 32/76. Self-report of symptoms over the past two weeks of mild to moderate level of depression, worries, anger, sleep problems, symptoms of intrusive thoughts and performing actions over and over like checking whether he had locked the doors at night. **Clinician: Children's Global Assessment Scale:** 73-Doing all	Both A-P pairs are seen as co-therapists, asking them questions, the trainer needs to use the A-P knowledge to reach their preferred future dream, mother the most knowledgeable on her own child

	right; but minor impairment; slight impairment in functioning at home, at school, or with peers. Some emotional distress and behaviour disturbance. Brief, transient interference with functioning. Minimal disturbance to others- not considered deviant by those who know him.	
Mother B	**DSM-5 self-rated** level 1 cross-cutting symptom measure-adult. Pre-intervention: 27/92. Self-reported symptoms of moderate intensity regarding depression and hopelessness, irritability, anger, worries; feeling nervous, anxious, frightened, feeling panic or being frightened, avoiding situations that made her anxious. DSM-5 Parent-rated symptom for child **WHODAS-self-report score:** 77/180. Moderate impairment in; communicating with biological mother, her sons and employer; getting along with people; life activities; difficulty to participate in community activities.	Both pairs: During conversations use terms: goals, solutions, expecting positives, strengths, resources Exercise: Re-enforcing strengths and what work: Each thinks about a previous dark/negative problem period; How did you overcome the difficulties previously?

Adolescent B	**DSM-5 self-rated** level 1 cross-cutting symptom measure-child age 6-17: Pre-intervention: 21/76. Self-report symptoms of moderate level: feeling sad, irritable, angry, anxious, scared of bullies; could not work at school; checked things over and over and had to do things in a certain way. **Clinician: Children's Global Assessment Scale:** 63. Some difficulty in a single area; but generally functioning well; fear and anxieties (bullies); did not lead to gross avoidance behaviour). Only those that know him well might express concern.	If you have a current problem; which former ways will you apply again? **Enhancing Hope** The role of HOPE in health: the power of real Hope: what are your best hopes? Hope is like a journey, a destination (goal). a roadmap (pathway thinking-mental map); always have a goal and reach that goal. Daily Homework: every morning: **Building a new habit:** Conversation: talk about your strengths; write down your strengths or name your 10 strong character strengths and 20 positives in your life; self-monitoring of your + experiences throughout the day daily exercise-brisk walk (30 minutes)

	3 Visit three **Training & Therapy**	4 Visit four **Training & Therapy**
A-**P Pairs A &A-P Pairs B**	Both A-P pairs completed homework successfully. **Emotion regulation** 1. **Traditional CBT (T-CBT): Assist A-P to identify and reality test unhelpful cognitions which underlie repeated negative patterns of emotion & behaviour.**	1.Building a positive alliance 2. Offering acknowledgement 3. Enhancing hope reinforcing strengths and 'What works" 4. Enhancing co-operation 5. Not resistance if clients do not do their homework; way of co-operation Assessment for P-CBT: explore what the client wants to change in his/her life- want is right rather than what is wrong. A-P Pairs A: Completed daily physical exercise successfully A-P Pairs B: Both only did exercises over the week-ends. Mother B worked long hours and Adolescent B had to look after his brother during the week with no time to exercise. Both pairs completed their homework.

	Mother: "My child must respect and obey me if not I feel like a worthless person" or 'If my child disobeys me, I think my child is worthless and bad' **3. P-CBT: Develop & test new adaptive cognitions to rise more + experience of self & world** **3. P-CBT: Focus spotlight** on: what is already working? Tell me about your successes. **Helpful and more adaptive cognitions**, beliefs & behaviour **already in possession. " I can stand it when my child disobeys me, although it is difficult for me to tolerate"** **4. Use of positive mental imagery:** imagining future success as used in sports psychology-enhance motivation, goal setting & skill development to achieve it. Academic or occupational success. Homework to continue: Name 10 successes or thinks to be thankful for; name 10 positive personal traits, name 10 ways of kindness to other; name 10 ways in which others support you. Write in a journal the first time; then say it out loud every day.	Both Pairs answered the **scaling question**: Where are your life today on a scale of 0 (equals how bad things were when you enrolled) and 10 (equals how your life will be when all is well). A-P A: reported life problems the ongoing fighting with his sister and mother- measuring on 5/10 A-P B pair reported life problems with communication and ongoing fighting. 3/10. Both A-P pairs: discuss their dreams and vision of how they would like their life to be: discuss setting goals Discussed to add more detail in their goals- being specific and realistic: educational goal; physical or emotional health; financial management; improve communication between A-P

Mother A	Transform & remove negative imagery. Positive imagery can be created and advanced. Example: imagining future success: enhance motivation to achieve it.	Setting a minimum of 4 goals: 1. To get a job. 2. To get a new place to stay 3. To get a new male friend. 4. To improve the relationship with her children.
Adolescent A	**Use motivational interviewing**: non-judgmental, non-confrontational, non-adversarial-combines patient awareness of potential problems caused by, consequences experienced & risks as a result of behaviour in question	Goals: 1. To complete his school. 2. To study as a land surveyor 3. To get a job. 4. To improve his relationship with his mother and sister.
Mother B	**Scaling question**: Put observations, impressions, or predictions on the scale: your life on a scale from 0 to 10. Zero equals how bad things were when you made the appointment and 10 equals how your life will be when all is going well. Also for what is already working: 10 equals your preferred future & 0 equals the worst situation you can imagine. Scaling for 'shaping'-Homework: A_P to start greeting each other in the morning and when they go to bed at night; as a daily routine.	Goal setting: 1.To complete matric (grade 12) 2. To save money to build her own house. 3. To have a stable relationship with both her children. 4. To get a job

Adolescent B	Use motivational interviewing: non-judgmental, non-confrontational, non-adversarial-combines patient awareness of potential problems caused by, consequences experienced & risks as a result of behaviour in question. Homework: A-P to start greeting each other in the morning and when they go to bed at night; as a daily routine.	1. To go on a school camp to Durban. 2. To complete school. 3. To become a policeman 4. To buy his own house one day.

	Visit 5	**Visit 6**
A-**P Pairs A &A-P Pairs B**	A-P Pairs A: Completed daily exercise successfully A-P Pairs B: Both only did exercises over the week-ends. Mother B worked long hours and Adolescent B had to look after his brother; asked his mom's brother to look after his brother during the week to enable him to do his exercise and homework.	Both A-P pairs had to indicate which other areas they would like to change in their lives: rate this area of desired change between 0-10. Communication A-P pairs: When was the problem their but to a lesser extent? When it is there; how would you be able to handle it better? Both A-P pairs was taught how do behavioural assessment (functional analysis methodology) to identify variables that influenced the occurrence of the problem behaviour- change antecedents (conditioned stimuli that cue behaviour- factors associated with the occurrence) and immediate consequences of the behaviour. Parent to become aware that to stop the behaviour will result in an unusual pattern; this will become a perceived perception on which they can build. What must you do differently to move up one point on your scale? Also discuss positive rewards for positive behaviour.
Mother A	Tailored: list the negative beliefs about parenting and about the specific child: "If my children disobeys me, it means I am worthless and bad". Discuss individually:	The problem with the increased anger started after the husband left them. Described what you have been doing somewhat better recently?

	to change the belief: "If I am not a good parent, it does not mean that I am worthless". My child must respect and obey me". "I can stand to be a bad parent".	She mentioned that she could survived her then husband's big car accident and alcohol abuse as well as her coping with the divorce proceedings so far. She had realized that she had achieved to become a survivor. Discussed tools to manage frustration. Discussed the reasons for conflict in relationships; identifying the stages of conflict development. Discussed conflict management and styles: compromise to resolve a conflict: to give and take- both give up first choice and select a second choice.
Adolescent A	"Excessive worrying about passing the exam and about his mother trying to cope without his dad". Discussed: "Identify the perceived threats and make some evidence-based predictions about how likely this is to happen" "Worst case scenario, best case scenario, and most likely scenario?" "If it did happen, what would you do to cope with it?"	His irritability and stress had started since the parents divorced. Described what you have been doing somewhat better recently? He decided to not respond on his sister's irritable mood but rather focus on asking her about her happy moments and activities (bright spots) that she had during the day. Positive interaction with sister rewarded with pocket money.
Mother B	Tailored: list the negative beliefs about parenting and about the specific child: "If my child disobeys me it means that I am worthless and i think my child is bad". Discussed individually to change the irrational belief to a rational belief: "If my child disobeys me it does not mean I am worthless". "I can stand it when my child disobeys me, although it is difficult, I can tolerate it".	Problem with anger and communication started after the second son became unmanageable. She had to describe what she had been doing during difficult times. She has used her difficult time at school when she fell pregnant and that she could survive then. She never thought of it that way. She realized that she had achieved something and that she had become a survivor. This improved her self-efficiency. Discussed tools that could help in overcoming anger; tools to manage frustration. Discuss the reasons for conflict in relationships; identifying the stages of conflict development. Discussed conflict management and styles: compromise to resolve a conflict: to give and take- both give up first choice and select a second choice.
Adolescent B	"Excessive worries about the bullies at school". Discussed: "Identify the perceived threats and make some evidence-based predictions about how likely this is to happen" "Worst case scenario, best case	He became more quiet and withdrawn since the bullies mocked him at school and his younger brother's behaviour had become out of control. Described what you have been doing somewhat better recently? Discussed him coping and his strengths to look after his brother and still manage to do

	scenario, and most likely scenario?" "If it did happen, what would you do to cope with it?" Discuss with teacher; go to the police station to lay a charge; be assertive and confront the bully and ask him to accompany you to the principal's office.	the household chores and his schoolwork. Also, as he stated to cope with the bullies and even started to greet them and use his old bus stop. His mother promised to pay for his school trip if he continued doing his chores and looking after his brother.

A-P pairs-both	**Week 7**	**Week 8 (Final assessment)**
	A-P A: discussed the study methods and future plans. A-P B: Used the Smart Heart Cards to discuss emotions and tell stories from the pictures.	A-P Pairs A: Completed daily exercise successfully A-P Pairs B: Both only did exercises over the week-ends. Mother B worked long hours and Adolescent B had to look after his brother during the week but ask his uncle to assist him so that he could exercise.
Mother A	Anger management using an anger thermometer to record intensity and frequency with problem solution skills Feed-back: Reported a positive mood and excitement as she had been successful in her application for a new job. She had met a new friend and started to socialize again.	Post-intervention: Self-report symptoms of depression, and sleep problems had improved to none. She was still smoking; but smoked less cigarettes per day; she still experienced slight irritation and worry at night but could fall asleep and slept well during the night. Symptoms on DSM-5 self-report symptoms dropped. Functioning also improved as the WHODAS score dropped to much improved functioning regarding daily activities, life activities, household activities, involvement in community; still experienced mild impairment regarding interpersonal functioning and communication.
Adolescent A	His irritability and stress had started since the parents divorced. Describing doing better recently: not responding on his sister's irritable mood but rather focus on asking her about her happy	Post-intervention: Self-Rating symptoms dropped. Denies any on-going depression or anxiety symptoms. Still mildly irritable at times with his sister. Checking much less whether he

	moments and activities (bright spots) that she had during the day. Positive interaction with sister rewarded with pocket money.	had locked the house. Self-Rating psychiatric symptoms improved. Only a slight brief impairment in functioning, but transient; when his sister became demanding.
Mother B	Session with cards: Mother could talk about her own emotions and told stories about the pictures (with and without her child).	Post-intervention: Self-Report regarding previous symptoms of depression and hopelessness have cleared up, symptoms of anger and worries have improved but were still an issue at a mild level. Post-intervention DSM-5 Self-Report symptoms dropped. WHODAS post-intervention: Functioning had improved in daily activities of living, and communication. Mild impairment in finding it difficult to start a conversation with her son.
Adolescent B	He found it difficult to talk about his emotions. He was seen alone and with his mom in a session but still experienced problems to speak spontaneously about his emotions. Homework: He did greet his mom sometimes. He reported his life was 8/10 ; he was doing all his chores and coping at school's his mom had bought his ticket for the school visit.	He reported a positive mood and that he had enjoyed the school camp. Post-intervention DSM-5 self-report symptoms had decreased to mild intensity. The Self-report symptoms of depression, anxiety and feeling scared had improved; but mild anger and irritability was less but still ongoing. CGAS improved; only slight impairment in functioning at home; Some emotional distress present in response to life stress, but are brief with transient interference with functioning at home.