HRV Biofeedback Training for Children with Behavioural Disorders in New Zealand: Three Case Studies

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Although treatments exist for children with behavioural disorders, they often require significant time and are costly. The current pilot study aimed to conduct a preliminary investigation to examine the feasibility of a brief heart rate variability (HRV) biofeedback intervention for children with behavioural disorders in New Zealand (NZ). Participants included 10 children aged between 6 and 11 years who were referred to secondary mental healthcare services in NZ to treat non-compliant and aggressive behaviours. Participants included in the study had at least one diagnosis of attention deficit disorder (ADHD), Oppositional Defiant Disorder (ODD) or Anxiety Disorder (AD). Participants took part in 2 baseline HRV biofeedback sessions to understand how the HRV biofeedback tool HeartMath worked. After these baseline sessions, participants completed between 1 and 10 sessions of the biofeedback tool. We describe in detail case reviews of 3 participants with varied responses. Data is comprised of HeartMath performance and coherence scores, SDQ scores pre-and post-intervention, and clinical observations. Participants' achievement and coherence scores displayed meaningful patterns that seemed to demonstrate that learning was taking place, but SDQ scores did not indicate improvement patterns in socio-emotional or life impact factors. Participants found the biofeedback tool easy to use, and the intervention was easy to implement across environments. Given the need for low cost and accessible interventions, HRV biofeedback training may be a feasible and promising approach to support children with behavioural disorders in developing key self-regulation skills within the NZ context. However, more research is required to explore the potential of biofeedback interventions.

Keywords: *Biofeedback, Children, HRV, ODD, ADHD, Anxiety Disorder*

INTRODUCTION

Oppositional defiant disorder (ODD) is classified in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) as a pattern of angry or irritable mood, argumentative behaviour, or vindictiveness which must occur for at least 6 months (American Psychiatric Association, 2013). The prevalence of ODD is estimated to range from 1.4% to 12.3% (Copeland et al., 2013; Cohen et al., 1993), with males more likely to be diagnosed with ODD than females (Demmer et al., 2016). As most symptoms such as irritable mood can begin to emerge during preschool and middle childhood (Kessler et al., 2005), young children with ODD often experience difficulties with emotional control and interacting with peers and family and are more likely to be diagnosed with other psychiatric difficulties (Greene et al., 2002). For example, disorders most often associated with ODD include anxiety disorders (AD) and attention-deficit/hyperactivity disorder (ADHD). As these emotional and behavioural challenges are often complex and have wide implications, it can be difficult for professionals to prioritise their treatment interventions.

Evidence-based interventions for children with behavioural disorders can broadly be categorised into parent-focused and individual-focused treatments. The Incredible Years (IY) Parenting Training (PT) is a popular parent-focused treatment. This comprehensive and evidence-based (Menting et al., 2013) 14-session program for parents of children aged 3 to 8 is often recommended for helping parents learn skills to better manage children with challenging behaviour through techniques such as setting rules and instituting reward charts. Although there is substantial evidence for the efficacy of the IY PT for children with challenging behaviours, attrition in IY programs is often over 40% (Abraharmse et al., 2016) due to factors such as the long period of commitment to the program. Further, there is less consensus about the program's efficacy for children with additional symptomology or diagnoses such as ADHD (Murray et al., 2017).

Cognitive behavioural therapy (CBT) is an intensive program that aims to teach children with behavioural challenges a series of techniques for managing anger. Although a meta-analysis of CBT for children with anger outbursts has shown promising efficacy (Sukhodolsky et al., 2004), there is a lack of research examining the effectiveness of CBT for children with ODD and ADHD. Such interventions often require 12 weeks of one-hour sessions and a trained specialist to adapt components of

the program for the individual. With medication not recommended as a standalone intervention for children with ODD, OCD, or ADHD (Kültür, 2017), identifying accessible, time-efficient, and scalable interventions that can be delivered to support children with complex behavioural challenges is essential (Amray et al., 2019).

Biofeedback refers to electrical or electromechanical equipment that measures a user's physiological signals, such as heart rate or respiration. This information from the user's body about their physiological response is then made available to them, thus helping the user develop greater awareness and control within their bodies with and without equipment (Culbert et al., 1996; Dillion et al., 2016). As physiological information is accessible to the user, s/he can deliberately practise critical self-regulation skills (such as diaphragmatic breathing and mindfulness) to relax physically in ways that support emotional regulation. This practice aims to strengthen preparation for using these skills in real-world settings.

Research on biofeedback is still emerging; however, there appears to be promising efficacy for its use with psychiatric disorders such as anxiety (Banerjee & Argáez, 2017). Recently, in a systematic review of biofeedback interventions for treating anxiety and depression in children and adolescents with long-term physical pain, Thabrew et al. (2018) reported limited yet encouraging evidence for their efficacy, mainly when a multi-modal biofeedback approach was used to treat psychological distress (i.e., anxiety) in children and adolescents. Although encouraging, there appears to be limited research on biofeedback interventions for children with both behavioural and emotional disorders. This represents a significant gap in the literature, given the serious short- and long-term implications for children with behavioural and emotional comorbidities.

The aim of this pilot study was to conduct a preliminary investigation into the feasibility of a brief biofeedback intervention for children with behavioural disorders in the New Zealand (NZ) context. Specifically, we sought to discover whether such technology would be acceptable to the children, their whanau (family), and school personnel; and explore whether this intervention could be practically implemented with primary school-aged children in the school setting. Because of the exploratory nature of the pilot study, our results were not intended to meet the clinical trial criteria and are reported here in the form of case studies describing the experiences of three representative participants. These preliminary findings have informed a current research proposal for a more systematic and formal investigation into biofeedback for children with complex behavioural challenges.

METHOD

A pilot programme was designed to examine the experience of primary school-aged children with behavioural challenges who received basic HRV biofeedback for a minimum of 4 sessions. The protocol described below includes adjustments due to Covid as well as learnings during the course of the pilot. This pilot study was not registered as a trial so a trial registration number is not available.

Participants

We sought to recruit between 10 and 15 students between the ages of 4 and 10 who had been referred for mental health services due to clinically significant levels of anger and aggression. In all, ten children (8 boys and 2 girls) were enrolled; during the study, 2 participants moved out of the country, and 2 participants declined to continue treatment after the first treatment session.

Measures

EmWave: *Coherence score* – Coherence refers to a physiological state involving a balance between the parasympathetic and sympathetic nervous systems with an eventual relative increase in parasympathetic activity. Other physiological components coordinate with the heartbeat, and heart activity and brain activity become synchronised. It is typically indicated by a "large, characteristic spectral peak" recorded at around 0.1 hertz in the low-frequency band. A coherence score is a ratio based on a proprietary algorithm that reflects the level of coherence, calculated in 5-second intervals (HeartMath, n.d.)

Coherence ratio – HeartMath divides coherence into 3 levels– low, average, and high. The portion of the total session time spent in each level is represented by a coherence ratio score. The sum of all three ratio scores for each session will always total 100 (HeartMath, Inc., 2020).

Achievement score – This score reflects the sum of all individual coherence scores across the length of a single session. Achievement scores are increased when higher coherence scores are achieved during a session, and more extended amounts of time are spent in coherence (HeartMath, Inc., 2020).

Strengths and Difficulties Questionnaire (SDQ): The (SDQ; Goodman, 1997) is a 3-point Likert Scale questionnaire with well-documented acceptable reliability and validity. It can be administered to parents, teachers, and the children themselves, who report on behavioural, emotional, and social experiences. For this study, parent data was collected pre-and post-intervention.

Clinical observations: Data was collected from informal interviews with teachers, support staff, and parents. Clinical observation notes were taken in each session and used to provide a richer understanding of the biofeedback effects across environments, as well as providing context for each case. Initial attempts at developing overarching themes through the use of NVivo qualitative software were abandoned due to the limitations of the data collected, both in quantity and scope. Ultimately, observations were organized around (a) the main focal points of the pilot study, namely usability and acceptance, and the participant's ability to follow the protocol (e.g., sit still while using the emWave, follow instructions during deep breathing exercised); and (b) feedback from parents and school staff concerning changes in behavioural regulation. These are reported in the results section for each child.

Procedure

The study was proposed to run between September 2019 to April 2020. Due to Covid-19 restrictions, it was extended to November 2020, with a break during NZ's

lockdown period. A minimum of two baseline HRV and 3 intervention HRV sessions was required for inclusion. Session timing was initially planned at the convenience of participants' whānau or schools but soon moved to a regular weekly schedule.

Intervention: The planned intervention contained three brief activities carried out in close succession:

Approximately 60 seconds of deep breathing exercises using puppets and modelling

Two to three repetitions of a 45-second mindfulness exercise involving a Tibetan bell app available on smartphones

A coherence-building biofeedback session using HeartMath's emWave technology. Participants are supported to sit quietly, breathe along with the prompt to the best of their ability, and think about their heart and a happy memory or place (see HeartSmarts Adventure Leader's Guide (HeartMath Institute, 2019).

Biofeedback technology: Biofeedback therapy was provided using the emWave Pro from HeartMath (HeartMath Inc., 2019) loaded onto a laptop computer. It consisted of pulse sensors for the ear and thumb and a software programme that collects data and provides a graphic display for feedback of pulse, heart rate coherence, and other performance indicators. A breathing prompt was available on the screen and was used with participants in this pilot. The cost for this product, including the finger sensor, was approximately $470 NZD.

RESULTS

The research protocol was carried out by and large as proposed, with the exception of intervention sessions and data collection being paused during Covid-19 lockdown periods. Other small adjustments were made as a result of learnings acquired during the pilot implementation, including. For instance, creating a more structured session and at a consistent time. We learned that schools provided a more consistent and accessible setting for intervention activities, and thus by the end of the pilot, all sessions were scheduled in schools.

Setting a target time of 3.5 minutes for emWave sessions as it became apparent that sustaining a coherence focus for longer did not improve coherence performance and could contribute to frustration for the participant.

CASE 1

Background: L is an 8-year-old NZ/European male who lives with his mother and older sister. L's aggressive behaviours at home and school resulted in a referral for specialised behavioural support, and though undiagnosed, L demonstrates behaviours consistent with ADHD. His mother experiences high levels of anxiety, and her whānau (family) provide regular parenting support for the 2 children. At home, L was described as uncooperative and physically aggressive. He had witnessed family violence in the past. School reports indicated L had a tendency to engage in externalising behaviours and required frequent teacher aide support to provide classroom safety, avoid dysregulation, and enable him to follow through with instructions.

Intervention

Biofeedback sessions began in the home, where L was introduced to the technology and was able to try it out with his mother. During Baseline 1, L was fidgety and distracted. He found it difficult to sit still, and when he realised he could manipulate lines on the screen by moving his sensor finger, he persisted in wiggling this finger despite attempts to support him in staying still. During Baseline 2, L could sit still and be more compliant with instructions. He played happily with other toys using his non-sensor hand and asked questions about what he saw on the computer screen. By the following session, L had learned the routine and was able to engage for brief periods during the session.

After the 3 sessions that led up to the Christmas break, L's mother did not re-engage with our service following the holidays. We had decided to switch to school-based sessions by the end of February, but our research was then interrupted by multiple Covid-19 lockdown periods. Thus, it was June before we were able to re-initiate biofeedback sessions with L, and we arranged with his school to meet there in order to establish as consistent a schedule as possible under Covid-19 conditions. Despite multiple interruptions, L quickly became engaged again. In the following weeks, his enjoyment increased along with his ability to focus for longer periods of time. By this time, we had also learned the ear sensor was more effective than the finger sensor for L and most of our other participants.

Results

As demonstrated in Figures 1, 2 and 3, L's scores do not reflect any clear pattern of improvement in achievement or coherence ratio scores. However, the uneven frequency of treatment sessions may well have impacted this result. The length of time L was able to sustain coherence appears to have grown with practice.

There was no apparent increase in L's achievement or coherence scores. In addition, his SDQ score rose 5 points, indicating his mother perceived L to be experiencing increased difficulties by the end of the pilot programme. Also, his SDQ impact score of 5 was unchanged from pre- to post-intervention.

Nonetheless, school staff indicated that L looked forward to biofeedback and was observed running down the hall in excitement when told we were there. We capitalised on L's eagerness with the biofeedback tool and collaborated with school staff on a self-regulation plan for L that used parts of the breathing and mindfulness exercises developed for our pilot study. For instance, L brought one of the toys from our sessions into the classroom to remind him how it felt to be in coherence. He would use this cue when he became anxious about not being able to do what was being asked of him, such as during handwriting practice.

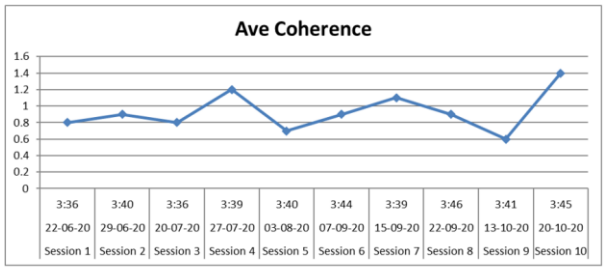

Figure 1. Average Coherence Score for L

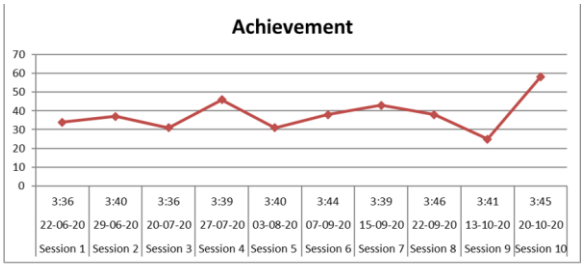

Figure 2. Average Achievement Score for L

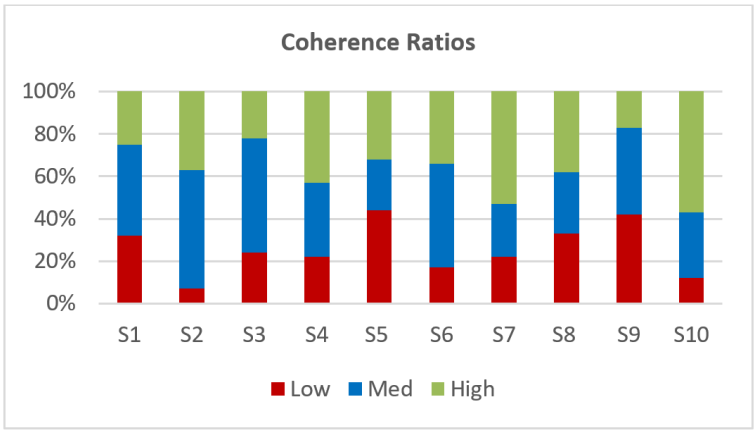

Figure 3. Coherence Ratios for L

Interviews with school staff after sessions during the latter stages of the pilot suggested L's aggressive behaviours at school had decreased to the point where it was no longer an issue. This enabled the adults around him to better understand L's anxious and challenging behaviours and respond accordingly. Further assessment revealed a pattern of performance anxiety became the focus of teacher and staff support rather than any aggression. At the time of his last session, his family was living in emergency housing, frequently moving between motel rooms. While he displayed heightened levels of anxiety during this upheaval, it did not stop L from continuing to enjoy himself in session and improve his biofeedback performance; he reached his highest achievement scores at this session.

CASE 2:

Background: T is a 7-year old NZ/European male who lives with his biological parents. T was referred for specialised support as he had been demonstrating an increase in anxiety and aggressive behaviours at home and school. Two important events occurred during the pilot study that appeared to influence T's behaviour and his self-regulation capabilities. First, he was clinically diagnosed with ADHD and began taking medication to help manage his symptoms. During initial adjustments and over time, T demonstrated changes in his affective and behavioural control. Secondly, T's parents enrolled in a 5-session group parenting course on emotional regulation skills offered by the clinical programme sponsoring this pilot study. T's parents attended every session and appeared fully engaged; their feedback reflected they had learned a significant amount of new information and had started to implement new strategies from the programme.

Intervention

During Baseline sessions, T demonstrated curiosity and a willingness to engage. He enjoyed playing with the sensor, was interested in how it impacted what was happening on the screen and gradually came to understand the goal of the activity. During the pilot programme, T experienced increased stress at home and school, and his parents indicated his angry and anxious behaviours were increasing. After one particularly aggressive and explosive incident, he arrived at Session 2 with dark circles under his eyes, subdued but cooperative. He was able to engage well during the session, and his scores demonstrated improvement over the previous session. Interestingly, Session 3 fell on his birthday—an affectively and emotionally aroused day for him. He was excited and happy yet was still able to participate fully in the session, and his scores reflected this. Following this positive experience, there was a long break due to Covid-19 lockdown restrictions. Over the course of his remaining sessions, T's effect varied. Despite this, his ability to focus and engage with the biofeedback tool consistently progressed, and he developed the ability to enter his zone at the start of biofeedback and remain in it for the entirety of the

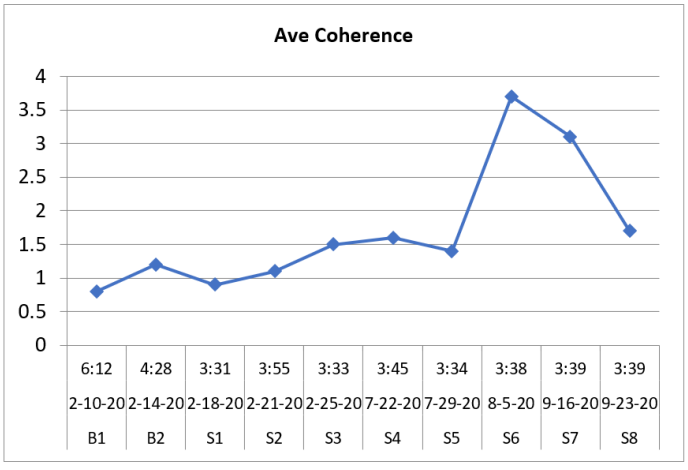

Figure 4. Average Coherence Scores for T.

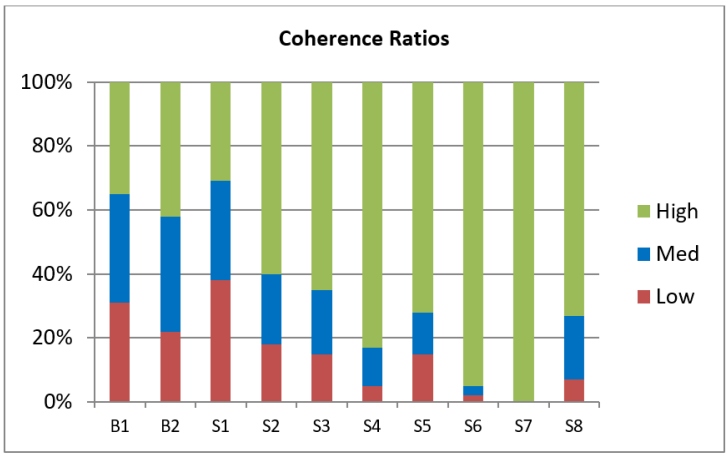

Figure 6. Average Coherence Ratios for T.

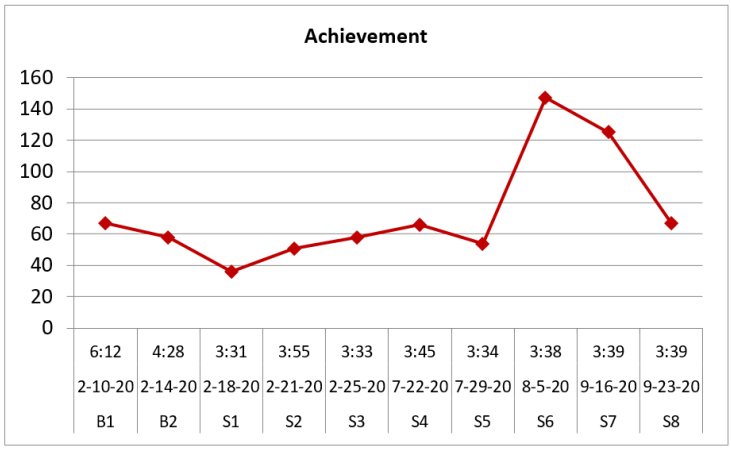

Figure 5. Average Achievement Scores for T.

session. By August 2020, he was earning near-perfect scores, and despite further Covid-19 disruptions, by the end of September, he had achieved 100% high coherence for an entire session.

Unfortunately, this progress with biofeedback was not matched by a parallel improvement in behaviour or self-regulation across environments. Only 48 hours after his 'perfect' high coherence session, T became severely dysregulated at home and injured himself badly enough to require surgery. In retrospect, the team realised this incident occurred during the period his medication was being adjusted; however, the fact remains that his behaviour stood in stark contrast to his improving biofeedback performance.

Results

T's achievement and coherence scores demonstrate a steady improvement after baseline, with a spike in both scores in the last three sessions. His coherence ratio distribution shows an increase over time in minutes spent in a high coherence state during each session. In-session observation notes indicate that regardless of T's presenting emotional state, he was able to engage successfully with the biofeedback process and move toward improved coherence.

In addition, T's general SDQ score increased by 9 points indicating his parents considered T to be experiencing a higher level of difficulties by the end of the pilot programme. At the same time, his SDQ impact score dropped from 6 to 5, possibly reflecting T's increased ability to manage the challenges he was experiencing.

By session 8, T was demonstrating clear behavioural improvements at school. His teacher reported classroom aggression had decreased, and T's ability to follow instructions and focus in class had grown. However, he continued to struggle with regulating his emotions, especially when things did not go his way in class. Discussions with T's parents indicated that practises in the home had altered during the pilot study due to the previously mentioned parenting course they were attending, which likely represents another contributing factor behind some of T's behavioural change.

CASE 3

Background: W is a 7-year old male who identifies as Māori. He lives with his maternal grandmother after being removed from his biological mother's care due to care and protection concerns. W receives medication to help with symptoms of ADHD and ODD. W also displays characteristics that align with early trauma and disrupted attachment. Covid-19 impacted W's whānau through a loss of employment for his grandmother. This resulted in a need for revised childcare arrangements to accommodate a new job with late working hours. During the pilot, W also experienced increased visitation with his biological mother, as well as weekly visits at a child and adolescent respite facility. Not surprisingly, the school were struggling more than ever with W's increased aggression toward and intimidation of other students, as well as his high levels of reactivity to all sorts of environmental and social triggers. More support was provided, but W still found it difficult to stay in the classroom and on task.

Intervention

W has engaged in 2 baselines and 3 regular sessions of biofeedback over approximately 4 months. While interruptions due to Covid-19 and school holidays impacted his participation rate, he sometimes refused to attend the session or was deemed too fragile and dysregulated to participate by school staff. When W attended biofeedback sessions, he appeared to enjoy both the novel experience and the challenge involved. Over successive sessions, he became less talkative and restless and more focused on meeting his own performance goals. Even when presenting with elevated affect or following an aggressive encounter, he has been able to focus on the feedback screen and tried to follow the breathing prompt.

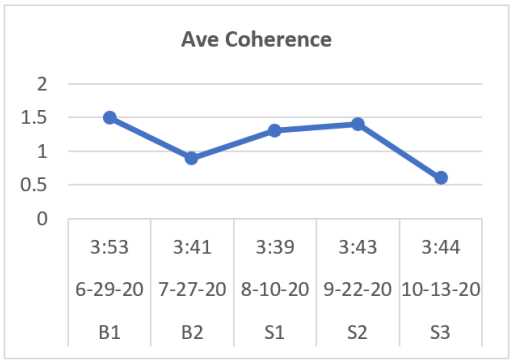

Figure 7. Average Coherence Scores for W.

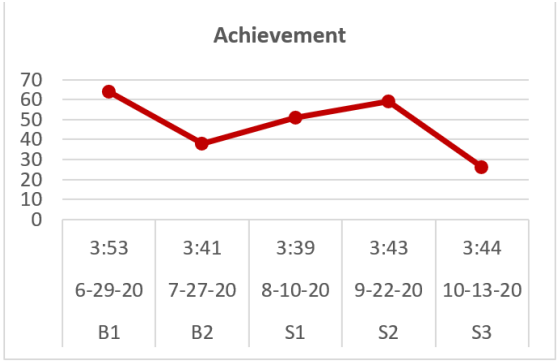

Figure 8. Average Achievement Scores for W.

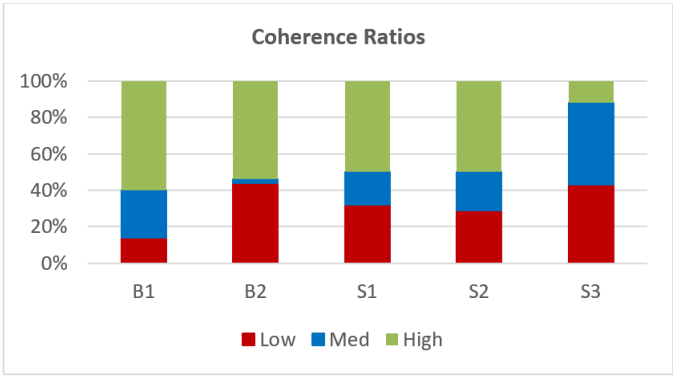

Figure 9. Average Coherence Ratios for T.

Results

Coherence and achievement scores from W's 5 biofeedback sessions demonstrate improvement over time after an initial drop from Baseline 1 (this drop is characteristic of all clients' scores) and another drop at his last session. Despite the long intervals between sessions, W remembered the routine, which involved focused and mindful breathing. Each time W was engaged in the session, he was eager to improve his results from his previous session, but this also elevated him into counterproductive performance pressure.

Missing data precludes SDQ score analysis for this client. No reduced aggression or improved regulation was noted by school personnel, and in fact, W was stood down from school just prior to the conclusion of the study.

DISCUSSION

We examined the feasibility of a biofeedback intervention for children with behavioural disorders in NZ. Data from the pilot programme, including the three participants documented in this study, indicate that HeartMath, a biofeedback HRV intervention, is an acceptable, engaging, and relevant tool to increase achievement and coherence scores for children with complex behavioural challenges.

Adherence, Engagement and Acceptability

Of the four participants who left the study early, two moved out of the country, and the other two declined to continue. Reasons for dropping out were not related to aversion to the biofeedback sessions but rather the severe level of dysregulation and external stressors the participants and their whānau were experiencing at the time. The high dropout rate in the current study is consistent with findings from systematic reviews and meta-analyses for engagement with parent management programs (Michelson et al., 2013; Michael, 2018). For instance, in a meta-analysis investigating the dropout rates of parent management training in clinical and community settings, Michael (2018) found attrition rates ranged from zero to 70%, with an average mean weighted attrition rate of 26.2%. Although the current study recruited a small number of participants, a similar level of attrition was reported in the current study. Thus, it is essential to consider the diverse factors that may function as barriers to engagement with such interventions for families.

In general, we noted a positive response to the biofeedback equipment and software that included curiosity and enjoyment of a novel experience. Participants followed the session routine in the first session, and the basic concepts described during the sessions were understood by all our participants irrespective of cognitive or adaptive functioning levels. While there was an occasional need to scaffold participants' learning and provide extra time for comprehending instructions, overall, participants in the study were quick to understand how to use biofeedback. This finding aligns with previous research on the ease with which children aged 5 to 15 with learning disabilities and ADHD can understand and use biofeedback to regulate their emotions (Culbert et al., 1996; Linden et al., 1996). Further, despite various

uncontrollable factors such as the Covid-19 pandemic implications and medication changes, our data documents the promising potential of participant willingness to engage with this biofeedback tool and work toward increasing their achievement and coherence scores. This finding was also consistent with adults who were accepting of the equipment, routine, and concepts involved in this basic biofeedback approach. Parents who tried out the HeartMath programme enjoyed the experience and were open to helping their children use the concepts and practices in their daily routines. When we had requests from school staff who wanted a chance to try out our equipment and intervention, we received unanimously positive feedback. Overall, the pilot programme was successfully accepted by the students, their whānau, and their schools.

The biofeedback intervention's acceptability may be partly due to its brevity, as it was delivered in a short amount of time, with sessions typically lasting less than 30 minutes. We learned ways to administer the treatment programme more efficiently, such as setting up a regular time slot. Eventually, we were able to complete a session with a child in approximately 20 minutes. While more research is needed to discover what, if any, effect shorter sessions may have on performance, it is interesting to consider the scalability of such time-efficient treatment, whether as an intervention for clinical disorders in individual students or as a more broadly administered wellness programme. This stands in contrast to treatments such as CBT which require an expert understanding of the child's developmental and cognitive skills to adapt and tailor each intervention to an appropriate level. This often requires a considerable amount of time and skill on the part of clinicians (Beidas et al., 2010; van Starrenburg et al., 2017;).

In addition, clinical observations indicate the need to understand the role performance anxiety may have on inhibiting achievement scores for participants. As anxiety can be a significant contributor to aggression in children (Bilgiç et al., 2017; Cooley et al., 2017), future investigation of this potential obstacle would be important. This point is of particular interest, as we note the two participants who declined to continue in our pilot study had not yet made significant progress with other forms of treatment, making the identification of an effective alternative intervention even more critical. Thus, learning to successfully address the objections of children who do not initially engage with biofeedback would allow them to participate without reservation, introducing a promising alternative therapy.

An increasing amount of recent research has started to examine the use of biofeedback for children by adapting game-based technology to use competitive stress as a means of helping children practise relaxation and down-regulation under pressure (Fish, 2018; see also Mightier.com). Playing biofeedback games to strengthen self-regulation may seem counterintuitive, as performance anxiety and the stress of competition rise as children progress through the game. However, to win the challenge, a child must learn to calm their body faster than other players and thus practice using his/her biofeedback tools under pressure, just like in real-life situations (Fish, 2018; Kahn et al., 2013;).

Achievement, Coherence, SDQ Scores, and Behavioural Change

Overall, there was a mixed agreement between emWave-generated scores, SDQ scores, and observations of behavioural change. While HRV coherence appears to have improved for 2 of the 3 participants, SDQ scores, for the most part, did not demonstrate any improvement but rather indicated an increase in difficulties. Observations and reports from whānau and teachers indicated a mix of behavioural changes, along with the presence of notable stressors such as family homelessness and parental health concerns. Thus, it seems the participants were successful in learning and improving coherence-based skills, which coincided with some reports of improved emotional and behavioural regulation at school. However, parents perceived their child's difficulties to have worsened throughout the pilot programme. It is important to note that other studies which have investigated the efficacy of HeartMathsuch as Bradley et al. (2010), have asked participants to take part in more frequent sessions. Therefore, more sessions biofeedback sessions may have provided participants with more opportunities to practice self-regulation skills.

There was wide variation in the amount of behavioural change reported by parents and school personnel and the participants themselves. Interestingly, the child with the best achievement and coherence scores exhibited the most violent aggression simultaneously; his biofeedback skills were improving most notably. Meanwhile, the participant whose scores did not indicate any meaningful pattern of progress was reported to have significantly reduced his aggressive behaviours. Thus, a link between improved achievement and coherence scores and reduction in challenging behaviours was not in any way established. Still, investigating this potential remains important, considering only a small number of case studies have reported on this association (Hughes et al., 1980; O'Neill & Findlay, 2014).

Confounding and extraneous variables

While the present study was intended to explore, rather than establish a correlation between, biofeedback performance and behavioural improvement, the presence of confounding and extraneous variables was carefully noted. Variables included the introduction of new medications, the occurrence of major life events, and procedural changes in the implementation of the study, both imposed and voluntary. Our goal was to discover and document these factors in order to have an informed understanding of what we might need to be prepared to control for in future, more rigorously designed studies.

Limitations

There are several limitations to the current study. First, as this was a small-scale pilot study, it is not appropriate to make any definite conclusions about the acceptability of this specific biofeedback tool, let alone draw any inferences about the effectiveness of biofeedback interventions. Still, investigating this potential remains important, considering only a small number of case studies have reported on this association (Hughes et al., 1980; O'Neill & Findlay, 2014).

Perhaps due to the exploratory nature of the motivation for this study, our qualitative data collection was characterised by a somewhat informal process and this could have impacted our ability to accurately discern the implications of the biofeedback intervention across home and school contexts. This may have been particularly impactful to our understanding the cultural acceptability of the biofeedback intervention for participant D and their whānau.

Finally, due to the complexities of Covid-19, it was difficult to deliver biofeedback systematically with our participants. This may have impacted our results and affected the validity of our findings.

Future Research

In light of these limitations, our next steps in researching the impact of biofeedback as an intervention with behaviourally challenged children would include hightened focus on introducing more control and structure to the research process. Data from this pilot would be used to inform decisions about the treatment timeline including the number and frequency of sessions. Plans for ensuring systematic intervention could be fortified with more details around treatment delivery in the face of ongoing disruptive conditions, such as continuing surges of Covid-19 and the accompanying restrictions.

In addition, the management of confounding and extraneous variables could be standardised by factoring their inclusion into the recruitment criteria or the research design. For example, participants with changes to medication during the trial could be excluded, and comparisons of medicated vs non-medicated groups could be made. Cultural differences could be explored more systematically as well. Although research on HeartMath has been carried out internationally with different culturally diverse populations (e.g. Edwards, 2018, 2019; Hlongwane et al., 2018), it would be essentialto explore the acceptability in the New Zealand context of biofeedback interventions among Māori and Pacifica communities.

Finally, as outlined in a recent systematic review by Thabrew et al. (2018), there appears to be a lack of consensus around biofeedback modalities due in part to the small number of studies that comprise the literature. It is possible that different biofeedback devices or games may yield different results. Future research should examine this idea and develop more rigorous and systematic processes to evaluate the acceptability and effectiveness of different biofeedback interventions for young children with behavioural disorders. One example would be comparing various biofeedback games, as this approach may prove even more engaging and motivating for young children (Eysenbach et al., 2017). There is already research showing commercially available biofeedback games can effectively increase stress resiliency and emotional regulation skills among young people with behavioural disorders (Fish, 2018; Kahn et al., 2013).

Conclusion

Findings from this exploratory study suggest that HRV biofeedback training may be a feasible and promising approach to support children in New Zealand to develop self-regulation skills. However, more robust research methods and assessments are required to fully explore this new mechanism's potential and cultural acceptance fully.

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