SUMMARY

Despite advances in combination antiretroviral therapy (cARTs), children in Sub-Saharan Africa continue to experience neurocognitive deficits due to the virus crossing the blood-brain barrier (BBB). Based on the principles of neuroplasticity, our study sought to investigate the feasibility of introducing a pencil and paper cognitive rehabilitation tool called Brainwave-R, to ameliorate the effects of HIV neurocognition amongst children from a low socioeconomic background in rural South Africa.

Five HIV positive and six HIV negative children were assigned to either an experimental or control group. The experimental group underwent two months of cognitive rehabilitation therapy to remediate sustained attention, using Brainwave-R, whereas the non-contact control group took part in placebo activities. Sustained attention measures were taken before and after the intervention training sessions, using a sustained attention subtest. The control group later received cognitive intervention three months following the conclusion of the research study.

A Mann Whitney U Test revealed that the experimental group (Mdn=38.50) did not differ significantly from the control group (Mdn=37.00) after the cognitive rehabilitation intervention, \( U = 12.00, \ z = -.55, \ p = 0.66, \ r = -0.17 \). A Wilcoxon Signed Rank Test found that there was a significant improvement from pretest scores (Mdn=31.00) to post test scores (Mdn=38.00) following the rehabilitation for HIV positive participants in the sample, \( T=15.00, \ z = -2.02, \ p = 0.04, \ r = -0.90 \).

The findings of our study raise the feasibility of a pencil and paper cognitive rehabilitation method to supplement antiretroviral (ARV) therapy in paediatric HIV.

Key words: neurocognition, neuroplasticity, sustained attention, Sub-Saharan Africa

1 Candice Basterfield (South African National Research Foundation); Sizwe Zondo (South African National Research Foundation, Thuthuka Grant, TTK200408511634, Rhodes University Research Committee Grant).
INTRODUCTION

Human Immunodeficiency Virus (HIV) continues to be a global health challenge. According to the World Health Organization (WHO), as of 2018 there were approximately 37.9 million people across the globe living with HIV [UNAIDS, 2019]. Of this number, approximately 20.6 million were living in East and Southern Africa. Most pertinent, data from Statistics South Africa indicates that South Africa has the highest burden of HIV/AIDS infection globally, with approximately 7.8 million individuals living with the virus [StatsSA, 2020]. HIV is a ribonucleic acid (RNA), single-stranded retrovirus [Poltronieri et al., 2015] that targets cells in the immune system. Of the two types of HIV (HIV-1 and HIV-2) [Zayyad & Spudich, 2015], the HIV-1 type has more pathogenic consequences and is the most dominant strand in Sub-Saharan Africa [UNAIDS, 2019].

HIV and Neurocognition

Germane to the current study, HIV has been indicated to cross the blood-brain barrier (BBB) and infect the integrity of nerve cells [Das et al., 2016; Wilmshurst et al., 2018]. Physiologically, the BBB is formed of capillary endothelial cells and a basement membrane composed of astrocytes. These astrocyte projections maintain complex, tight junctions in the basement membrane of the BBB, thus selectively regulating the entry of substances into the brain and the central nervous system (CNS) [Abbott et al., 2006]. Through a mechanism, which is not entirely understood, HIV can permeate the BBB and enter the brain through the differentiation of monocytes into macrophages [Wilmshurst et al., 2018]. The eventual cascade of events leads to macrophages infecting other cells in the CNS, such as microglia and astrocytes [Filipowicz et al., 2016; Sillman et al., 2018], leading to neurocognitive problems, collectively referred to as HIV-associated neurocognitive decline (HAND) [Smail & Brew, 2018; Walker & Brown, 2018]. Of further concern, HIV has been indicated to affect catecholaminergic neurotransmission. Catecholamines are monoamine, organic compounds that include dopamine, norepinephrine, and epinephrine, derived from the amino acid tyrosine [Nolan & Gaskill, 2019]. Collectively, catecholamines are thought to be responsible for higher-order cognitive functions such as executive function and attention [Chandler et al., 2014; Logue & Gould, 2014; Thiele & Bellgrove, 2018], and their dysregulation, due to HIV, is indicated in HAND [Matt & Gaskill, 2019; Nickoloff-Bybel et al., 2020; Nolan & Gaskill, 2019].

Neurocognition and Socioeconomic Status

The neurocognitive profile of HAND is complex and multifactorial in nature. For example, burgeoning research in HIV neurocognition [Arentoft et al., 2015; Benki-Nugent & Boivin, 2019; Kvalsvig et al., 2013] indicates that cognitive performance is mediated by socioeconomic status (SES). For example, Arentoft et
al. (2015) investigated the neuropsychological profile of 134 HIV positive research participants on diverse neuropsychological assessments. Significantly, the study found that SES was significantly correlated to neuropsychological performance on multiple neuropsychological tests including executive functions, attention, memory, and processing speed. More significantly, a binary logistic regression indicated that low SES (compared to higher economic status) was a significant predictor of diminished neuropsychological performance, and a key predictor of HAND diagnosis. Simply stated, the study found that HIV participants from a lower economic strata are more likely to be diagnosed with HAND, compared to those from a higher economic strata (Arentoft et al., 2015). These findings are supported by other studies indicating that children from lower SES backgrounds living with HIV perform suboptimally on neurocognitive assessments that require executive attention (Walker & Brown, 2018), selective attention (Rice et al., 2014) and language skills (Benki-Nugent & Boivin, 2019). A further explanation for suboptimal performance on neuropsychological assessments in low SES participants could be explained by SES-dependent prefrontal hypoactivation (Moriguchi & Shinohara, 2019), where data seem to suggest that living in low SES environments may be linked with reduced cognitive stimulation (Farah, 2017; Finn et al., 2017; Moriguchi & Shinohara, 2019), leading to diminished prefrontal development.

Statement of the Problem and Rationale for the Study

While pharmacological interventions have improved cognitive outcomes in HIV positive children, the extent to which antiretrovirals (ARVs) assist with treating or reducing the impact of cognitive impairments, such as HAND, remains elusive (Lanman et al., 2019; Yuan & Kaul, 2019). It has been particularly noted that the effectiveness of ARV drugs on neurocognitive functioning remains largely variable (Weber et al., 2013). One of the reasons for this variability includes the discovery that ARVs vary in their ability to cross the BBB and their ability to act upon the CNS viral reservoir (Benki-Nugent & Boivin, 2019; Iglesias-Ussel & Romerio, 2011). For example, Underwood et al. (2015) found that prolonged treatment with Efavirenz (a non-nucleoside reverse transcriptase inhibitor) (NNRTI) may play a role in HIV-associated cognitive decline and poorer cognitive function in children. Similarly, Hammond and colleagues (2019) found that children in a South African study showed no cognitive gains from receiving Efavirenz. Correspondingly, a study involving 396 children who were HIV positive found an association between early viral suppression and improved neurocognitive outcome; however, the results of the study did not find an association between a high CNS Penetration-Effectiveness score (CPE) and neurocognitive improvement in children living with HIV (Crowell et al., 2015).

Despite the above limitations linked to ARV penetration, a few studies have begun to investigate the efficacy of computer-based cognitive rehabilitation protocols to reverse HAND in paediatric HIV. For example, Boivin et al. (2010) conducted a study comprised of 60 HIV positive Ugandan children, who were randomly assigned to either a control (n=32) or intervention group (n=28). Results indicated
that children in the intervention group, who received computerised cognitive rehabilitation (Captain’s Log), showed significantly improved results in executive functions (p<0.001) and attention (p<0.001) domains, compared to the passive control group post-intervention. Similarly, a South African study conducted by Fraser and Cockcroft (2020) examined the efficacy of computerised cognitive rehabilitation (Jungle Memory [video game], 2008) to rehabilitate working memory in HIV positive adolescents. Results indicated that participants in the intervention group (n=31) showed significantly improved results in working (p<0.001) compared to the passive control (n=32). Other computer-based intervention studies have since been published (e.g., Boivin et al., 2016; Giordani et al., 2015; Vance et al., 2018) indicating the efficacy of computer-based interventions. Nonetheless, scholars have raised caution over the use of computerised intervention techniques in the Sub-Saharan Africa context (Bangirana et al., 2013; Ferreira-Correia et al., 2018). The section below briefly summarises some of these limitations and provides a rationale for exploring the efficacy of a pencil and paper cognitive rehabilitation protocol to train attention skills in children living with HIV in a disadvantaged rural area in South Africa.

Rationale for the Current Research

Unique socioeconomic and historical variables exist in rural South Africa, where our study was conducted. Firstly, resulting from South Africa’s adverse colonial history and planned segregation policies, most critical services, including mental health service, tend to be disproportionately apportioned to urban regions of the country (Lund et al., 2012; Rural Doctors Association of Southern Africa [RuDASA], 2015; Sukeri et al., 2014; Vergunst, 2018). For this reason, there tends to be a scarcity of mental health professionals providing psychological services to children living with HIV/AIDS in the country’s rural areas (RuDASA, 2015; Sukeri et al., 2014; Vergunst, 2018). The dearth of mental health services in rural South Africa has been described as ‘dehumanising’ by the South African Rural Mental Health Campaign Report (RuDASA, 2015). This ‘dehumanising’ fact has been declared a human rights issue that needs urgent attention (Burns, 2011). Moreover, as identified by Schrieff-Elson et al. (2017), there is a particular scarcity of neuropsychological intervention services in most South African regions, mainly due to infrastructural and resource limitations.

Although computer-based HIV cognitive rehabilitation interventions have been shown to offer high levels of customisation and efficacy (e.g., Bangirana et al., 2013; Boivin et al., 2019), it is worth noting that ‘interventions with proven high efficacy do not emerge fully formed from the literature or from the research laboratory’ (Schrieff-Elson et al., 2017, p. 162). As such, it has been suggested that cognitive intervention programmes need to be contextualised to meet the needs of the research context. With specific regard to the use of computerised cognitive rehabilitation protocols in South Africa, a recent study by Ferreira-Correia et al. (2018) highlighted the limitations of such an approach. The authors identify the difficulty of accessing computers and the limited reach to internet-based services
that could hinder the successful application of computerised rehabilitation protocols. Moreover, as determined by Bangirana et al. (2013), computer-assisted cognitive rehabilitation may further be hampered by the lack of consistent reliable electricity supply, thus inhibiting the execution of computer-based interventions. All the above factors were key in the authors’ decision to study the pencil and paper cognitive rehabilitation technique called Brainwave-R and its efficacy within a rural South African setting. The subsequent section briefly discusses Brainwave-R and details further modifications that we made to contextualise the technique for our context.

**Brainwave-R**

Brainwave-R is a cognitive rehabilitation technique that consists of five modules specifically designed to train attention, visual processing, information processing, memory and executive functions (Malia et al., 2002). The module’s pencil and paper-based brain exercises are hierarchically presented in the progression of difficulty within each level of the training manual. Moreover, the brain training exercises are hierarchically organised according to Luria's (1970) theory of brain function, which suggests that complex cognitive processes are not localised, but distributed throughout functional brain systems. Similar to other cognitive training programmes, progress and training through Brainwave-R are independently determined by the training manual based on the participants’ performance. With specific reference to ‘Attention remediation’, which was the focus of our study, the manual consists of exercises to train focused, sustained, selective, and alternating attention. Our research specifically focused on improving focused and sustained attention skills. All in all, our study involved 12 brain training exercises. Briefly, the 12 brain exercises combined both auditory and visual attention training tasks such as listening, detecting specific targets within the presence of a distracter noise, and listening for numbers while trying to find them on a piece of paper (e.g., Dot-to-Dot pictures). Several Brainwave-R tasks were modified for the South African rural context, where our study was executed, for contextual purposes. The sections below provide a brief overview of the modifications made to the brain training exercise.

**Modifying Brainwave-R**

For the purposes of our study, we modified three of the 12 exercises on the Brainwave-R, namely: Exercise Two, Exercise Seven, and Exercise Eight. For the sake of brevity, the section below details the modifications that we made to two of the exercises. Exercise Two was a paced random words exercise. In this exercise, participants were instructed to carefully listen to a random selection of words that were read aloud to them on a CD, and each time the word ‘tree’ was read out, they had to circle it on their worksheet. For contextual reasons, Exercise Two was edited as the words from the Brainwave-R task were not commonly used in South African English. For example, words like *hymn*, *lobster*, *snow*, *magnolia* and *gull* are not familiar to children in South Africa. For contextual rea-
sons, a list of preschool Dolch words was used. The Dolch word list lists the most commonly used words in the English language (Johnson, 1971). These words were inserted into Microsoft Excel and were randomly assorted to match the Brainwave-R set; the only word retained was the target word ‘tree’. All Dolch words were presented to the research participants, and they were asked to explain what the word meant in English inorder to ascertain familiarity and understanding.

Similarly, Exercise Seven consisted of a categorising random words task. Several words had to be classified into conceptual categories. Participants were instructed to listen carefully to the researcher who presented a number of words, each belonging to different conceptual categories, such as: (a) animal, (b) shape, and (c) tree. Each time a word was read, the participants had to look at their worksheet and place a checkmark under the heading that best described the category to which the word belonged. This task was edited as the words were not common to South African English; for example, words like oak, maple, redwood, raccoon and gerbil were replaced with pre-school Dolch words belonging to the aforementioned conceptual categories (Johnson, 1971). The rest of the instructions pertaining to this task were followed as per the guideline of the Brainwave-R manual. In summary, three (Exercise Two, Seven, and Eight) of the 12 attention training tasks were edited for contextual purposes. The brain training exercises were delivered one-on-one, over 12 sessions (approximately 45 minutes each), at least three times per week for two months. The duration of the cognitive intervention is consistent with other neurocognitive interventions for attention training (e.g., Boivin et al., 2010; Nejati et al., 2013; Towe et al., 2017).

Research Hypotheses

Hypothesis 1: After Brainwave-R rehabilitation, the posttest scores of the HIV positive experimental group will be better than the posttest scores of the HIV positive control group. This hypothesis was inclusive of HIV positive and HIV negative children.

Hypothesis 2: Brainwave-R rehabilitation improves sustained attention in both the experimental group and control group. This hypothesis was inclusive of only HIV positive children (i.e., HIV positive participants from the experimental and control group combined).

MATERIAL AND METHODS

Study Population and Recruitment

Participants were purposively selected from a school situated in Grahamstown, South Africa. Eleven participants (7 males; 4 females) were assigned to either the experimental or control group. Participants were either included or excluded from the study based on the following criteria: (a) they were between the ages of 10-15 years of age, (b) either HIV positive or HIV negative, (c) HIV positive participants were included only if they were on a course of ARV therapy; (d)
they were adequately proficient in English. The exclusion criteria excluded chil-
dren with (e) auditory deficits, (f) visual impairments, (g) illness such as TB, and
(h) other CNS diseases (i.e., cerebral palsy, post meningitis neurological dis-
ease). From the pool of 20 participants, 11 participants met the inclusion criteria,
and they were divided into experimental and control groups and matched as far
as possible on HIV status, age, gender, and grade at school (See Table 1 for
group characteristics). Written informed consent was obtained from the parents
and guardians of study participants, and assent was obtained from all partici-
pants aged 10 and older. Ethical approval for this study was granted by the
Rhodes University Ethical Standards Committee.

Neuropsychological Assessment
The instrument used in assessing sustained attention was the code transmis-
sion subtest from the Test of Everyday Attention for Children (TEA-Ch). The TEA-
Ch is a standardised clinical battery inclusive of nine subsets for the assessment
of attention (Manly et al., 1999). Version A and Version B of the TEA-Ch were used
to measure pre- and post-measures of attention.

Cognitive Intervention
The instrument used for the intervention was the Brainwave-R (Malia et al.,
2002). Brainwave-R consists of hierarchically organised tasks that exercise dif-
ferent components of attention commonly impaired after brain injury, including
sustained, selective, alternating, and divided attention. Modifications made on
the Brainwave-R for contextual purposes are detailed above. Since our study
was an efficacy study, this necessitated a relatively small experimental and con-
trol group due to the rigorous and time-consuming nature of the intervention.

Placebo Activities
The active control group did not receive the intervention but participated in two
placebo activities: namely (a) construction of The Rey Complex Figure, and (b)
completing exercises from the Wechsler Adult Intelligence Test (Symbol Search).

Table 1. Group demographics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Experimental Group n=6</th>
<th>Control Group n=5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age</td>
<td>12.00</td>
<td>1.26</td>
</tr>
<tr>
<td>Number (%)</td>
<td>Number (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4 (66.7%)</td>
<td>3 (25.0%)</td>
</tr>
<tr>
<td>Female</td>
<td>2 (33.3%)</td>
<td>2 (40.0%)</td>
</tr>
<tr>
<td>HIV positive</td>
<td>3 (50.0%)</td>
<td>2 (40.0%)</td>
</tr>
<tr>
<td>HIV negative</td>
<td>3 (50.0%)</td>
<td>3 (60.0%)</td>
</tr>
</tbody>
</table>
Procedure

Two groups were utilised in this research, and these included: (a) an experimental group, which received the cognitive intervention, and (b) an active control group (non-therapeutic exposure). This longitudinal research study contained a four-phase intervention. In Phase One, the researcher conducted a baseline assessment of sustained attention with individual participants using the Code transmission (sustained attention) of the TEA-Ch (Version A). In Phase Two, the experimental group took part in the intervention which was conducted over a two-month period. Participants in the intervention group took part in 12 intervention exercises lasting 25–45 minutes each. Afterward, a follow-up assessment of sustained attention with the code transmission of the TEA-Ch (Version B) was conducted. In Phase Three, the control group participated in sessions of the same frequency length but did not receive the intervention yet participated in placebo activities. This phase was immediately followed by an assessment of the TEA-Ch (Version B) on the control group. In Phase Four the control group took part in the intervention for 12 exercises over two months, lasting 25–50 minutes each. Thereafter, a follow-up assessment of sustained attention (Version A) was conducted.

Statistical Analyses

For Hypothesis 1 a Mann Whitney U Test was run to detect any differences on the posttest score of sustained attention between the HIV positive experimental group and the HIV positive control group. Hypothesis 2 used a Wilcoxon Signed Rank Test run on the primary outcome measure of sustained attention, in order to detect any differences in the pretest and posttest scores of the HIV ‘combined sample’ of positive participants.
RESULTS

Baseline Sustained Attention Assessment
Sustained attention was measured with the TEA-Ch. Participants’ attention scores ranged between the bottom 3.3% to the top 93.3% of their age range. The HIV positive group scores ranged from 0.6% to performing better than 56.6% for their age and sex norms. The HIV negative participants’ scores varied between 0.2% all the way up to performing better than 93.3% of their age and sex norms.

Hypothesis 1
Hypothesis 1 states that HIV positive participants in the experimental group will show improved posttest scores on sustained attention compared to the HIV positive participants in the control group after receiving the Brainwave-R cognitive rehabilitation. A Mann Whitney U Test revealed that the HIV positive experimental group (Mdn=38.00) did not differ significantly from the HIV positive control group (Mdn=34.00) after the cognitive rehabilitation, \( U=1.00, z=-1.15, p=.40, r=-0.52 \).

Hypothesis 2
This hypothesis states that there will be a significant difference in pre- and post-attention scores following the Brainwave-R intervention scores with regard to the HIV positive participants. The Wilcoxon Signed-Rank Test revealed that there was a statistically significant effect between pretest scores (Mdn=31.00) and posttest scores (Mdn=38.00) after the intervention for the HIV positive participants from the combined sample, \( z = -2.02, p=0.04, r=-.90 \). This contrasts with the HIV negative group, who did not improve with rehabilitation.

Table 3. Clinical characteristics of the sample before and after the intervention

<table>
<thead>
<tr>
<th>Participants</th>
<th>Pretest Score</th>
<th>Posttest Score</th>
<th>Percentile Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV+</td>
<td>30</td>
<td>36</td>
<td>1.5–3.3</td>
</tr>
<tr>
<td>HIV+</td>
<td>31</td>
<td>38</td>
<td>3.3–6.7</td>
</tr>
<tr>
<td>HIV+</td>
<td>38</td>
<td>39</td>
<td>43.4–56.6</td>
</tr>
<tr>
<td>HIV+</td>
<td>35</td>
<td>38</td>
<td>12.2–20.2</td>
</tr>
<tr>
<td>HIV+</td>
<td>29</td>
<td>40</td>
<td>0.6–1.5</td>
</tr>
<tr>
<td>HIV-</td>
<td>38</td>
<td>39</td>
<td>43.4–56.6</td>
</tr>
<tr>
<td>HIV-</td>
<td>40</td>
<td>40</td>
<td>87.8–93.3</td>
</tr>
<tr>
<td>HIV-</td>
<td>28</td>
<td>38</td>
<td>0.6–1.5</td>
</tr>
<tr>
<td>HIV-</td>
<td>39</td>
<td>40</td>
<td>56.6–69.2</td>
</tr>
<tr>
<td>HIV-</td>
<td>26</td>
<td>40</td>
<td>0.2–0.6</td>
</tr>
<tr>
<td>HIV-</td>
<td>40</td>
<td>39</td>
<td>87.8–93.3</td>
</tr>
</tbody>
</table>
DISCUSSION

Cognitive psychology research suggests that sustained attention deficits are the cornerstone of HIV-associated neurocognitive decline in paediatric HIV (Ar- entoft et al., 2015; Hoare et al., 2012). Additionally, neuropsychological tests on attention have found that attention functioning is worse in HIV positive children compared to HIV negative children (Watkins et al., 2000). Cognisant of this, we sought to investigate the efficacy of a pencil and paper cognitive rehabilitation protocol to rehabilitate sustained attention skills in a cohort of children living with HIV in rural South Africa. Our findings found that Hypothesis 1 of the study was disconfirmed. HIV positive participants in the experimental group (Mdn=38.00) did not show improved post-attention scores (on the TEA-Ch) following the intervention compared to the HIV positive participants in the control group (Mdn=34.00). Although these results did not reach statistical significance in the experimental group, there was an improvement in sustained attention scores following the rehabilitation compared to the control group. It is interesting to note that when the HIV negative participants were removed from the second statistical analysis, this analysis reached statistical significance suggesting that some of the HIV negative participants may have not needed the rehabilitation and therefore did not improve on the posttest measures.

With regard to Hypothesis 2, (a) in order to increase the sample size and (b) for ethical reasons, participants in the control group underwent the cognitive rehabilitation intervention. The result of the HIV positive control group receiving the intervention was that a composite HIV positive group consisting of five participants could be analysed. Similar to the experimental group, HIV positive participants in the control group were guided through a drill and practice of re-training sustained attention which is compromised in HIV-associated brain injury (Benki-Nugent & Boivin, 2019; Posada et al., 2012). Hypothesis 2 thus predicted that with ‘one composite group’ that had received cognitive rehabilitation, all HIV positive participants would show improved attention scores following the cognitive rehabilitation. A Wilcoxon Signed Rank Test confirmed Hypothesis 2 (p= 0.04; r =0.90).

Our findings regarding the benefits of cognitive rehabilitation in a paediatric HIV population are similar to others in the field (e.g., Boivin et al., 2016; Fraser & Cockcroft, 2020), indicating the benefits of cognitive rehabilitation therapy. Of primary importance, our study develops on the insights of Schrieffl-Elson et al. (2017), who state that the process of implementing cognitive rehabilitation programmes with limited efficacy such as pencil and paper interventions allows for the opportunity to develop and refine these interventions for particular contexts. In our study, we implemented a pencil and paper cognitive rehabilitation technique called Brainwave-R. The significant results of the study (Hypothesis 2) support the possibility of the pencil and paper technique being suitable to remediate attention skills in specific contexts, such as in rural regions that may not use computer-based interventions. Although there is growing evidence to support the use of computer-based cognitive rehabilitation techniques to remediate cog-
nition in paediatric HIV, especially in the South African context (e.g., Fraser & Cockcroft, 2020), there is a lack of studies that promote the use of pencil and paper techniques. Our research study thus provides evidence for the efficacy of non-computer-based interventions for paediatric HIV, especially in rural South Africa, where there is a particular need for mental health services (Vergunst, 2018).

**LIMITATIONS**

Due to the lack of objective histological analyses, the present study cannot confirm whether the observed improvements are necessarily due to neural or dendritic change in the cerebral cortex. In principle, compensatory brain strategies, as practiced in this research, could rely on brain plasticity by modifying existing synapses or through creating novel circuitry so that the lost cognitive function is remediated in the brain. Future research could benefit from conducting objective neuroimaging analyses such as employing functional near-infrared spectrometry (fNIRS) to validate the effect of the cognitive rehabilitation on research participants. Similarly, the significant findings in Hypothesis 2 could be attributed to natural brain maturation processes independent of the cognitive rehabilitation (Marsden & Torgerson, 2012). The results obtained can be explained using the microgenetic theory of symptom changes in people with a variety of brain injuries during the cogitove rehabilitation (cf. Pachalska 2019).

**CONCLUSION**

Although plagued by small sample size (N=11), our study shows the efficacy of pencil and paper-based cognitive rehabilitation techniques in resource-poor settings, as in rural South Africa, to ameliorate the effect of HIV on paediatric neurocognition. Future research could investigate the impact of further customisation of the Brainwave-R technique by including indigenous and context-specific stimuli for the brain training exercises to enhance participant’s interest and motivation in the brain training.

**Acknowledgement**

The researchers would like to thank the parents and children who took part in this research.

**Ethics**

This project received ethical clearance from the Rhodes University Ethics Committee and the Rhodes University Faculty of Humanities.

**REFERENCES**


**Corresponding Author**

Sizwe Zondo
Department of Psychology, Rhodes University
1 University Road, Grahamstown, 6139
e-mail: s.zondo@ru.ac.za
ORCID: 0000-0002-2592-6171