Towards Naturalistic Data Collection in South Africa: Feasibility of Home-based Smartphone Recordings of Caregiver-Child Interactions for Coding with the Joint Engagement Rating Inventory (JERI)

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Abstract

Background

Naturalistic developmental behavioural interventions (NDBI) represent an evidence-based group of early interventions for autism. The COVID-19 pandemic forced autism interventions globally to switch to telehealth that utilised smartphone technology. Even though the evidence base for NDBI in low-and middle-income countries (LMIC) is very limited, early research has suggested that the tele-delivery of NDBI could be feasible in LMIC contexts such as in South Africa.

The Joint Engagement Rating Inventory (JERI) is a behavioural coding system that has shown utility in measuring intervention outcomes in low-resource South African environments under controlled 'laboratory' conditions. To date, no studies in LMIC have examined the feasibility of using smartphone recordings made by families in their own 'naturalistic' home environments as data sources for coding with the JERI. In this study, we sought to answer two specific questions – first, to assess whether the home-based recordings of interactions between caregivers and their young autistic children had the necessary technical elements to be coded with the JERI; second, whether the JERI could be coded with confidence and whether satisfactory inter-rater reliability could be achieved when coding smartphone-recorded caregiver-child interactions.

Methods

Young autistic children (between 18-72 months) and their caregivers (≥18 years) were recruited as part of a larger project. Caregivers were provided with instructions to record 6-minute interactions with their child using their own smartphones and play materials available at home, pre-and-post 12 non-specialists delivered NDBI caregiver coaching sessions. Data were rated by two research-reliable JERI raters to assess 1) technical feasibility, and 2)

raters' confidence, coding difficulty and inter-rater reliability using 16 pre-selected items of the JERI. Quantitative descriptive analyses were performed.

Results

Data were available on 18 smartphone recordings representing 108 minutes of data. All recordings had acceptable audio and visual quality and captured adequate data to allow coding on the JERI. In terms of rater confidence, the rater indicated being "sure of ratings" and "somewhat sure of ratings" for a majority of JERI items in the majority of the smartphone data (15-18/18 recordings). The rater experiences no difficulties coding five JERI items in most (12-15/18) smartphone recordings but reported difficulties coding eleven JERI items in 1-6 smartphone recordings. The JERI inter-rater agreement (within one scale point) ranged between 71-100% for all JERI items. Eleven of the 16 JERI items had weighted kappa values of one and observer estimated accuracy values of >99% (within one scale point).

Conclusion

Results of this study suggested that smartphone recordings of interactions between caregivers and their young autistic children were technically suitable to code with the JERI. The majority of smartphone-recorded caregiver-child interactions could be coded with only some difficulty and with good inter-rater reliability on the JERI. These findings suggest that smartphones could be used as naturalistic data collection methods to measure and track the impact of NDBI in a South African environment.

Keywords: autism, NDBI, JERI, smartphones, naturalistic data collection

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Abbreviations

NDBI – Naturalistic Developmental Behavioural Interventions

LMIC – Low- and Middle-Income Countries

HIC – High-Income Countries

JERI – Joint Engagement Rating Inventory

SRQC – Smartphone Recording Quality Checklist

RRC – Rating Review Checklist

DSM-5 – Diagnostic and Statistical Manual (5th Edition)

ADOS-2 – Autism Diagnostic Observation Scale (2nd Edition)

CCI – Caregiver-Child Interaction

Chapter 1 Background

Background to the Dissertation

This dissertation assesses the technical feasibility of using smartphones to record caregiver-child interactions in the home setting and to code these confidently and reliably using the Joint Engagement Rating Inventory (JERI). Chapter 1 provides background information on naturalistic developmental behavioural interventions (NDBI) for autism spectrum disorder in low- and middle-income countries (LMIC). Additionally, the chapter highlights the need for contextually and culturally appropriate tools to track the impact of NDBI in LMIC. Chapter 2 describes the methods of the study. In Chapter 3, we present the results of the study. Chapter 4 discusses the study findings, limitations, recommendations for future research, and brief conclusions.

Autism Spectrum Disorder

Autism spectrum disorder (hereafter referred to as 'autism') is a neurodevelopmental condition that typically emerges in early childhood (American Psychiatric Association, 2013). Autism is characterised by developmental differences, including difficulties in social communication and interaction with others, and a range of stereotypes, repetitive or rigid behaviours and/or unusual interests (American Psychiatric Association, 2013). There is a high prevalence of co-occurring conditions among children with autism, such as the disrupted or delayed acquisition of expressive and receptive language skills, mood disorders and attention deficit/hyperactivity disorder (Lord et al., 2022; Neumeyer et al., 2019; Rubenstein et al., 2018). Autism can be identified and diagnosed early, even in the first three years of life (Lord et al., 2022; Shulman et al., 2020). Research has indicated that the impact of autism on an individual's developmental trajectory can be reduced by interventions targeting child adaptive behaviour, social communication, language and cognitive skills (Bryson et al., 2003; Kodak & Bergmann, 2020; Lord et al., 2022; Mayo et al., 2013; Sandbank et al., 2020). A growing body of research suggests that Naturalistic

Developmental Behavioural Interventions (NDBI), a group of evidence-based approaches, can support growth in these child outcomes (Crank et al., 2021; Lord et al., 2022; Sandbank et al., 2020; Schreibman et al., 2015).

Naturalistic Developmental Behavioural Interventions (NDBI)

Naturalistic Developmental Behavioural Interventions (NDBI) is an umbrella term for various intervention approaches that use a combination of the principles of behavioural and developmental psychology domains (Crank et al., 2021; Sandbank et al., 2020; Schreibman et al., 2015; Tiede & Walton, 2019). These interventions were first grouped as NDBI in 2015 and were described in a seminal paper by Schreibman and colleagues (2015). NDBI have core components that can be included in three general areas. First, NDBI are implemented in the child's 'naturalistic' environment and involve socially engaged activities between the child and an adult (Schlebusch et al., 2020; Schreibman et al., 2015). For example, mealtimes are a daily living activity that can be socially engaged between the child and an adult, within which NDBI can be implemented (Ramseur et al., 2019). This represents the 'N' in NDBI. Second, NDBI target child outcomes in various 'developmental' domains (the 'D'), including, for example, cognition, motor systems, language, social and play skills (Crank et al., 2021; Schreibman et al., 2015; Tiede & Walton, 2019). They promote the generalisation and integration of skills learned in one domain into another (Schreibman et al., 2015). For example, the development of a newly learned language skill can be integrated with the development of play or social skills. Third, NDBI use 'behavioural' strategies (the 'B') (for example, modelling, prompting, or shaping) to support child developmental growth and use natural reinforcements by having the interventionist use motivating activities with a highly predictable rewarding experience to teach a skill (Crank et al., 2021; Sandbank et al., 2020; Tiede & Walton, 2019). The 'I' characterises the various 'interventions' that are aimed at supporting the child's developmental trajectory (Sandbank et al., 2020; Schlebusch et al., 2020; Schreibman et al., 2015; Tiede & Walton, 2019). Some of the best-researched interventions that fall within the NDBI category include, but are not limited to, the Early Start

Denver Model (ESDM) (Dawson et al., 2010; Fuller et al., 2020; Rogers et al., 2012), Project ImPACT (Improving Parents As Communication Teachers) (Ingersoll & Wainer, 2013a, 2013b; Sengupta et al., 2020), and Joint Attention Symbolic Play Engagement and Regulation (JASPER) (Kaale et al., 2012; Kaale et al., 2014; Kasari et al., 2006; Kasari et al., 2010; Kasari et al., 2014). Trained professionals such as speech and language therapists and psychologists can implement NDBI, but caregivers may also be coached to deliver NDBI strategies to their young autistic child (Makombe et al., 2019; Schlebusch et al., 2020; Schreibman et al., 2015). Caregivers can be coached to use NDBI strategies to support their child's developmental growth during naturalistic daily activities and interactions with materials available in the home rather than at a set time or place using pre-specified materials (Makombe et al., 2019; Ramseur et al., 2019; Schlebusch et al., 2020; Schreibman et al., 2015). Implementing NDBI in naturalistic environments during naturally occurring daily shared activities and routines supports generalisation of skills.

Being able to track and measure the impact of NDBI delivered in these naturalistic environments is important (Frost et al., 2020). However, doing this may be challenging due to the need for validated, affordable and appropriate measures that detect response to intervention, particularly in low- and middle-income countries (de Vries, 2016; Lord et al., 2022; Schlebusch et al., 2020).

NDBI in Low- and Middle-Income Countries (LMIC)

The estimated worldwide prevalence of autism is 1-2%, and the majority of autistic individuals live in low- and middle-income countries (LMIC) with limited access to services and support (Baxter et al., 2015; de Vries, 2016; Lord et al., 2022; Olusanya et al., 2018). While NDBI are emerging as an evidence-based practice, these approaches were developed in high-income countries (HIC), with predominantly monolingual, English-speaking participants from upper/middle-income families (Fannin, 2017; Lord et al., 2022; Nielsen et al., 2017). To date, very little NDBI research has been conducted in LMIC, such as in South Africa (de Vries, 2016; Franz et al., 2017; Lord et al., 2022; Schlebusch et al., 2020). There

is a need for NDBI research that is representative of culturally and linguistically diverse populations, as we have yet to determine whether NDBI can improve outcomes in diverse contexts and across cultures. NDBI may require adaption and research to determine whether they improve outcomes in culturally and linguistically diverse LMIC. Schlebusch et al. (2020) identified four fundamental considerations for implementing NDBI in low-resource environments, including 1) understanding the naturalistic context in which NDBI are implemented, 2) identifying the developmental and 3) behavioural strategies that need to be prioritised in a specific context, and 4) identifying culturally and contextually appropriate tools to measure their impact in the given context (see Figure 1.1). In South Africa, some steps have been taken towards adapting and implementing NDBI for culturally and linguistically diverse families. Franz and colleagues collected data to inform the adaptation and implementation of NDBI caregiver coaching for young autistic children and their families in South Africa (Guler et al., 2018; Makombe et al., 2019; Ndlovu, 2022; Ramseur et al., 2019; Schlebusch et al., 2020).

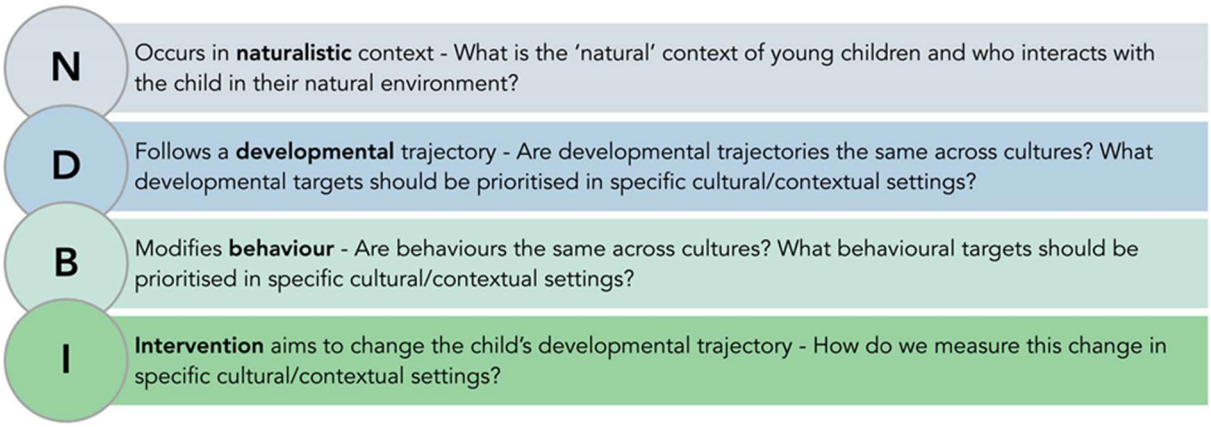


Figure 1.1

Key Considerations for Implementing Effective Naturalistic Developmental Behavioural Interventions (NDBI) in Resource-Limited Contexts (From Schlebusch et al., 2020. Reprinted with permission).

Tools to Track the Impact of NDBI in LMIC

Adapting and implementing NDBI in LMIC requires using culturally and contextually appropriate tools to measure and track intervention impact within that context. In order to evaluate the impact of NDBI, it is essential to *measure* a range of outcomes, including intervention outcomes, fidelity outcomes and implementation outcomes (Dawson-Squibb & de Vries, 2020; Frost et al., 2020; Lord et al., 2022; Schlebusch et al., 2020). Intervention outcomes include child outcomes, caregiver outcomes, and caregiver-child dyadic outcomes. Few studies have investigated whether outcome measurement tools developed in HIC are feasible for use also in LMIC contexts. Researchers at the Centre for Autism Research in Africa (CARA) recently conducted a study to understand the nature of caregiver-child interactions of young autistic children and their caregivers in a low-resource South African environment (Ndlovu, 2022; Rieder et al., 2023). One of the components of the project included assessing whether the Joint Engagement Rating Inventory (JERI) could quantify caregiver-child interactions (Ndlovu, 2022). The JERI is a behavioural coding

system applied to video-recorded observations of caregiver-child interactions to characterise joint engagement and communication dynamics that occur during these interactions between caregivers and their young children who are typically developing or have developmental disabilities, including autism (Adamson et al., 2012; Adamson et al., 2019a, 2019b; Adamson et al., 2010; Hirsh-Pasek et al., 2015; Suma et al., 2017; Suma et al., 2016). The findings of the study that assessed the utility of the JERI suggested that, under controlled 'laboratory'-based conditions, the JERI could be a useful tool to quantify interactions between caregivers and their autistic children from low-resource communities in Cape Town (Ndlovu, 2022). A complimentary linked study (master's thesis in prep) also identified that the JERI could potentially detect *changes* in child behaviour, caregiver behaviour and caregiver-child dyadic interactions in response to NDBI caregiver-coaching in young autistic children and their caregivers in South Africa (Dawood, 2023). These findings are encouraging first steps towards describing and evaluating NDBI outcomes in a South African context.

The JERI coding system requires the caregiver-child interaction recordings to have specific technical elements and for specific reliability procedures to be followed. For coding on the JERI, the video-recorded observations of caregiver-child interactions must be made using a standardised interaction protocol, such as the Communication Play Protocol (Adamson et al., 2012; Adamson et al., 2020; Suma et al., 2017; Suma et al., 2016). The video recordings are required to capture as much of the triadic interaction as possible in which the child, caregiver and play materials are visible and the dyad is audible (Suma et al., 2017). Furthermore, JERI procedures recommend an assessment of inter-rater reliability where 15-20% of randomly-selected caregiver-child interaction videos are rated by two trained raters (Suma et al., 2017). Using the JERI to code observational techniques like the video recording of caregiver-child interactions can facilitate the measurement of intervention response. However, the majority of families who live in low-resource settings in South Africa have limited access to tertiary research centres where laboratory-based video recordings of

caregiver-child interactions can take place. This highlights the need for data collection methods that are more accessible to caregiver-child dyads who live in underserved and low-resource settings in LMIC. This, therefore, raises an important empirical question of whether home-based data collection methods that more appropriately represent the naturalistic environment for learning could be feasible and be coded on the JERI.

Using Smartphones as Observational Data Collection Tools for NDBI

Digital technologies can potentially promote the implementation of autism intervention (Franz et al., 2022; Kumm et al., 2022). However, in the context of LMIC, it is essential to consider the existing 'digital divide' or disparities in access to digital technologies between high-income and LMIC contexts (de Vries, 2016; Kumm et al., 2022). Individuals who live in South Africa and other LMIC have access to entry-level smartphones with lower specifications, such as Android smartphones, given their lower costs (Groupe Spéciale Mobile Association, 2020; Kumm et al., 2022). Due to their increasingly widespread usage and increasing availability of affordable internet for mobile usage, affordable smartphones have been identified as a technology that would be most feasible for autism research and implementation in LMIC contexts without reinforcing the existing disparities in digital technologies (Kumm et al., 2022). Given that many South African families do not have access to research centres, widespread smartphone usage could potentially lead to increased access to autism intervention services by limiting the need for families to travel to research centres and any related economic costs (Ingersoll et al., 2017; Kumm et al., 2022). Researchers in South Africa have started to collect data that helps consider the 'fit' of telehealth using smartphones in LMIC contexts (Franz et al., 2022). As a result of the COVID-19 pandemic, researchers at CARA transitioned from implementing in-person to telehealth-delivered NDBI-informed caregiver-coaching using smartphones (Franz et al., 2022).

To determine whether NDBI delivered in the home environment through telehealth impact outcomes of interest (including child and caregiver behaviours), it is essential to

identify appropriate measurement tools to detect signals of change. Naturalistic, home-based data collection methods using smartphones create opportunities for the impact of NDBI to be measured and tracked. However, there is limited evidence of whether smartphones can be used in a home environment to capture data with the key technical elements (such as audio-visual quality and following a standardised interaction protocol) to be coded on the JERI and determine the impact of NDBI. Therefore, the key research questions of this study were whether home-based smartphone recordings of caregiver-child interactions would be technically feasible in low-resource South African contexts to allow confident and reliable behavioural coding using the JERI.

Purpose of the Study

The purpose of this study was to determine the technical feasibility of using smartphones to record caregiver-child interactions in the home setting and whether they could be reliability coded using the Joint Engagement Rating Inventory (JERI).

Aim 1: Technical Feasibility of the Smartphone-Recorded Caregiver-Child Interactions

The first aim was to assess whether home-based smartphone recordings of interactions between caregivers and their young autistic child could capture the necessary audio-visual quality, sufficient caregiver-child 'on screen' time, and caregiver-child interaction protocol set-up required to be coded with the JERI.

Aim 2: Coding Difficulty and Reliability on the Joint Engagement Rating Inventory

The second aim was to assess whether two trained raters experienced coding difficulties attributable to the technical limitations of smartphone recordings or child/ caregiver behaviour and could achieve inter-rater reliability when coding the smartphone-recorded caregiver-child interactions using the JERI.

Chapter 2 Methods

Study Design

This study design was a secondary analysis of a subset of data collected in a larger primary project (University of Cape Town HREC 468/2019 and Duke University IRB Pr00103045). The primary project sought to adapt a caregiver-coaching version of the Early Start Denver Model (ESDM), an NDBI, for implementation by non-specialist early childhood development (ECD) practitioners in the Western Cape Province of South Africa (Makombe et al., 2019; Rieder et al., 2023). COVID-19 necessitated adaptions to the coaching approach for delivery via telehealth. All study procedures were adapted for remote delivery using caregiver smartphones. The project used a longitudinal pre-post-study design in which autistic children and their caregivers received 12 NDBI-informed caregiver coaching sessions delivered via a telehealth approach by non-specialist ECD practitioners (Franz et al., 2022).

Baseline assessments included questions about demographics, about technology use, a caregiver-child interaction that was recorded on the caregiver's smartphone, an Autism Diagnostic Observation Schedule Second Edition (ADOS-2), and the Vineland Adaptive Behaviour Scales Third Edition (VABS-3). The ADOS-2 and VABS-3 were administered by a research-reliable South African clinician. Post-intervention assessment included a caregiver-child interaction recorded on the caregiver's smartphone and the VABS-3. The Joint Engagement Rating Inventory (JERI) was applied to the caregiver-child interaction smartphone recordings and used as an outcome measure to detect signals of change in child behaviours, caregiver strategies, and caregiver-child dyadic interactions from baseline assessment (pre-intervention) to the follow-up assessment (post-intervention). This secondary study utilised a descriptive quantitative design to determine the technical feasibility of smartphones to record caregiver-child interactions in the home setting and to assess whether they could be coded confidently and reliably using the JERI.

Participants

This study used the data of all participants from the project, which included nine caregivers and their children with autism.

Inclusion Criteria

To be eligible to participate in the primary project, (a) caregivers had to be 18 years old, (b) the child had to be between 18-72 months of age, and (c) had to meet the criteria for autism spectrum disorder (ASD) based on the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5) including meeting an autism classification on the ADOS-2 (Autism Diagnostic Observation Schedule, 2nd Edition) (Lord et al., 2012) administered by a research-reliable rater. In addition, (d) caregivers had to speak one of the four high-frequency languages of South Africa (isiXhosa, isiZulu, Afrikaans, or English), and (e) the child and caregiver had to be Black African, Coloured or Indian in terms of self-declared race/ethnicity. South Africa has very high socio-economic inequality and disparities in access to intervention for young children with autism (de Vries, 2016) and race/ethnicity remains a strong 'proxy' for these disparities. For this reason, we deliberately focused on families that would represent low-resource environments with little or no access to early interventions.

Exclusion Criteria

The exclusion criteria of the primary study were (a) a child with a history of severe head injury or a neurological disorder of known aetiology (such as Fragile X syndrome), (b) a child with a significant sensory or motor impairment that would prevent their use of play materials, and (c) a caregiver-child dyad that was unable to complete assessments and attend the 12 caregiver-coaching under the primary project.

Recruitment and Enrolment

Eligible families with an autistic child aged 18-72 months were identified and recruited from two Western Cape Education Department (WCED) schools. These WCED schools had records of children with an autism diagnosis and were on a waiting list for public school placement. The school staff invited caregiver-child dyads to participate in the primary

project. The project coordinator then contacted interested caregivers and conducted a screening of the inclusion/exclusion criteria over the phone. If the dyad met the study criteria, caregivers were invited to join the study and were given and read a copy of the consent document to review. Once caregivers verbalised understanding of the consent document and provided informed verbal consent through an electronic consent process, the dyad was enrolled.

Human Research Ethics

The primary project was granted ethical approval by the University of Cape Town (UCT) Human Research Ethics Committee (HREC 468/2019) and from Duke Health Institutional Review Board (IRB Pr00103045). The project also received approval from the Western Cape Education Department (Reference: 20180215–9358). Due to COVID-19, the consent process was remote and took place telephonically. Before the caregiver provided consent, the study coordinator discussed all study information with the caregivers and answered all study-related questions to ensure that the participants understood the project before consenting to participate. All the caregivers were ≥18 years of age. Given that all child participants were under the age of seven and had diagnoses of autism, no express assent was sought from them. See Appendix A for the remote enrolment and consent script.

The author of this dissertation was a research assistant on the primary project. For degree purposes, this study was a secondary analysis of data collected under the primary project. The secondary study proposal was reviewed and approved following standard procedures in the Department of Psychology at the University of Cape Town. See Appendix B for the Department of Psychology Ethics approval letter.

Measures

Three measures were used to determine the technical feasibility of using smartphones to record caregiver-child interactions in the home setting and to code them confidently and reliably using the Joint Engagement Rating Inventory (JERI). The first two

were measures designed by the study team for the purposes of assessing technical feasibility, (1) the Smartphone Recording Quality Checklist (SRQC) and (2) the Rating Review Checklist (RRC). The third measure was the JERI.

Smartphone Recording Quality Checklist (SRQC)

The research team developed a Smartphone Recording Quality Checklist (SRQC), to assess whether the home-based smartphone recordings of caregiver-child interactions captured the necessary audio-visual quality, caregiver-child 'on screen' duration, and interaction protocol set-up required for JERI coding. The SRQC was developed through iterative consensus-building by the research team. The items in this checklist were informed by factors JERI raters need to consider when assigning codes, such as the child and caregiver's expressive language, gestures, eye contact and affective facial expressions during the caregiver-child interaction. To assign codes for the child's joint engagement, child behaviour, caregiver behaviour and shared dyadic interaction, the rater must be able to see the child, the caregiver and the play materials as well as hear the child and caregiver (Adamson et al., 2020; Suma et al., 2017). JERI ratings also consider the quality of behaviour and usually include a time requirement. As shown in Table 2.1, the SRQC was divided into three parts. The first part consisted of six questions on a 5-point Likert scale based on frequency to assess the audio quality of the smartphone recordings. The second part consisted of six questions also on a 5-point Likert scale on frequency to assess the visual quality of the smartphone recordings. Parts I and II had a Likert scale based on frequency because many JERI items already account for time to provide a rating. For example, child engagement items are observed as a 'state' with a duration of at least 3 seconds and are assessed based on frequency and quality. The third part of the SRQC consisted of five questions that assessed whether the CCI protocol smartphone recording instructions were implemented. The rater's responses to these questions were in open-text format.

Table 2.1.

Smartphone Recording Quality Checklist (SRQC)

	Rating				
Part I: Audio Quality	**1=Never**	**2=Seldom (25% of the time)**	**3=Sometimes (50% of the time)**	**4=Frequently (75% of the time)**	**5=Always (100% of the time)**
1. Is the audio clear?	☐	☐	☐	☐	☒
2. Are there background noises that interfere with the ability to hear the caregiver/child?	☐	☐	☐	☐	☐
3. Are there echoes that interfere with the ability to hear the caregiver/child?	☐	☐	☐	☐	☐
4. Can you hear the caregiver?	☐	☐	☐	☐	☐
5. Can you hear the child?	☐	☐	☐	☐	☐
6. Are the audio and video in sync?	☐	☐	☐	☐	☐
	Rating				
Part II: Visual Quality	**1= Never**	**2= Seldom (25% of the time)**	**3= Sometimes (50% of the time)**	**4= Frequently (75% of the time)**	**5= Always (100% of the time)**
7. Is the video clear (not blurry or grainy)?	☐	☐	☐	☐	☐
8. Does the video play smoothly?	☐	☐	☐	☐	☐
9. Are the play materials visible?	☐	☐	☐	☐	☐

10. Is the caregiver visible (face and hands)?	☐	☐	☐	☐	☐
11. Is the child visible (face and hands)?	☐	☐	☐	☐	☐
12. Are the caregiver and child both visible?	☐	☐	☐	☐	☐

Part II: Implementation of Caregiver-Child

13. Was the caregiver asked to record and upload the interaction video again (is this the first recording attempt)? If so, why?

Click or tap here to enter text.

14. How many segments is the video recording?

Click or tap here to enter text.

15. How long is the recording in total?

Click or tap here to enter text.

16. Are there distractions in the room that significantly impact the quality of the video (e.g., is there another person in the room who is distracting the child)?

Click or tap here to enter text.

17. Are there additional toys or objects that are not listed on the CCI protocol present?

Click or tap here to enter text.

Rating Review Checklist (RRC)

The research team developed a Rating Review Checklist (RRC) to assess whether a rater had coding difficulties for each JERI item and whether these were related to the technical aspects of the smartphone recording or child and/or caregiver behaviour during the caregiver-child interaction. Technical aspects include the audio-visual quality of the recording and the caregiver-child 'on screen' duration. The RRC was developed through iterative consensus-building by the research team aimed to include all the items or elements that may influence the coding of JERI items. As shown in Table 2.2., the RRC consisted of the 16 JERI items with two rating scales. The first rating scale was a Likert scale of 1-3, where the rater judged how confident they felt about assigning each JERI rating. The confidence level was evaluated based on the technical aspects of the smartphone recording of the caregiver-child interaction. The second rating scale was dichotomous (Yes or No), where a rater indicated whether they experienced difficulties coding each JERI item. These difficulties were related to the child or caregiver's behaviour in the caregiver-child interaction. For example, if a rater assigned a JERI rating of 4 for the child's expressive language level (which characterises a child who uses many single words with no or few word combinations during the recording), they assigned two additional ratings on the Rating Review Checklist, first, on how confident they felt about their JERI coding of the child's expressive language level JERI rating based on the technical aspects of the smartphone recording, and second, whether they had coding difficulties with coding this JERI item based on any aspects of the child/caregiver behaviour.

Table 2.2.

Rating Review Checklist (RRC)

	Confidence level based on technical aspects of smartphone recording			**Were there coding difficulties related to child/caregiver behaviours despite technical aspects?**	
	1=Unsure	**2=Somewhat Sure**	**3=Sure**	**Yes**	**No**
Engagement State Items					
Unengaged	☐	☐	☐	☐	☐
Object Engaged	☐	☐	☐	☐	☐
Joint Engagement	☐	☐	☐	☐	☐
Supported Joint Engagement	☐	☐	☐	☐	☐
Coordinated Joint Engagement	☐	☐	☐	☐	☐
Symbol Infused Joint Engagement	☐	☐	☐	☐	☐
Child Activity Items					
Responsiveness	☐	☐	☐	☐	☐
Language level and use	☐	☐	☐	☐	☐
Attention to Caregiver	☐	☐	☐	☐	☐

	Confidence level based on technical aspects of smartphone recording			Were there coding difficulties related to child/caregiver behaviours despite technical aspects?	
	1=Unsure	**2=Somewhat Sure**	**3=Sure**	**Yes**	**No**
Caregiver Activity Items					
Scaffolding	☐	☐	☐	☐	☐
Following In	☐	☐	☐	☐	☐
Caregiver Affect	☐	☐	☐	☐	☐
Language Facilitation	☐	☐	☐	☐	☐
Communicative Temptations	☐	☐	☐	☐	☐
Dyadic Interaction Items					
Fluency and Connectedness	☐	☐	☐	☐	☐
Shared Routines and Rituals	☐	☐	☐	☐	☐

Joint Engagement Rating Inventory (JERI)

The JERI (see Appendix C) is an established behavioural coding system that consisted of 32 items on a 7-point Likert scale that were developed to characterise (1) child behaviours (for example, joint engagement, language use and attention to caregiver), (2) caregiver behaviours (for example, caregiver's ability to follow their child's focus of attention and support and expand their child's communication and play) and (3) the overall flow of the caregiver-child dyadic interaction (for example, the fluency and connectedness of the interaction between the caregiver and their child) (Adamson et al., 2020). In discussion with the developers of the JERI, 16 items that addressed the specific aims of the primary project were identified. These 16 JERI items were used in this study to rate child and caregiver behaviour during the play interaction captured by the smartphone recordings. As shown in Table 2.3., the 16 JERI items were divided into four categories. The first category consisted of six child engagement state items, which captured the child's interests and engagement with their caregiver, objects or events (Adamson et al., 2020). The second category consisted of three child activity items that captured the child's verbal and non-verbal communication during an interaction with their caregiver (Adamson et al., 2020). The third category consisted of five caregiver activity items that characterised how the caregiver uses behaviours and skills that support and expand the child's language and engagement with an object or event (Adamson et al., 2020). The fourth category consisted of two items that captured how the caregiver-child dyad interacted in sharing an experience, topic or object. The JERI items considered the quality of the child and caregiver's behaviours or skills during the interaction, and most items considered the frequency of the behaviour.

Table 2.3.

Categories of Pre-Selected Items in the Joint Engagement Rating Inventory (JERI)

Category	Items
Child Engagement State Items	1. Unengaged
	2. Child's Object Engagement
	3. Child's Joint Engagement
	4. Child's Supported Joint Engagement
	5. Child's Coordinated Joint Engagement
	6. Child's Symbol-Infused Joint Engagement
Child Activity Items	7. Child's Responsiveness to Partner's Communication
	8. Child's Expressive Language Level and Use
	9. Child's Attention to Caregiver
Caregiver Activity Items	10. Caregiver's Scaffolding
	11. Caregiver's Following in on Child's Focus
	12. Caregiver's Affect
	13. Caregiver's Language Facilitation
	14. Caregiver's Communicative Temptations
Dyadic Interaction Items	15. Fluency and Connectedness
	16. Routines and Rituals

Procedures

Caregiver-Child Interaction Smartphone Recording Procedure

Caregivers followed a standardised caregiver-child interaction (CCI) protocol (see Appendix D) to record interactions with their child at home, using their own smartphones and available play materials. The CCI instructions were sent to the caregivers via email or WhatsApp based on their preference. The instructions were followed by a WhatsApp phone call with the project coordinator, who explained the CCI instructions and addressed the caregiver's questions. In the CCI instructions, caregivers were asked to record a 6-minute-long play interaction with their child using a smartphone, using various types of play materials similar to those shown in Figure 2.1**.** Caregivers were asked to use as many of these types of play materials that they already had at home. They were informed that it was acceptable if they did not have a specific type of material and were told that they did not need to purchase any new play materials for the study. However, caregivers were encouraged not to use play materials significantly different from those shown in the CCI instructions (for example, a ball is a type of play material that does not match those in the CCI instructions). For the room set-up, caregivers were asked to find a quiet room (if possible) and place all the play materials on the floor. They were asked to position their mobile or smartphone device in a place that would allow them to capture the child and the caregiver's faces, hands and play material for the duration of the video.

Caregivers followed detailed instructions (see Appendix E) to upload their smartphone-recorded 6-minute-long play interaction on StrongBox, a HIPAA (The Health Insurance Portability and Accountability Act) compliant Duke Box folder. They were asked to upload two smartphone recordings (one pre-intervention and one post-intervention) that would be used for JERI coding. In addition, caregivers were asked to record and upload 12 smartphone recordings that were used as a behavioural sample for discussion during the 12 NDBI-informed caregiver coaching sessions. Given that this study focused on the pre-and-post-intervention smartphone recordings, in-session data were not included in the analysis

here. Once caregivers uploaded their smartphone recordings onto StrongBox, the project coordinator (who is not trained in JERI coding) viewed and checked the recordings to ensure the quality and accuracy of the data. Caregivers were reimbursed for internet data (costs for the WhatsApp communication and uploading the recordings to StrongBox).

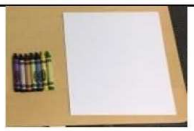
Type of toy(s)/materials	Example
A car, truck, train, boat or plane	
A few little people, animals, figurines, dolls or stuffed animals	
Some type of building toy, such as plastic blocks, wooden blocks, Duplos, or Legos	
Playdough or bubbles	 
Any children's book	
Any type of paper and something to draw with, such as crayons, pens or markers	

Figure 2.1

Examples of Play Materials for Home-based Caregiver-Child Interaction (CCI) Recordings

Rating Procedures

A student (the author of this dissertation) and the principal investigator (PI) of the primary project were trained by a JERI master trainer to research reliability. The PI then took on the role of master rater in the study. On all three measures, the student rater rated 18 randomised smartphone recordings (pre- and post-intervention), blind to the pre- or post-intervention status of recordings. The master rater was assigned seven randomly selected smartphone recordings (~40%) to rate independently on all three checklists. Ratings of the student and master rater were then compared to assess reliability. The student rater was not informed which seven smartphone recordings were selected for double-coding. For standardisation, if a caregiver uploaded a recording that was longer than the recommended 6-minutes, ratings were only completed up to the 6-minute mark. The JERI coding was completed first, followed by the completion of the RRC and the SRQC. After completing the SRQC and RRC independently, the ratings of the two raters were compared to assess whether the raters could determine the source of the disagreement.

Data Analysis

The data from the SRQC and the RRC were analysed using descriptive statistics, including an examination of median values and frequency analyses.

Data from the JERI were analysed using Cohen's weighted kappa to assess inter-rater reliability (Cohen, 1968). The weighted kappa provides a metric with reliability information that can be used to track rating performance during data collection. This information includes 1) whether disagreements between raters are by one scale point or more, 2) most recurring disagreements, and 3) whether one rater tends to give higher ratings than the other. The weighted kappa was computed using the KappaAcc program, which uses a metric whereby differences of one rating scale point between raters were weighted as 1, thereby regarded as agreements. Differences greater than one rating scale point were regarded as disagreements (Bakeman, 2018). For example, if the student rater assigned a rating of 4 for the child's object engagement and the master rater assigned a rating of 5 for

the same item, this was considered an agreement (because there is a difference of one scale point between the ratings). However, the difference was considered a disagreement if the student rater assigned a 3 and the lead rater a 5 (difference of two scale points). The observer estimated accuracy was also computed using the KappaAcc program. The observer estimated accuracy indicates the probability that a rater will correctly rate a particular item in an interaction (Bakeman, 2018). With guidance from the JERI master trainer and the JERI Procedures Technical Report (Suma et al., 2017), we set the following reliability goals for this study: 1) percent agreements of at least 80% and 2) weighted kappas of at least 0.75.

Chapter 3 Results

Overview of Results

In this chapter, the results of the study will be presented in the following order: 1) the participant demographics, 2) results from the Smartphone Recording Quality Checklist (SRQC) on the technical feasibility of the smartphone recordings, 3) the results from the Rating Review Checklist (RRC) on the coding difficulties with the Joint Engagement Rating Inventory (JERI), 4) the reliability results of JERI coding.

Participant Demographics

This study had access to the data of nine caregiver-child dyads for whom smartphone-recorded caregiver-child interaction videos from pre- and post-intervention were available. Participant demographics are presented in Table 3.1 and Table 3.2. The children in this study were between 24 – 72 months of age, with a median age of 50 months. Seven of the children were male, and two were female. All children met the DSM-5 criteria for autism spectrum disorder and were classified as autistic on the ADOS-2 administered by a research-reliable administrator. Two children were administered the Toddler Module of the ADOS-2 and the range of concern for both was moderate-to-severe. Six children were administered Module 1 of the ADOS-2 with comparison scores between 7-10. One child was administered Module 2 of the ADOS-2 with a comparison score of 8.

Caregivers were between 29 – 48 years of age, with a median age of 36 years. The primary caregivers in this study were seven mothers and two fathers. Five caregivers had a grade 12 level of education, two had a post-grade 12 certificate or diploma, and two had received tertiary education. Five caregivers were unemployed, and four were employed. Four families had a monthly income between ZAR12501 – ZAR30000 (~USD726.46 – USD1743.38).

All the caregiver-child dyads were self-classified as Black African, Coloured or Indian.

Table 3.1.

Demographic Data of Child Participants (n=9)

Age in months at study entry	Media (Range)	50 (24 – 72)
Gender	Female	2
	Male	7
Ethnicity/Race	Black African	2
	Coloured	6
	Indian	1
ADOS-2 Module	Toddler Module (Range of severity)	3
	Module 1	5
	Module 2	1
ADOS-2 Comparison Score	**Toddler Module**	
	Range of Concern	Moderate to High Severity
	Module 1	
	Mean (SD)	7.80 (1.30)
	Range	7 – 10
	Module 2	
	Mean (SD)	8 (0)
	Range	-

Table 3.2.

Demographic Data of Caregiver Participants (n=9)

Age in years	Median (Range)	36 (29 – 48)
Relationship to child	Mother	7
	Father	2
Ethnicity/Race	Black African	2
	Coloured	6
	Indian	1
Highest level of education	Grade 12/Matric	5
	Post-grade 12 certificates or diploma	2
	Tertiary	2
Employment status	Unemployed	5
	Employed, part-time/casual	2
	Employed full time	2
Total household income (monthly)	Less than ZAR4500	2
	Between ZAR4501 and ZAR12500	2
	Between ZAR12501 and ZAR30000	4
	Between ZAR30001and ZAR52000	1

Technical Feasibility of Smartphone Recordings

Audio-Visual Quality of Smartphone Recordings

As shown in Figure 3.1, the median rating for all the audio quality items was 5. The audio was “always” clear in 17 smartphone recordings and “sometimes” clear in one of the 18 smartphone recordings. Sixteen smartphone recordings did not have any background noise that interfered with the rater’s ability to hear the caregiver or child, and one smartphone recording “sometimes” did. None of the 18 smartphone recordings had any echoes that interfered with the rater’s ability to hear the caregiver or child. The rater could “always” hear the caregiver in 17 recordings and could “frequently” hear the caregiver in one of the 18 smartphone recordings. The rater could “always” hear the child in 17 smartphone recordings and could “seldom” hear the child in one of the smartphone recordings. The audio and video of all 18 smartphone recordings were in sync.

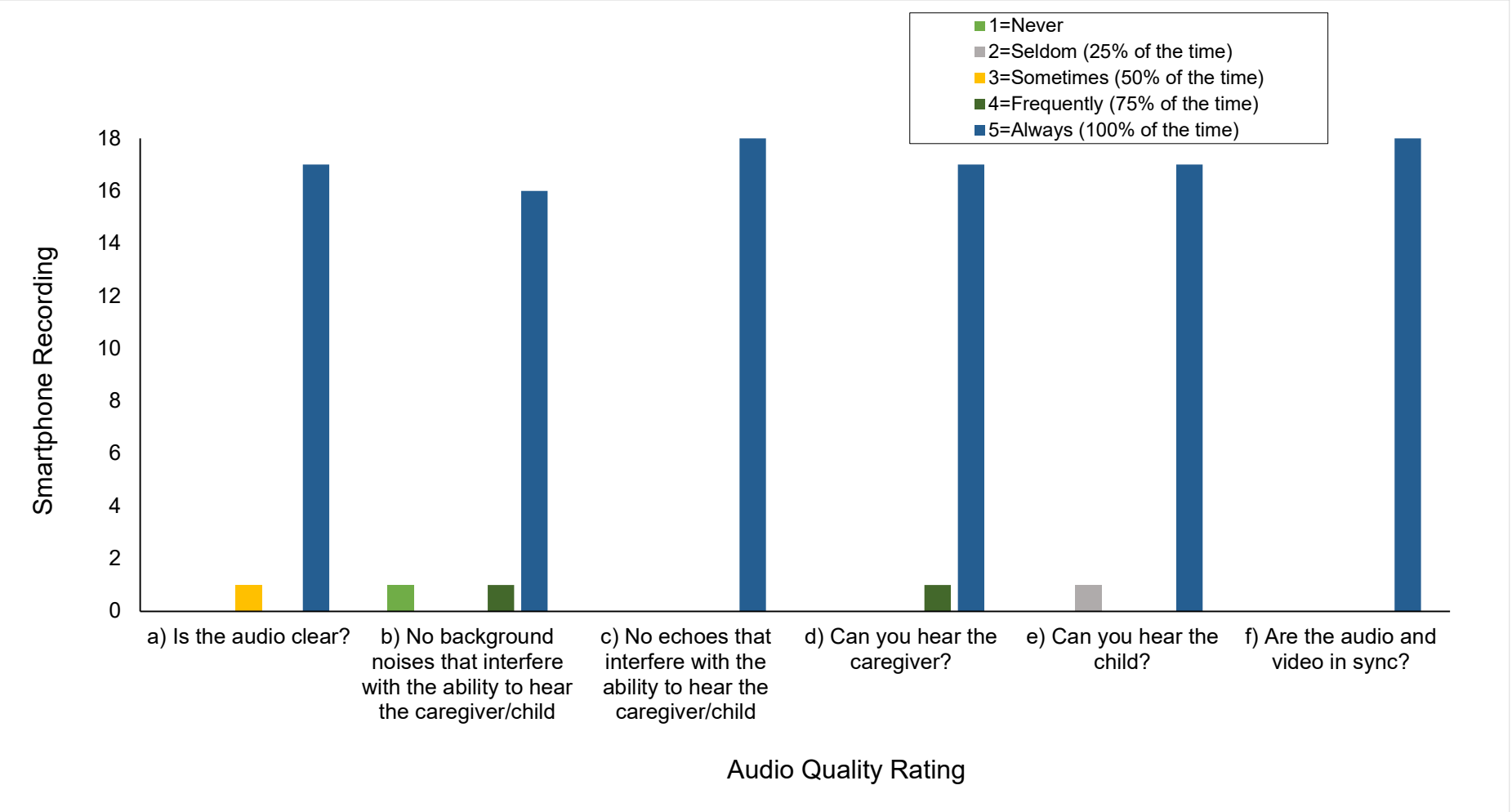


Figure 3.1

Audio Quality of Homme-Based Smartphone Recordings as Rated on the Smartphone Recording Quality Checklist

Figure 3.2 shows the result of the visual quality of the smartphone recordings. The median rating for four items was 5 (which indicates “always” or 100% of the time) ‘Is the video clear?’, ‘Does the video play smoothly?’, ‘Are the play materials visible?’ and ‘Is the caregiver visible?’. The median rating for the following three items was 4 (which indicates frequently or 75% of the time): ‘Is the caregiver visible?’, ‘Is the child visible?’ and ‘Are the caregiver and child both visible?’. The video was “always” clear in 16 of the 18 smartphone recordings, “frequently” clear in one, and “seldom” clear in one smartphone recording. The video in all the 18 smartphone recordings “always” played smoothly. Play materials were “always” visible in 13 of the 18 smartphone recordings, “frequently” visible in four, and “sometimes” visible in one smartphone recording. Caregivers were “always” visible in 12 of the 18 smartphone recordings, “frequently” visible in five and “seldom” visible in one of the 18 smartphone recordings. Children were “always” visible in five smartphone recordings and “frequently” visible in 13 of the 18 smartphone recordings. The child and caregiver were “always” visible in seven smartphone recordings. In 10 recordings, the child and caregiver were “frequently” visible and “seldom” visible in one of the 18 smartphone recordings.

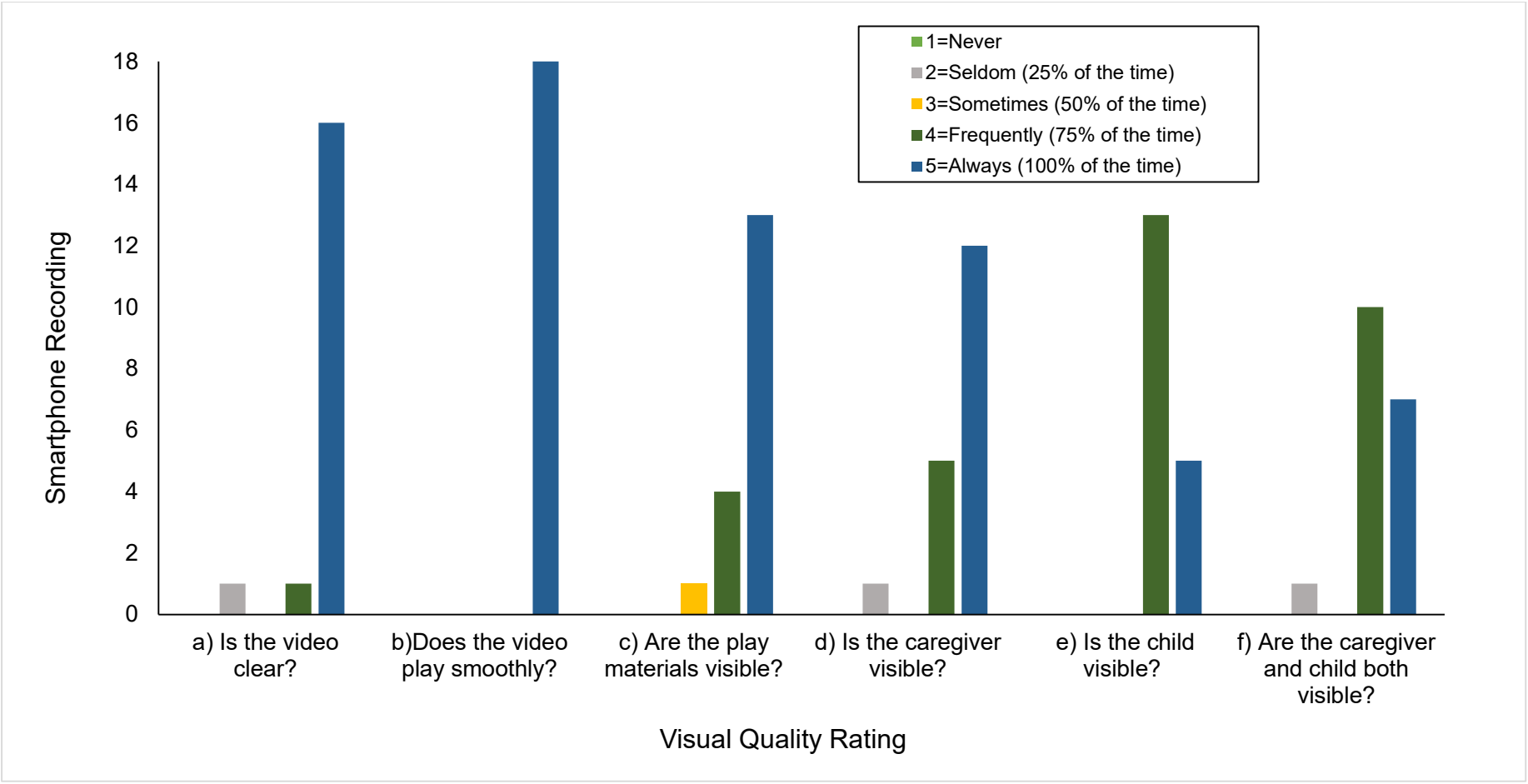


Figure 3.2

Visual Quality of Home-Based Smartphone Recordings as Related on the Smartphone Recording Quality Checklist (SRQC)

Caregiver Implementation of Caregiver-Child Interaction (CCI) Protocol

Figure 3.3 and Figure 3.4 illustrate the results of the caregiver's implementation of Caregiver-Child Interaction (CCI) protocol instructions. All 18 caregiver-child interactions were recorded in one segment. The length of the smartphone recordings ranged between 05:03 – 15:05 minutes. Twelve of the 18 smartphone recordings were between 6 – 6:30 minutes long. Two of the 18 smartphone recordings were shorter than the required six minutes (05:03 and 05:37 minutes, respectively), and four were significantly longer than six minutes (between 06:45 – 15:05 minutes). See Figure 3.3 for the length of the smartphone recordings. Figure 3.4 shows that 17 of the 18 smartphone recordings were a first attempt to record and upload to StrongBox. After viewing and checking the uploaded interaction recordings (for quality control), the project coordinator asked one of the caregivers to re-record and re-upload their caregiver-child interaction video because the initial recording was completely unclear. Figure 3.4 shows that in 16 of the 18 smartphone recordings, there were no distractions in the room that significantly impacted the video quality. Fifteen of the 18 smartphone recordings included only play materials similar to those listed in the CCI protocol instructions, while three recordings had play materials similar to those listed in the instructions as well as additional play materials not listed in the CCI instruction (Figure 3.4).

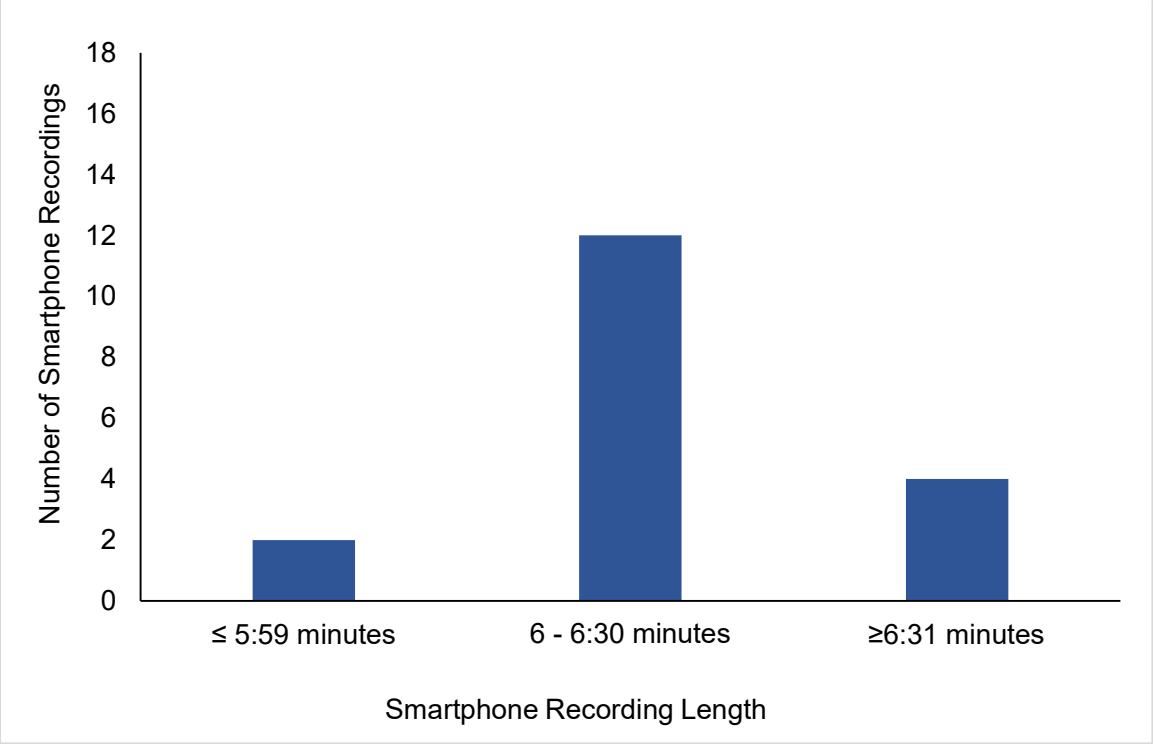


Figure 3.3

Smartphone Recording Length Range (The caregiver-child interaction protocol outlines that the smartphone recording should be six minutes long).

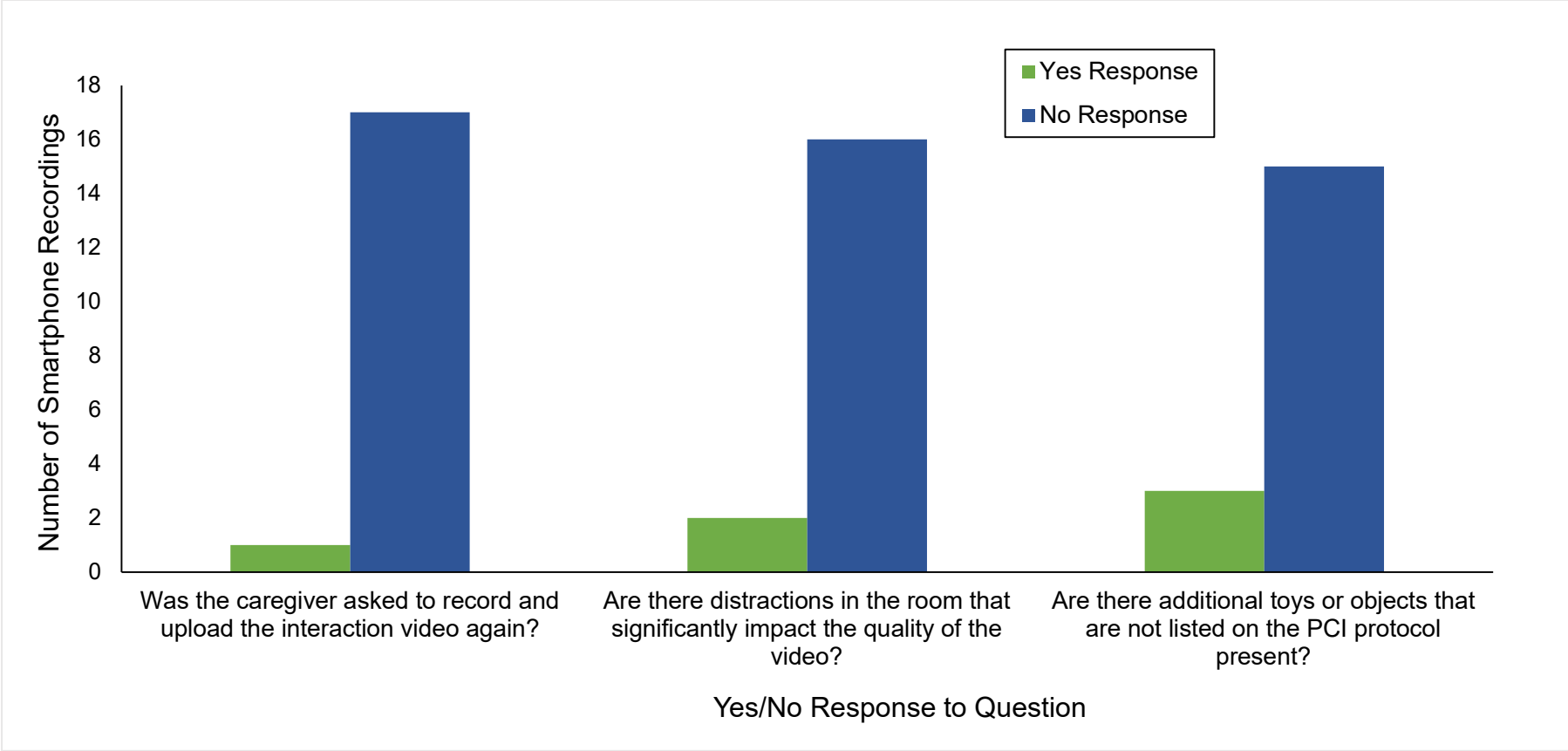


Figure 3.4

Graph Showing Yes/No Responses to Questions on Caregiver-Child Interaction Protocol Instructions

Coding Difficulties with the Joint Engagement Rating Inventory

Confidence Level Based on the Technical Aspects of the Smartphone Recordings

Figure 3.5 shows the results for the rater's confidence level for each JERI rating based on the technical aspects of the smartphone recordings. The median rating on the RRC for the rater's confidence level on the JERI ratings was 3 ("sure of the rating"). In all 18 smartphone recordings, the rater was "sure of the rating" for eight of the 16 JERI items. The rater was "sure of the rating" for two of the 16 JERI items in 17 smartphone recordings. They were also "sure of the rating" for two JERI items in 16 recordings and four JERI items in 15 of the 18 smartphone recordings. The rater was "somewhat sure of the rating" for four JERI items in three of the 18 smartphone recordings, for one JERI item in two recordings, and were also "somewhat sure of the rating" for three JERI items in one smartphone recording. The rater was "unsure of the rating" for one JERI item in one smartphone recording.

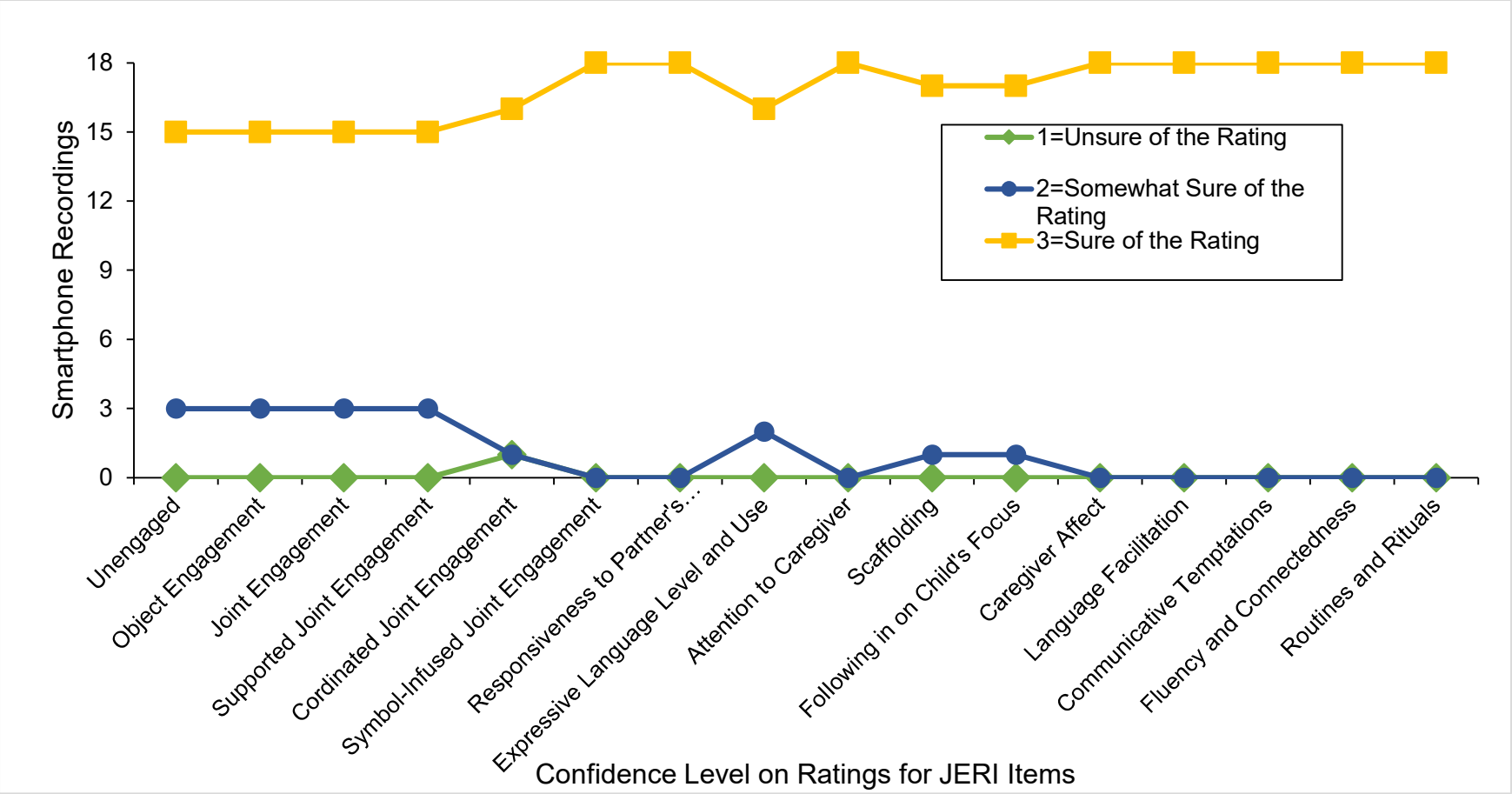


Figure 3.5

Confidence Level on Joint Engagement Rating Inventory Based on Technical Aspects of Smartphone Recordings as rated on the Rating Review Checklist (RRC).

Coding Difficulties Related to Child/Caregiver Behaviour

Figure 3.6 shows the results of rater reporting of coding difficulties with the JERI related to child and/or caregiver behaviour. The median rating for the rater's report on coding difficulties with the JERI was 2 ("no difficulties"). The rater did not report experiencing difficulties with coding up to five JERI items in 12-18 smartphone recordings. In all 18 smartphone recordings, the rater did not report experiencing difficulties with coding five of the 16 JERI items. The rater also did not experience coding difficulties with four JERI items in 12 smartphone recordings, three items in 16 recordings, two items in 17 recordings and one item in 14-15 smartphone recordings.

The rater reported experiencing difficulties with coding up to four of the 16 JERI items in 1-6 of the 18 smartphone recordings. The rater also "had difficulties" coding four JERI items in six smartphone recordings, three JERI items in two recordings, two JERI items in one recording, and they "had difficulties" coding one JERI item in 3-4 smartphone recordings.

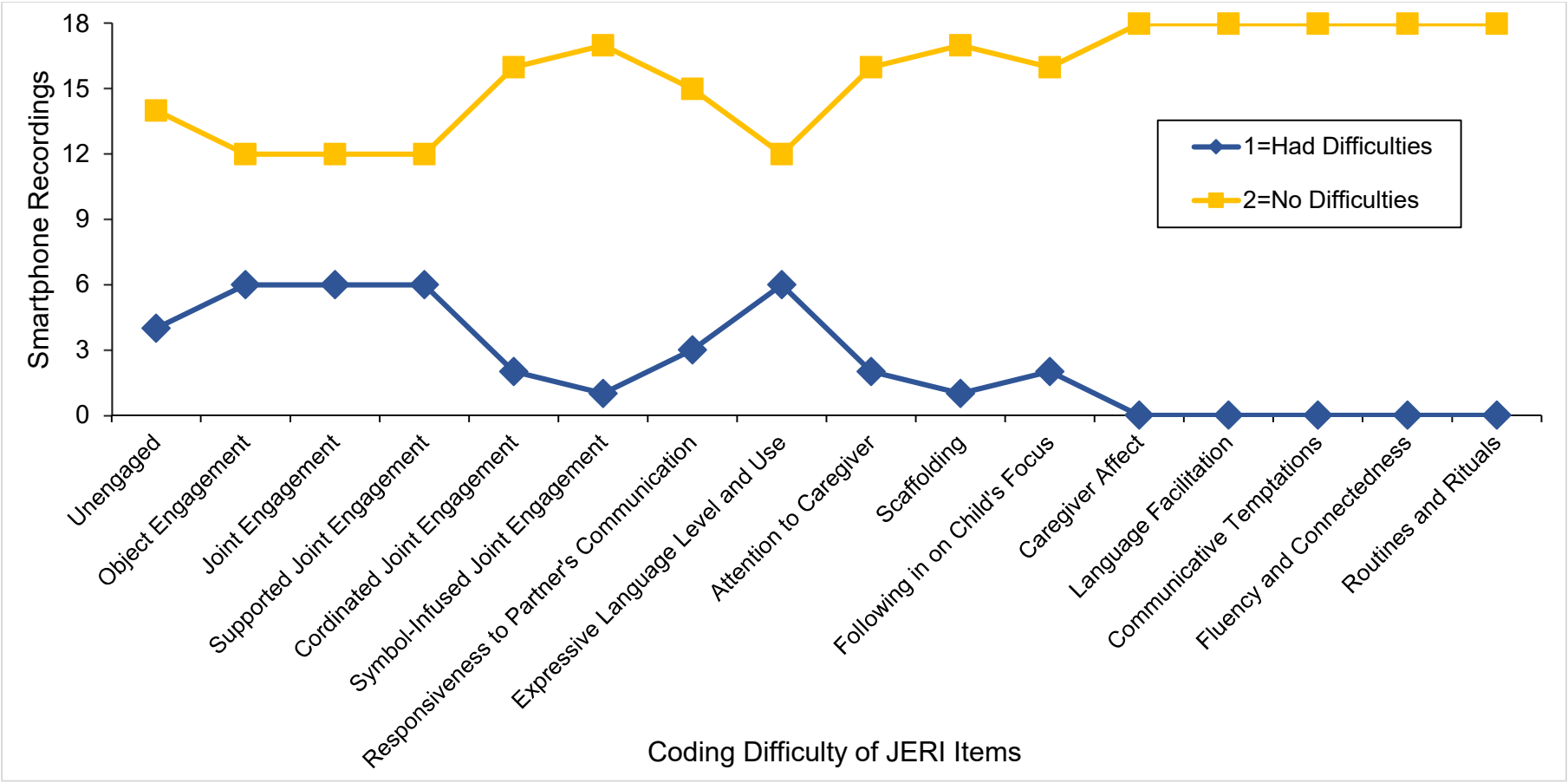


Figure 3.6

Difficulties with Coding the Joint Engagement Rating Inventory Due to Child/Caregiver Behaviour as rated on the Rating Review Checklist (RRC)

Reliability on the Joint Engagement Rating Inventory

Table 3.3 shows the inter-rater reliability results on the Joint Engagement Rating Inventory (JERI) ratings of the smartphone-recorded caregiver-child interactions. The weighted kappa values, within one scale point, for all the JERI items ranged between 0-1, with observer estimated accuracy values between 36–99%, and percentage agreements, within one scale point, between 71-100%. Observer agreement for the following 11 items was reasonable and within the desired reliability goals: object engagement, joint engagement, supported joint engagement, coordinated joint engagement, symbol-infused joint engagement, responsiveness to partner's communication, expressive language level and use, attention to caregiver, scaffolding, caregiver's affect, and fluency and connectedness. The weighted kappa value for the 11 items within one scale point was 1, the observer estimated accuracy was >99%, and percentage agreements (within one scale point) were 100%.

There were low observer agreements for five items (unengaged, caregiver's following in on child's focus, caregiver's language facilitation, caregiver's communicative temptations, and shred routines and rituals). The observer estimated accuracy for unengaged was <36%, with a weighted kappa and percentage agreement (within one scale point) of 0 and 86%, respectively. The observer estimated accuracies for following in on the child's focus, language facilitation, and communicative temptations were 67%, 69%, and 65%, with weighted kappa values (within one scale point) of 0.30, 0.36, and 0.26 and percentage agreement values (within one scale point) of 71%. The observer estimated accuracy for routines and rituals was <36% with a weighted kappa and percentage agreement, within one scale point, of 0 and 86%, respectively.

Table 3.3

Reliability on the Joint Engagement Rating Inventory (JERI)

JERI Item	Weighted kappa[1]	Observer Estimated accuracy[2]	Exact percentage agreement[3]	Percentage agreement within 1 scale point[4]
Child Engagement Items				
Unengaged	0	<36%	43%	86%[b]
Object Engagement	1[a]	>99%	57%	100%[b]
Child's Joint Engagement	1[a]	>99%	43%	100%[b]
Child's Supported JE	1[a]	>99%	29%	100%[b]
Child's Coordinated JE	1[a]	>99%	71%	100%[b]
Child's Symbol-Infused JE	1[a]	>99%	86%	100%[b]
Child Activity Items				
Child's Responsiveness to Partner's Communication	1[a]	>99%	71%	100%[b]
Child's Expressive Language Level & Use	1[a]	>99%	86%	100%[b]

[1] Weighted kappa refers to the degree of disagreement between the raters within one scale point (Sim & Wright, 2005).
[2] Observer estimated accuracy is the probability that a rater will correctly rate a particular item in an interaction (Bakeman, 2018).
[3] The exact percentage of agreement between two raters without a weighting scheme (McHugh, 2012).
[4] The percentage agreement between raters when differences within 1 scale point are regarded as agreements and greater differences as disagreements.

JERI Item	Weighted kappa[1]	Observer Estimated accuracy[2]	Exact percentage agreement[3]	Percentage agreement within 1 scale point[4]
Child's Attention to Caregiver	1[a]	>99%	86%	100%[b]
Caregiver Activity Items				
Caregiver's Scaffolding	1[a]	>99%	14%	100%[b]
Caregiver's Following in on Child's focus	.30	67%	43%	71%
Caregiver's Affect	1[a]	>99%	71%	100%[b]
Caregiver's Language Facilitation	.36	69%	43%	71%
Caregiver's Communicative Temptations	.26	65%	29%	71%
Dyadic Interaction Items				
Fluency & Connectedness	1[a]	>99%	86%	100%[b]
Shared Routines & Rituals	0	<36%	43%	86%[b]

Note. JE = Joint Engagement

[a] Indicates weighted kappa values of ≥ 0.75.

[b] Indicates percentage agreements within 1 scale point of ≥ 80%

Chapter 4 Discussion and Conclusion

Autism is increasingly identified in low- and middle-income countries (LMIC), but autistic children and their families typically receive no or very little services and support (de Vries, 2016; Franz et al., 2017; Lord et al., 2022; Olusanya et al., 2018). Naturalistic developmental behavioural interventions (NDBI) have emerged as a group of international approaches that may be feasible to deliver even in LMIC (Lord et al., 2022; Schlebusch et al., 2020; Schreibman et al., 2015). A recent study in South Africa using the Early Start Denver Model, one of the NDBI approaches, showed that such interventions may be feasible to be delivered by non-specialist providers in low-resource contexts (Makombe et al., 2019; Rieder et al., 2023).

To conduct intervention research, appropriate and acceptable outcome measures are required. Most measures used in autism research have been developed in high-income, English-speaking countries, thus raising concern about their feasibility in LMIC contexts. However, an earlier South African study conducted by our research group showed that we could collect behavioural data from caregivers and their autistic children under ‘laboratory-based’ conditions and that these data could be coded using the Joint Engagement Rating Inventory (JERI) (Ndlovu, 2022).

As a result of the COVID-19 pandemic, many autism interventions, including our own, had to switch to tele-delivery (Franz et al., 2022). W We were able to adapt our in-person intervention programme to be delivered via WhatsApp in a feasible and acceptable way. However, one of the key outstanding questions was whether families could collect caregiver-child data at home on their own smartphones and whether those data would be of sufficient quality to code with the JERI. This was a fundamental research question that had yet to be addressed in any LMIC.

The study presented here therefore set out to assess whether smartphone recordings of interactions between caregivers and their young autistic children in naturalistic

home settings could be technically suitable to code with the Joint Engagement Rating Inventory (JERI). To answer the question, the study had two main aims. The first was to determine whether home-based smartphone recordings of caregiver-child interactions could be captured with the necessary audio-visual quality, sufficient caregiver-child 'on screen' time and caregiver-child interaction protocol set-up required to be coded with the JERI. The second aim examined whether two research-reliable raters experienced difficulties coding these home-based smartphone recordings and could achieve inter-rater reliability when coding the caregiver-child interactions using the JERI.

Nine South African caregiver-child dyads who self-identified as Black African, Coloured, or Indian (representing highly under-presented groups in autism research) were included in the project, and pre- and post-intervention data were available on these participating families. In the Smartphone Recording Quality Checklist (SRQC), a tool developed by us to capture the audio and visual quality of individual recordings, most smartphone recordings were reported to have sufficient audio-visual quality, caregiver-child 'on screen' duration, recording length and suitable play materials. The Rating Review Checklist (RRC), developed in the study to record rater difficulties with JERI coding. The results from the RRC showed that the rater was "sure of the rating" for most JERI items across the 18 smartphone recordings. The rater did not report difficulties with coding most JERI items across the 18 smartphone recordings. On the key outcome measure, the JERI, reliability was attained for most of the 16 JERI items, with a 0-1 range of weighted kappa values, observer estimated accuracy of 36-99% and percentage agreements of 71-100%, within one scale point. Below we will provide further reflections on the key findings of the study.

Technical Feasibility of Smartphone Recordings

In this study, caregivers were asked to follow a specific protocol to record play interactions with their young autistic children using their own smartphones in their home environments. The results from the Smartphone Recording Quality Checklist (SRQC)

suggested that caregivers could implement these caregiver-child interaction protocol instructions and produce caregiver-child interaction smartphone recordings that mostly had acceptable audio-visual quality. The audio quality of the smartphones was mostly acceptable for JERI coding, had clear audio of the caregiver-child dyads, and had minimal factors (background noises or echoes) that interfered with a rater's ability to hear the dyad. Various items in the JERI assess the child's language use, social communication abilities and overall pattern of attention to objects, symbols and their caregiver in an interaction, as well as the caregiver's use of language to support the child's social communication skills and language development (Adamson et al., 2020). Coding these JERI items (such as the child's expressive language level and use or the caregiver's language facilitation) requires clear audio to enable the rater to hear the child and caregiver's use of speech and language during the interaction. Given that language and communication are essential outcomes of naturalistic developmental behavioural interventions (NDBI) (Sandbank et al., 2020), it was very encouraging that our findings showed that home-based smartphone recordings of caregiver-child interactions had sufficient audio quality to capture the speech and language of the caregiver-child dyads adequately during the interactions, to be coded on the JERI.

The visual quality of the smartphone recordings was mostly clear and acceptable. The data suggested that in most smartphone recordings, the caregiver-child dyads were visible for about 75% of the recording, even though children were less frequently visible than the caregivers. We propose that factors such as the positioning of the smartphone, and the range of the child or caregiver's movement during in the room, may have affected the caregiver-child dyad's visibility. The JERI procedures recommend that when recording caregiver-child interactions, the device used for recording should be mounted or fixed on a support, like a wall, to provide stability of the recording and be manned (by another adult and not the caregiver) to capture the triadic or dyadic interaction (Suma et al., 2017). These recommendations will most likely be implemented in a controlled research laboratory environment where camera mounting systems are available and other research members

can operate the recording. However, this is not representative of the home environment, and in this study, caregivers used smartphones which are mobile, as opposed to being mounted like in a laboratory setting. Caregivers could have used phone stands for the smartphones. However, this was not included in the instructions, and the study did not provide phone stands for the caregivers. Additionally, it may not always be the case that a caregiver can receive assistance from another adult to film the interaction, leaving the responsibility to the caregiver themselves. The challenges experienced by caregivers in this study may still be experienced in a laboratory environment, as children often move and may create a block for the observer's viewing angle, even with mounted camera equipment. Despite the potential challenges for families to record these caregiver-child interactions on their own, the caregivers and children were on screen for 75% of the time in most cases, which was sufficient to allow JERI coding. These are very encouraging findings, and given the circumstances, there were not a significant number of issues.

Difficulties with Coding on the Joint Engagement Rating Inventory

The Rating Review Checklist (RRC) was designed to assess a rater's confidence in rating each JERI item. We felt that this was an essential element to add to the study because we wanted to differentiate whether a rater experienced coding difficulties due to the technical aspects of the recording (such as the audio-visual quality not being sufficient) or due to child and/or caregiver behaviours (independent of the technical quality of the smartphone recording).

Given that JERI coding requires a recording to capture a dyadic and triadic interaction between the child, caregiver and/or play materials, we propose that the visual quality of the smartphone recordings where the caregiver-child dyads and play materials were not always visible may have influenced the rater's confidence on the JERI rating in some smartphone recordings. The results from the RRC indicated that based on the technical aspects, the rater was "somewhat sure of the rating" for eight JERI items in a minority of the smartphone recordings. However, the overall results for the rater's confidence

level showed that the rater was “sure of the rating” assigned for most JERI items. These findings suggested that the technical quality of the smartphone recordings minimally affected the rater’s confidence in rating the caregiver-child interactions on the JERI and that home-based smartphone recordings of caregiver-child interactions could be coded confidently on the JERI.

The results from the RRC indicated that, independent of the technical quality of the smartphone recordings, raters reported difficulties in coding 11 of 16 JERI items in only a minority of the smartphone data (1-6 of 18 smartphone recordings) due to child and/or caregiver behaviour (and not due to technical difficulties with recordings). The magnitude of these difficulties was not assessed given that raters were only required to record whether they had difficulties coding each JERI item for all the smartphone recordings. The items that the rater reported experiencing difficulties with assessed the child’s social communicative acts, patterns of attention and expressive language, and the caregiver’s use of strategies to support these child behaviours (Adamson et al., 2020). While these questions were not necessarily related to the technical aspect of the recording, we propose that child behaviours that may have influenced the rater coding difficulties could relate to periods of lower (frequent rather than constant) child and caregiver visibility, which may affect the duration of the child’s involvement with an object or their caregiver. However, the rater did not report experiencing JERI coding difficulties that were due to the caregiver and/or child’s behaviour in the majority of the smartphone recordings. Although it was not the main inquiry of this study, these findings are encouraging and highlight the usefulness of the JERI to describe relevant intervention outcomes (such as child, caregiver, and caregiver-child dyadic interaction behaviour), even from data captured using smartphones in home environments. Moreover, these findings contribute to the growing work on the utility of the JERI in low-resource environments (Ndlovu, 2022).

Reliability on the Joint Engagement Rating Inventory

Inter-rater reliability was achieved on the JERI for most of the items. Inter-rater reliability was assessed using Cohen's weighted kappa, where differences within one scale point were regarded as agreements and greater differences as disagreement (Bakeman, 2018; Cohen, 1968). Within one scale point, the weighted kappa values (degree of disagreements between raters) for five items (unengaged, following in on child's focus, language facilitation, communicative temptations, and routines and rituals) were 0-0.36. These low weighted kappa values may imply that the two raters had little to no agreement. However, the raters had a high percentage agreement for these items at 71-86%. We propose that the low weighted kappa values for these items might also be attributed to low variability in ratings due to the low spread of ratings across the 7-point scale (the majority of the ratings ranged between 1-2). The observer estimated accuracy (the probability of a rater correctly rating an event) for these items ranged between <36-69%, and unlike the weighted kappa, observer estimated accuracy is less sensitive to truncated variability on any given scale. For the caregiver activity items (including following in on child's focus, language facilitation, and communicative temptations), JERI raters need to focus on both the caregiver and the child when coding because all items consider the caregiver's use of skills in relation to the child's focus of attention and developmental level (Adamson et al., 2020). Low reliability ratings on these items may be due to various factors, including visibility of the caregiver-child dyad. Given that dyads were visible for about 75% of the recording time (based on results from the technical aspects of the smartphone recordings), it is likely that reliability results may have been due to the rater difficulties evaluating both the child's developmental level and how the caregiver used specific strategies to expand child abilities.

It is worth noting that the number of interaction videos compared between the two raters (40% of 18) was less than the number of comparison videos generally used when coding the JERI as the minimum for reliability information. The reliability results may therefore have been affected by this aspect of coding. Interestingly, the JERI inter-rater

reliability results of this study are comparable to previous laboratory-based findings where the JERI was used to measure the behaviours of young autistic children and their caregivers during caregiver-child interactions in South Africa (Ndlovu, 2022). For example, in the laboratory-based findings, there were low weighted kappa values (which were zero) and high percentage agreements (100%) for two items (coordinated joint engagement and shared routines and rituals) where the majority of ratings ranged between 1-2 on the 7-point Likert scale. These similarities in reliability between the laboratory-based and home-based findings suggest that the JERI is a consistent measure that can be used to describe and assess child, caregiver and caregiver-child dyadic interaction behaviour captured either in a laboratory-based environment or in the home environment using smartphones.

Strengths and Limitations of the Study

To our knowledge, this was the first study to assess the technical suitability of smartphone recordings of caregiver-child interactions for coding on the Joint Engagement Rating Inventory (JERI). Considering South Africa's high inequality rates and disparities in access to intervention services for young children with autism, caregivers can play a crucial role in delivering interventions for their young autistic children in LMIC contexts (de Vries, 2016). This study contributes to the literature on naturalistic developmental behavioural interventions (NDBI) by showing the possibility of using smartphones for data collection to measure child, caregiver and caregiver-child dyadic behaviour without the need for highly specialised laboratory conditions. By providing access to remote measurement of caregiver-child interactions, smartphone technology may provide a relatively affordable option for tracking response to NDBI intervention compared to the costs associated with in-person lab-based assessments. Finally, this study also contributes to the literature on appropriate measures to track the impact of NDBI by utilising the JERI and showing its reliability in observing child and caregiver behaviour even from interactions captured using smartphone technologies in the home setting.

While this study contributes to the literature on naturalistic data collection for early autism intervention in low- and middle-income countries (LMIC), we acknowledge the following limitations. Firstly, the sample size of the study was small (nine caregiver-child dyads). Therefore, the findings are not generalisable to the broader population of young autistic children and their caregivers in South Africa. The small sample size was a result of limitations on enrolment and recruitment procedures related to the COVID-19 pandemic. The enrolment and recruitment of the caregiver-child dyads in this study took place as part of the primary project's transition from in-person to telehealth-delivered NDBI-informed caregiver coaching using smartphones in Cape Town, South Africa (Franz et al., 2022). However, although the study only had nine caregiver-child dyads, it presented 18 smartphone recordings amounting to 108 minutes of data. Additionally, to our knowledge, this study presented the first-ever examination of home-based recordings for JERI coding in an LMIC context which is a valuable contribution to knowledge on data collection that is more representative of the naturalistic home environment of families.

A second potential limitation is that the Smartphone Recording Quality Checklist (SRQC) and the Rating Review Checklist (RRC) were developed and used for the first time in this study. To increase the robustness of findings, 10% of randomly selected data were coded by the senior investigator, but we acknowledge that we do not have any published data on the psychometric properties of these measures. In spite these limitations, the measures provided a systematic approach to assessing whether raters experienced difficulties coding the smartphone-recorded caregiver-child interactions on the JERI.

Recommendations and Implications for Future Research

We are very encouraged by the potential of using smartphones to track response to intervention in LMIC. This could be of great benefit to autism research and intervention monitoring in LMIC such as South Africa where this study was conducted. However, many people who live in these LMIC have very limited access to affordable internet services and, where available, internet data costs to upload caregiver-child interaction smartphone

recordings as well as the cost to raters to download and review data may prove to be a significant barrier to scale-up of such approaches (de Vries, 2016; Kumm et al., 2022). The families in this study were compensated for the internet data costs to upload their recordings. It will be critical to understand how these methods of data collection and storage are sustainable and scalable if participants or raters do not have available or reliable internet connection or cannot afford internet data costs without the support of an ongoing research study. Moreover, for future research, we recommend that large-scale and creative solutions will be required to ensure that families who need it most (and may be the hardest to reach) have free access to reliable internet and data. In a country like South Africa, where 'loadshedding' (regular power cuts) have become part of the fabric of our lives, smartphones and technology such as the ones explored in this project can only work if these macro-economic challenges such as power and internet can be resolved.

The JERI is a standardised behavioural coding scheme and was shown to be useful in two local studies – first our 'lab-based' investigations (Ndlovu, 2022), and secondly, in this thesis using 'home-based' recordings. However, the standard JERI coding procedures required a significant amount of time and effort in order to train to research reliability (Suma et al., 2017). Therefore, the JERI itself, as an outcome measure, may not be scalable, particularly in resource-limited environments. We therefore recommend that future research efforts consider the possibility of automated methods of behavioural coding for early autism intervention, which may provide truly scalable and sustainable solutions to collect and quantify behavioural data of interest for children with autism and related neurodevelopmental disabilities.

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