UNDERSTANDING AND TRAINING EMOTION REGULATION IN CHILDREN AND ADOLESCENTS

by

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ABSTRACT

Emotion regulation (ER)—the ability to change an emotional experience in relation to a desired emotional goal is linked to broad psychosocial outcomes. In addition, early adolescence presents a sensitive period in the malleability of ER processes and is a period of particular risk for ER difficulties and the development of psychopathology. Utilising a mixed methods approach, this thesis explores the use of ER skills through childhood and adolescence within the context of social functioning (study 1, chapter 2); and leading from this, the training of ER skills via digital intervention approaches (study 2, chapter 3). Chapter 4 applied the findings of chapters 2 and 3 by presenting the evidence and codesign informed development of a prototype novel digital game for training specific ER strategies in early adolescence. Results demonstrate the importance of the development and use of adaptive ER skills through childhood and adolescence, and that issues around engagement, access, acceptability, and stigma in traditional and wider-reaching preventative intervention frameworks may be addressed by training ER via codesigned digital games. The applied implications of the thesis centre around the importance of training ER via appropriately codesigned digital technology in broad samples of early adolescents to address negative social experiences and linked psychological outcomes.

To my Dad, who didn't get to see my adventures in academia.

"May you always keep your memory and keep your spirit free."

Steve Ashley

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PUBLICATIONS LIST

Below is the published paper that is within this thesis (Reynard et al., 2022; study 2, chapter 3). In addition, the associated published protocol is also listed.

Studies 1 and 3 (chapters 2 and 4) will be submitted for peer-reviewed publication and have been written as such.

Study 1 ‘The association between peer victimisation, emotion regulation strategies, empathy and callous-unemotional traits in children and adolescents’, will be submitted to *European Child & Adolescent Psychiatry*.

Study 3 ‘The collaborative development of a BRAINZ prototype: A universal emotion regulation game for early adolescents’, will be submitted to the *Journal of Medical Internet Research.*

Reynard, S., Dias, J., Mitic, M., Schrank, B., & Woodcock, K. A. (2022). Digital Interventions for Emotion Regulation in Children and Early Adolescents: Systematic Review and Meta-analysis. *JMIR Serious Games*, *10*(3), e31456. https://doi.org/10.2196/31456

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CONTENTS LISTING

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1,

GENERAL INTRODUCTION

Emotion regulation (ER) is defined as the attempt by an individual to exert a modulating or controlling influence on an emotional response to a perceived internal or external stimulus. Importantly, ER is a transdiagnostic construct (Aldao et al., 2016; Cludius et al., 2020), and research has demonstrated key developmental and longitudinal associations between ER and psychological and social outcomes, as well as physical health and academic functioning in adolescence (e.g., Ahmed et al., 2015; Cloitre et al., 2019; Feldman, 2021; Davis & Levine, 2013; English et al., 2021). In early adolescence, brain networks implicated in ER processes are highly malleable (Adrian et al., 2019), and may be influenced by the external social environment (van Harmelen et al., 2017; Schriber & Guyer, 2016). Hence, early adolescence presents a highly appropriate epoch in which to train adaptive ER skills. However, go-to face-to-face psychotherapeutic approaches, such as cognitive behavioural therapy (CBT) and dialectical behavioural therapy (DBT), that focus on training cognitive- and attention- focused ER strategies raise questions around acceptability, accessibility and engagement in child and adolescent populations (Radez et al., 2021; de Haan et al., 2013). Further, traditional psychological interventions require substantial resources (Chiles et al., 1999). This may not align with the ongoing funding cuts to Child and Adolescent Mental Health Services (CAMHS) within the National Health Service (NHS) (Mattheys, 2015; Ani et al., 2022), and increasing demand for such services within the UK (Huang & Ougrin, 2021) and globally (Benton et al., 2021; Racine et al., 2021). This indicates a worldwide requirement for preventative ER interventions that are effective, accessible, acceptable, and economically viable. Digital interventions—specifically, digital games, may provide a promising means of addressing this need (see chapter 3, Reynard et al., 2022).

Emotion Regulation Development

The development mismatch hypothesis, inclusive of the dual and triadic systems perspectives (Casey et al., 2008; Ernst, 2014), suggests that ER is poor during adolescence because sub-cortical brain structures involved in emotional experience have undergone more rapid development than the cortical structures involved in regulation. Indeed, developmental reductions in frontoparietal grey matter via synaptic pruning (Blakemore, 2008; Zimmermann et al., 2019), occur concurrent to maturation of subcortical structures (Mills et al., 2014). The emotion generating, subcortical structures are hypothesised to be largely mature by early adolescence (Gogtay et al., 2004; Mills et al., 2014). For example, the volume of the amygdala increases by around 7% between late childhood and adolescence, and on average there is no significant change after age 14 (Mills et al., 2014).

Cognitive-based ER strategies that may require the integration of shared ER and social cognitive neural networks are presumed to be adaptive and more sophisticated in nature (e.g., McRae et al., 2012; McRae & Gross, 2020). In line with the normative protracted development of frontoparietal brain networks (Ahmed et al., 2015; Zimmermann et al., 2019), such strategies may develop more gradually than other potentially less sophisticated strategies (Gross & Cassidy, 2019). Less complex, and potentially less adaptive ER strategies are more readily accessible and develop at a faster rate from early childhood (Eisenberg et al., 2010; Gross & Cassidy, 2019). In addition, research has indicated that between age 12 to 15 years, less of the adaptive (e.g., problem solving, distraction) and more of the maladaptive (e.g., avoidance, withdrawal, aggressive behaviour) ER strategies are used when compared to younger and older age groups (Cracco et al., 2017). Specifically, in a large Dutch sample, the use of maladaptive strategies across age 8 to 18 was largely represented as nonlinear asymmetrical curves (Cracco et al., 2017). Here, use was relatively stable between 8-11 years, with an increase between ages 12 to 15, and a curtailment, but not to the same level as between age 8 to 11, by age 18.

Efforts to elucidate the processes underpinning the normative protracted development of ER have primarily been facilitated via cognitive reappraisal ER strategy tasks (i.e., reinterpreting the situation or the emotional goal(s)) within neuroimaging studies (Ochsner & Gross, 2005; Braunstein et al., 2017; Kohn et al., 2014). Here, higher-level cognitive processing cortical networks (i.e., frontoparietal) are linked to successful top-down modulatory processes (Wessing et al., 2015) in which successful modulation of bottom-up amygdalo-striato activation, via down-regulation from functionally connected frontoparietal networks serves to regulate emotional responses. Hence, a developmental mismatch hypothesis may explain the heightened emotional reactivity, difficulties in ER and associated use trajectories in different ER strategies experienced through childhood and adolescence.

Factors that Influence Emotion Regulation Development

Normative ER development as described above is highly malleable and influenced by the external environment and individual differences (e.g., Adrian et al., 2019; Gross & Cassidy, 2019). There are a number of common environmental and individual factors across development that may contribute to differential patterns of ER. These include caregiver practices (Larsen et al., 2012; Di Giunta et al., 2022; Diaz & Eisenberg, 2015), peer relationships (Foulkes and Blakemore, 2018; Larsen et al., 2012; Andrews et al., 2021; Telzer et al., 2018; Güroğlu, 2022; Zeman & Shipman, 1997), cultural and societal differences (Foulkes & Blakemore, 2018; Morelen et al., 2012; Herd et al., 2020; Farah, 2018), genetics (Hawn et al., 2015; Nigg et al., 2020; Borelli et al., 2017) and personality traits (Craig & Moretti, 2019; Trumello et al., 2018). Below, an overview of these environmental and individual factors will be presented before considering broad outcomes that are related to ER.

Caregiver Practices

Evidence suggests that caregiver practices may influence children's evaluation of emotional situations, subsequent need for regulation, and selection and implementation of ER strategies (Gross & Cassidy, 2019; Diaz & Eisenberg, 2015). For example, the suppression of emotional expression (i.e., an ER strategy in which an individual refrains from outwardly showing an emotional response) in childhood has been linked to children's self-reported expectations, and caregivers' provision of emotional support after children's demonstration of emotional distress (e.g., Larsen et al., 2012). Research adopting longitudinal designs to examine parenting and linked factors may highlight the complexity and causative influence of environmental factors in ER development. Herd et al. (2020)

reported mediating latent change effects of positive family context (parent ER, parenting practices, parent-adolescent relationship quality) in the relationship between ER ability and socioeconomic risk (socioeconomic status and household chaos) in early adolescents. Specifically, decreased socioeconomic risk at age 13–14 years was associated with increased positive family emotional context. This was then associated with increased yearly improvements in ER, over 4 years. Taken together, these findings suggest that interactions with family in early life and linked socioeconomic risk may predict future ER capabilities, potentially influencing an individual's use of ER in peer relationships (Floyd & Olsen, 2017; Al-Yagon, 2016; Bierman & Smoot, 1991).

Peer Relationships

Peer relationships may be a particularly important environmental factor to consider in the development of ER (Foulkes & Blakemore, 2018). This is because late childhood through to adolescence is characterised by growing independence and increased potential for engagement in risk-taking behaviours (Powers & Casey, 2015). This is accompanied by increasing time spent with progressively complex networks of peers, with greater importance being placed on such relationships (Foulkes & Blakemore, 2018; Lam et al., 2014; Lamblin et al., 2017; Blakemore & Mills 2014; Brown & Larson 2009). Further, in line with normative ER development, adolescents have stronger negative emotional reactions, more variations in affect and are more sensitive to rewarding experiences, when compared to young children and adults (Schweizer et al., 2020; Riediger et al., 2011; Spear, 2011). Taking this into account it may be unsurprising that the decision to use ER in childhood may be influenced by expected peer responses to emotional reactions (Zeman & Shipman 1997). Indeed, negative emotional responses in childhood are reported to be linked to the anticipation of undesirable peer reactions (e.g., taunting) (Zeman & Shipman 1997). This may encourage the suppression of outward displays of negative emotional reactions, such as anger and sadness (Larsen et al., 2012). Consequently, it is postulated that differential patterns of ER use may occur that are dependent in part upon the perceived behaviour and views of the peers that an individual interacts with in childhood.

Cultural and Societal Differences

Considering cultural and societal differences, cross-national research carried out in low-, middle-, and high-income countries suggests that there are country specific patterns of ER strategy use. Morelen and colleagues found that adolescents from Ghana reported less suppression of the expression of anger than adolescents from Kenya; and adolescents from the United States reported less expression of sadness than both Kenyan and Ghanaian adolescents (Morelen et al., 2012). Examining urbanicity in Ghana, adolescents who resided in a village reported greater suppression of anger than those who resided in an urban environment (Morelen et al., 2012). Hence, there is likely differences in ER use between countries, and within different socio-economic and geographical contexts within individual countries and societies.

The use of self-report measures and cross-national design detailed above somewhat balances the over reliance on neuroimaging methods—largely within high-income countries—used to examine the normative development of ER. However, the limited expansion of cross-national research in low- to middle-income countries suggests a pervasive need to address the westernisation, and subsequent generalisability and validity, of ER development research.

Individual Differences

Individual characteristic factors such as personality traits, sex and genetics may interact with the aforementioned normative ER development and environmental influences (e.g., Craig & Moretti, 2019; Trumello et al., 2018; Hawn et al., 2015). For example, research has indicated potential moderating effects of a child's genetic makeup on the impact of the caregiver environment on ER strategy tendences (Borelli et al., 2017). Here, the FKBP5 genotype was isolated and a standardised stress induction laboratory task was completed by child participants. Findings indicated that in children of diverse socioeconomic backgrounds who were FKBP5 minor allele carriers, attachment security was negatively associated with cognitive rumination, and the suppression of emotional expression (Borelli et al., 2017). That is, the negative association between attachment security and both rumination and emotional expression suppression may depend in part upon the expression of an individual's genetic factors. This work demonstrates how a child's environment and genetic predisposition may encourage less adaptive ER responses in laboratory settings. The notion that a child's genetic risk may influence the regulation of emotions is also supported by research examining clinical samples (e.g., Nigg et al., 2020). Using a person-centered structural equation modelling approach, Nigg and colleagues found that ADHD genome-wide polygenic risk scores (PRS) were raised in an emotionally dysregulated sub-group of children diagnosed with ADHD, independent of ADHD severity. Hence, the expression of multiple genes implicated in ADHD development risk likely also contributes to ER development in ADHD samples.

The research reviewed demonstrates that wide-ranging external and individual factors impact upon ER development in broad samples of children and adolescents, and these likely interact in a highly complex manner. Subsequently, it is vital to understand the outcomes of differential ER capacities and strategy use patterns, to inform ER intervention and appropriate related targets.

Outcomes Related to Emotion Regulation

Different ER strategies may place different demands on cognitive resources and linked social cognitive processes (e.g., Sheppes et al., 2014; Pfeifer & Blakemore, 2012; McRae et al., 2012). Further, ER strategies diverge in their context-appropriateness (Lindsey, 2020; Sheppes et al., 2011; Doré et al., 2016), success (e.g., Hermann et al., 2017); and importantly, ER ability and use may impact upon broad social, psychological, academic and physical health outcomes in adolescence and beyond (e.g., Chervonsky &

Hunt, 2019; Cloitre et al., 2019; Davis & Levine, 2013; McRae & Gross, 2020; Gross & Cassidy, 2019). Below, an overview of specific outcomes in relation to ER are provided.

Peer and Family Relationships

As well as peer and family relationships influencing the development of ER in childhood and adolescence, an individual's ER abilities and strategy use may predict outcomes pertaining to peer, caregiver and broader familial contexts. A recent meta-analysis found that ER ability and positive affect emerged as key factors that were positively associated with several adaptive peer relationship outcomes in typically developing samples (Mitic et al., 2021). These included friendship quality, attachment, support, closeness, reciprocity, authority and intimacy; dyadic friendship quality; friendship quantity (i.e., number of friends); feelings of belonging, relatedness and connectedness. Although these findings offer important information on the breadth of positive peer relationship factors that may be linked to ER and affect in childhood and adolescence, a focus on typically developing samples, cross-sectional data and positive outcomes limits generalisability, ability to infer causation and the capacity to understand negative social outcomes related to ER in adolescence.

Further research including clinical and disadvantaged child and adolescent samples has also demonstrated positive associations between ER ability and friendship quality (e.g., Kouvava et al., 2022). In addition, research examining negative social outcomes of ER demonstrates negative associations between ER ability and relational aggression tendencies, peer rejection, and the experience of peer victimisation (defined as the experience of intentional physical, psychological, emotional or personal property-focused harm, by an individual's peer(s), for example by being socially manipulated or physically attacked) in both typically developing and clinical samples (e.g., Kokkinos et al., 2019; Herd et al., 2021). Moreover, Demkowicz et al., (2023) examined perceived ER (i.e., an individual's perception of the efficacy of their own ER) longitudinally in early adolescents residing in disadvantaged regions in England, in relation to self-reported depth of connection to family and peers. Findings indicated that perceived ER at time 1 (age 11-12) shared small significant positive correlations with peer and adult family connections at time 3 (age 13-14). Such that, higher *perceived* ER ability predicted adolescents' future better connection to both peers and family.

As suggested in recent research (e.g., Schwartz-Mette et al., 2021; Lindsey, 2021), it is also important to note that social outcomes in childhood and adolescence, including interpersonal difficulties, may interact with ER processes to predict the development of maladaptive behaviour and psychopathology.

Psychopathology

Recent research has shown that ER may be a transdiagnostic marker in wide-ranging psychiatric and neurodevelopmental disorders (Cludius et al., 2020; Aldao et al., 2016; Caviccioli et al., 2023). Cludius and colleagues critically examined the use of cognitive ER strategies in adult samples and found that different patterns of use may relate to certain psychiatric diagnoses. Specifically, the infrequent and/or unsuccessful use of cognitive reappraisal has been linked, however largely in a cross-sectional nature, to depression, bipolar disorder, psychosis episodes and generalized anxiety disorder (Cludius et al., 2020). Moreover, the increased frequency of negative rumination has been linked longitudinally to depression, post-traumatic stress disorders, eating disorders and substance use disorders; whereas increased positive rumination has been linked cross-sectionally to mania in bipolar disorder (Cludius et al., 2020).

Importantly, neurodevelopmental and psychiatric disorders often emerge in early life (Parenti et al., 2020; Solmi et al., 2022). A recent extensive meta-analysis reported 14.5 years of age as the worldwide peak for psychiatric disorder emergence (Solmi et al., 2022). Focusing on the potential for ER strategy use patterns in childhood and adolescence to serve as identifiable risk factors for psychopathology, Caviccioli et al. (2023) conducted a large-scale meta-analysis using a cross-lagged, longitudinal approach. Showing early evidence for alignment with findings from adult populations (e.g., Cludius et al., 2020), difficulties in adaptive ER strategy use (e.g., attentional control, cognitive reappraisal, problem solving) was more associated with externalising psychopathology (e.g., as observed in Conduct Disorder, ADHD, mania), and maladaptive ER strategy use (e.g., avoidance, rumination, non-acceptance) was more associated with internalising psychopathology (e.g., as observed in depression and anxiety). Further, the use of maladaptive ER strategies was a significant risk factor for later psychopathology (Caviccioli et al. 2023). In addition, the habitual use of expressive suppression has been widely associated with internalising symptoms in adolescence, spanning wide-ranging cultures and ages (Gross & Cassidy, 2019).

Considering positive outcomes related to the use of ER strategies in adolescence, Caviccioli et al., (2023) reported that the use of adaptive ER strategies was a significant protective factor for later psychopathology. Indeed, the ability to successfully use adaptive ER strategies whilst navigating new and occasionally adverse social experiences may mitigate against poor mental health outcomes (Ahmed et al., 2015). For example, a recent longitudinal neuroimaging study found that maltreated children and adolescents aged 8-17, who demonstrated successful modulation of bottom-up amygdala activation during a cognitive reappraisal task, experienced lower depression risk over time (Rodman et al., 2019).

Academic Success

As well as key social and psychological outcomes, emerging research suggests that the ability to successfully use adaptive ER skills and experience related positive affect may be linked to broad academic outcomes in childhood and adolescence. These outcomes include academic achievement (Gumora & Arsenio 2002; Camacho-Morles et al., 2021; Wang et al., 2022; Davis & Levine, 2013), academic engagement and school attendance (Eriksen & Bru 2022; Kearney et al., 2019) and school wellbeing (Beaumont et al., 2023).

Physical Health

Key physical health outcomes such as obesity (Shriver et al., 2019; Gouveia et al., 2019), sleep quality and quantity (Wall et al., 2022) and physiological stress response measures (Rnic et al., 2022) have also been shown to be linked to ER in broad adolescent samples. Although at the physiological level (for example ER strategy associations with heart rate and cortisol level), the emerging evidence appears less clear when compared to adult samples (Rnic et al., 2022; Gross, 2013; Gross & Cassidy, 2019).

Interim Summary

Given the array of important outcomes associated with ER, demonstrable developmental links to the external environment, normative challenges in affect and ER, and heightened malleability of associated brain networks in adolescence, it is clear that ER is a worthy and suitable target for preventative intervention.

Further, the influential and consequential associations between peer relationships and ER across childhood and adolescence, and the potential influence of both ER and peer relationships in the development of psychopathology suggests it is vital to better understand the experience of negative social outcomes when creating ER interventions. This is because it may ensure that interventions are relevant and present maximum potential for optimal long-term impact.

Theoretical Accounts of ER

A number of theories and conceptual accounts attempt to describe and contextualise the experience of human emotion and its regulation. Here, an overview of common theoretical accounts and perspectives are provided; with a justification of the theory that will subsequently inform this thesis.

Appraisal Theories

Appraisal theories of emotion generation and ER, which are believed to be borne out of early stress- and coping-based models (e.g., Lazarus, 1966), focus on the role that interpreting (i.e., appraising) emotional situations in terms of their meaning has on how the emotional response is organised—based on the coordination of behavioural, experiential, and physiological systems, and how multiple emotional responses are discerned from each other (e.g., Yih et al., 2018; Gross & Barret, 2011). Such models consequently consider emotions as multifaceted states that allow an individual to respond to a given emotional situation. Some common appraisal features that are reported across appraisal theories include relevance (i.e., how imperative the emotional situation is in regard to the individual's goal(s)); valence (i.e., negativity or positivity of a given situation); likelihood (i.e., likelihood of an event taking place in the extant emotional situation) (Yih et al., 2018). It is these appraisals, which are highly personal in terms of their meaning, that are believed to shape an individual's emotional experience (Gross & Barret, 2011). Indeed, the focus on the personal meaning of event- or stimuli-related appraisals may be a strength of appraisal models, as it emphasises a person-centered and individualised approach to the theoretical understanding of emotion and ER. However, possibly due to the implied notion that emotions act to create meaning in relation to the world, social constructivist approaches to appraisal models lack reference to typical or stereotyped emotional reactions, leading such appraisal models to be agnostic as to mechanisms that bring about emotion (Gross & Barret, 2011).

Systems Theory

As with appraisal models of emotion, systems theory argues that emotional responses come about via the integration and coordination of multiple systems (Thompson, 2008; 2011). However, unlike appraisal models, more focus is placed upon how ER unfolds over time, giving a more complete and holistic picture of the emotion generation and ER process. Indeed, critics also highlight a lack of clear specification concerning how ER comes about following appraisal as a key weakness of appraisal models (e.g., Yih et al., 2018). Further, systems theory postulates that ER is a coactive and dynamic process in response to an emotional stimulus or situation; and that it is not theoretically distinguishable from the emotion generation process (Thompson, 2008; 2011). It is suggested that information from multiple behavioural and neurobiological systems are integrated via interactional feedback loops and modulation processes to produce the emotional response (Thompson, 2008; 2011).

Process Model

In contrast to the systems theory of ER (Thompson, 2008; 2011), the process model of ER assumes that emotional experience and regulation are *different*, yet linked processes (e.g., Gross, 1999). The process model of ER stipulates that an individual's emotional experience may be regulated at one of four parts of an emotion generation sequence. These are coined the situation stage; attention stage; appraisal stage; response stage. Different ER strategies are proposed to be used at different parts of this emotion generation sequence. For example, the suppression of an emotional expression is proposed to occur late in the emotion generation sequence (i.e., at the response stage) (Gross, 1999).

Extended Process Model

The *extended* process model (EPM) (Gross, 2015) of ER differs from the original process model in two clear ways. The EPM distinguishes 3 stages of the ER cycle which are embedded within the emotion generation sequence (Gross, 2015). These 3 stages are 1) identification of the need to regulate an emotional experience, 2) subsequent selection of an appropriate ER strategy, 3) implementation of the preferred strategy. The second difference is that effort is placed on describing the nature of the cybernetic system dynamics that arise as the second level valuation system iterates across time (Gross, 2015). To put this into context within the EPM, the first level valuation system is proposed to be the system that generates the emotional response; the second level valuation system is the ER iterative cycle. Here, the first level (i.e., the emotional response), is taken as the second level's informational input or cue. Then, identification of a need to regulate is considered before ER strategy selection and implementation takes place (Gross, 2015).

Early Models

Comparing the EPM to early stress- and coping-based models (e.g., Lazarus, 1966), these are considered to encapsulate a broader human experience than ER, and ‘coping’ may include non-emotional aspects, and be temporally broader than ER—which is postulated to occur iteratively over seconds or minutes (Gross, 1999). Similarly, the psychoanalytic study of emotions (e.g., Freud, 1926) in which the modern study of emotion and ER originated, did not place a specific focus on *how* positive and negative emotion may be up- or down-regulated (i.e., via specific ER strategies). Yet, this is a key focus of the EPM and related contemporary ER research.

Justification of the Extended Process Model

The EPM will inform the work that is presented in this thesis. The different stages in the ER cycle that are described within the EPM support the understanding of transdiagnostic ER difficulties across psychopathologies (Coulacoglou & Saklofske, 2017). Indeed, the aforementioned evidence from studies examining longitudinal associations between ER strategy use and broad psychopathology outcomes in adolescence suggests that deficits or difficulties in the identification, selection and implementation stages of the EPM may predict the development of psychiatric illness (e.g., Caviccioli et al., 2023). Hence, the EPM is a fundamental framework for understanding the transdiagnostic importance of ER, and subsequently its application to ER preventative intervention development (Coulacoglou & Saklofske, 2017).

Traditional ER-focused interventions such as dialectical behavioural therapy (DBT) (Linehan, 2015) targets features of distinct regulatory stages of the EPM to improve overall ER functioning. For example, acceptance-focused ER strategies, which are represented within the appraisal stage of the emotion generation system of the EPM are a core feature in the up-skilling involved in DBT treatment (Linehan, 2015).

Increasingly, novel ER interventions, including those that are delivered via digital modalities for children and adolescents, align with the EPM via the training of multiple ER strategies (e.g., attentional control, positive self-talk, deep breathing) across broad stages of the emotion generation process (Reynard et al., 2022). This is also in line with a body of research that has found that flexibility and variability in ER strategy use is a determinant of adaptive functioning and reduced negative affect as it may allow individuals to respond flexibly to diverse situational and contextual demands (e.g., Aldao et al., 2015; Blanke et al., 2020). Additionally, the evaluations of such interventions support the assertion that emotion generation and ER are distinct processes as outcome measures pertaining to emotional experience and ER ability have consistently been monitored separately to inform the development of efficacious digital ER interventions (Reynard et al., 2022).

Comprehensive Overview of the Extended Process Model of Emotion Regulation

The EPM is a conceptual framework of ER which posits that the ER process is iterative and begins with emotion generation, with subsequent acknowledgement and identification that the generated emotional experience requires regulation, in relation to a desired emotional goal (Gross, 2015). Emotion generation occurs within a first level valuation system through a sequential cycle—situation, attention, appraisal, and response (Gross, 2015; McRae & Gross, 2020). Here, an individual is posited to be in a particular *situation* or, is imagining a *situation* (e.g., standing with a group of peers at school), and they *attend* to certain feature(s) of the situation (e.g., two members of the group are whispering to each other and laughing). Further, the attended feature(s) are *appraised* in relation to extant emotional goal(s) (e.g., the individual interprets the whispering and laughing as negative and about them), and the individual's emotional *response* is experienced behaviourally, experientially, or physiologically (e.g., the individual starts to pull at their school bag straps, experiences worry, and feels their heart beating faster). The response(s) is then fed back into the sequential cycle, thereby creating a more complex situational starting point (Gross, 2015; McRae & Gross, 2020).

Embedded within the emotion generation system of the EPM is the second level valuation system, which uses the emotional response as input to select and implement an ER strategy (Gross, 2015). Gross proposes that several potential ER strategies are represented within the selection stage, within a perception sub-stage. Evaluation of these potential strategies takes place by considering available cognitive and physiological resources, and the intensity of the generated emotion that is to be regulated (Gross, 2015). There are five ER strategy families—these are conceptualised and identified by the point in the emotion generation sequence that they are first utilised (Gross, 2015). Specifically, ER strategy families are 1) situation selection *(situation part of emotion generation sequence)*, 2) situation modification *(situation part of emotion generation sequence)*, 3) attentional deployment *(attention part of emotion generation sequence)*, 4) cognitive change *(appraisal part of emotion generation sequence)*, 5) response modulation *(response part of emotion generation sequence)*, (Gross, 2015). See Table 1.1 for a breakdown of ER strategy families that are represented within the selection stage, example strategies and examples of their implementation.

Situation selection and situation modification focus on the manipulation of the situation (Gross, 2015). An example of a situation selection strategy is avoidance (i.e., completely avoiding engagement with the situation). An example of a situation modification strategy is direct request (i.e., purposefully asking for component(s) of the situation to be altered when already engaged). Attentional deployment focuses on the shifting or direction of attentional resources, for example via distraction (i.e., directing one's own or others attention away from emotionally evocative features of the situation, or to a different situation) (Gross, 2015). Cognitive change focuses on the evaluation of the attended features of the situation, either re-evaluating or purposefully not evaluating them, e.g., cognitive reappraisal (i.e., re-evaluating the situation or the emotional goal(s)) (Gross, 2015). Response modulation focuses on the manipulation of the emotional response, for example expressive suppression (i.e., refraining from outwardly exposing the emotional response) (Gross, 2015).

Table 1.1

The Extended Process Model of ER: ER strategy families, associated part of emotion generation sequence, example ER strategies and their implementation, adapted from McRae and Gross (2020)

Strategy families	Emotion generation sequence component	Strategy example represented in selection stage	Example of strategy implementation within implementation stage (in a school-based peer victimisation context)
Situation selection	Situation	Avoidance	Not engaging with emotional event (e.g., not going to a lesson at school)
Situation modification	Situation	Direct request	Doing something to influence an emotional event when in it (e.g., asking a teacher to do group work with a different group of peers)
Attentional deployment	Attention	Distraction	Guiding internal or external attention to non-emotional aspects of the event or to a different (non-emotional) situation entirely (e.g., focusing on schoolwork rather than what a peer is saying)
Cognitive change	Appraisal	Cognitive reappraisal	Reinterpreting the emotional event and/or your emotional goal(s) (e.g., reminding yourself that your peer picks on others also)

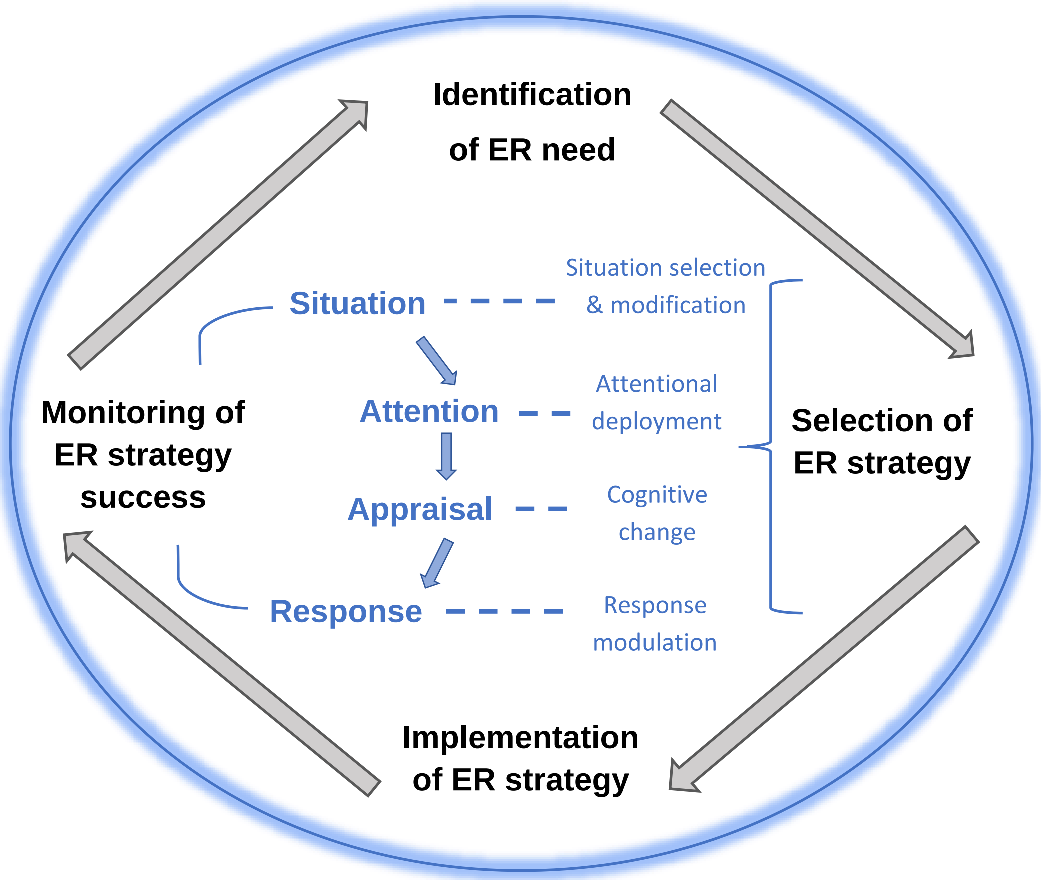
Response modulation	Response	Expressive suppression	Not outwardly showing internal emotional experience (e.g., not showing an angry face when your peer calls you a name)

Note. Identification of an ER need occurs prior to strategy selection; monitoring of ER strategy success occurs following strategy implementation.

Following the selection and implementation of an ER strategy, monitoring takes place (Gross, 2015; Sheppes et al., 2015). Here, it is postulated that the success of the ER strategy could be monitored by the individual asking themselves questions, for example, 'Is my heart rate slowing?', and by observing environmental cues, such as others' reactions (McRae & Gross, 2020; Thompson et al., 2019). Depending upon the outcome of monitoring, the use of the selected strategy may be halted, continued or a different strategy may be selected (McRae & Gross, 2020). See Figure 1.1 for a visual depiction of the different valuation components of the EPM that are embedded together to form an iterative, cybernetic system (Gross, 2015; McRae & Gross, 2020).

Figure 1.1

The Extended Process Model of Emotion Regulation, adapted from McRae & Gross, (2020).



Thesis Outline and Aims

Broadly, this thesis aims to add to the extant knowledge on the link between ER and negative social experiences in childhood and adolescence, and the development and application of digital preventative interventions for promoting adaptive ER in childhood and early adolescence. There are identified issues regarding engagement, acceptability, and feasibility in the emerging field of ER digital intervention in childhood and early adolescence. Appropriately addressing such issues in ER digital intervention is therefore vital for the field's progression.

The specific aims of the thesis are:

1. To examine the associations between cognitive reappraisal and expressive suppression ER strategy use, cognitive and affective empathy, and callous-unemotional traits with the experience of peer victimisation, in children and adolescents.
2. To synthesise the existing evidence on the efficacy, feasibility, and acceptability of ER digital interventions in children and early adolescents, using a systematic review and meta-analytic approach.
3. To detail the early interdisciplinary and international codesign of an early prototype-stage, universal ER psychoeducation smartphone game for early adolescents aged 10-12, called BRAINZ.

In this section, each subsequent chapter within the thesis will be outlined.

Chapter 2: Study 1

Chapter 2 aimed to highlight the importance of ER and related individual factors, through their link to negative social outcomes in childhood and adolescence. Informed by the Extended Process Model (Gross, 2015), and An Integrative Account of Empathy and Emotion Regulation (Thompson et al., 2019), and emerging research findings, a cross-sectional approach was taken to analyse correlations between ER strategy use, affective and cognitive empathy, callous-unemotional (CU) traits and the experience of peer victimisation. The data were taken from a large existing dataset, within a cross-national European study (FemNAT-CD; Freitag et al., 2018).

Moving on to an applied ER research approach, in which the heightened malleability of developing ER processes may be harnessed to train adaptive ER skills, chapters 3 and 4 present the extant novel ER digital intervention research, and an example of the international and collaborative development of one prototype ER digital game, respectively.

Chapter 3: Study 2

Chapter 3 (which is a published paper in the *Journal of Medical Internet Research, Serious Games*, see Reynard et al., 2022), used a systematic and meta-analytic approach to detail the ER digital intervention technologies that have been developed and evaluated in terms of their efficacy, feasibility, and acceptability, in child and early adolescent populations.

Chapter 4: Study 3

Chapter 4 furthered the thesis research via the practical application of the findings and recommendations presented in chapters 2 and 3. The aim of chapter 4 was to present the development of a novel game for training adaptive ER strategies in early adolescents, using the Medical Research Council (MRC) (Skivington et al., 2021) and Bevan Jones' and colleagues (Bevan Jones et al., 2018, 2020) guidelines for complex and digital intervention development.

Chapter 5: General Discussion

Following chapters 2, 3, 4, a final general discussion chapter (chapter 5), summarises and reflects upon the research conducted in the thesis. In addition, recommendations and considerations for future research are provided.

Methodological Justification

Here, the methodological decisions made in the thesis will be summarised and justified.

Overarching Approach

The research conducted and presented in this thesis represents a mixed methods design, owing to the use of both quantitative and qualitative approaches. As discussed by Creswell and Plano Clarke (2017), there are several mixed method typologies that are commonly employed across broad research domains (e.g., social sciences, nursing, evaluation, education). In this thesis, a convergent mixed methods approach, under the lens of pragmatism was employed. Such convergent designs are typically characterised by the separate collection and analysis of quantitative and qualitative data, and amalgamation of their complementary findings, to provide real-world solutions to extant issues (Creswell & Plano Clarke 2017). Further, pragmatism assumes that knowledge, as created via the complex interface between person and environment, is both constructed and based on mind-independent reality (Shan, 2021). Hence, this design was applied to ensure that a complete and holistic understanding of the complex research problem explored within the thesis could be achieved. Further, owing to the highly collaborative and applied nature of the later thesis work (chapter 4), it was appropriate to draw upon qualitative skills across the international interdisciplinary team (Creswell & Plano Clarke 2017).

Implementation

Quantitative data were explored within chapter 2 to understand the importance of adaptive ER strategies and potentially related personality traits and skills in childhood and adolescence, within the context of adverse social outcomes. In chapter 3, the efficacy, feasibility, and acceptability of various digital approaches to training adaptive ER strategies was synthesised quantitatively. Further, the systematic review component of chapter 3 incorporated a narrative synthesis-based qualitative approach (Popay et al., 2006) and was merged with the meta-analytic component to generate appropriate interpretations and recommendations. The quantitative and qualitative findings included in chapters 2 and 3 complemented and informed chapter 4—which was largely qualitative in nature. Here, the collaborative development of a prototype smartphone game to train adaptive ER strategies in early adolescents transitioning to secondary school was presented.

Chapter 2: Study 1

A cross-sectional approach was employed within chapter 2 as it permitted the concurrent assessment of associations between ER strategy use, cognitive and affective empathy, CU trait and peer victimisation self- and informant-report questionnaire data. Owing to the novel combination of variables that were examined in chapter 2, a cross-sectional approach was appropriate at this stage (Wang & Cheng, 2020). Spearman's rank zero order correlations were computed as data were largely non-normal and were continuous and count in nature. Due to the count nature and Poisson distribution of the peer victimisation (outcome) variable, a Poisson regression approach was taken to explore the shared variance of the variables (Huang & Cornell, 2012). Indeed, prior research examining peer victimisation data in children and adolescents commonly adopts the Poisson regression approach due to the nature of its distribution (Huang & Cornell, 2012). See chapter 2 for a detailed account of the research methodology.

Chapter 3: Study 2

A meta-analytic and systematic review approach was implemented within chapter 3. This approach has recently been used by researchers examining broader psychological targets for digital intervention in youth, such as depression (e.g., Hollis et al., 2017; Grist et al., 2017; Grist et al., 2019, Weisel et al., 2019). The meta-analytic and systematic review approach permitted the computation of summary effect estimates (as informed by Harrer et al. 2021) and narrative syntheses (as informed by Popay et al. 2006) from the included studies to determine the overall strength of efficacy, feasibility and acceptability evidence present within digital interventions for ER in children and early adolescents. A broad search strategy, including feasibility and acceptability data, was employed to capture a true picture of the state of ER digital interventions and their development across wide-ranging samples. Further, previous reviews highlighted above tended to focus on a wide age range, from childhood to early adulthood. This may not have permitted the focused understanding of the impact that digital tools may have within the critical period of normative ER development (i.e., from childhood through early adolescence) (Schriber & Guyer, 2016); and time of great interest in, and engagement with the internet (Crone & Konijin, 2018). Hence, the meta-analysis and systematic review presented in chapter 3 focused on child and early adolescent samples only. See chapter 3 for a detailed account of the research methodology.

Chapter 4: Study 3

A codesign approach was employed in chapter 4 to understand diverse users' needs and facilitate creative ideation in the development of a prototype ER smartphone game for early adolescents. There are extant issues around the definition and use of codesign and its related coproduction approach in the intervention development literature. A recent systematic scoping review concluded that rather than pursuing rigid definitions for the two approaches, applied researchers should consistently state, implement, and document their core principles and standards (Masterson et al., 2022). Indeed, codesign is a creative partnership between experts and various stakeholders which places ideation, empathy with users' needs, and prototype construction and evaluation as key components; coproduction places a focus on experts and users sharing power and building relationships, with users actively contributing to their own health outcomes (Bevan Jones et al., 2018, 2020; Robert et al., 2022; Masterton et al., 2022).

Chapter 4 followed the MRC's complex intervention development guidelines (Skivington et al., 2021) and Bevan Jones et al., (2018, 2020) phased approach for digital intervention development and associated documentation as they provided a comprehensive and clear framework to support evidence-based, context informed, empathic, user-centered and creative digital intervention development and documentation. In addition, it permitted existing issues within the ER digital intervention field around engagement, feasibility, and acceptability to be carefully considered. Further, forming part of the codesign phase, a content analysis was conducted on workshop data within chapter 4 (Morgan, 1993). This was appropriate as it permitted the reliable and rapid analysis of qualitative codesign data, allowing concise information to be shared and discussed with the interdisciplinary team in a timely manner. See chapter 4 for a detailed account of the research methodology.

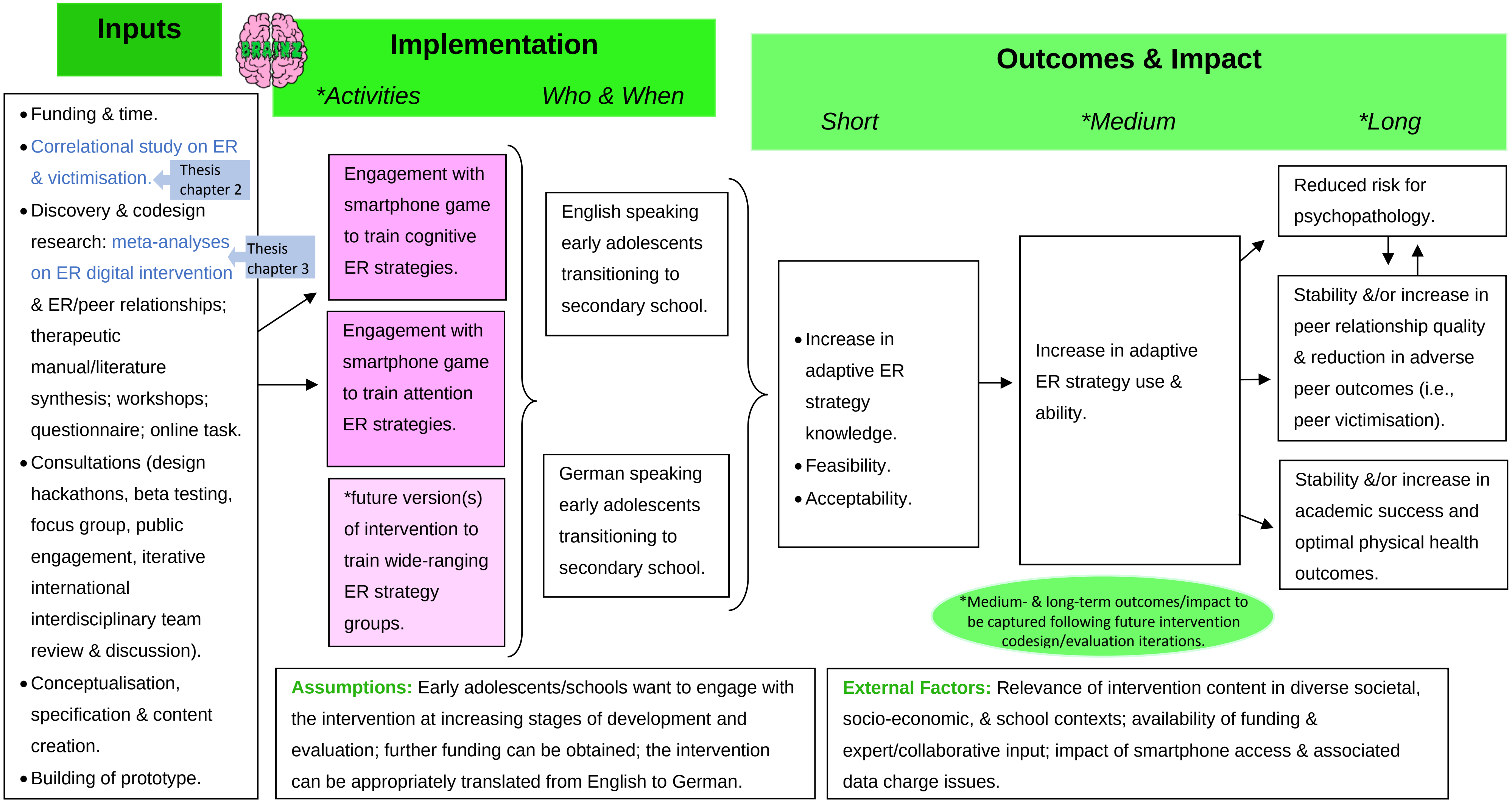
Logic Model

To provide further clarity regarding how the convergent mixed methods approach implemented within the thesis complemented and culminated in the creation of a prototype smartphone game intervention for ER in early adolescence, a logic model was created (Figure 1.2). As indicated by the MRC complex intervention development guidelines, process evaluation framework and related research, logic models provide a visual representation of the theory around how an intervention purports to produce outcomes, to inform its evaluation(s) (Moore et al., 2015; Skivington et al., 2021; Maini et al., 2018; Cook et al., 2018). Components of such logic models include 1) the inputs or resources that are required to inform and create an intervention, 2) the activities that form the intervention, how they are delivered, and in what sample(s), 3) specific outcomes or impact that arise because of the intervention, 4) contextual factors and researcher assumptions that may be linked to how the intervention functions, 5) relationships between the aforementioned components/mechanisms of impact. The creation of a logic model at this early stage of intervention development is appropriate as it can be used to facilitate clarity, inform evaluation(s), research questions and understanding of mechanistic action (Moore et al., 2015; Skivington et al., 2021). The logic model will be refined and adapted in the future, reflecting ongoing iterative codesign and evaluation.

Figure 1.2

Logic Model: Training adaptive ER in early adolescence with a smartphone game called BRAINZ.

Situation: ER is linked to several positive & negative psychosocial outcomes; early adolescence is a particularly suitable time to train ER; there are barriers to traditional ER intervention success; digital games are effective at training ER in early adolescence.



Note. Inputs derived from work detailed in chapter 4 unless otherwise indicated.

CHAPTER 2,

STUDY 1:

THE ASSOCIATION BETWEEN PEER VICTIMISATION, EMOTION REGULATION STRATEGIES, EMPATHY AND CALLOUS-UNEMOTIONAL TRAITS IN CHILDREN AND ADOLESCENTS

Abstract

Background: The experience of peer victimisation in childhood and adolescence has been linked to poor psychosocial outcomes across diverse samples. Previous research has highlighted the need to examine individual differences that may predict the experience of peer victimisation. Callous-unemotional traits have been shown to be positively associated with peer victimisation, however findings pertaining to empathy and emotion regulation strategies (specifically cognitive reappraisal, which is an adaptive strategy, and expressive suppression, which is a less adaptive strategy), have been mixed. Further, despite their potential interactive nature, these factors have not been concomitantly studied.

Objective: We examined the links between emotion regulation strategy use, cognitive and affective empathy, callous-unemotional traits, and peer victimisation frequency in a large European multi-site study.

Methods: Cross-sectional self- and parent-report data from 969 children and adolescents (61% female) aged 9-18 years were analysed.

Results: Zero-order correlations revealed significant, albeit small, negative associations between cognitive reappraisal and peer victimisation frequency ($r(967) = -.08$, $p = .02$), and cognitive empathy and peer victimisation frequency ($r(967) = -.21$, $p = <.001$). Further, significant, small, positive associations were found between expressive suppression and peer victimisation frequency ($r(967) = .12$, $p = <.001$), and callous-unemotional traits and peer victimisation frequency ($r(967) = .28$, $p = <.001$).

Conclusion: Here we identify the need to train ER and related factors universally in childhood and adolescence to address the burden of peer victimisation. Strengths of this study focus on the use of a large, broad, and well-characterised sample, while limitations focus on the cross-sectional design. Future research should investigate causal associations between the variables to identify directions of effects and potential moderating and mediating mechanisms to inform future preventative efforts that target diverse child and adolescent samples.

Adolescence is a critical period for social development, in which increasing time is spent with peers, and sensitivity to social feedback is heightened (Schweizer et al., 2020). Positive social input, such as high-quality peer relationships, may promote good psychological functioning across adolescence (van Harmelen et al., 2017; Schriber & Guyer, 2016). Specifically, perceived peer quality, quantity and availability, is associated with psychosocial resilience both concurrently and longitudinally (van Harmelen et al., 2017). The experience of negative social input, such as peer victimisation, may result in poor psychological functioning and mental health (Lamblin et al., 2017; Stewart-Tufescu et al., 2021). Peer victimisation in childhood and adolescence, defined as exposure to intentional harm by one's peers (Graham & Bellmore, 2007; Herd & Kim-Spoon, 2021), occurs at such high prevalence (30.5% within a 30-day period), that it may be considered a global public health problem (Biswas et al., 2020; Pengpid & Peltzer, 2019). Individual differences in personality traits and psychological coping mechanisms may explain why victimisation is experienced more frequently in some children and adolescents (e.g., Chow et al., 2022; Herd & Kim-Spoon, 2021; Pengpid & Peltzer, 2019)—thus, by examining how developing affective and cognitive skills and personality traits relate to concurrent victimisation, recommendations for preventative intervention targets may be made.

ER and Victimisation

Consistent with the Extended Process Model, we define emotion regulation (ER) as a multimodal construct, in which the need to regulate an emotional experience is identified, and ER strategies are selected and monitored to achieve a desired emotional goal (Gross, 2015; McRae & Gross, 2020; Sheppes et al., 2015). Importantly, prefrontal neural networks implicated in ER undergo protracted refinement through adolescence into early adulthood, and this process is impacted through social input (Adrian et al., 2019; Thompson, 2011). Given the sensitivity to social feedback and increasing reliance on often-unstable friendships in adolescence (Schweizer et al., 2020), it is unsurprising that individual differences in ER appear to be related to peer victimisation (Herd & Kim-Spoon, 2021). Specifically, a recent systematic review of cross-sectional and longitudinal data shows that good ER is associated with a reduced risk of experiencing peer victimisation in adolescence (Herd & Kim-Spoon, 2021).

However, the link between victimisation in adolescence and specific ER strategies is less clear. ER consists of specific adaptive and maladaptive cognitive, attentional and behavioural strategies (McRae & Gross, 2020). The habitual use of two such strategies—cognitive reappraisal (*an adaptive strategy whereby the meaning of an emotion-eliciting event is reinterpreted*) and expressive suppression (*considered a less adaptive strategy whereby the experienced emotion is hidden from others*) have recently been examined in relation to victimisation in adolescence, but findings have been mixed. For example, evidence suggests that expressive suppression may be prospectively associated with increased peer victimisation in adolescent males, but not females (Chervonsky & Hunt, 2019). However, Larsen et al. (2012) observed no such prospective association in an adolescent sample. Using a cross-sectional approach, Vranjes et al. (2018) reported associations between ER strategy use and *cyber*-victimisation in adolescents. Specifically, being *cyber*-victimised is associated with increased use of expressive suppression and decreased use of cognitive reappraisal. However, Chervonsky and Hunt (2019) reported no association between cognitive reappraisal and victimisation either cross-sectionally or longitudinally in an adolescent sample. Finally, cognitive reappraisal has been shown to successfully reduce emotional reactivity brought about by victimisation in controlled experimental settings (Platt et al., 2015; Miller et al., 2019), and expressive suppression has been shown to be positively associated with maladaptive coping in a school-based peer victimisation context (Gardner et al., 2017).

The mixed findings described above may be attributed to a number of methodological issues and inconsistences across studies. For example, cyber-victimisation, as examined by Vranjes et al. (2018), is different in nature to traditional peer victimisation (e.g., Thomas et al., 2015; Dooley et al., 2009). In addition, differences in study design related to sample age range, potential impact of sex, gender bias, and measurement across studies likely influenced the reported findings. Crucially, however, as we discuss below, other skills and traits related to victimisation may influence the association between ER strategy use and victimisation. Yet, to our knowledge there has been no research on the association between ER strategies and victimisation that also examines linked affective and cognitive skills and personality traits in adolescence. We will firstly consider empathy.

Empathy, Victimisation and ER

Empathy is a complex social construct that is often compartmentalised into two sub-domains; cognitive empathy—*the ability to understand the emotions of others*, and affective empathy— *the ability to experience the emotions of others* (Zych et al., 2019; Weisz et al., 2021; Dadds et al., 2008). Previous work has highlighted the association between empathy and differences in social adjustment in adolescence, including the quality of peer relationships (Deković & Gerris, 1994), social competences (Saarni, 1990) and externalising behaviours (Barr & Higgins-D'Alessandro, 2007). However, in a recent meta-analysis, Zych and colleagues (2019) reported non-significant associations between cognitive and affective empathy and the experience of peer victimisation.

Conceptual and empirical work appears to demonstrate a link between empathy and ER. Incorporating the Extended Process Model of ER, Thompson and colleagues (2019) posit an iterative and context-dependent circular framework in which an 'observer' empathises with an 'other'. They argue that attentional ER strategies (e.g., distraction) implemented earlier (at a *perceptual stage*) rely on concrete empathy cues (e.g., facial expression of the other) and cognitive ER strategies (e.g., cognitive reappraisal) implemented later (at a *cognitive processes stage*) rely on abstract empathy cues (e.g., prior knowledge about the other). Use of modulatory ER strategies (e.g., expressive suppression) occurs at the last stage of the process (coined the *self-emotion stage*); sometimes following automatic mimicry or embodiment mechanisms brought about by the *perceived* emotion of the other (see Thompson et al., 2019, for a comprehensive account).

Supporting Thompson's framework, cognitive neuroscientific evidence suggests the existence of shared neural networks between ER processes and related empathic processes in adolescence (e.g., McRae et al., 2012; Ferschmann et al., 2021; Desatnik et al., 2021). For example, medial prefrontal cortex (mPFC) activation—which is associated with mental state attribution (i.e., cognitive empathy), has been reported during successful cognitive reappraisal in a pictorial computer-based task (McRae et al., 2012). In addition, behavioural studies suggest a link between ER strategy use and empathy. For example, habitual use of expressive suppression is negatively associated with self-reported propensity to experience others' emotions (Lockwood et al., 2014), whereas cognitive reappraisal is positively associated with this propensity (Lockwood et al., 2014; Tully et al., 2016; Powell, 2018). Given the theoretical and experimental demonstration of a close association between ER strategy use and empathy, it is suggested that empathy may influence victimisation by influencing ER strategy use.

CU Traits, Victimisation, ER and Empathy

Callous-unemotional (CU) traits are conceptualised within psychopathic diagnostic models as a set of personality traits indexing an insensitive or cold use of others, lack of remorse and diminished or shallow emotional reactivity (Despoti et al., 2021; Waller et al., 2020). Importantly, CU traits may be related to social adjustment in adolescence (Fanti et al., 2017), such as, for example, social support from peers. The trajectories of CU traits across adolescence have indeed been shown to relate to self-report measures of peer social support—adolescents who experience increasing CU traits report less peer social support than those who experience low and stable CU traits (Fanti et al., 2017). Further, a small, significant positive association between CU traits and victimisation has been identified in a meta-analysis (Zych et al., 2019). It should be noted, however, that further recent research, including a comprehensive cross-national study, found no such association (Fanti et al., 2018; Despoti et al., 2021). To address the inconsistency between recent cross-national research and meta-analytic findings, the relationship between CU traits and the experience of peer victimisation warrants further examination using a cross-national approach.

Considering ER, emerging work suggests that the use of expressive suppression may play a key role in the development of CU traits in children who have experienced severe adverse events, such as maltreatment (Bennett & Kerig, 2014; Craig & Moretti, 2019; Ezpeleta et al., 2017). Coined the ‘secondary variant’ of CU traits, conceptual accounts propose that such negative social input may give rise to emotional detachment as a coping mechanism (e.g., Ford et al., 2006). Supporting this, Bennett and Kerig (2014) reported significantly greater non-acceptance and numbing of emotional experiences in adolescents with CU traits who had experienced trauma vs. those who had not experienced trauma.

Further, a growing body of literature has examined the association between CU traits and affective and cognitive empathy in children and adolescents. Evidence suggests a negative association between the cognitive and affective components of empathy and CU traits (e.g., Georgiou et al., 2019; Jones et al., 2010; Waller et al., 2015), with a significantly stronger association between affective empathy and CU traits than cognitive empathy and CU traits (Jones et al., 2010; Waller et al., 2015). Moreover, a recent meta-analysis reported moderate-to-large negative associations between empathy and CU traits, from both self- and informant-reports (Waller et al., 2020). However, in contrast to earlier findings, the association between CU traits and *cognitive* empathy was stronger than the association between CU traits and affective empathy (Waller et al., 2020). Although this was evident only in informant-report, and self-report in young children (Waller et al., 2020).

To summarise, CU traits may be directly related to peer victimisation in children and adolescents; or potentially be indirectly related through their association with reduced empathy or developmental link to altered ER strategy use.

Current Research

ER strategy use, empathy and CU traits may play a role in the experience of victimisation in adolescence and appear to be related to one another. Indeed, a recent school-based preventative intervention program demonstrated decreased CU traits and improved peer relations in adolescents following the inclusion of ER strategy and cognitive and affective empathy components (Kyranides et al., 2018). However, the evidence to date remains mixed and the potential dimensional, interactive nature of the variables has not been examined. Hence, to inform the development of effective preventative intervention strategies, it is valuable to further explore the experience of peer victimisation in children and adolescence by investigating its association with ER strategy use, cognitive and affective empathy and CU traits. Here, we will examine the associations between ER strategy use, cognitive and affective empathy and callous-unemotional traits with the experience of peer victimisation frequency, and their potential interactive nature, using a European multi-site sample of children and adolescents aged between 9-18 years from a study focusing on sex differences in Conduct Disorder (CD).

Research Questions and Hypotheses

Due to the unclear nature of the association between ER strategy use and victimisation frequency, and empathy and victimisation frequency in children and adolescents, we refrain from positing specific hypotheses; rather, we formulated the following research questions:

1. Is expressive suppression use associated with the frequency of peer victimisation in children and adolescents?
2. Is cognitive reappraisal use associated with the frequency of peer victimisation?
3. Is cognitive empathy associated with the frequency of peer victimisation?
4. Is affective empathy associated with the frequency of peer victimisation?
5. To what extent is expressive suppression use associated with victimisation frequency and is this association moderated by CU traits and cognitive and affective empathy?
6. To what extent is cognitive reappraisal use associated with victimisation frequency and is this association moderated by CU traits and cognitive and affective empathy?

Further, in line with the recent meta-analysis documenting an association between CU traits and victimisation (Zych et al., 2019), we formulated the following hypothesis:

- There will be a significant, positive correlation between CU traits and victimisation frequency.

Methods

Participant Recruitment and Eligibility Criteria

Data collected from the FemNAT-CD sample between 2014 to 2018 were acquired in February 2021 for the current study (Freitag et al., 2018). Recruitment of female and male participants aged 9-18 was conducted across 10 European sites via healthcare providers and mental health services, mainstream and special schools, youth and community groups, youth offending services, and by word-of-mouth. Participating countries included Germany; UK; Switzerland; Ireland; Spain; Hungary; Greece. Inclusion in the FemNAT-CD sample was determined by in-person clinical interview; participants were excluded if they had a diagnosis of a learning disability (IQ<70), current or past diagnosis of psychosis, autism spectrum disorders (ASD), genetic disorder or neurological disorder. In addition, typically developing participants were required to have no current mental health disorders or history of bipolar disorder, externalising disorder, or manic episodes. Monetary compensation or an equivalent voucher-based compensation were provided to all participants as approved by the appropriate ethics committees. Of the full FemNAT-CD child and adolescent sample (N = 1,743), 969 had complete data for the measures of victimisation, ER, empathy and CU traits, and were included in the analyses.

Procedure

Written informed assent and consent was obtained from participants age <16 and legal guardians, respectively. If it was not possible to gain consent from a participant’s legal guardian, the participant could only be included in the study if their age met the ethical requirements in the respective country (16 or over in Switzerland and the UK, 18 or over in all other countries). Before completing the measures in-person, participants were given the opportunity to ask questions to a researcher and both legal guardians and participants were informed that they could withdraw from the study at any point. Local ethics committees at each site approved the study protocol. Using a cross-sectional approach, data from the questionnaires described below were collected at one time point from participant or guardian informants.

Questionnaire Measures

Outcome Variable

Social and Health Assessment (SAHA), Bullying Subscale. The SAHA, developed by Richters and Saltzmann (1990), and amended by Schwab-Stone et al. (1995; 1999) and Ruchkin et al. (2004) is a 182-item school, community and risk-behaviour self-report measure in children and adolescents (Weissberg et al., 1991). Only the bullying subscale (9-items), which measures the frequency of peer victimisation over a school year, was used in the present study. Peer victimisation components included in the items are: *physical victimisation* (e.g., ‘Other kids … hurt me physically in some way’), *social manipulation* (e.g., ‘…tried to get me into trouble with my friends’), *verbal victimisation* (e.g., ‘…called me names or swore at me’) and *attacks on property* (e.g., ‘…tried to break or damage something of mine’). Items are rated on a 4-point Likert scale (*1 = ‘not at all’, 2 = ‘once’, 3 = ‘two to three times’, 4 = ‘four or more times’*). Total scores range from 9 to 36, with higher scores reflecting more frequent victimisation and lower scores reflecting less frequent victimisation. Previous cross-sectional research in a large universal sample of adolescents has demonstrated high internal consistency (α = .84) (Stickley et al., 2013). Cronbach’s alpha in the present sample (bullying α = .88) indicated high internal consistency.

Predictor Variables

Emotion Regulation Questionnaire (ERQ). The ERQ (Gross & John, 2003) is a 10-item self-report ER measure in children and adolescents which assesses habitual use of cognitive reappraisal (6-items) (e.g., ‘I control my emotions by changing the way I think about the situation I’m in’), and expressive suppression (4-items) (e.g., ‘I control my emotions by not expressing them’). Items are rated on a 7-point Likert scale from 1 (*strongly disagree*) to

7 (*strongly agree*). Total scores for the cognitive reappraisal scale range from 6 to 42, with higher scores reflecting greater habitual use of cognitive reappraisal and lower scores reflecting less habitual use of cognitive reappraisal. Total scores for the expressive suppression scale range from 4 to 28, with higher scores reflecting greater habitual use of expressive suppression and lower scores reflecting less habitual use of expressive suppression. Previous research in young adult samples indicates that the ERQ has high internal consistency (cognitive reappraisal α = .79, expressive suppression α = .73) and 3-month test–retest reliability (*r* = .69 for both scales), as well as good discriminant and convergent validity (Gross & John, 2003; John & Gross, 2004). Recent research examining the psychometric properties of the ERQ in universal European adolescent samples has demonstrated acceptable internal consistency (cognitive reappraisal *McDonalds omega* = .78, expressive suppression *McDonalds omega* = .75) and test–retest reliability (cognitive reappraisal *r* = .55, expressive suppression *r* = .44), and acceptable criterion validity in both scales (Gómez-Ortiz et al., 2016). Cronbach's alpha in the present sample (cognitive reappraisal α = .80, expressive suppression α = .68) indicated high and adequate internal consistency, respectively.

Griffith Empathy Measure (GEM). The GEM (Dadds et al., 2008), adapted from the Bryant Index of Empathy (Bryant, 1982), is a 23-item parent-report empathy measure in children and adolescents, which assesses cognitive empathy (6-items) (e.g., 'My child can't understand why other people get upset'), and affective empathy (9-items) (e.g., 'My child cries or gets upset when seeing another child cry'). Items are rated on a 9-point Likert scale from -4 (*strongly disagree*) to 4 (*strongly agree*). Items 3, 6, 13, 17, 20, 21 and 23 are reverse coded. Total scores for the cognitive empathy scale range from -24 to 24, with higher scores reflecting more displays of empathy according to a caregiver, and lower scores reflecting less displays of empathy according to a caregiver. Total scores for the affective empathy scale range from -36 to 36, with higher scores reflecting more displays of empathy according to a caregiver, and lower scores reflecting less displays of empathy according to a caregiver. The cognitive empathy and affective empathy subscales were used in the present study. Adequate discriminative validity and internal consistency (cognitive empathy α = .62, affective empathy α = .83) of the GEM was reported by Dadds et al. (2008). Cronbach's alphas in the present sample (cognitive empathy α = .75, affective empathy α = .79) indicated adequate internal consistency.

Inventory of Callous-Unemotional Traits, Parent-Report Version (ICU). The ICU (Essau et al., 2006) is a 24-item parent-report CU traits measure in children and adolescents, with a total score and three subscales (unemotional, uncaring and callous). Items are rated on a 4-point Likert scale from 0 (*not at all true*) to 3 (*definitely true*). Total scores range from 0 to 72, with higher scores reflecting greater CU traits, according to a caregiver, and lower scores reflecting lower CU traits, according to a caregiver. The overall total score was used in the present study. Validity and reliability of the informant report versions of the ICU in wide-ranging child and adolescent samples are demonstrated in a recent meta-analysis (Cardinale & Marsh, 2020)—external validity and internal consistency (total score α = .87) were acceptable, and greater than those reported from the self-report ICU. Cronbach's alpha in the present sample (total score α = .92; callousness α = .85; unemotional α = .76; uncaring α = .88) indicated high internal consistency.

Imputation of Missing Data

Missing data from the ICU parent-report and ERQ measures were imputed based on the full FemNAT-CD sample by Statisticians at the Institute of Medical Biometry and Statistics (a member of the FemNAT-CD consortium). As the bullying subscale of the SAHA and cognitive empathy and affective empathy subscales of the GEM were not completed in all participants (n = 1,014 out of N = 1,743), only those who completed these measures were included in the analyses. Cases with missing items (n = 45) were excluded, giving a final total of 969 cases in the present study. The full procedure is detailed in Appendix 1, "Imputation of Missing Data."

Data Analysis

Data preparation and analyses were conducted in Microsoft Excel and R (R Core Team, 2017). R packages used included ggplot2, version 3.3.3 (Wickham, 2016), tidyverse, version 1.3.0 (Wickham et al., 2019), data.table, version 1.14.6 (Dowle et al., 2019), corrplot, version 0.92 (Wei & Simko, 2021), dplyr, version 1.0.8 (Wickham et al., 2022), car, version 3 (Fox & Weisberg, 2019) and Hmsic, version 4 (Harrell, 2021).

Descriptive Statistics and Frequency Analysis

Examination of the distribution of the variables was conducted visually via histograms and QQ-plots, and statistically via the Shapiro-Wilks Normality Test. Data for all variables were not normally distributed (see Appendix 1, "Shapiro-Wilks Normality Test and Normality Plots"). Frequency counts and sample mean descriptive analyses were conducted within the cognitive reappraisal, expressive suppression, cognitive empathy, affective empathy, CU traits and victimisation variables from the FemNAT-CD sample. Prevalence rates of peer victimisation in the current sample were examined in line with recent global victimisation research (Biswas et al., 2020); responses were dichotomised to enable the classification of participants who had reported being victimised at least once as being *exposed to peer victimisation*.

Correlation Analysis

To test the hypothesis, research questions one, two, three and four, and examine the zero order correlations between cognitive reappraisal, expressive suppression, cognitive empathy, affective empathy, CU trait variables and victimisation, Spearman's rank correlations, associated scatterplots and a correlation coefficient matrix were used. The means and standard deviations for each variable were also included within the correlation matrix. The associated correlogram is presented in Appendix 1 "Correlogram". In reference to the general population, as the FemNAT-CD research consortium focused on the examination of CD in female adolescents, there is an over-representation of this population in the present study. Hence, for transparency, we also present post-hoc zero order correlational analyses split by sex (female/male) and group (CD diagnosis/typically developing control). Alpha was set at 0.05.

Poisson Regression Analysis

To address research questions five and six, two hierarchical regression models, each with three steps were planned to explain the shared variance between the variables of interest. Due to the positively skewed Poisson distribution and frequency count nature of the victimisation outcome variable, Poisson regression analyses were used (Huang & Cornell, 2012). As the variance (average of the squared differences from the mean) was greater than the mean in the victimisation outcome variable, it was likely that over-dispersion would occur in the Poisson models. One of the key assumptions for Poisson regression is equidispersion (the mean and variance of the distribution are equal) (Huang & Cornell, 2012); hence, a quasi-Poisson approach was used to attempt to address over-dispersion.

The first step in both regression models included only demographic predictors (sex, group, age), with victimisation as the outcome variable. The categorical variables sex and group were dummy coded. The second step in the first model included the addition of cognitive reappraisal as a predictor variable, and the second step in the second model included the addition of expressive suppression as a predictor variable. Cognitive reappraisal and expressive suppression are distinct ER strategies and correlate minimally, hence conducting two separate victimisation models was appropriate. The third step in both models included the addition of cognitive empathy, affective empathy, and CU traits as moderators between each ER strategy variable and victimisation. To create the interaction terms, continuous variables (expressive suppression, cognitive reappraisal and cognitive empathy, affective empathy and CU traits) were mean-centered in their respective models and multiplied.

Results

Descriptive Statistics and Frequency Analysis

Participants (female *n* = 592, male *n* = 377) were aged 9-18 years (*M* = 14.02, *SD* = 2.46). 43% (*n* = 413) were diagnosed with CD and 57% (*n* = 556) were typically developing controls. Across the whole sample, 73% of participants were exposed to peer victimisation over a school year. When considering only the CD group, this was 84%, and within the typically developing group, this was 65%. Finally, 72% of female and 75% of male participants were exposed to peer victimisation. A comprehensive table detailing each measures descriptive statistics is provided in Appendix 1, “Descriptive Statistics”.

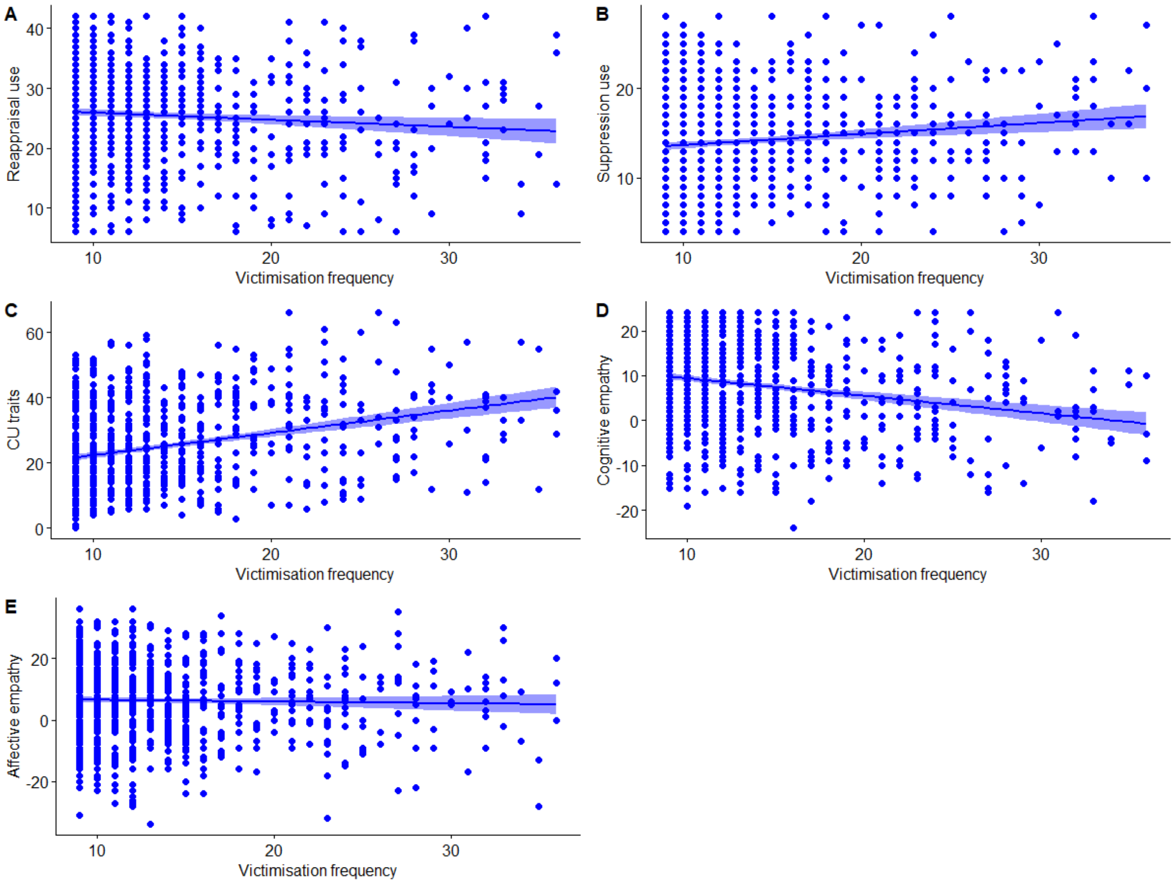
Correlation Analysis

Visual inspection of scatterplots indicated some degree of linear monotonic correlation between the variables (Figure 2.1). Spearman’s rank correlation analyses revealed small, significant zero order correlations between victimisation and expressive suppression, cognitive reappraisal, cognitive empathy, and CU traits (Table 2.1). Specifically, there were significant, small, positive correlations between victimisation frequency and both expressive suppression use and CU traits score. Further, there were significant, small, negative correlations between victimisation frequency and both cognitive reappraisal use and cognitive empathy score. However, there was no significant correlation between victimisation frequency and affective empathy score, ($r(968) = -.02$, $p = .62$).

In addition, there were significant correlations between CU traits, emotion regulation strategies and both cognitive and affective empathy. Specifically, there were significant, small to moderate, negative correlations between CU traits score and cognitive reappraisal, cognitive empathy and affective empathy, and a significant, small positive correlation between CU traits score and expressive suppression. Further, there was a significant, small, negative correlation between expressive suppression and cognitive empathy, and a significant, small, positive correlation between cognitive reappraisal and cognitive empathy (Table 2.1).

Figure 2.1

Spearman's rank scatterplots showing linear-monotonic associations between variables.



Note. Plot A shows the negative association between victimisation frequency and cognitive reappraisal strategy use. Plot B shows the positive association between victimisation frequency and expressive suppression strategy use. Plot C shows the positive association between victimisation frequency and CU traits. Plot D shows the negative association between victimisation frequency and cognitive empathy. Plot E shows no association between victimisation frequency and affective empathy.

Table 2.1

Correlation coefficient matrix with means (M) and standard deviations (SD) for victimisation, cognitive reappraisal, expressive suppression, cognitive empathy, affective empathy, and CU traits (N = 969)

	M	SD	Vict	Cog reap	Exp sup	Cog emp	Aff emp	CU traits
Vict	13.47	5.63	1					
Cog reap	25.49	7.86	-.08*	1				
Exp sup	14.08	5.31	.12***	.09**	1			
Cog emp	8.05	9.87	-.21***	.12***	-.15***	1		
Aff emp	6.29	12.17	-.02	.06	-.06	.06	1	
CU traits	24.74	12.96	.28***	-.22***	.20***	-.57***	-.26***	1

*p < .05. **p < .01. ***p < .001. Two–tailed.

Note. Vict=victimisation; Cog reap=cognitive reappraisal; Exp sup=expressive suppression; Cog emp=cognitive empathy; Aff emp=affective empathy.

Post-Hoc Correlation Analysis

Splitting the correlation matrix based on sex revealed similar patterns of small, significant zero order correlations between victimisation and CU traits, cognitive empathy, expressive suppression and cognitive reappraisal to those observed across the whole sample (Table 2.2). However, there was no significant correlation between cognitive reappraisal and victimisation in males, and the significant correlation between CU traits and victimisation was stronger for females than males.

Splitting the correlation matrix based on group revealed a small, significant zero order correlation between CU traits and victimisation in the typically developing group only (Table 2.3). No other variables correlated with victimisation in both the typically developing group and CD group. In addition, patterns of significant, small to moderate zero order correlations were observed in both groups between cognitive and affective empathy and CU traits—as observed across the whole sample. However, significant zero order correlations between cognitive and affective empathy and expressive suppression and cognitive reappraisal, and between CU traits and expressive suppression and cognitive reappraisal, were only evident in the typically developing group.

Table 2.2

Correlation coefficient matrix split by sex for victimisation, cognitive reappraisal, expressive suppression, cognitive empathy, affective empathy, and CU traits (female upper split, male lower split) (female n = 592; male n = 377)

	Vict	Cog reap	Exp sup	Cog emp	Aff emp	CU traits
Vict	**1**	-.12**	.12**	-.25***	-.02	.34***
Cog reap	-.01	**1**	.04	.12**	.01	-.22***
Exp sup	.11*	.15**	**1**	-.15***	-.05	.20***
Cog emp	-.14**	.13**	-.13**	**1**	.08	-.56***
Aff emp	0	.14**	-.02	-.01	**1**	-.27***
CU traits	.18***	-.23***	.17***	-.58***	-.21***	**1**

*p < .05. **p < .01. ***p < .001. Two–tailed.

Note. Vict=victimisation; Cog reap=cognitive reappraisal; Exp sup=expressive suppression; Cog emp=cognitive empathy; Aff emp=affective empathy.

Table 2.3

Correlation coefficient matrix split by group for victimisation, cognitive reappraisal, expressive suppression, cognitive empathy, affective empathy, and CU traits (typically developing upper split, Conduct Disorder diagnosis lower split) (typically developing n = 556; Conduct Disorder diagnosis n = 413)

	Vict	Cog reap	Exp sup	Cog emp	Aff emp	CU traits
Vict	**1**	.03	.03	-.07	.02	.09*
Cog reap	0	**1**	.09*	.03	.10*	-.06
Exp sup	.07	.19***	**1**	-.13**	-.08	.14***
Cog emp	-.07	0	-.03	**1**	.04	-.43***
Aff emp	.01	-.04	0	0	**1**	-.34***
CU traits	.01	-.04	.05	-.34***	-.22***	**1**

*p < .05. **p < .01. ***p < .001. Two–tailed.

Note. Vict=victimisation; Cog reap=cognitive reappraisal; Exp sup=expressive suppression; Cog emp=cognitive empathy; Aff emp=affective empathy.

Quasi-Poisson Hierarchical Regression Analysis

Due to the violation of necessary equidispersion, and normality and linearity of model residuals assumptions, it was not possible to conduct the planned Quasi-Poisson hierarchical regression analyses. Specifically, over-dispersion (the mean and variance of the distribution in a given variable are not equal) was indicated in the peer victimisation outcome variable. Although a quasi-Poisson approach was used to attempt to address this, division of the residual deviance values by the degrees of freedom in the resulting models revealed quotients greater than 1. Further, residual QQ plots, model fit residual plots and residual normal distribution plots revealed some inhomogeneity (heteroscedasticity), non-normality and non-linearity in the models (see Appendix 1, “Quasi-Poisson Regression Plots”).

Discussion

This study addressed peer victimisation in children and adolescents by investigating the factors associated with risk for peer victimisation, including habitual ER strategy use, cognitive and affective empathy, and CU traits. We first investigated the association between victimisation frequency and habitual use of ER strategies—greater use of expressive suppression was associated with higher frequency of peer victimisation, and greater use of cognitive reappraisal was associated with lower frequency of peer victimisation. Next, we investigated the association between victimisation frequency and cognitive and affective empathy. Here, there was a negative association between cognitive empathy and peer victimisation, but no significant association for affective empathy. Next, we investigated the association between victimisation frequency and CU traits, hypothesising that there would be a significant, positive correlation between victimisation frequency and CU traits. Supporting this, we found that increased CU traits occurs concurrently with the increased frequency of peer victimisation. Finally, we aimed to explore the potential moderating role of CU traits and cognitive and affective empathy on the association between both expressive suppression and victimisation frequency, and cognitive reappraisal and victimisation frequency, using quasi-Poisson regression. However, this was unsuccessful. Although, it was possible to explore the relationships between CU traits, ER strategies and cognitive and affective empathy and there were significant correlations between many of these variables. Here, we discuss the key findings and provide recommendations for future research.

Emotion Regulation and Victimisation Frequency

Our findings show that in a European child and adolescent sample, ER strategies are associated with the frequency of peer victimisation. This finding, from a highly powered, multi-site European sample, may begin to offer some clarity on the previous mixed findings pertaining to the cross-sectional link between ER strategy use and peer victimisation in children and adolescents.

Consistent with existing research and models of ER, in which cognitive reappraisal in childhood and adolescence is considered more adaptive than expressive suppression (e.g., Carthy et al., 2010; McRae & Gross, 2020), we show that cognitive reappraisal and expressive suppression were differentially related to the adverse social experience of peer victimisation. That is, cognitive reappraisal shared a negative association, and expressive suppression shared a positive association with peer victimisation. This suggests that the habitual use of less adaptive ER strategies is associated with increased peer victimisation in children and adolescents within a school year. However, it is important to consider that the success of the ER strategies is unknown in the current study (i.e., a strategy may be used habitually; however, the ability to reach an emotional goal via the successful implementation of that strategy is not measured by the ERQ). Hence, this somewhat limits the ability to generate highly meaningful inferences in children and adolescents when using the ERQ. Precisely, the *success* of an ER strategy may be more relevant for an individual's emotional experience and importantly, necessary interventions. Indeed, despite the increasing awareness of the role of ER in adaptive functioning across the lifespan and need for early intervention in this domain (e.g., Hoffmann et al., 2020; Durlak et al., 2011; England-Mason & Gonzalez, 2020), there are limited psychometrically sound ER measures for youth (e.g., Zhou et al., 2020). To further the field, a more nuanced approach to understanding the link between ER strategy use and victimisation is required, by considering in addition, the influential role of ER strategy success, and cognitive and affective empathy and CU traits. To support this recommendation, researchers must create valid ER measures for child and adolescent samples that permit the measurement of all stages of the Extended Process Model (Gross, 2015).

It is important to note that the correlations between ER strategy use and peer victimisation were small, suggesting that other important factors are at play. Although, it is also important to acknowledge that small effects are common and expected in psychological research, particularly when assessing individual differences (e.g., Gignac & Szodorai, 2016). Hence, early, preventative universal interventions that focus on training adaptive ER strategy use may also benefit from addressing related factors, which similarly contribute to the global burden of psychosocial issues in childhood and adolescence, and beyond (Lamblin et al., 2017; Stewart-Tufescu et al., 2021).

CU Traits and Victimisation Frequency

Supporting the extant meta-analytic evidence on victimisation in youth (Zych et al., 2019), and empirical work reporting poor social support in youths with increasing CU trait trajectories (e.g., Fanti et al., 2017), CU traits were positively correlated with victimisation frequency in the current study. This was the strongest correlation (r = .28) observed between the individual difference variables and peer victimisation. Indeed, recent longitudinal research has indicated that adolescents who demonstrate high CU traits experience greater verbal and physical peer victimisation (Fontaine et al., 2018). The association between CU traits and peer victimisation is likely due to aggressive behavioural tendencies among youth with CU traits (Despoti et al., 2021), and deviant peer affiliation (Barker & Salekin, 2012). Thus, involvement with deviant peers accompanied by aggression may ultimately provoke experiences of victimisation. These findings provide further evidence for the association between CU traits and the experience of victimisation, and in addition, the need to target both ER, and CU traits to address the burden of peer victimisation.

Cognitive and Affective Empathy and Victimisation Frequency

In contrast to recent meta-analytic findings (Zych et al., 2019), cognitive empathy was negatively associated with peer victimisation. Indeed, the ability to understand peers feelings may support the positive navigation of social relationships in adolescence (Portt et al., 2020), and thus aid in the prevention of adverse social outcomes. However, affective empathy did not correlate with peer victimisation, a finding that is consistent with the meta-analytic findings by Zych et al. (2019). As highlighted by Zych and colleagues, this may be considered unusual given affective empathy's similarity to, and negative association with the construct of CU traits (Jones et al., 2010; Waller et al., 2015; Waller et al., 2020). Further, there is growing evidence for a significant positive association between CU traits and victimisation, evident within the extant literature (Zych et al., 2019), and the current study. However, CU trait measurement *also* encompasses specific items focused on 'lack of guilt' and 'coldness' (Zych et al., 2019; Essau et al., 2006), which are not measured in affective empathy scales. Further, where significant, the associations reported are normally small. In addition, differing methodologies and analytical approaches in the extant studies likely contribute to divergent findings. In this context, future research that seeks to examine the associations between cognitive and affective empathy and peer victimisation in diverse child and adolescent samples, may provide clarity on the extant divergent findings.

Emotion Regulation, CU Traits, and Cognitive and Affective Empathy

We were unable to explore the moderating effects of CU traits and cognitive and affective empathy on the association between ER strategies and peer victimisation frequency as the necessary Poisson regression conditions were violated. Reasons for the violations may include unobserved heterogeneity in the sample, possible dependence of probability due to the influence of additional variables, potential outliers, and wide-ranging values within the CU traits and empathy scales, and due to cross-sectional data.

However, we presented the zero-order correlations between the planned predictor and moderator variables; and these are discussed below.

Cognitive reappraisal was negatively, while expressive suppression was positively associated with CU traits, respectively. To the best of our knowledge, no previous research has examined the cross-sectional zero-order correlations between cognitive reappraisal and CU traits (composite score) in children and adolescents. Although, there is emerging evidence for small, significant correlations between the individual components of CU traits (callousness, unemotional and uncaring) and both cognitive reappraisal and expressive suppression, in the wider context of internet addiction and cyberbullying in adolescents (e.g., Kokkinos & Voulgaridou, 2017; Trumello et al., 2018). Further, suppression may be linked to the development of a ‘secondary variant’ of CU traits, following early maltreatment (Ford et al., 2006; Bennett & Kerig, 2014). Indeed, early adversity, also extending to victimisation, may contribute to faster maturation of neural network connectivity, and suppression may develop quicker in these instances, where it serves an adaptive purpose (i.e., keeping safe by hiding emotional distress) (Gee et al., 2013; Gross & Cassidy, 2019). Taken together, this evidence suggests an important link between ER strategies and CU traits, which may pave the way for individualised targeted, preventative interventions in youth at-risk of early adversity.

CU traits were negatively associated with cognitive and affective empathy, and, in line with recent meta-analytic findings (Waller et al., 2020), the association between CU traits and cognitive empathy was stronger than the association between CU traits and affective empathy. This finding contrasts with earlier work in which the association with affective empathy was observed to be stronger (e.g., Jones et al., 2010; Waller et al., 2015). Although, both CU traits and empathy measures were parent-report only in the present study. Hence, it is not possible to consider Waller and colleagues discrepant findings pertaining to cognitive empathy, in which a stronger association with cognitive empathy was only found in parent- and teacher-reports, and self-report in young children

(Waller et al., 2020). Older children and adolescents reported a stronger link to affective empathy (Waller et al., 2020)—potentially due to deficits in cognitive empathy decreasing over time, in line with the development of social-cognitive skills (Choudhury et al., 2006; Waller et al., 2020). Hence, future research should examine this phenomenon further in broad child and adolescent samples by incorporating self-report empathy and CU trait measures into the research design.

In the current study, both ER strategies correlated significantly with cognitive empathy, but not affective empathy. Specifically, as cognitive empathy increased, cognitive reappraisal increased and expressive suppression decreased. Importantly, to the best of our knowledge, this is the first study to present the correlations between affective and cognitive empathy, and expressive suppression and cognitive reappraisal use in a youth sample.

Supporting the empathy and ER integrative framework and associated literature (Thompson et al., 2019; Lockwood et al., 2014; Tully et al., 2016; Powell, 2018), it is conceivable that the correctly represented affect of another and successful application of abstract empathy cues may facilitate the selection of complex ER strategies (e.g., cognitive reappraisal). Further, the selection of modulatory ER strategies (e.g., suppression), that is postulated to occur subsequent to automatic mimicry or embodiment processes at the same time as perceiving the affect of the other (i.e., affective empathy processes) (Thompson et al., 2019), suggests that there should be a negative link between *affective empathy* and expressive suppression—potentially over and above that of cognitive empathy. Indeed, the link between suppression and affective empathy processes has been demonstrated in empirical studies in adults (e.g., Lockwood et al., 2014). Additionally, evidence suggests that the reward-value attached to an individual (i.e., a peer), may modulate the level of automatic mimicry experienced by the observer in a given interaction (Sims et al., 2012; Thompson et al., 2019). Hence, there may be increased reliance on modulatory ER strategies (i.e., expressive suppression) when the perceived reward-value is high. This is especially pertinent to adolescence, in which sensitivity to social feedback is heightened (Spear, 2011; Schweizer et al., 2020). A possible explanation for the lack of association between expressive suppression and affective empathy in children and adolescents may be due to developmental differences in affective and cognitive empathy processes. Akin to the association between cognitive empathy and CU traits in youth, greater deficits in cognitive empathy may have determined the significant link to ER strategies—in line with the development of social-cognitive skills (Choudhury et al., 2006). As the examination of the associations between empathy and ER strategies in youth is an emerging research topic, further research is required alongside conceptual accounts that place a focus on childhood and adolescence.

Strengths and Limitations

This study has several strengths. Firstly, the data were derived from a large, multi-site, sample that was well-characterised. Further, the age range was broad (9-18 years)—this allowed us to assess the variables of interest across development. In line with this notion, the variable-centered approach that we adopted (by examining children and adolescents with and without a CD diagnosis but not limiting the analyses to diagnostic boundaries) ensured that a full range of CU traits in childhood and adolescence could be explored in relation to victimisation. In addition, ER and empathy are known to vary significantly across individuals (John & Gross, 2004; Gross & John, 2003; Lockwood et al., 2017; Stietz et al., 2019), and are transdiagnostic in nature within both emerging psychiatric disorders (Aldao et al., 2016) and models of resilience (Feldman, 2021), in adolescence and beyond. Hence, our variable-centered approach also permitted the dimensional examination of ER and empathy in relation to victimisation in youth.

The study also has several limitations. Firstly, we examined the data using a cross-sectional approach, which limits our ability to track variables over time and make causal inferences about the observed correlations. In addition, cross-sectional studies are more prone to non-response bias (i.e., when non-responders differ in a meaningful way to responders) and recall bias (i.e., when responders do not remember previous events or experiences accurately or omit details) (Wang & Cheng, 2020) and heteroscedasticity, which was observed somewhat in the current study. However, as we sought to examine a novel combination of variables, a more complex design may not have been appropriate at this stage (Wang & Cheng, 2020). Second, we were unable to explore the moderating role of CU traits and cognitive and affective empathy on the association between cognitive reappraisal, and expressive suppression on peer victimisation due to the violation of necessary assumptions. Yet, we explored and discussed the zero-order correlations between the predictors and potential moderators. In addition, it is acknowledged that the data could be explored using mediational analysis or path analysis. This may be a possible direction for future research exploring the same variables. Third, as highlighted previously, only parent-report CU traits data were examined. Although parent-report data on CU traits may present greater validity and reliability than self-report data (Cardinale & Marsh, 2020) and are often more useful, combining information from various informants (i.e., parent, teacher, self) is preferred (Docherty et al., 2017). Fourth, it may have been informative to include data on participants peer relationships (i.e., quality, quantity, availability), however this was not available within the FemNAT-CD dataset. In future studies, authors should endeavour to include such information on participants peer relationships. Fifth, aggression was not included as a variable in this study. Given its potential link to the variables focused on in this study (e.g., Bass et al., 2022; Kokkinos et al., 2019; Uddin & Rahman 2022; Ritchie et al., 2020), it may be valuable to include aggression in future studies exploring the same variables. Finally, both the ER and empathy measures used in the current study have limitations. Specifically, the ERQ was not created for use with child and adolescent samples; this reflects the aforementioned issues in the measurement of ER in children and adolescents. Further, the GEM is a parent-report measure only, and recent research has highlighted potential issues regarding its ability to distinguish accurately between affective and cognitive empathy (Murphy, 2019a; Murphy, 2019b).

Conclusion

In summary, we show that ER strategy use, CU traits and cognitive empathy are related to the frequency of peer victimisation in children and adolescents. Affective empathy was not associated with peer victimisation frequency. This adds clarity to the growing body of work focused on the factors that are implicated in peer victimisation in youth. In addition, we show for the first time that both expressive suppression and cognitive reappraisal correlate significantly with cognitive empathy, but not affective empathy. We suggest that future research should further explore the associations presented in the current study and investigate their potential causal associations to identify directions of effects and moderating and mediating mechanisms. Further, researchers should create valid and reliable ER measures for youth. Taken together, these recommendations seek to better inform future preventative interventions that target diverse child and adolescent samples.

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CHAPTER 3,

STUDY 2:

DIGITAL INTERVENTIONS FOR EMOTION REGULATION IN CHILDREN AND EARLY ADOLESCENTS: SYSTEMATIC REVIEW AND META-ANALYSIS

Abstract

Background: Difficulties in emotion regulation (ER) are common in adolescence and are associated with poor social and mental health outcomes. However, psychological therapies that promote adaptive ER may be inaccessible and unattractive to youth. Digital interventions may help address this need.

Objective: The aim of this systematic review and meta-analysis was to synthesize evidence on the efficacy, feasibility, and acceptability of ER digital interventions in children and early adolescents aged 8 to 14 years.

Methods: Systematic searches of Web of Science, MEDLINE, PsycINFO, EMBASE, Education Resources Information Centre, ACM Digital Library, and IEEE Xplore up to July 2020 identified 39 studies, of which 11 (28%) were included in the meta-analyses (n = 2476 participants). A bespoke tool was used to assess risk of bias.

Results: The studies evaluated digital games (27/39, 69%), biofeedback (4/39, 10%), virtual or augmented reality (4/39, 10%), and program or multimedia (4/39, 10%) digital interventions in samples classified as diagnosed, at risk, healthy, and universal. The most consistent evidence came from digital games, which reduced negative emotional experience with a small significant effect, largely in youth at risk of anxiety (Hedges g = –0.19, 95% CI –0.34 to –0.04). In general, digital interventions tended to improve ER, but this effect was not significant (Hedges g = 0.19, 95% CI –0.16 to 0.54).

Conclusions: Most feasibility issues were identified in diagnosed youth, and acceptability was generally high across intervention types and samples. Although there is cause to be optimistic about digital interventions supporting the difficulties that youth experience in ER, the predominance of early-stage development studies highlights the need for more work in this area.

ER difficulties are prospectively associated with negative social outcomes (Chervonsky & Hunt, 2019) and psychiatric disorders in youth (McLaughlin et al., 2011). This is particularly significant considering that half of all lifetime psychiatric disorders begin by the age of 14 years (Kessler et al., 2005), and a recent large-scale meta-analysis reported 14.5 years as the worldwide peak age of psychiatric disorder onset (Solmi et al., 2022). The malleability of affective neural circuitry is heightened from late childhood through early adolescence (Schriber & Guyer, 2016; Steinberg, 2005). Hence, this is a period of particular interest for harnessing adaptive ER strategies, which may support positive social outcomes and psychological wellbeing (Mitic et al., 2021; Lamblin et al., 2017; Birkeland et al., 2014) and reduce risk for psychopathology (Caviccioli et al. 2023). Proximal social input that manipulates the environment in a positive manner, such as targeted intervention, can improve ER ability (Thompson, 2011; Sukhodolsky et al., 2016). Digital interventions may constitute efficacious, accessible, and attractive interventions in youth (Hollis et al., 2017). However, there is no systematic understanding of existing ER digital interventions and their efficacy in youth. Consequently, the aims of this systematic review and meta-analysis were to present a comprehensive understanding of the extant evidence on digital interventions that target ER in youth to provide recommendations for this emerging field.

Emotion Regulation in Youth

ER is operationalised as the attempt to recognise positive and negative emotional reactions in ourselves and to increase or decrease these in ourselves or others (McRae, 2020; Sheppes et al., 2015). The Extended Process Model of ER provides a framework of ER stages (identification, selection, implementation, and monitoring) and strategies in relation to an emotional goal (refer to the study by Gross, 2015 for a comprehensive account) and is consistent with the way many extant digital interventions for ER have been designed.

The developmental trajectories of improvements in different stages of the Extended Process Model are not equivalently linear (Schweizer et al., 2020). In line with this, neural networks implicated in ER follow a pattern of protracted refinement and reorganisation through synaptic pruning and myelination through late childhood and adolescence into early adulthood (Schriber & Guyer, 2016; Sukhodolsky et al., 2016). This may explicate adolescents' heightened sensitivity to rewarding experiences, increased experience of negative emotions, and variability in affect compared with young children and adults (Schweizer et al., 2020; Spear, 2011; Riediger et al., 2011). Indeed, strengthening ER relies on improved connectivity between affective and reward-processing networks and prefrontal cognitive control networks (Ahmed et al., 2015). This key developmental process is malleable and influenced by internal and external factors, such as hormonal changes and social relationships (Thompson, 2011; Sukhodolsky et al., 2016). Critically, this malleability is somewhat heightened from late childhood through adolescence (Schriber & Guyer, 2016; Steinberg, 2005; 2016).

Emotion Regulation Interventions in Youth

Proximal social input that manipulates the external environment in a positive manner, such as targeted interventions, can improve ER in youth include cognitive-, emotion-, and mindfulness-based talking therapies such as cognitive behaviour therapy (CBT) (Beck & Dozois, 2011), rational emotive behaviour therapy (Abrams & Ellis, 1994), and dialectical behaviour therapy (Linehan, 2015). These are facilitated by a psychologist in 1:1 sessions or small groups, depending upon the needs of the individual and available resources. CBT aims to reduce the selection and implementation of maladaptive cognitive ER strategies (e.g., rumination) and instead promote adaptive ones (e.g., cognitive reappraisal). CBT is effective in adolescent populations (James et al.,2015). However, such therapies are time, money, and personnel intensive (Chiles et al., 1999), and youth may experience traditional programs as unattractive because of perceived mental illness

(Moses, 2014; Wright et al., 2011) and related help-seeking stigma (Mukolo et al., 2010). Negative attitudes toward traditional approaches may be reflected in poor engagement, as evidenced in dropout rates of up to 75% (de Haan et al., 2013).

Preventive ER programs that are wider reaching than traditional therapies focus on the engagement and education of the caregivers of youth (McRae & Gross, 2020). Such programs encourage explicit tangible learning and practice of adaptive ER strategies (McRae & Gross, 2020) either in the classroom (Hoffmann et al., 2020; Durlak et al., 2011; Greenberg et al., 2003) or through home-based socialisation (Hajal & Paley, 2020). Although highly encouraging, these interventions may not be accessible or appropriate for all young people. For example, disadvantaged youth demonstrate an increased potential for withdrawal from mainstream services (Keppens & Spruyt, 2018) through which wider-reaching interventions are provided.

Digital Interventions in Youth

Mental health digital interventions for youth have attracted a number of recent systematic reviews and meta-analyses (Hollis et al., 2017; Grist et al., 2017; Grist et al., 2019, Weisel et al., 2019). The most common types of digital interventions include virtual and augmented reality, internet therapy, biofeedback and neurofeedback, digital games, and web-based programs (Hollis et al.,2017; Grist et al., 2017; Grist et al., 2019). Although this is an emerging field, preliminary evidence suggests that digital technologies may constitute clinically effective, economical, accessible, and attractive interventions for mental health problems in youth (Hollis et al., 2017). Moreover, the internet is widely accessible, even to populations who may not have access to support using traditional means (Naslund et al., 2017).

However, previous reviews have focused on a broad age range, encompassing childhood, early adolescence, late adolescence, and early adulthood. This may not permit the understanding of the impact that digital tools have within childhood and early adolescence—a critical period of brain development (Schriber & Guyer, 2016) and time of newly increased interest in, and engagement with, web platforms (Crone & Konijin, 2018).

This Study

Considering ER specific digital interventions, an example is the small number of freely available mobile apps accessible through the UK National Health Service (NHS) digital technology library for mental health. These claim to support well-being through heart rate biofeedback, breathing techniques, and gamified calming strategies. Such freely available interventions are born out of national health care provision policy implemented by the NHS, which is driven by clinical need and economic considerations; yet, there is no empirical research to provide evidence for the efficacy of these apps. Furthermore, no extant systematic reviews or meta-analyses present such evidence for ER digital interventions in children and early adolescents.

In parallel to the question of efficacy, the study by Bevan Jones et al. (2020) highlighted concerns regarding levels of user engagement, uptake, and adherence in mental health digital interventions for youth. This is discussed in line with best practices in digital intervention development in which active involvement of key stakeholders (e.g., early adolescents) is recommended to facilitate the feasibility of digital interventions as well as their acceptability (Bevan Jones et al., 2020). A systematic understanding of how far digital interventions for ER have achieved feasibility and acceptability and how these are evaluated is also important. In this systematic review and meta-analysis, we aimed to evaluate the extant evidence base for the use of digital technologies to improve ER in children and early adolescents and provide recommendations for the progression of the field.

Research Questions

We formulated the following research questions:

.1 What are the characteristics of digital interventions that have been evaluated in terms of the efficacy and feasibility of their impact on ER in children and early adolescents?

.2 How efficacious and feasible are ER digital interventions in children and early adolescents?

.3 What are the experiences of children, early adolescents, and other stakeholders regarding the acceptability of ER digital interventions that evaluate efficacy or feasibility?

Methods

Details of the protocol for this systematic review and meta-analysis were registered on PROSPERO (Reynard & Woodcock, 2018).

Information Sources and Search

Web of Science, MEDLINE, PsycINFO, EMBASE, Education Resources Information Centre, ACM Digital Library, and IEEE Xplore electronic databases were used to identify studies. Groups of search terms pertaining to children and early adolescents, digital interventions, and ER were identified through scoping searches and combined using OR (within groups) and (across groups) Boolean operators and syntax. Search terms and associated Boolean operators and syntax were adapted for different databases as necessary. See Appendix 2 “Full Search Strings” for the search strings used in each database. Gray literature searching using Open Science Framework Preprints and OpenGrey electronic databases, as well as forward and backward tracking, was used to identify further studies. An author voluntarily sent one study to the authors. Searches were initially run in August 2018 and repeated as a top-up search in July 2020. The initial search was broader than the top-up search. Before the top-up search in July 2020, the inclusion criteria were reviewed. Because of the need to narrow the focus of the review, studies targeting social cognition only and acceptability or qualitative design only, theses, and studies in which samples were aged <8 years or >14 years were excluded. Therefore, at this stage, the social cognition search terms were removed from the search string. The age of 14 years was determined as the upper age limit because of increasing evidence of the need for early ER intervention efforts from an empirical as well as public health and economic perspective (Solmi et al., 2022; Hoffmann et al., 2020; Durlak et al., 2011; England-Mason & Gonzalez, 2020; McDaid et al., 2019).

Eligibility Criteria

Studies were included if they met the following inclusion criteria: (1) used digital technology as an intervention strategy, (2) aimed to improve ER and associated neurobiological mechanisms, (3) targeted children and early adolescents (mean age between 8 and 14 years), and (4) reported data on the efficacy or feasibility of the digital intervention with or without acceptability data. Studies reporting only acceptability data without corresponding efficacy or feasibility data were not included. Studies meeting these inclusion criteria and published after 2008 in peer-reviewed journals presented in English, German, Portuguese, Spanish, Italian, Serbian, Croatian, or Hebrew were considered for inclusion. Studies published after 2008 were included because scoping searches conducted in August 2018 revealed that ER digital interventions were developed after 2008. Quantitative and mixed methods studies that used any relevant outcome measure were considered for inclusion. The associated PICO(T)-informed inclusion model was 1) Population: children and early adolescents, 2) Intervention: digital technology, 3) Comparison or Control: any comparison/control group; no comparison/control group, 4) Outcome: improvements or change in ER; feasibility, 5) Time: over any time.

Studies were excluded if they met any of the following exclusion criteria: (1) not original research paper, extended conference paper, or preprint (i.e., book, book chapter, commentary, conference abstract, or conference poster), (2) development or testing of technical intervention component only (e.g., statistical simulation without assessment of a psychological variable), (3) animal population, and (4) population with organic neurological disorder, and if they did not meet the inclusion criteria.

Please refer to the Meta-analyses' subsection under the Methods section for specific information on meta-analysis eligibility criteria.

Study Selection and Data Collection

Using the web-based reference management software Covidence (Veritas Health Innovation Ltd), two independent reviewers (SR and JS) conducted record screening (Veritas Health Innovation, 2020). Any conflicts between the reviewers' screening decisions were resolved through consensus, with involvement of a third experienced researcher if necessary. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2015) and a bespoke risk-of-bias assessment tool (refer to the next section) were used when designing and conducting the data extraction protocol. A piloted standardised Microsoft Excel table was used to extract data from the included studies for evidence synthesis and risk-of-bias assessment (refer to the online supplementary material "Extraction Table" via the reference Reynard et al., 2022, for the extraction table). The first author (SR) completed this task.

Assessment of Risk of Bias

A tool for risk-of-bias assessment was created using evidence-based information and guidance. This was sourced from the Cochrane Collaboration's tool for assessing risk of bias in randomised trials (Higgins et al., 2011), Cochrane Methods risk-of-bias online library (Cochrane Methods Webpages) (n.d.), NHS National Institute for Health and Care

Research guidance for feasibility and pilot intervention studies (Williams, 2018), and the Newcastle-Ottawa Scale for assessing the quality of non-randomised trials (Deeks et al., 2003). Wide-ranging information and guidance were required because of the breadth of research designs and associated methodological characteristics included. Care was taken to feature the risk-of-bias domains relevant to the included studies and questions in the review. The tool consisted of 6 domains: (1) selection bias, (2) performance bias, (3) detection bias, (4) attrition bias, (5) reporting bias, and (6) other bias. The risk-of-bias assessment was conducted independently by two trained reviewers. Any conflicts were resolved through discussion, with involvement of a third experienced researcher if necessary. Refer to Appendix 2 "Risk-of-Bias Tool Domains" for a description of the risk-of-bias domains.

Clustering and Coding of Included Studies

Guidance on the conduct of narrative synthesis in systematic reviews (Popay et al., 2006) was followed to generate a thematic understanding of the included digital interventions. The included studies were coded and clustered using defined criteria based on the key category of intervention type. The criteria and definitions that were used to cluster the included studies are detailed in Textbox 3.1. Studies were further coded based on the population type. These were identified as diagnosed: children and early adolescents diagnosed with a physical or mental health disorder; at risk: children and early adolescents at risk of a mental health disorder (e.g., elevated anxiety); healthy: typically developing children and early adolescents with no identified diagnosis; and universal: no exclusion criteria applied. The studies' outcome targets were coded based on what they measured. These were ER: recognition of emotions in oneself and the increase or decrease of these emotions; emotion experience: negative (e.g., frustration) or positive (e.g., joy) emotions or symptoms; and physiological regulation: brain or bodily signals associated with ER and emotion experience (e.g., heart rate).

Tables were created to summarise the characteristics of the included studies and the efficacy, feasibility, and acceptability data. Within the tables that present the efficacy, feasibility, and acceptability findings, we provide the raw reporting risk-of-bias information at the measure level for information and transparency.

Textbox 3.1

Clustering of included studies based on intervention type.

Cluster and definition
• Biofeedback: A digital physiological monitoring aid • Digital game: An electronic game with functions to achieve specific goals, with or without biofeedback • Virtual reality and augmented reality: A simulated environment (i.e., a digital immersion experience with no physical world input); an enhanced reality (i.e., a digital sensory component on a live smartphone view) • Program and multimedia: A program or multimedia application

Acceptability, Feasibility, and Efficacy

Acceptability and feasibility data were synthesised within intervention clusters with validity and reliability reporting bias and attrition bias information where appropriate. In studies not included in the meta-analyses, within-intervention group before-and-after ER, emotion experience, and physiological regulation efficacy data were further synthesised with significance and effect size information where available. Hedges *g* (the summary measure) was calculated in R (R Core Team, 2017) using the esc package, version 0.5.1 (Lüdecke, 2019) to indicate whether significant observed effects were small (0.2), medium

(0.5), large (0.8), or very large (1). In a very small number of studies, it was not possible to calculate Hedges *g* or convert to it (e.g., where only η^2 value was provided).

Meta-analyses

Studies included in the systematic review were considered for inclusion in the meta-analytic component if they were randomised controlled trials (RCTs) (Higgins et al., 2019). Of the 39 studies included in the systematic review, three (8%) were not sufficiently homogeneous to other included studies; therefore, they were not included in the meta-analyses. Of these three studies, two (67%) used informant report only and reported ER effects alongside emotional expression as a composite score and one (33%) implemented a crossover design. In addition, another study did not provide data to calculate effect sizes and hence was not included. Non-inferiority RCTs (which compared the intervention to efficacious group face-to-face CBT and hypothesised nonsignificant differences between groups), which are increasingly prevalent in the intervention literature, were included in the meta-analyses. Including non-inferiority trials is a more conservative approach in terms of the resultant effect sizes that would be expected; the majority (6/9, 67%) of the other studies included in the meta-analyses used an active control, and some of these were class-based psychoeducation, which has demonstrated beneficial effects. Thus, non-inferiority studies were deemed similar enough to other RCTs to be included (Wang et al., 2020). It is acknowledged that this may have resulted in the pooled effect being lower than if non-inferiority effect estimates had been excluded. Including non-randomised studies was considered; however, such studies were not reasonably resistant to biases—they were all judged as high risk of bias, inclusive of confounding bias, and varied greatly in methodological design (Higgins et al., 2019).

Meta-analyses using a very small number of studies may negatively affect the estimation of between-study variance (Davey et al., 2011). Therefore, a threshold of four studies was established as a suitable minimum. Thus, two meta-analyses were conducted, focusing on ER and emotion experience outcomes, respectively. From each study, one effect was selected for each meta-analysis to ensure the independence of effect sizes (López-López et al., 2017). All the studies used self-report measures; therefore, one self-report effect from each included study was selected. Where studies provided multiple self-report effects for each outcome target type, constructs from self-report scales or subscales that were most similar to each other across the included studies were selected. For example, most emotion experience effects measured anxiety across the included studies; hence, where possible, anxiety-based effects were selected for meta-analysis. Where studies used multiple comparison groups, the active control group data were used. Further standardisation was facilitated by computing post intervention standardised mean differences only. This is because follow-up data collection was not incorporated into the designs of all meta-analytic studies, and where it was, the length varied greatly across studies. Studies were also coded based on intervention type (biofeedback, digital game, and program and multimedia), population type (diagnosed, at risk, healthy, and universal), training of additional skills (yes or no), use of additional mode of intervention delivery (yes or no), and measure risk of bias (low or high). In addition, dropout rate was included in the results of the meta-analyses.

Analyses were conducted in R (R Core Team, 2017) using meta-analyses packages tidyverse, version 1.3.0 (Wickham et al., 2019), meta, version 4.11-0 (Balduzzi et al., 2019), metafor, version 2.4-0 (Viechtbauer, 2010), and dmetar (Harrer et al., 2021). The studies included in the meta-analysis varied somewhat in methodological design; therefore, a degree of heterogeneity was assumed. In line with this, random effects models were applied (Cuijpers, 2017). The restricted maximum likelihood estimation of tau-squared (τ^2) between-study variance was used because it corrects for negative bias within continuous data (in which large tau-squared is reported when the number of studies and individual studies' sample sizes are small), unlike the standard DerSimonian-Laird method (Veroniki et al., 2016). The mean and SD of each study's selected effect was used to calculate Hedges *g* and it's SEs. Hedges *g* was computed because the commonly used Cohen *d* (Cohen, 1988) may demonstrate a slight bias in small studies in which effects are overestimated (Hedges, 1981). In each meta-analysis, study ID was the unit of analysis, and the effect size (*g*) for each study was the level of analysis (Hedges & Olkin, 1985).

Heterogeneity was estimated using I^2, tau-squared, and the prediction interval (range into which the effects of future studies are expected to fall) because of the possibility that any one measure on its own is inadequate (Harrer et al., 2021). Specifically, although I^2 is insensitive to increases or decreases in the number of studies, it relies on each individual study's sample size to predict the amount of variability in the effect sizes *not caused by sampling error* (Harrer et al., 2021; Borenstein et al., 2017). I^2<25% indicates low heterogeneity, I^2=50% indicates moderate heterogeneity, and I^2>75% indicates high heterogeneity (Higgins et al., 2003). Tau-squared, the between-study effect size variance estimator, is insensitive both to each study's sample size and the number of studies in a meta-analysis, but the meaning of tau-squared might be difficult to interpret alone (Harrer et al., 2021).

Outlier analyses were conducted to determine whether extreme effect sizes contributed to between-study heterogeneity, using a CI-based approach (Harrer et al., 2021). Influence analyses were conducted to determine the robustness of the pooled effect estimates using leave-one-out principles (Harrer et al., 2021). Influential cases were examined in subplots (Viechtbauer & Cheung, 2010). These revealed how much the predicted pooled effect changed in SD units after excluding a given study, the distance between the value when the study was included versus excluded (the Cook distance), and the covariance ratio. Extreme values were shown in red. In addition, the plots were examined to detect any extreme cases not defined by the Viechtbauer and Cheung threshold (Viechtbauer & Cheung, 2010). Baujat plots were created to determine each study's heterogeneity input (Baujat et al., 2002).

Finally, two leave-one-out forest plots that ordered studies by I^2 between-study heterogeneity and effect size (low value to high value) were created to provide further evidence of influential studies (Harrer et al., 2021). As digital games constituted most (9/11, 82%) of the studies in the meta-analyses, additional meta-analyses were conducted using only digital game effect sizes where appropriate.

Publication Bias

Several steps were taken to investigate potential publication bias, which occurs because of selective publication of significant findings with large effects (Harrer et al., 2021; Rothstein et al., 2005). Particularly in small studies, where very large effects are needed to reach statistical significance, the results are more likely to be statistically significant if their effect sizes are high. First, contour-enhanced funnel plots were examined visually. Contour-enhanced funnel plots, which present colour shading linked to significance levels, allow the distinguishing of publication bias from other sources of asymmetry, for example, variable study quality (Peters et al., 2008). The Egger test of the intercept quantified funnel plot asymmetry—a statistically significant result (p <.05) determines asymmetry (Egger et al., 1997) although this possesses low statistical power in <10 studies (Higgins et al., 2019). Where the Egger test was significant, the Duval and Tweedie trim-and-fill method was used to estimate the actual effect size had the missing small studies been published (Duval & Tweedie, 2000). Missing studies were imputed into the funnel plot until symmetry was attained.

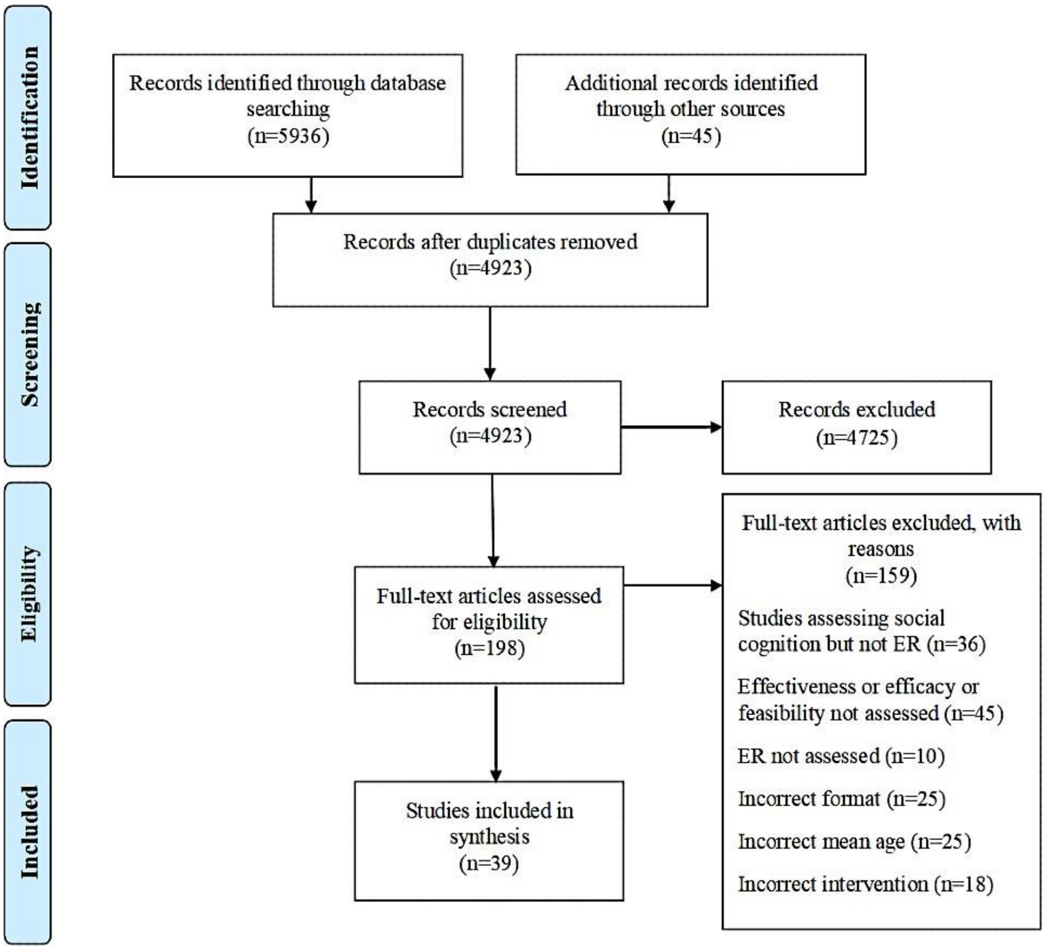
Results

Study Selection

The use of the inclusion and exclusion criteria as previously defined resulted in 39 studies being included in the systematic review and meta-analysis (Moher et al., 2009) (Figure 3.1).

Figure 3.1

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for study inclusion (adapted from Moher et al., 2009), which is published under Creative Commons Attribution 4.0 International License). ER: emotion

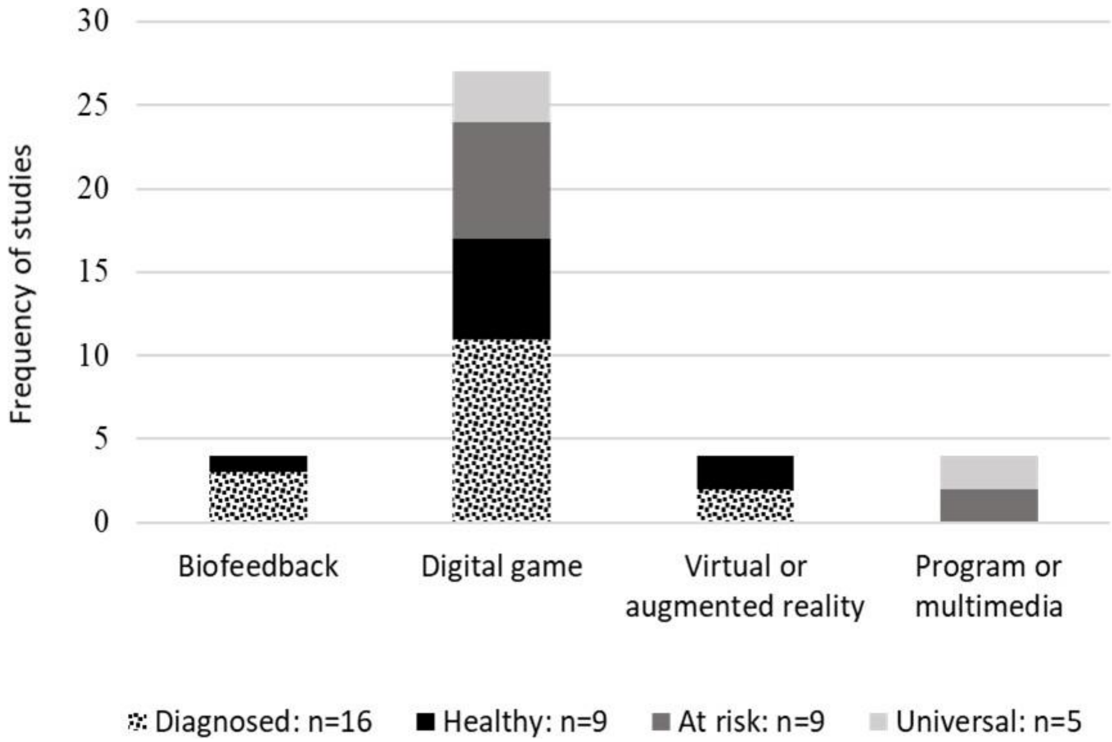


Description of Study Clustering

As shown in Figure 3.2, most (27/39, 69%) of the studies assessed digital game interventions in children and early adolescents who had received a diagnosis.

Figure 3.2

Study clustering findings with population characteristics.



Note. Of the 39 studies, one (3%) reported results for both populations who had received a diagnosis and healthy populations. The totals were calculated based on the main target population.

Study Characteristics

Appendix 2 "Study Characteristic Matrix" contains the characteristics of all included studies. The 39 studies had sample sizes ranging from 2-1645. Participants were aged 5-17 years, with a mean age, where reported, of 8-14 years. Studies provided data related to effectiveness (4/39, 10%); effectiveness and feasibility (11/39, 28%); effectiveness and acceptability (2/39, 5%); effectiveness, feasibility, and acceptability (9/39, 25%); efficacy (5/39, 13%); efficacy and feasibility (6/39, 15%); and efficacy, feasibility, and acceptability (2/39, 5%). Of the 17 studies that targeted children and early adolescents who had received a diagnosis, most (n = 9, 53%) targeted autism spectrum disorders (ASDs). Of the eight studies that targeted samples classified as at risk, half (n = 4, 50%) targeted elevated anxiety with digital games. Studies were conducted in Australia (9/39, 23%), Spain (8/39, 21%), The Netherlands (6/39, 15%), the United States (6/39, 15%), Hong Kong (3/39, 8%), Romania (3/39, 8%), Wales (1/39, 3%), Nepal (1/39, 3%), Belgium (1/39, 3%), and Germany (1/39, 3%). Differentiation between effectiveness and efficacy highly depends on study design and available resources; indeed, effectiveness reflects real-life conditions. Hence, throughout the reporting of the results, we use the term *efficacy* for simplicity.

In total, 11 studies were eligible for meta-analyses. These comprised 2476 participants (n = 1248, 50.4%, in intervention conditions and n = 1228, 49.6%, in control conditions). Sample sizes ranged from 20 to 1645. Most of the studies targeted samples classified as at risk or diagnosed (8/11, 73%) and were digital games (9/11, 82%). Of the nine digital games, four (44%) targeted children or early adolescents at risk of anxiety (n = 448); three (33%) targeted those diagnosed with posttraumatic stress disorder, anxiety with and without comorbid intellectual disability, and ASD with elevated anxiety (n = 178); and two (22%) targeted healthy early adolescents (n = 185). Of the 11 studies, one (9%) biofeedback study targeted youth (n = 20) diagnosed with anorexia nervosa, whereas one (9%) program and multimedia study targeted a universal sample (n = 1645). No studies in the virtual and augmented reality cluster were included. Regarding comparisons, the digital game cluster compared the intervention with an active control (n = 2), active control with (n = 1) and without (n = 2) treatment as usual, active control with separate wait-list (n = 2), and treatment as usual with (n = 1) and without (n = 1) wait-list. The biofeedback study compared the intervention with treatment as usual. The program and multimedia study compared the intervention with a web-based neuroscience program. Of the five studies that permitted continuance of usual treatment, three (60%) were in the digital game cluster.

Intervention Characteristic Summary

Of the 39 included studies, 22 (56%) clearly stated that they incorporated additional support, monitoring, or nondigital delivery. Most (3/4, 75%) of the program and multimedia studies incorporated class sessions and homework. Half (4/8, 50%) of the virtual and augmented reality studies as well as biofeedback studies and 56% (15/27) of the digital game studies incorporated non-digital delivery, additional support, or monitoring. Only the study by Wijnhoven et al. (2020) was included in the meta-analytic component. In total, 44% (17/39) of the studies trained other skills as well as ER. These were mostly (9/17, 53%) social skills and social cognition. A key pedagogical and therapeutic theme across all interventions was explicit ER strategy learning through digital characters or a face-to-face facilitator, with practice in a relevant and engaging but safe environment. Refer to Appendix 2 “Intervention Descriptions” for descriptions of all the interventions.

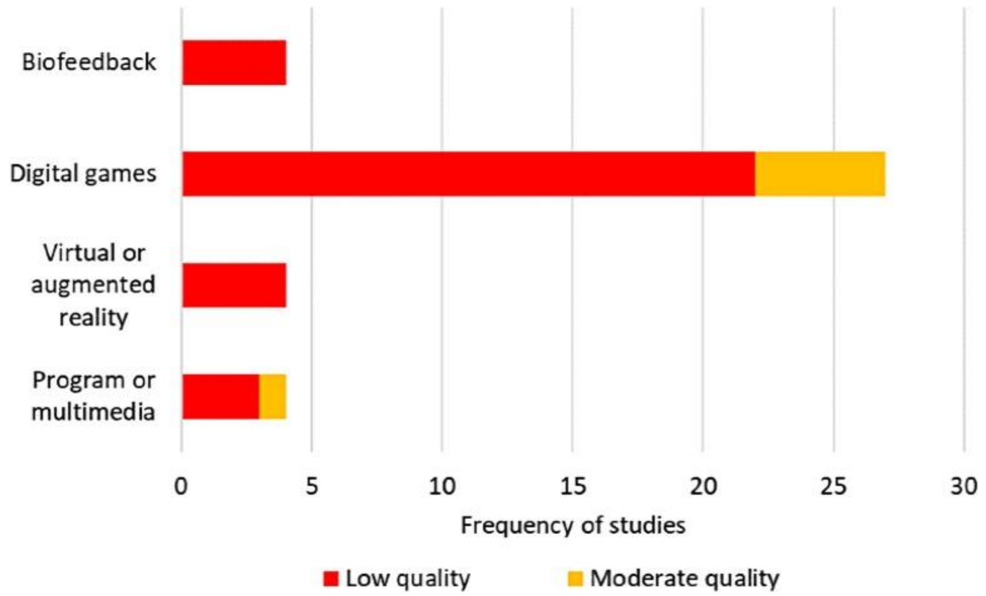
Risk of Bias

As demonstrated in Figure 3.3, most (33/39, 85%) of the studies were judged by reviewers as low quality. In total, 15% (6/39) of the studies, all of which were included in the meta-analytic component, gained moderate quality ratings. Although most (17/39, 44%) of the studies targeted diagnosed populations, reviewers judged all these studies as low quality. The highest proportion of moderate quality ratings was in the digital game cluster in populations classified as at risk. Overall, the distribution of risk-of-bias scores ranged from seven to 20 out of 26, with higher scores indicating higher quality. The interrater reliability was substantial (Cohen's $\kappa = 0.75$) (McHugh, 2012). Refer to Appendix 2 "Risk-of-Bias Findings Summary" for a detailed summary of the risk-of-bias findings.

Figure 3.3

Review authors' judgments regarding overall study quality in the intervention clusters.

Meta-analysis



Emotion Experience

Of the 39 included studies, 10 (26%) assessed group differences in emotion experience with self-report. Of these 10 studies, nine (90%) revealed effect sizes in favour of the intervention, with less negative ($k = 8$) or more positive ($k = 1$) emotion experience effects in the intervention group. However, of these 10 studies, only one (10%; digital game) revealed a significant effect (Table 3.1). This study targeted children at risk of anxiety. Only the study by Lackner et al. (2016) revealed an effect in the unexpected direction in which negative emotion experience was greater in the intervention group than in the control group after the intervention. This related to the only biofeedback study included in the meta-analysis, with the smallest sample size (*n* = 20; although the study also reported one of the lowest dropout rates of 9%). The very small, pooled effect was nonsignificant (*k* = 10; Hedges *g* = –0.12, 95% CI –0.26 to 0.02; *p* = .09; Figure 3.4A).

Tau-squared was low (τ^2 = .0176) indicating little variation among the studies. Yet, the I^2 value of 39.5% indicated low to moderate heterogeneity, and the somewhat broad prediction interval (–0.46 to 0.22) suggests that the very small observed pooled effect largely on negative emotion experience through ER digital interventions is not robust in every context.

Given the potential impact of the type of digital intervention on the pooled effect and heterogeneity outcomes, the emotion experience meta-analysis was conducted again with only the digital games studies (*n* = 9). All the digital game studies assessed negative emotion experience outcomes. The forest plot reveals a small negative pooled effect (Figure 3.4B). This was significant (*k* = 8; Hedges *g* = –0.19, 95% CI –0.34 to –0.04; *p* = .02).

Tau-squared was 0, indicating that variation in effect sizes among the studies was caused by sampling error rather than heterogeneity. The I^2 value of 0% corroborated this, and the narrow prediction interval (Hedges *g* = –0.34 to –0.04) suggests that the small observed pooled negative emotion experience effect through ER digital game interventions is robust across different contexts.

Figure 3.4

Meta-analytic forest plots (random effects model, Hedges g, restricted maximum likelihood tau-squared): (A) Emotion experience. (B) Emotion experience—digital game studies only. (C) Emotion regulation.

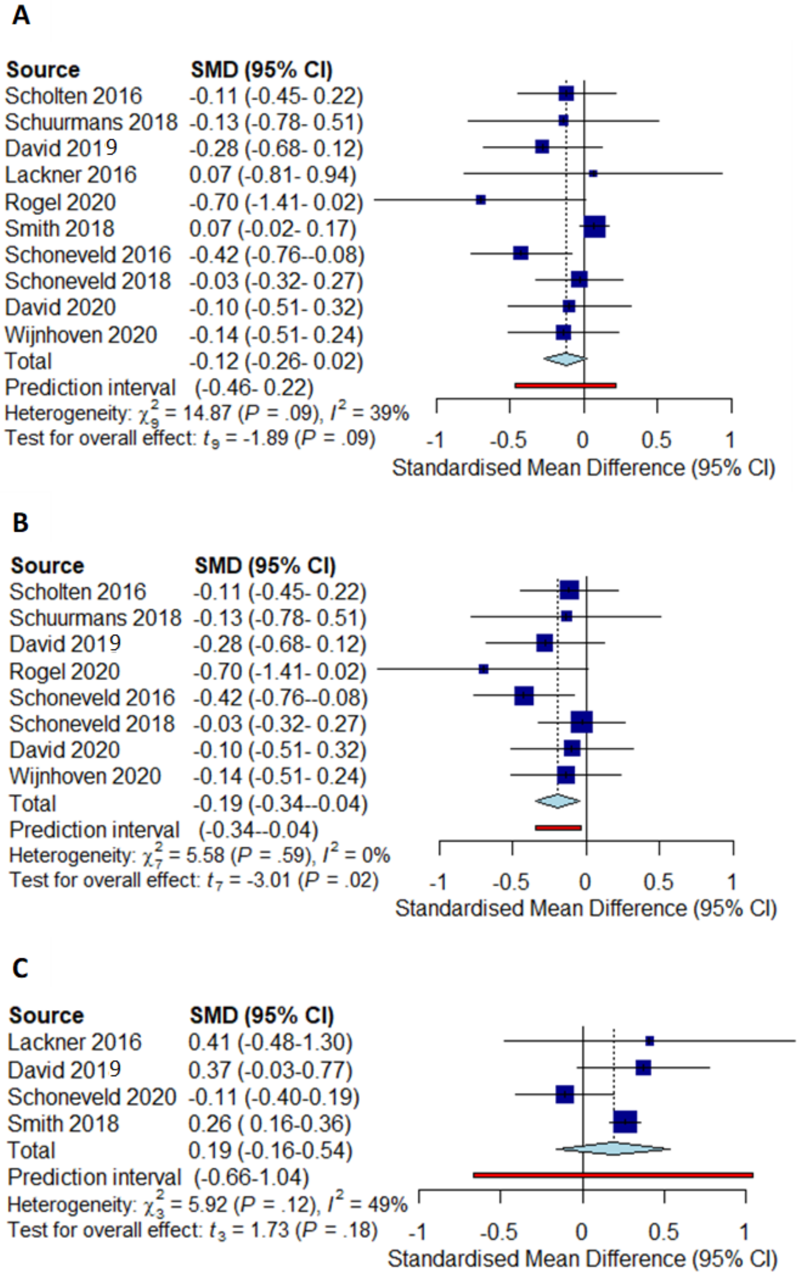


Table 3.1

Emotion experience and ER meta-analytic outcomes

	Hedge's *g* [95% CI]				Measures & risk of bias			
Study	ER	Emotion experience	Total *N*	Control	ER	Emotion experience	Dropout %	Other skill/ support
Lackner et al. (2016)[a]	0.41 [-0.48, 1.3]	0.07 [-.81, .94]	20	TAU	ECQ R	BSI A	9%	No
Scholten et al. (2016)[b]		-0.11 [-.45, .22]	138	Active		C-SCAS	8.7% ITT	No
Schuurmans et al. (2018)[a]		-0.13 [-.78, .51]	37	TAU		C-SCAS	34% ITT	No
David et al. (2019)	0.37 [-0.03, 0.77]	-0.28 [-.68, .12]	96	Active	ERICA C	SDQ-C E	7%	No

Rogel et al. (2020)[a]		-0.70 [-1.41, .02]	32	TAU-WL		TSC A	22% ITT	Executive function
Schoneveld et al. (2016)[b]		*-0.42 [-.76, -.08]	136	Active		C-SCAS	25.7% ITT	No
Schoneveld et al. (2018)[b,c]		-0.03 [-.32, .27]	174	Active		C-SCAS	12% ITT	No
David et al. (2020)		-0.10 [-.51, .32]	89	Active		PoAD A[d]	18.8%	No
Wijnhoven et al. (2020)[a]		-0.14 [-.51, .24]	109	Active		C-SCAS[d]	32%	Therapist
Schoneveld et al. (2020)[b,c]	-.11 [-0.4, 0.19]		174	Active	SEQ SE	-	12% ITT	No
Smith et al. (2018)[a]	**0.26 [0.16, 0.36]	0.07 [-.02, .17]	1645	Active	ATES[d]	EWS[d]	0 reported	ER adaptive attitude

*p < .05. **p < .01.

Note. Pooled Hedges *g* (random effects model, restricted maximum likelihood tau-squared): emotion regulation: Hedges *g* = 0.19 (95% CI –0.16 to 0.54); emotion experience: Hedges *g* = –0.12 (95% CI –0.26 to 0.02), game only Hedges *g* = –0.19 (95% CI –0.34 to –0.04). Overall dropout % *M* = 16.5%.

[a]=continuance of existing treatment permitted. [b]=continuance of existing treatment not permitted. [c]=non-inferiority (no significant between-group differences expected). [d]=high risk of bias.

ECQR: Emotional Competence Questionnaire, Regulating and Controlling Own Emotions subscale. BSIA: Brief Symptom Inventory, shortened from Symptom Checklist-90-Revised, Anxiety subscale. SCAS-C: Spence Children's Anxiety Scale. ERICA C: Emotion Regulation Index for Children and Adolescents, Control subscale. SDQ-CE: Strengths and Difficulties Questionnaire–Child Version, Emotional Symptoms subscale. TSCA: Trauma Symptom Checklist for Young Children, Anxiety scale. POAD A: Profile of Affective Distress, Concern and Anxiety subscale. SEQ SE: Self-Efficacy Questionnaire for Children, Emotion Self-Efficacy scale. ATES: Adaptive Theories of Emotions Scale. EWS: Emotional Well-Being in School Scale. Refer to Appendix 2 "Measures Matrix" for full measure details.

Emotion Regulation

Of the 11 studies included in the meta-analysis, four (36%) assessed group differences in ER with self-report. Only the study by Smith et al. (2018) revealed a significant effect (Table 3.1). The non-inferiority study by Schoneveld et al. (2020) revealed an effect in favour of the control group. Of note is the biofeedback study by Lackner et al. (2016) in which the control group improved compared with the intervention group; yet, because the intervention group's baseline mean was greater than that of the control group, the observed effect seems to be in favour of the intervention group. The pooled effect was non-significant (k = 4; Hedges g = 0.19, 95% CI –0.16 to 0.54; p = .18; Figure 3.4C). Tau-squared was low (τ^2 = .0274), suggesting little variation among the studies. However, the I^2 value of 49.3% indicated near-moderate heterogeneity, and the extremely broad prediction interval (–0.66 to 1.04) suggests that the nonsignificant small observed pooled effect on ER through emotion regulation digital interventions is not robust.

Outliers and Influential Cases

Outlier analysis did not detect any extreme effect sizes for the emotion experience or ER meta-analyses.

In the meta-analysis on emotion experience outcomes in digital games (significant), no studies were identified as extreme cases using the influential Viechtbauer and Cheung study threshold (Viechtbauer & Cheung, 2010) yet, visual inspection of the influence analysis subplots suggested that the studies by Schoneveld et al. (2016) and Schoneveld et al. (2018), both of which trained ER with an electroencephalogram (EEG) neurofeedback–based anxiety-induction digital game, presented extreme values. The Baujat plot corroborated this, indicating that these studies were highly influential in heterogeneity and pooled effect size. These studies also measured efficacy expectancy before the intervention and reported null between-group differences. Refer to Appendix 2 “Influence Analysis” for a detailed description of the influence analyses.

In summary, the meta-analytic evidence suggests that only digital game interventions significantly reduced negative emotional experience in children and early adolescents with a small effect, and this may be robust across different contexts; yet there is no evidence for improvements in self-reported ER abilities through digital intervention.

Publication Bias

Visual inspection of the contour-enhanced funnel plots (Figure 3.5) indicated some asymmetry. Importantly, there was only one significant effect size in each funnel plot. This suggests that asymmetry may have been due largely to factors other than publication bias (e.g., variations in study quality and methodology).

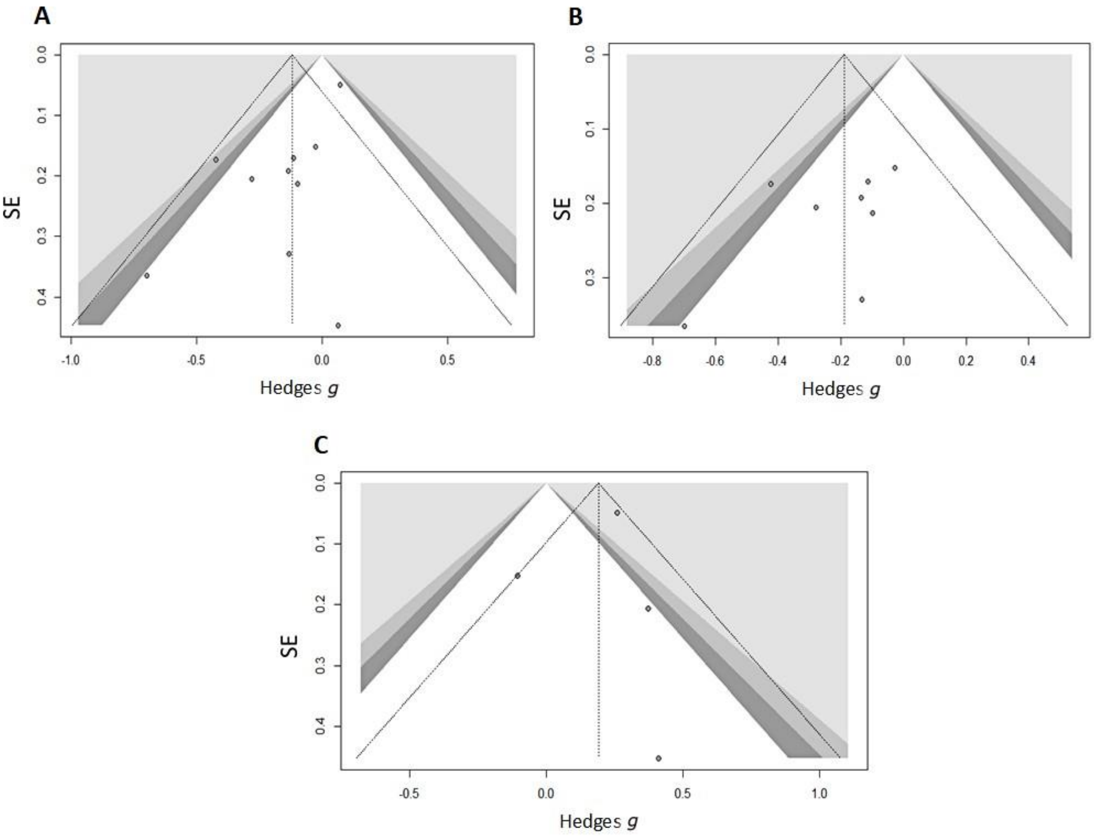
The Egger test of the intercept was non-significant for both the ER (k=4; regression intercept –0.409, 95% CI –3 to 2.19; p = .79) and emotion experience digital game–only meta-analyses (k = 8; regression intercept –1.514, 95% CI –3.87 to 0.84; p = .25). However, it was significant for the emotion experience meta-analyses that included all relevant studies (k = 10; regression intercept –1.462, 95% CI –2.36 to –0.57; p = .01). Hence, there was substantial asymmetry within this funnel plot potentially because of variations in study quality and methodology.

A trim-and-fill analysis was conducted on the significant emotion experience effect (refer to Appendix 2 “Trim and Fill Analysis” for the associated funnel plot). The five added effects were larger in magnitude, and the pooled effect was smaller and remained non-significant (k = 15; Hedges g = –0.019, 95% CI –0.16 to 0.2; p = .82). Tau-squared was moderate (τ^2 = .05), indicating variation among the studies. I^2 was 56%, indicating moderate heterogeneity.

In summary, the small, significant impact of digital games on negative emotional experience in children and early adolescents was likely not overestimated because of either publication bias or variations in study quality and methodology.

Figure 3.5

Meta-analytic contour-enhanced funnel plots between the SE and Hedges g. (A) Emotion experience. (B) Emotion experience—digital game studies only. (C) Emotion regulation.



Note. Light grey shading: p <.01; grey shading: p <.025; and dark grey shading: p <.05. No shading: non-significant (p <.05).

Overview

Appendix 2 “Intervention Efficacy Matrix” contains the within-intervention group pre- to post intervention efficacy summaries of ER, emotion experience, and physiological regulation domains from all studies not included in the meta-analyses (28/39, 72%). Where available, follow-up data are also provided. Studies were non-randomised or noncontrolled or judged to not be adequately resistant to biases and of variable methodological design. Therefore, the synthesis assessments described in the following sections should be interpreted accordingly. Where it was not possible to synthesise before-and-after efficacy data (e.g., single-session experiments, post intervention interviews, and field notes), data were synthesised in line with the measures and design from which they were borne.

Biofeedback Studies

Of the three biofeedback studies that provided efficacy data, only one (33%) used measures that were judged as low risk of bias. All three studies provided data on physiological regulation. Children and early adolescents significantly altered their physiology as directed by the intervention in heart rate variability (HRV)–EEG and functional magnetic resonance imaging (fMRI) biofeedback-neurofeedback and neurofeedback interventions. ER was assessed in 67% (2/3) of these studies: ER correlated with increased ER network activation in the fMRI neurofeedback study, whereas ER improved significantly with a large effect in HRV biofeedback but not in combined HRV-EEG biofeedback-neurofeedback in the second study. This study also assessed negative emotion experience—emotional lability and negativity decreased significantly with a large effect. Anxiety reductions were non-significant.

Digital Game Studies

Of the 27 digital game studies, 18 (67%) provided efficacy data. Of these 18 studies, three (17%) assessed the success of frustration or joy emotion induction within a virtual reality–enabled ER game across different mediating devices. Frustration increased significantly after the frustrating game in 33% (1/3) of the studies but not when mediated by a camera device. Increases in joy after the joyful game were non-significant across all device types in 33% (1/3) of the studies.

The strongest evidence for positive change brought about by digital games was the reduction of negative emotion experience (anxiety). Of the 18 studies, seven (39%) measured this; of these seven studies, three (43%) were statistically significant with small to large effects.

Of the 18 studies, eight (44%) measured ER, which largely improved. Where pre-post statistical information was available (5/8, 63%), improvements were significant, with medium to large effects. However, the significant findings were reported on the same game.

Of the 18 studies, five (28%) assessed physiological regulation. In total, 20% (1/5) of the studies reported significant reductions in heart rate and 20% (1/5) reported non-significant reductions in heart rate.

Virtual and Augmented Reality

All four virtual and augmented reality studies provided efficacy data, largely with measures judged as low risk of bias. Most (3/4, 75%) of the studies only measured ER. Individual exposure but not group exposure to immersive virtual reality emotion and social skill practice was linked to significant improvements in ER in a sample with high-functioning ASD, with a small effect (from 2/4, 50%, studies).

Program and Multimedia

Of the four program and multimedia studies, three (75%) provided efficacy data, all of which assessed one multimedia modular program. Intensity of emotions was assessed in 67% (2/3) of these studies—intensity of negative emotions only decreased significantly in 50% (1/2) of these studies, with a small effect. Intensity of positive emotions decreased significantly in both studies, with small to large effects.

Summary of Efficacy Data

The most consistent evidence comes from digital game interventions in the reduction of negative emotion experience.

A note of caution is recommended when interpreting these findings owing to the varied methodology, high risk of bias, and overall low quality of the included studies. Furthermore, the evidence base for the impact of digital interventions on physiological indices of ER is much smaller and less consistent.

Feasibility

Appendix 2 "Intervention Feasibility Matrix" contains the feasibility summaries from the included studies. Feasibility data were provided for 72% (28/39) of the studies. All studies that provided feasibility data used measures judged as high risk of reporting bias.

Of the 28 studies, 18 (64%) digital game studies provided feasibility data for various aspects of feasibility, including engagement, implementation, adherence, expectations, and transference to real life. Where the dropout rate was particularly high (>30%), studies targeted samples who had received a diagnosis and the dropouts were largely attributed to personal or family issues. Most feasibility issues were in early-stage small studies (3/18, 17%) in which interventions were prototypes not previously evaluated or were delivered by individuals inexperienced in the intervention technology.

All (4/4, 100%) the virtual and augmented reality studies provided feasibility data encompassing engagement, implementation, and transference to real life. Of these four studies, two (50%) reported dropout rates, and these were very low.

Of the four program and multimedia studies, three (75%) provided feasibility data encompassing implementation and engagement. Of these three studies, two (67%) reported dropout rates, and these were very low.

In summary, most feasibility issues were in early-stage interventions targeting samples who had received a diagnosis. Digital game interventions that incorporated biofeedback provided the most evidence for transference of learned ER skills to real life. However, digital games also presented the highest dropout rate, and all measures across all clusters were judged as high risk of reporting bias.

Acceptability

Appendix 2 “Intervention Acceptability Matrix” contains the acceptability summaries from the included studies. Acceptability data were provided for 33% (13/39) of the studies. The biofeedback cluster did not contain acceptability data.

Of the nine digital game studies that measured acceptability, six (67%) reported moderate to highly positive results for at least one aspect of acceptability, including likability, flow, usability, helpfulness, difficulty, appeal, usefulness, and relevance. The only study that reported mainly negative acceptability findings highlighted a link between guided imagery, visualisation, and deep breathing games being too difficult or easy and poor likability in children diagnosed with ASD.

Of the four virtual and augmented reality studies, two (50%) that evaluated acceptability in two interventions reported mainly positive findings for fun, educational impact, likability, motivation impact, and experienced happiness. The only study across all clusters that used a measure judged as low risk of reporting bias assessed an outdoor augmented reality quest (which involved meeting other players). Importantly, it was viewed as potentially dangerous, although the authors did not elucidate exactly to what this danger pertained.

Of the four program and multimedia studies, two (50%) that evaluated acceptability in a school-based program reported high likability and a moderate educational impact.

In summary, ER digital interventions were largely acceptable to children and early adolescents, as well as other key stakeholders. However, of the 20 measures, 19 (95%) were judged as high risk of reporting bias. Negative acceptability findings were mainly in small early-stage digital game interventions targeting samples who had received a diagnosis.

Adverse Effects

As advised by the Cochrane Adverse Effects Methods Group (Peryer et al., 2022), it is important to assess and present the measurement and reporting of adverse effects within the studies included in this review. An opportunistic capture (exploratory) approach revealed that no studies appeared to explicitly measure and report on potential adverse effects of the digital interventions. However, some instances of apparent adverse effects were noted. Specifically, mini-games within a prototype game for children diagnosed with ASD were linked to very high levels of anger in one participant, and potential provocation of repetitive behaviour in one participant (Carlier et al., 2020). Further, in a biofeedback game evaluated by Amon and Campbell (2008), side effects of dizziness, emotional outbursts, tiredness, low appetite, and hyperactivity were reported in up to one quarter (25%) of participants diagnosed with ADHD. However, it is not clear whether these were evident prior to intervention engagement. Additionally, Yuan and Ip (2018) reported that VR goggles were linked to distress within the first three virtual reality intervention sessions (12 in total) in an ASD sample, and Lutz (2014) noted some performance anxiety in a youth offender sample characterised as emotionally disturbed, whilst engaging with a biofeedback game.

Further, some selective and incomplete reporting which could be linked to potential adverse effects was evident in 3 studies (Heinrich et al., 2020; Rogel et al., 2020; Wijnhoven et al., 2020). Specifically, Heinrich et al., (2020) did not provide mean and standard deviation data across all time points and did not provide these at all for the control group. Rogel et al., (2020) appeared to not present all data from all measures (e.g., the NFT Symptom Checklist and Child Dissociative Checklist). Lastly, Wijnhoven et al., (2020) did not present post-intervention parent interview findings.

Discussion

This systematic review and meta-analysis aimed to evaluate current digital interventions that train emotion regulation in children and early adolescents published in peer-reviewed articles up to July 2020. In summary, digital games were the most prevalent intervention type: 69% (27/39) of the studies evaluated digital games. Digital games decreased negative emotional experience with a small significant effect, mainly in samples at risk of anxiety. In addition, digital interventions improved ER; yet, this effect was non-significant. Furthermore, acceptability was strong across all intervention types and samples, and most feasibility-related problems were in samples who had received a diagnosis. In the following sections, we discuss the key findings and provide recommendations for the field's progression.

Efficacy

Examined through meta-analysis and systematic review, digital games provided evidence for a significant reduction in negative emotional experience with a small effect, largely in samples at risk of anxiety, using validated and reliable outcome measures. This suggests that digital games are the most advanced and efficacious digital interventions for training ER in children and early adolescents. This important finding may be partly explained with cognitive load theory, which postulates that limited novel information can be processed at once in working memory (Sweller et al., 2011). Indeed, to optimise learning in a digital environment, balance must be sought between presenting information in a manner that meets an individual's cognitive needs, yet with sufficient complex information to facilitate understanding of the given topic, and learning must be active to enhance the development of cognitive schemas (Sweller, 2015; Wouters et al., 2008). Such optimisation may be achieved with certain pedagogical techniques. For example, pacing serves to decrease cognitive load on working memory by relying on the user or system to control information presentation (Wouters et al., 2008). This may be achieved by pausing material delivery or going back to look at previous material. In line with these digital pedagogical principles, the included digital game studies largely presented learning tasks that focused on different ER strategies within separate parts of the game, with gradual user-led increases in difficulty and complexity, and a simple user-friendly interface, with animated characters that provided information about different ER strategy elements and in-game support.

In combination with digital game design methods that optimise cognitive flow (Catalano et al., 2014), feelings of autonomy (Whyte et al., 2015; Przybylski et al., 2010), and fun (Ávila-Pesántez et al., 2017), digital game training may have increased motivation and engagement, which are recognised barriers to efficacy in digital interventions in children and early adolescents (Bevan Jones et al.,2020).

Neurofeedback may also be key to this finding; meta-analytic influence analysis indicated that the digital game studies that incorporated EEG neurofeedback (2/27, 7%) drove the small significant pooled effect. This is in line with the embodied ER framework (Guendelman et al., 2017), which proposes a distinction between cognitively based top-down (cognitive labelling, mindful detachment, meta-awareness, and cognitive reprisal) and affect-driven bottom-up (sensory perception and interceptive proprioception) ER strategies and argues that they work together as part of an integrated ER system. Hence, it is possible that these interventions successfully addressed both top-down and bottom-up strategies, which increased efficacy. In addition, the real-time visual neurofeedback may have further increased immersion within the digital game and, subsequently, engagement (Bevan Jones et al., 2020). However, neurofeedback information provided to players was collected using non–research-grade EEG equipment, and double blinding was not incorporated. In this context, the role of placebo effects on the apparent impact of neurofeedback on clinical symptomatology must be considered. This was discussed in three studies (Fovet et al., 2017; Schabus, 2017; Schabus et al., 2017) in line with prior clinical neurofeedback research in which diligent methodological rigour is not evident; yet, significant intervention effects are routinely reported. The ER digital intervention field should address concerns around potential placebo effects in neurofeedback through the application of methodological rigour, including double-blind, placebo-controlled trials (Schabus, 2017).

When planning placebo-controlled trials it is important to consider that expectations around intervention effects may influence placebo effects; yet, such expectations are rarely measured in light of this (Tsai et al., 2018). The higher-quality digital game studies (2/27, 7%) in this review that drove the emotion experience findings measured intervention expectation at baseline and reported null between-group effects. However, earlier-stage studies, not included in the meta-analytic component, did not. As the field progresses, intrinsic motivation must be harnessed in double-blind, placebo-controlled trials, with expectancy measured at baseline, particularly in studies that incorporate neurofeedback components. In addition, although portability and ease of use drive the use of non–research-grade EEG equipment, it is argued that such issues must be balanced against the impact on the credibility of the tool. That is, if digital ER training in children and early adolescents relies on suboptimal technology, are we really driving the field forward?

There was limited measurement of ER across all included studies; hence, the available ER efficacy findings must be interpreted with caution. The lack of focus on ER may be due to the included studies focusing somewhat on children and early adolescents at risk of anxiety and the concurrent training of social cognition and social skill difficulties; hence, these constructs were the key outcomes. In addition, there are limited psychometrically sound ER measures for children and adolescents, despite increasing awareness of the importance of its adaptive development (Zhou et al., 2020). To advance the field, there is a requirement for researchers to create and validate ER measures for diverse child and early adolescent samples, and digital intervention studies should objectively assess improvements in ER ability after the intervention and at follow-up.

Considering ER knowledge, medium to large significant improvements were observed in digital game studies that also applied additional therapeutic support, parental guidance, or targeted social cognitive skills, particularly in samples with ASD. Indeed, research has highlighted associations between brain regions implicated in cognitive ER and social cognition in youth (Ferschmann et al., 2021) and the requirement of perspective taking (McRae et al., 2012) and abundant semantic representations (Messina et al., 2015) for successful alternative representations of emotion-inducing stimuli (i.e., cognitive reappraisal). Furthermore, the integration of caregivers in interventions for samples with ASD may boost the generalisability of learned skills (Burrell & Borrego, 2012) and increase engagement with the intervention (Girolametto & Tannock, 1994). Hence, the inclusion of social cognition training as well as caregiver support may have positively influenced the ER improvements observed in these studies. Therefore, it may be beneficial to include social cognitive training and parental support within ER digital interventions that target samples with ASD because this may enhance their efficacy. However, as ER knowledge improvement was only assessed in a small number of lower-quality studies, we recommend that caution must be taken when interpreting such findings.

Feasibility

Small early-stage digital game studies that targeted ASD, attention-deficit/hyperactivity disorder, and samples with undefined emotional disorders identified several important feasibility issues linked to generalisation, implementation, technical issues, and physiological and emotional symptoms. Interindividual variability and related intervention difficulties are common in samples with neurodevelopmental disorders (Jouen et al., 2017). Hence, greater feasibility difficulties in such samples are expected. Furthermore, had feasibility issues not been picked up at this early stage of evaluation, full-scale evaluation may have yielded less favourable findings. A program and multimedia intervention assessed in slightly larger studies (2/39, 5%) found that the content was too complex for children at risk of exclusion or suspension from school, and post intervention reductions in the intensity of emotions were variable. Had the ability of the target sample to understand intervention content been checked at an early intervention development stage, efficacy outcomes might have been more consistently positive because the key messages would have been better understood. The relative importance of early-stage studies is emphasised through the consideration of the Medical Research Council’s guidelines for complex intervention development (Craig et al., 2008). Here, the impact of contextual factors on intervention success is highlighted and has recently been discussed further in a digital intervention context (Bevan Jones et al., 2020)—it is advised that iterative feasibility assessments that examine the issues revealed throughout intervention development are key to understanding contextual factors.

A further key finding was the higher dropout rate in samples who had received a diagnosis, especially in the digital game cluster. It is possible that because digital games made up a high proportion of the included studies, they also presented the most realistic picture of dropouts in digital interventions for ER. Moreover, because digital games were largely evaluated in terms of their effectiveness in real-world settings (e.g., school, home, and inpatient care) this may have affected adherence and, subsequently, dropouts. Certainly, adherence to digital interventions outside of research settings in children and early adolescents is an extant key issue (Hollis et al., 2017; Fleming et al., 2019). Involving the population in the design process who will ultimately use the digital intervention may lead to the iterative development of tools that are feasible and address the high dropout rate (Bevan Jones et al., 2020). Methods to involve youth in digital intervention development may be optimised to increase engagement (Bevan Jones et al., 2020). These include using progress bars, animations, and multiple platforms in web-based questionnaires; usability think-aloud protocols instead of standard interviews (observed and/or interviewed simultaneously while using the intervention); clear rules and use of materials (e.g., screens and devices) in focus groups; and principles applied to focus groups with wall storms (sticky notes on a wall) and word clouds (grouping of key words) in participative workshops (Bevan Jones et al., 2020).

As digital games that incorporated biofeedback provided the greatest evidence for generalizability of learned ER skills, this suggests that biofeedback-based digital games may be the most appropriate ER digital intervention for transference to real life; yet there is no extant empirical research to support this. Objective assessment of generalisation was only conducted in biofeedback-based digital games in samples who had received a diagnosis (psychiatric and neurodevelopmental disorders); hence, this finding may simply be an artifact of the relative prominence of biofeedback-based digital game interventions and inadequate measurement of generalisation in the other included studies, although it is important to consider the significance of the specific ER strategies—deep breathing and cognitive emotion regulation—that seemed to demonstrate the greatest real-life generalisability in children and early adolescents who had received a diagnosis.

fMRI-based and self-report–based evidence in adult populations suggests that cognitive reappraisal may be linked to future rather than immediate ER success in reducing negative emotion (i.e., when emotion-inducing stimuli are re-encountered at a later date) (Hermann et al., 2017). This suggests that the real-life relevance of content within digital cognitive ER training may be particularly important such that it should clearly relate to the target samples' real-life experiences and difficulties to promote future use of learned strategies. In addition, higher cognitive reappraisal frequency is linked to reduced risk for psychiatric symptomatology (Cludius et al., 2020), optimal academic attainment (Davis & Levine, 2013), social outcomes (English et al., 2012), and psychological wellbeing (Gross & John, 2003).

Researchers should collaborate with key stakeholders to create highly relevant and engaging intervention components of appropriate complexity to produce improvement in indices of emotion regulation with real-world generalisability (Bevan Jones et al., 2020; Yardley et al., 2015). Importantly, generalisability should be consistently assessed to determine the ER digital interventions that are most appropriate across different child and early adolescent samples.

Acceptability

The only study that provided solely negative acceptability data assessed ER mini-games in an early-stage small evaluation. Here, poor likability was linked to unsuitable difficulty for individuals' needs in a sample with high-functioning ASD. As mentioned previously, a key factor in the presentation of ASD and associated interventions is interindividual variability and related intervention difficulties (Jouen et al., 2017). Digital technologies allow for greater person-centred training through the involvement of caregivers and the ability to engage with the intervention at home (Jouen et al., 2017). However, if the caregiver is not able to quickly and easily adjust the difficulty of the intervention or if it is not programmed to adapt dynamically, as also reported in the highlighted study, such caregiver involvement may be in vain (Robb et al., 2019). Hence, it is recommended that ER digital games, especially those designed for children and early adolescents with neurodevelopmental disorders, should incorporate game mechanics that adapt dynamically to an individual's needs, permitting increases and decreases in difficulty as required in real time. For this to be successful, interdisciplinary collaboration is required at all stages of conceptualisation, specification, and programming (Thabrew et al., 2018). Specific collaborators may include psychologists, cognitive neuroscientists, educators, therapists, engineers, and, principally, the target of the intervention (i.e., youth) (Bevan Jones et al., 2020; Yardley et al., 2015; Mohr et al., 2014).

A further notable finding was the importance of relevance in ER digital games. Specifically, in an immersive EEG-neurofeedback and anxiety-induction game set within a haunted mansion with ghosts, the experience of relevance to real life was significantly less than that in a group-based CBT comparator but not less than that in a non-therapeutic commercial game comparator. Hence, it may be important to include explicit training content in ER games that clearly relates to the target samples real-life experiences and difficulties and encourages children and early adolescents to practice learned skills in their daily lives, optimise acceptability, and encourage generalisation, as practiced in traditional talking therapies (e.g., CBT and dialectical behaviour therapy) (Beck & Dozois, 2011; Linehan, 2015).

However, appeal and flow were also key to the experience of acceptability in ER digital games—the evidence suggests that the experience of these aspects of acceptability may be inferior in ER games compared with commercial games. Consequently, because relevance, appeal and flow may come into conflict in ER digital game acceptability, it is recommended that a balance between them should be struck to optimise acceptability. This requires iterative co-development at all stages of evaluation (Bevan Jones et al., 2020; Yardley et al., 2015).

Of vital importance to any research activity is the safety of participants, both objectively and through their own subjective experience. Perhaps reflective of the limited acceptability evaluation yet great variability in the type of acceptability assessed in the included studies, only 3% (1/39) of the studies assessed feelings of safety—a commercial augmented reality outdoor-based quest (Pokémon GO) found that participants experienced high levels of perceived danger when engaging in the intervention. Although details were not reported, it is sensible to construe that this may be in relation to the potential for harm from strangers because of interaction with unknown players.

Hollis et al., (2020) provided an overview of the extant cultural and political debate and related research concerning the role and impact of digital technology in the lives of youth. Describing it as a triple-edged sword, the authors stated that it fosters personal development and growth; may detect and address mental health issues; and yet could pose purported social, intellectual, and mental health risks. This debate is increasingly heightened because digital technology (and the means to access it) is more important than ever in supporting the educational and socioemotional needs of youth through the COVID-19 pandemic. Crucially, most social, intellectual, and mental health concerns around the impact of new digital technologies—largely driven by population as well as political and academic arenas—may be challenged through nuanced research examining the impact of digital technology on those using it (Orben, 2020).

Limitations

Considering the included studies, it is necessary to interpret the significant meta-analytic effect on the reduction of emotional experience in digital games with caution because of potential placebo effects, as discussed previously. In addition, only post intervention results were presented in the majority (28/39, 72%) of studies. This limited the ability to assess whether immediate improvements persisted and for how long. Hence, it is recommended that follow-up assessments should be conducted in large-scale studies that assess efficacy. Moreover, systematic review findings and subsequent discussions should be interpreted with caution because of the high risk of bias exhibited within the outcome measures. Researchers should endeavour to use validated and reliable acceptability and feasibility measures, and where this is not possible (e.g., when obtaining nuanced qualitative information in iterative development workshops, web-based activities, focus groups, or interviews), a clear acknowledgment and explanation of the implications of using measures that may bias the outcomes should be provided. Finally, evident in this review is the limited number of large-scale RCTs. To push the ER digital intervention field forward, a transformation of the ethics and review board application process is required (Thabrew et al., 2018). Currently, funding review panels frequently require highly detailed study protocols, with little to no consideration for the flexibility that is necessitated in collaborative design (Thabrew et al., 2018). Encouraging greater flexibility in ER digital intervention development and evaluation plans may permit a stronger research focus on vital acceptability and feasibility features and lead to the successful growth of this emerging field.

Although the findings discussed here reveal potential benefits of and provide recommendations for the rigorous progression of ER digital interventions in children and early adolescents, this systematic review and meta-analysis does include some limitations. The search strategy was broad, which may be seen as a strength at this early stage of the field’s progression because it is imperative to understand the breadth of factors that may be implicated in its advancement. By contrast, this increased the number of required focal points of the review, which may have reduced its specificity.

Furthermore, the focus on childhood and early adolescence is a strength—it enabled a nuanced understanding of this important developmental period. However, the meta-analysis did not include informant-reported effects. Although this decision was made to ensure homogeneity of the selected effect sizes, it might have limited the understanding of the benefits of ER digital intervention.

Conclusion

In conclusion, this review provides an important first step in the progression of ER digital interventions by synthesising efficacy, feasibility, and acceptability data, published from 2008 to 2020, with a focus on childhood to early adolescence. The most consistent evidence came from digital games in the reduction of negative emotions, principally in children at risk of anxiety. However, variable methodologies, lack of follow-up assessment, and high risk of bias, inclusive of potential placebo effects within statistically influential neurofeedback-based digital game studies, limit definitive conclusions that may be made regarding the efficacy of such interventions. Engaging iterative intervention co-development with the sample who will eventually use the digital intervention and properly adjusting the difficulty to the intervention target is vital in achieving optimal acceptability and, specifically, addressing concerns around engagement. Finally, large-scale studies that assess ER as a key outcome using valid and reliable measures are urgently required to assess the extent to which ER ability may be improved in different samples of children and early adolescents through digital technology.

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CHAPTER 4,

STUDY 3:

THE COLLABORATIVE DEVELOPMENT OF A BRAINZ PROTOTYPE: A UNIVERSAL EMOTION REGULATION GAME FOR EARLY ADOLESCENTS

Abstract

Background: ER is transdiagnostic in nature and influenced by the external environment. Further, ER processes are highly malleable in early adolescence and adolescence is a period of increased risk for difficulties in ER and development of psychopathology. Previous research highlights the potential for ER digital intervention to address extant issues around resource availability, stigma, engagement, access, and acceptability in traditional and wider reaching ER-focused intervention for adolescents. Further, increasing awareness of the need to actively involve the end user(s) at all stages of development may address concerns around feasibility and engagement in ER digital intervention.

Objective: We aim to describe the interdisciplinary, international, collaborative development of *BRAINZ*: an early-stage prototype ER smartphone game for early adolescents.

Methods: The prototype was informed by (1) findings from 52 evidence gathering workshops and a questionnaire with early adolescents, (2) two meta-analytic reviews focused on i) factors implicated in positive peer relationships, and ii) ER digital intervention in early adolescence, respectively, (3) a systematic overview of ER strategies, and (4) two codesign workshops and one codesign feedback task with early adolescents. In addition, further codesign consultations involved graphic design hackathons, beta testing, an online focus group, public engagement and iterative feedback and discussions. This work took place from 2019 to 2022.

Results: Key findings related to the mode of intervention, difficulties around interpersonal stressors and ER throughout secondary school transition, preference for explicit delivery of psychoeducation information and simple, bright graphical content, and need for relatable and engaging text-based content.

Conclusion: Here we present the collaborative and user-centered development of an early-stage prototype of BRAINZ, a psychoeducation smartphone game for training ER strategies in early adolescents. Future research will report on the early evaluation of *BRAINZ*, which will inform further development prior to effectiveness testing via randomised control trial*.* Through the presentation of the development of the early-stage prototype of *BRAINZ*, we provide a useful tool for researchers to refer to, to conduct and present future rigorous, ER digital intervention development work.

Emotion regulation (ER) is transdiagnostic in nature (Aldao et al., 2016; Cludius et al., 2020) and associated with psychosocial and academic functioning in adolescence (e.g., Feldman, 2021; Davis & Levine, 2013; English et al., 2021) and beyond (Feldman, 2021). Importantly, adolescence presents a sensitive period in which ER processes are highly malleable (Adrian et al., 2019), and may be influenced by positive social input (van Harmelen et al., 2017; Schriber & Guyer, 2016; Thompson, 2011). Hence, it is vital *and* possible to promote good ER in adolescence. Yet, traditional psychotherapeutic intervention requires substantial personnel, economic and temporal resources (Chiles et al., 1999) and may not be attractive to, or promote engagement in adolescents (Radez et al., 2021; de Haan et al., 2013). This indicates a need to create accessible, attractive and economically viable preventative ER interventions. Digital interventions, precisely, digital games, may offer a promising means of addressing this need (Reynard et al., 2022; Granic et al., 2014). However, to successfully optimise engagement and subsequent effectiveness, such technologies must be developed in line with the needs and wishes of the population for which they are intended, via the adoption of design thinking principles and codesign methods (e.g., Scholten & Granic, 2019; Bevan Jones et al., 2020; Fleming et al., 2019; Thabrew et al., 2018; Brown & Wyatt, 2010). Here, we aim to detail the interdisciplinary, international codesign of an early prototype-stage ER psychoeducation smartphone game for early adolescents.

Codesign of Digital Interventions with Adolescents

Although digital interventions for adolescents that are grounded in psychological theory and empirical evidence are increasingly prevalent—demonstrated by several outcome-focused meta-analyses and systematic reviews (e.g., Hollis et al., 2017; Grist et al., 2017; Grist et al., 2019), less attention has been given to the importance of how they are developed. This may be largely attributed to the lack of available guidance that details clear and specific information on how to optimally create evidence-based digital tools for different psychological skills and populations. Yet, in the context of adherence issues and high dropout rates in digital psychological interventions for adolescents (Bevan Jones et al., 2020; Hollis et al., 2020; Fleming et al., 2019), it is vital that researchers optimise acceptability and feasibility at all stages of evaluation, before large-scale efficacy trials (Bevan Jones et al., 2020). Further, evidence from adult samples suggests that dropout rates are larger in digital interventions that encourage self-guided engagement (Karyotaki et al., 2015). This is supported by a recent meta-analysis and systematic review, where we found that additional support (i.e., from a teacher, parent or therapist) in adolescents with an ASD diagnosis may support ER digital intervention success (Reynard et al., 2022). However, as aforementioned, the need for digital psychological intervention in adolescents is partly borne out of the lack of availability and accessibility of traditional psychotherapy (Chiles et al., 1999).

To support researchers to develop evidence-based interventions, discover feasibility issues, that may often be conflicting—and ultimately promote intervention success, the Medical Research Council (MRC) published guidance on complex intervention development and evaluation. Here, it is recommended that existing evidence is gathered on similar interventions, a theoretical understanding of the process of change is identified and developed, and specific feasibility issues relevant to the intended intervention users and context are examined and addressed iteratively with relevant stakeholders (Skivington et al., 2021). The gathering of such information promotes the understanding of contextual factors that may contribute to effective complex interventions.

Literature and practice reviews and proposed frameworks have presented concrete examples of ways in which one may engage a target population with mental health-focused digital intervention development to improve their acceptability and feasibility (e.g., Mummah et al., 2016; Orlowski et al., 2015; Scholten & Granic, 2019; Bevan Jones et al., 2020). Grounded in the principles of design thinking, namely, placing emphasis on user's needs, multidisciplinary ideation and testing prototypes (Brown, 2008; Brown & Wyatt, 2010); earlier reviews necessitate the inclusion of the intended users, but in a largely consultative role (e.g., Mummah et al., 2016; Orlowski et al., 2015).

More recently, Bevan Jones and colleagues explain that researchers increasingly adopt an active, collaborative codesign approach with adolescents at all stages of the early development of mental health digital interventions (Bevan Jones et al., 2020). The authors highlight a common three-step iterative approach across included studies. Firstly, stakeholders (including the intended adolescent users) engage in scoping and 'discovery' work with researchers to identify needs and preferences (e.g., via workshops, focus groups or interviews) and researchers synthesise this along with additional evidence (e.g., from academic literature, psychological theory, best practice and therapeutic guidelines). Next, interdisciplinary collaborative codesign occurs, with multiple iterations of user engagement in different aspects of the digital intervention (Bevan Jones et al., 2020). Finally, early prototype(s) are evaluated in terms of their acceptability and feasibility (Bevan Jones et al., 2020). Bevan Jones suggests methods to optimise adolescent engagement in codesign, for example using progress bars and animations in digital questionnaires and 'think-alouds', in which users are observed or interviewed whilst using the technology (Bevan Jones et al., 2020). Important to note is that different studies reported differing levels and types of iterative engagement with users and other stakeholders, likely due to diverse adolescent samples, wide-ranging contexts and extraneous factors, and varied levels of resources. Indeed, the work by Bevan Jones and colleagues is particularly useful as it provides clear and practical guidance, with specific examples for collaborating with adolescents.

ER Digital Game Interventions for Adolescents

In a recent meta-analysis and systematic review, we found that digital games provide the strongest evidence for a decrease in negative emotional experiences in children and early adolescents, relative to other digital ER interventions (Reynard et al., 2022). Indeed, appropriately designed digital game interventions may offer high levels of usability, intrinsic motivation, appropriate cognitive demand, and feelings of relevance, flow and enjoyment, whilst imparting subject-specific knowledge, with the opportunity to practice new skills in a safe and fun environment (Granic et al., 2014; Scholten & Granic, 2019; Reynard et al., 2022).

As highlighted in numerous reviews in which guidance on the codesign of digital tools for children and adolescents is provided, tools must be acceptable and feasible in the target population to address issues around engagement and motivation (Bevan Jones et al., 2020; Fleming et al., 2019; Thabrew et al., 2018). Indeed, emerging evidence suggests that recent empirically assessed digital game interventions are rated high in acceptability and feasibility by adolescents (Reynard et al., 2022)—unlike other modes of digital intervention, such as online therapy, that are not as attractive to adolescents as the technology that they engage with on a day-to-day basis (*The Lancet*, 2018; Pennant et al., 2015).

Although digital game interventions clearly offer an advantageous means of appealing to ‘digital natives’, they are not without their specific difficulties (Scholten & Granic, 2019; Reynard et al., 2022). Content relevance, graphic and animation quality, cognitive flow, personalisation, pacing and dynamic difficulty adaptation are optimised in commercial games (e.g., Fortnite, version 21.20), but often remain targets for improvement in digital game interventions, along with issues around the sometimes didactic nature of the pedagogical approach (Scholten & Granic, 2019).

However, such issues may be highlighted and addressed via appropriate interdisciplinary involvement throughout the iterative discovery and codesign work (Bevan Jones et al., 2018, 2020). Hence, as with other digital interventions for adolescents, digital games for ER require appropriate collaborative and interdisciplinary development to ensure that they are acceptable, feasible, and ultimately successful (Bevan Jones et al., 2020; Fleming et al., 2019; Thabrew et al., 2018).

Current Research and Aims

We present the development of a universal ER psychoeducation smartphone game that has been created in line with guidance and information on the development of complex and digital interventions (Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021; Bevan Jones et al., 2018, 2020). Here, we will detail the early interdisciplinary and cross-national development of BRAINZ—an early prototype-stage, universal ER psychoeducation smartphone game for early adolescents aged 10-12.

Methods

Research and Game Development Strategy

We conducted the research and game development in line with the '*identifying existing evidence*' and '*identifying and developing theory'* phases of the MRC development of complex intervention guidance (Craig et al., 2008; Craig & Petticrew, 2013), and the '*discovery*' and '*codesign*' phases of Bevan Jones and colleagues' digital intervention work and practitioner review (Bevan Jones et al., 2018, 2020). The interdisciplinary and cross-national collaborative project was led by SR and informed by theory, empirical evidence, and practice in the areas of early adolescent ER development, early adolescent ER strategy use, learning in digital environments, ER digital intervention and collaborative, interdisciplinary design.

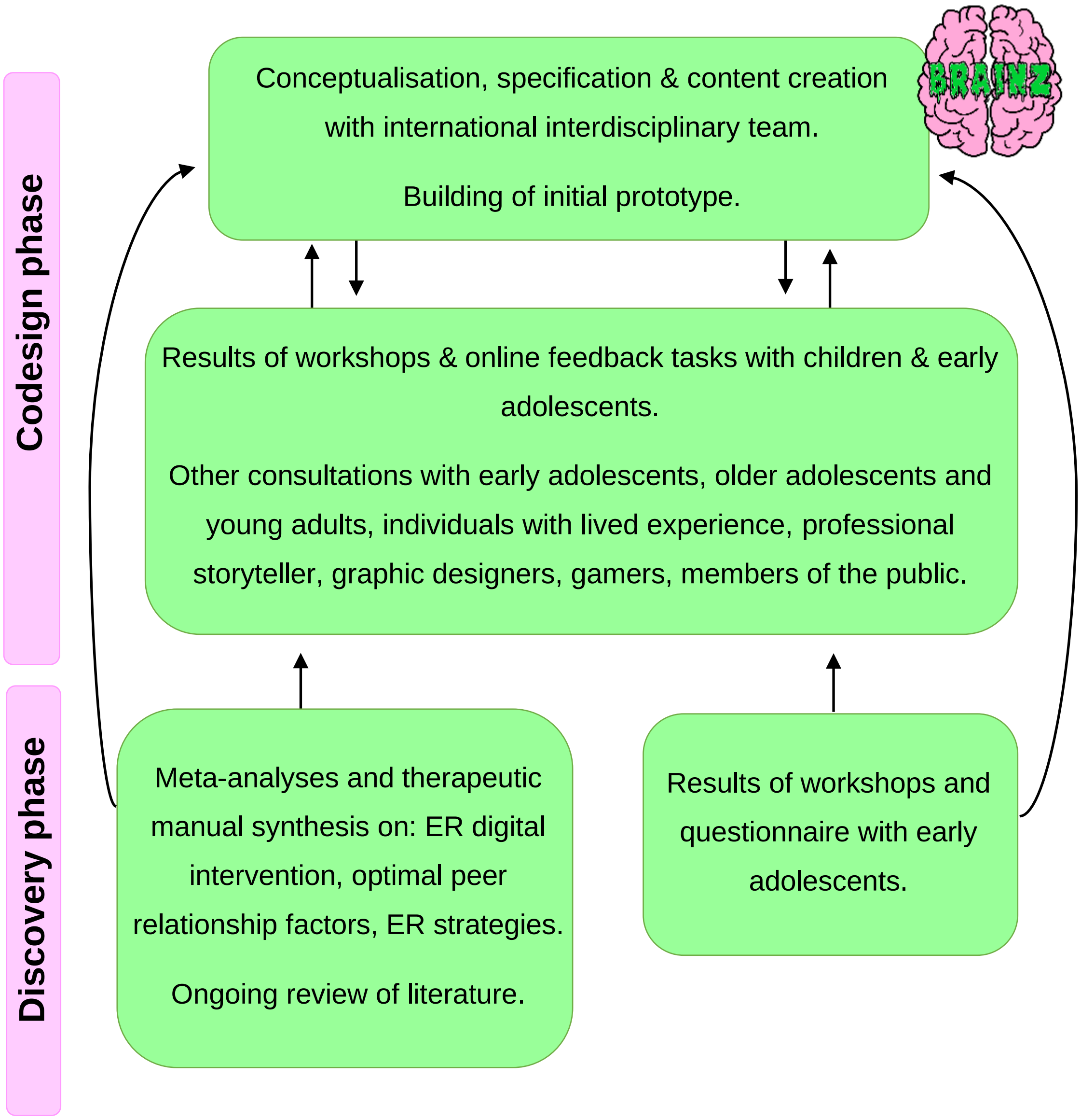
We strove to adopt a user-centered, iterative, collaborative design approach, as outlined in recent adolescent-focused digital intervention guidelines (e.g., Bevan Jones et al., 2020; Thabrew et al., 2018; Fleming et al., 2019; Scholten & Granic, 2019). Here, largely qualitative discussions, engagement and other consultation with stakeholders including the intended users, those with lived experience, older adolescents and young adults, psychologists, psychiatrists, a professional storyteller (playwright), graphic designers, engineers, computer scientists and gamers across the development stages allowed the collection of diverse ideas and perspectives to be integrated into the first iteration prototype smartphone game.

First, to inform both BRAINZ and a linked broad package of school-based socio-emotional interventions, members of the interdisciplinary team conducted a program of arts-based workshops, which included a questionnaire collecting written responses, with early adolescents in schools in Lower Austria. Here, information gathering focused on peer relationships; engagement with technology and gaming; and experiences, fears, and coping mechanisms around moving to secondary school. For the purposes of the development of BRAINZ, we used relevant findings from these workshops to guide the discovery phase and codesign phase (see Figure 4.1). Next, meta-analytic reviews were conducted to synthesise empirical evidence pertaining to factors linked to optimal peer relationship experiences in early adolescence (Mitic et al., 2021) and ER digital interventions (Reynard et al., 2022).

In addition, utilising a systematic methods overview approach (Gentles et al., 2016; O'Cathain et al., 2019), ER strategies in adolescence were collated and synthesised from therapeutic manuals and conceptual and empirical research. From here, discussions, workshops, and online feedback tasks with various stakeholders continued throughout the period of conceptualisation, game content creation and specification. Refinement and interdisciplinary collaboration were ongoing through this codesign phase and culminated in the creation of a first iteration prototype smartphone game for ER. In addition, consultation with the public occurred at a public engagement in science event. See Figure 4.1 for a visual overview of the integration of evidence and collaborative design borne out of literature reviews, workshops, questionnaires, online feedback, discussions, and other consultations.

Figure 4.1

Discovery and codesign phase information that informed the design and content of the first iteration prototype of BRAINZ—a psychoeducation smartphone game for ER in early adolescents aged 10-12 years.



Note. The nonlinear interaction between phases throughout development is highlighted via the back-and-forth arrows. *Other consultations* included graphic design hackathons, beta testing, an online focus group, public engagement and iterative feedback and discussion.

Discovery Workshop and Questionnaire (Discovery Phase)

Recruitment, Eligibility and Demographic Information

Between September 2018 to March 2019, 52 2-hour discovery phase workshops were conducted with early adolescents. Schools in Lower Austria were recruited through direct contact, flyers, social media and contact with teachers during training events. No restriction was placed on school type and the only participant inclusion criteria were that they were in the last year of primary school or first year of secondary school. There were no exclusion criteria. Interested schools received written information about the study. Upon agreement to participate, parents received detailed study information. Parents provided written informed consent. Early adolescents were informed about the study and provided workshop leaders with verbal assent. See Mittmann et al. (2021) and Stiehl et al. (in press), for a detailed description of the recruitment process, ethical approval and demographic information for the discovery phase workshops and questionnaire.

Discovery Workshop and Questionnaire Procedure

Workshops were coordinated by collaborators (IP, IK) in Lower Austrian schools, within participants' classrooms. One of the workshop activities involved a vignette about school transition fears, which was created with participants. Next, participants engaged in small group discussions (3-6 participants per group), in which strategies to cope with transition-related fears were discussed, with support from a workshop facilitator. It is this activity that provided data, which informed BRAINZ development. Data were analysed using thematic analysis (Stiehl et al., in press). Participants completed the questionnaire within the workshop. This took 5-10 minutes. Questions focused on the type of device(s) used (computer, laptop, console, tablet, smartphone), as well as the frequency, context of, and reason for use. See Mittmann et al. (2021) for a detailed description of the questionnaire and Stiehl et al. (in press) for a detailed description of the workshop procedure.

Discovery Workshop Data Analysis

The discovery workshops were coded and analysed using thematic analysis (see Stiehl et al., in press, for a detailed overview of the qualitative analysis plan).

Discovery Questionnaire Data Analysis

The online communication questionnaire was analysed with descriptive statistics and Chi-square tests using IBM SPSS Statistics for Windows, version 24 (IBM Corp., 2016, Armonk, NY).

In the results, we present a summary of the discovery workshop findings that were used to inform the development of BRAINZ.

Codesign Workshop and Codesign Online Feedback (Codesign Phase)

Codesign Workshop Recruitment, Eligibility and Demographic Information

Following the discovery workshops and questionnaire, and initial interdisciplinary ideas generation, in June 2019, early adolescents from Lower Austria took part in one of two 1-hour pedagogy-focused codesign workshops. The only inclusion criteria were that participants were in the last year of primary school or first year of secondary school. There were no exclusion criteria. The Austrian school was recruited via the existing school recruitment network. Contact with teachers was first conducted via email and this was followed up with a telephone call. Upon agreement to participate, parents received detailed study information. Parents provided written informed consent. Early adolescents were informed about the study and provided workshop leaders with verbal assent.

Codesign Online Feedback Recruitment, Eligibility and Demographic Information

Children and early adolescents also took part in an online codesign phase feedback study. The only inclusion criteria were that participants were aged 8-14 years and had access to a computer, tablet, or smartphone. There were no exclusion criteria. Recruitment was conducted via the parent researcher online collaborative, Children Helping Science (n.d.). Study information sheets were distributed via email to interested parents and children. Parents provided written informed consent and assent for the child participant.

Codesign Workshop Procedure

Codesign workshops were facilitated by SR and supported by German speaking colleagues GM, SD, IP, and JR, in one Lower Austrian grammar school, within participant’s classrooms. In small groups (3-5 participants per group, nine groups in total), six different digitised pedagogical delivery methods (quiz, rap video, book animation, game, cartoon with implicitly presented information, cartoon with explicitly presented information) were each presented via two examples, within short (<5min) clips using a laptop. See Figure 4.2 for stills of a selection of the clips used. We aimed to broadly explore how the different methods influenced participants understanding of information and enjoyment, to inform the psychoeducative methods in the prototype. As initial interdisciplinary ideas focused on the game being set inside a human body, several of the clips across different methods were set inside the human body. In addition, as the discovery phase findings indicated the need for a digital game that trained ER, we sought to include clips of digital pedagogical methods that included emotion-based content. Importantly, we wanted to gauge early adolescents’ understanding when engaging with both explicit and implicit learning, to inform game design. Hence, we included both implicit and explicit clips. After the presentation of each method, facilitators encouraged groups to discuss their experience of the clips, within the context of learning new information.

Examples of specific prompts include: What do you think the clip is trying to tell you? Why do you think it is trying to tell you that? Is there anything that makes the clip easy/difficult to understand? What do you like about it? What do you not like? Each group was supported by 1-2 workshop facilitators. Workshops were audio-recorded via a digital voice-recording device and subsequently transcribed. German was translated to English within transcription.

Figure 4.2

Stills of video clips used to demonstrate different digitised pedagogical methods in codesign workshops with early adolescents.

Codesign Online Feedback Procedure

Following the codesign workshops, further interdisciplinary team ideas generation and conceptualisation, evidence gathering, other consultations and early content creation, broad online feedback pertaining to short stories and game concept was sought from children and early adolescents in August 2020. Qualtrics (Qualtrics, Provo, UT) was used to present information about the game concept and a small number of in-game short stories. The following questions were asked: Do you have any ideas for how we can make the short story more interesting or enjoyable to read? What do you think about the setting for the stories in this mobile game? How horrible do you think the situation is in the story? (5 extremely horrible, 3 neutral, 1 not horrible). Upon completion, participants were sent digital certificates and offered the opportunity to engage in further iterative codevelopment tasks. This was conducted by SR.

Codesign Workshop Data Analysis

The codesign workshops were coded and analysed using content analysis by SR (Morgan, 1993). First, coding ideas were discussed and reviewed with AK and EN and the protocol was refined accordingly. Any disagreements on definitions and names for codes were reviewed together until a consensus was reached. In cases of uncertainty, KW was consulted. Microsoft Excel was used to support content analysis. Transcripts were carefully inspected to identify the codes. Counts were completed at the N group level (i.e., the number of workshop groups in which a code was identified was counted). Interrater reliability was completed by SR and SS with the kappa statistic, using IBM SPSS Statistics for Windows, version 24 (IBM Corp., 2016, Armonk, NY). It is important to acknowledge that the codes drawn from the data were influenced by the workshop aims, plan and pedagogical considerations that the interdisciplinary team wished to explore, to inform the initial prototype.

Codesign Online Feedback Data Analysis

As the codesign online feedback study included a very small number of participants (n = 3), these findings were collated on an Excel sheet and summarised for inclusion within the codesign process.

For both the discovery and codesign phase activities, appropriate ethical approvals were granted from local ethics committees.

Other Consultations

As well as the workshops, questionnaire and online feedback, SR conducted other informal discussions and iterative feedback, online focus group, collaborative engagement, graphic design hackathons, public engagement and beta testing with intended users, young adults, individuals with lived experience of emotional difficulties and early disadvantage, graphic designers, a professional storyteller, engineers, and gamers from the UK and across Europe.

Graphic Design Hackathons

Two graphic design hackathons were conducted with a universal sample of adolescents aged 11-17 years at a youth club in Birmingham, UK (n = 8), in September 2019. The hackathons were supported by SS, CM, MC, JP and AK. Here, the aim was to generate ideas for the main character graphics with the young people and a graphic design company (Studio14). Specific ideas generation related to how to make similar characters distinct from each other and how characters could represent different psychological concepts. Adolescents were encouraged to draw and discuss their ideas and discuss their thoughts and feelings around example images of characters sourced from the internet. Information was captured via field notes and the drawings created in the sessions.

Online Focus Group

One online focus group was conducted with a group of Austrian young adults (*n* = 4) with lived experience of early disadvantage and emotional distress, in April 2020. This was supported by NR and SBP. Here, the aim was to gain feedback on first drafts of psychoeducation scripts used in BRAINZ. A specific focus was placed on how to increase clarity and relatability. Information was captured via note taken during the focus group.

Beta Testing

The BRAINZ prototype was beta tested with a universal sample of adolescents aged 11-17 years at a youth club in Birmingham, UK (*n* = 10) and adult members of the international interdisciplinary team (*n* = 11), which included both game developers and gaming novices, in October 2021. Here, the aim was to identify issues which negatively impacted the experience of engaging with the prototype so that these could be refined prior to early evaluation. At the youth club an informal 'think-aloud' approach was used which was supported by AF and MP. Information was captured via field notes and in-game data. Beta testing with adults was conducted remotely, whereby users were asked to engage with the prototype as fully as possible and provide feedback on a shared Excel sheet. The information was collated and organised into themes and sub-themes and shared with the interdisciplinary team for review.

Public Engagement

The first iteration of the BRAINZ prototype was presented at a public engagement event in March 2022 in Birmingham, UK, for Brain Awareness Week, managed by the Dana Foundation (n.d.). This was supported by MP, CP, GB, and AT. Here, children and adults were offered the opportunity to learn about the development of BRAINZ and engage informally with the early-stage prototype. Users provided feedback, which was captured via field notes.

Iterative Feedback and Discussion

Regular interdisciplinary team meetings were held in Austria, Portugal, and the UK throughout both the discovery and codesign phases. Here, SR led the presentation of ongoing evidence review findings, and extant development of the game concept, content, ideas and specifications, and discussions around appropriate next steps. Key discussions are specified within the results section.

Results

Discovery Phase

Discovery Workshop and Questionnaire Participants

Nine hundred and six early adolescents from 29 Lower Austrian schools completed the online communication questionnaire. Of these participants, 896 (*M* age = 10.40, SD = 0.839; 46% female, 52% male) also took part in discovery workshops. See Mittmann et al. (2021) and Stiehl et al. (in press) for a full breakdown of participant demographics.

Summary of Discovery Workshop and Questionnaire Results to Inform the Initial Prototype

Mittmann et al. (2021), found that early adolescents from Lower Austria have a great interest in and high engagement with both social media and serious games. In the context of the development of BRAINZ, serious games are defined as a smartphone-based game that is created for educational purposes. Broadly, serious games applications are not limited to one mediating device, but may be designed using many digital devices, such as a computer, tablet, or laptop (Avila-Pesantez et al., 2019; De Lope & Medina-Medina 2017; Laarmarti et al., 2014). Smartphones were reported to be used very often and were reported as the most accessible and acceptable digital device. Indeed, 88% of participants reported that they play games on their smartphone.

As indicated by Stiehl et al. (in press), early adolescents from Lower Austria experienced fears in relation to moving from primary school to secondary school. Key themes in relation to this were largely limited to interpersonal and social difficulties. They include: (1) fear of being victimised by peers, (2) fear of feeling alone, (3) fear of being victimised by authority figures (i.e., teaching staff), and (4) fear of academic failure. Fear of peer victimisation was the only fear that was reported across all discovery workshops. In addition, further themes indicated that although early adolescents can identify some appropriate coping strategies to manage fears when moving to a new school environment (e.g., seeking help from an adult), there was disagreement and concern around how their use may impact upon relationships with peers (e.g., may be called a “tell-tale” and ostracised). Further, participants also often reported relying on less adaptive ER strategies, such as avoidance and suppression.

These findings indicated that it was appropriate to design a universal ER intervention that trains adaptive ER strategies. Further, as the transition from primary to secondary school is a stressful period and linked with distinct fears and difficulties, it was evident that the intervention should be implemented at and/or before this time (i.e., age 10-12) and include content that relates to the identified social and interpersonal fears, with a greater focus on peer victimisation. Indeed, peer victimisation is highly prevalent globally in youth (30.5% average prevalence within a 30-day period) (Biswas et al., 2020), and is linked to adverse ER and mental health outcomes (Herd & Kim-Spoon, 2021; Lamblin et al., 2017; Stewart-Tufescu et al., 2021). Moreover, supporting previous literature on the accessibility and acceptability of digital devices in youth (e.g., Hollis et al., 2017; Naslund et al., 2017), the intervention should be digital and delivered via a smartphone device.

Meta-Analyses

Providing further evidence of the need to train ER skills in early adolescence, the meta-analysis by MM (which examined wide ranging skill-, individual-, environmental-, health- and internet use-based determinants of supportive peer relationships), indicated that ER ability is a key factor in promoting supportive peer relationships (Mitic et al., 2021). Social cognitive factors (affective social cognition, prosocial motivation and sympathy, cognitive social cognition), were also significant determinants of good peer outcomes.

The meta-analysis conducted by SR focused on the efficacy, feasibility, and acceptability of different types of digital interventions used to train ER in children and early adolescents (Reynard et al., 2022). Here, digital games provided the most consistent evidence for training ER in wide-ranging child and adolescent samples. In addition, the relevance of included content may support the generalisation of learnt skills and increase acceptability. Further, the ER digital games within the review incorporated scaffolding-based, system-led strategies that promote active learning, better understanding of material, autonomy in system navigation and use, and decrease on working memory load.

The meta-analytic findings indicated that it was appropriate to train ER via a digital game, as well as supporting training around social cognitive skills, where up-to-date literature indicated a need. The further information on the use of relevant content indicated that the game should include information pertaining to the fears identified in the discovery workshops. See results section ‘Pedagogical Approach and Considerations’ for details on how scaffolding was integrated into the design of the initial prototype.

Theoretical Approach: Therapeutic-Empirical ER Strategy Synthesis

The collation and synthesis of ER strategies for early adolescents (which was conducted by SR and supported by ST, GM, and JR)–identified both personal and interpersonal ER strategies, inclusive of specific examples of their implementation. These were sourced from scientific literature and wide-ranging youth-focused therapeutic manuals, including cognitive behavioural therapy (CBT), dialectical behavioural therapy (DBT), cognitive therapy (CT) and rational emotive behaviour therapy (REBT) approaches. Through iterative discussion with KW, the strategy examples were organised into personal and interpersonal ER clusters representing nine broad groups of ER strategies. The groups were named and defined and included: (1) Changing Thoughts, (2) Attention, (3) Compassion, (4) Acceptance, (5) Controlling Behaviour, (6) Bodily Action, (7) Humour, (8) Monitoring, and (9) Reinforcement.

During interdisciplinary discussion, it was decided that BRAINZ would train personal ER and another game within the broader socio-emotional intervention package would train interpersonal ER. Further, the grouping of ER strategies informed the concept and specifications for the structure and mechanics of the game, and the included content. See results section 'Development of the Initial Prototype' for further details.

Codesign Phase

Codesign Workshop and Online Feedback Participants

Thirty-one early adolescents (*M* age = 10.77, SD = 0.48; 58% female, 42% male) from one Lower Austrian private grammar school took part in the codesign phase workshops.

Three 9–12-year-old children and early adolescents (1 female, 2 male) located in the United States of America (*n* = 2) and South Africa (*n* = 1) took part in the online feedback study.

Summary of Codesign Workshop Results to Inform the Initial Prototype

The codes identified in the codesign workshops could be grouped into 5 major categories. These were: (1) understanding, (2) general acceptability, (3) setting, (4) graphics and (5) sound. The categories and codes that arose are presented in table 4.1. See Appendix 3, “Codesign Workshop Code Frequencies” for code count Figures within each category. The interrater reliability was perfect (Cohen’s $\kappa = 1$) across all codes apart from ‘General negative opinion about graphics’, which was moderate (Cohen’s $\kappa = .57$) (McHugh, 2012). Within each coding category, we present counts across both examples of the methods and how the findings impacted the design of the prototype.

Table 4.1

Codes from the codesign workshops

Category	Code
1. Understanding	Key message and context understood
	Key message and/or context not understood/difficult to understand
2. General acceptability	Expression of general positive feelings
	Expression of general negative feelings
	Found example too boring
	Found example funny
	General positive opinion
	Positive opinion about multiple-choice questions
	Example aimed at younger children
3. Setting	General positive opinion about setting
	General negative opinion about setting
	Liked use of shooting in human body
	Disliked use of shooting in human body

4. Graphics	General positive opinion about graphics
	General negative opinion about graphics
	Visual aid useful for facilitating understanding
5. Sound	Liked voice and/or acoustic features
	Disliked voice and/or acoustic features

Coding Category 1: Understanding. The book animation method was optimal in facilitating understanding of key messages, which were presented explicitly. Across both examples shown, 6/9 groups (67%) reported consistent high understanding. In addition, no groups reported difficulties in understanding the book animation. This was also noted for the explicit cartoon and quiz methods. Although, one group noted some complex vocabulary in book animation one.

Difficulties in understanding key messages was greatest when information was presented implicitly. Within the implicit cartoon method, 6/9 (67%) and 5/9 (56%) groups indicated low understanding in example one and two, respectively. Whereas, within the explicit cartoon method, only example one, which delivered information about the human respiratory system, was linked to some low understanding (2/9, 22% groups). In the context of low understanding of implicitly delivered information, some participants reported that a fun character should explain complex content. In addition, some low understanding in rap videos were linked to the fast delivery speed of graphic and audio information.

These findings indicated that the prototype should contain largely explicitly delivered psychoeducation via text with age-appropriate language. In addition, it provided evidence for giving autonomy over the speed of the delivery of information—players should move onto the next part of psychoeducative information by tapping on the phone screen. Finally, the interdisciplinary team decided that engaging brain cell characters would deliver the psychoeducation and game instructions.

Coding Category 2: General Acceptability. Rap videos and book animations were the most acceptable digital learning methods, with 8/9 (89%), 6/9 (67%), and 9/9 (100%), 4/9 (44%) groups expressing positive opinions about examples one and two, respectively.

Acceptability in one implicit cartoon set inside the human body was linked to interest in blood cell characters in 5/9 (56%) groups. Further, within the game method, 2/9 (22%) groups experienced positive feelings; this was linked to helping people by fighting illnesses. However, groups also reported negative feelings in games about illness set inside the human body (4/9, 44%; 5/9, 56%). In addition, it was reported that it is boring for an educational game to be *only* inside the human body.

Finally, across both examples shown, three groups (33%) stated that they liked the use of multiple-choice questions (MCQs) in quizzes. No groups reported not liking MCQs.

These findings provided further evidence for the use of text with supporting illustrations in the delivery of psychoeducation in the prototype. As indicated by the positive response to educational rap videos, future iterations of the game will integrate rap audio in some of the psychoeducative delivery. Unfortunately, we did not have sufficient resources to include rap within the current prototype. In addition, the findings provided further indication of the appropriateness of fun brain cell characters to deliver psychoeducative content. Further, the subsequent story concept for the game focused on a brain whose ER networks had been damaged by a naughty, shrunken zombie character, rather than damage caused by an illness. Moreover, we conceptualised the game to have two settings: inside a brain *and* in a zombie slime laboratory. Finally, MCQs were included.

Coding Category 3: Setting. Groups were split in terms of whether they liked or disliked shooting inside the human body in an example of a game about fighting serious illness. Three out of nine (33%) groups reported that they did not like shooting, and 4/9 (44%) reported that they did like shooting inside a human body. Linked to this was that similar educational games would be better if they contained a doctor character who does something other than only shooting cells.

These findings indicated that fun and engaging elements of the game that support psychoeducational content should not only focus on shooting, rather, there should be a mixture of action- and puzzle-based approaches. Further, the player's character was conceptualised as a young Trainee Scientist who helps to fix brain networks by learning new information.

Coding Category 4: Graphics. Book animation example one (7/9, 78%) and two (4/9, 44%) were the most, and least liked respectively, in terms of graphical content. Both book animations contained very simple, hand drawn illustrations to support the information being delivered, yet they differed in their style and use of colour. Specifically, example one contained emojis with bright colours, and example two contained black and white figures.

Within the prototype, we included digital illustrations (created by AM) to supplement text-based vignette content and promote engagement. Further, a graphic designer (JC) created brain cell characters that delivered psychoeducation and game instructions. Colours used in both the digital illustrations and brain cell character graphics were bold and bright, and the illustrations and graphics were simple, to ensure clarity.

Coding Category 5: Sound. Rap videos (example one and two) were the most liked method in regard to sound (4/9, 44%). Conversely, rap video (example two) and implicit cartoon (example one) were the least liked, with two groups (22%) linking this to poor rap voice quality and lack of clarity, respectively. In addition, some participants reported that background music would make learning via online quizzes more fun and interesting.

In future iterations of BRAINZ, users will have the option to listen to the text-based instructions and psychoeducation that is delivered by brain cell characters. Importantly, the findings highlight that it is vital to engage with the intended users to determine what features of narrator's voices promote acceptability *and* clarity. Further, we included background music across the prototype which could be turned on or off, as preferred.

See the below section, 'Development of the Initial Prototype' for further details of how the findings were used to develop the prototype.

Summary of Online Feedback Results to Inform the Initial Prototype

Within the online feedback study, all three participants were positive about a zombie slime laboratory being the setting for stories to support psychoeducation within mini games: "Amazing idea!", "I think it's a good setting". Further, to make stories more interesting and enjoyable, one participant stated that text should be more spread out, with more pictures so it is like a comic book. Another participant stated that more detail is needed in the stories. Finally, there was a wide range of experiences in the perceived intensity of stories. One participant rated the story as four, one as three, and one as two (5 indicated that the story was extremely horrible).

These findings indicated that the zombie slime lab was an acceptable setting for stories in the game. Hence, within mini-games that required vignette-based content, we based these around time spent in and around the zombie slime lab. We strove to include sufficient detail in stories to make them engaging, yet not too much to make them too long. In addition, psychoeducative vignettes, instructional information and mini-game vignettes were supplemented with illustrations, graphics, and animations to support understanding and engagement. They were included alongside and in-between segments of text to maintain interest. Lastly, as the intensity of the stories were perceived differentially across the three participants, when conceptualising and creating the short stories and associated mini games, we acknowledged that all users would not experience the stories in the same way. See the 'Development of the Initial Prototype' section for information on the iterative and collaborative process involved in creating the mini-game short stories.

Development of the Initial Prototype

Design and Content of Initial Prototype

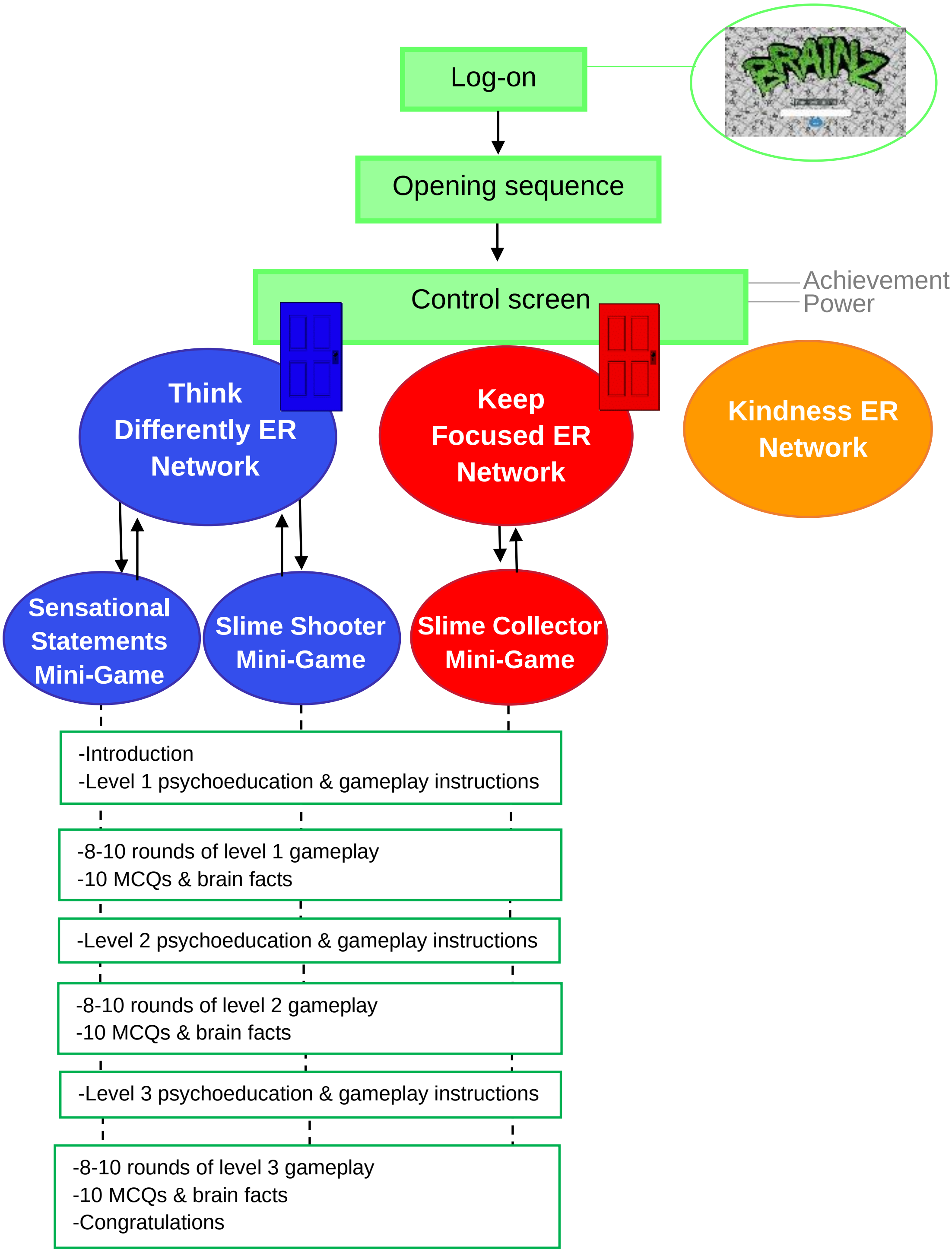
Story and Setting. As aforementioned, findings from the discovery and codesign workshops, codesign online feedback study, and other consultations informed the ideas, concept, design, and content of the initial prototype of BRAINZ. SR created the concept for the broad story and setting of BRAINZ, with KW. The story integrated the human brain and zombie slime lab settings and began with a Zombie character escaping from its enclosure at a zombie slime lab. Next, a professor character (Prof. Zed) uses a shrink gun to shrink the zombie to a manageable size. However, the zombie jumps into the professor's ear. From here, the zombie makes their way to the professor's brain and covers their ER brain networks in slime. The professor then loses control of their emotions. The user, whose role is a newly appointed Trainee Scientist, is also caught by the laser and shrunk. They enter the professor's brain to fix the ER brain networks by learning about different ER strategies, with the help of brain cell characters. Before the user plays the prototype game, they are presented with an illustrative opening sequence that describes the above story and game aims (see Graphics and Illustrations section for illustrations). SR consulted with a professional storyteller (AB) about aspects of the story concept following its creation.

Structure and Functionality. Through interdisciplinary discussions, incorporating information from the therapeutic-empirical ER strategy synthesis and participants, the game structure was conceptualised and specified. The game was built by an engineer (AZ). It is accessed via smartphone on a webpage using JavaScript. To enter the game, users login on a webpage. Data security and user confidentiality was ensured via anonymity (no personal data collected, only in-game progress), and login via alphanumeric passcode. The game was designed to be accessed unsupervised. Information presented was designed with the intention of being clear, concise, relevant, fun, age-appropriate and scientifically accurate regarding ER strategy implementation.

See Figure 4.3 for a visualisation of the overall structure of the initial prototype and an example flow/structure of a mini game. Following the opening sequence, users enter the control screen, which contains a door for each ER network in the professor character's brain. Users tap on the door of the ER strategy network that they wish to enter.

Figure 4.3

BRAINZ user flow and mini-game structure.



The included networks drawn from the therapeutic-empirical ER strategy synthesis were: Think Differently (renamed for acceptability purposes from Changing Thoughts), Keep Focused (renamed for acceptability purposes from Attention) and Kindness (renamed for acceptability purposes from Compassion). The initial prototype was designed and built with the intention of additional ER networks being added to the control screen in future iterations of the game. The control screen was also conceptualised to contain links to a power screen, where users could see the points won across all mini-games, and an achievements screen, where users could see achievements won across the meta-game and mini-games. These acceptability-focused features will be integrated in future versions of the game.

Mini-Games. Once users entered their chosen network in the professor's brain, they were presented with the respective network screen. Here, users choose between a number of mini-games—each focused on training and practicing a specific ER strategy from the ER network. Three mini-games were developed for the initial prototype. As with the networks, mini-games can be added to each network screen in the future.

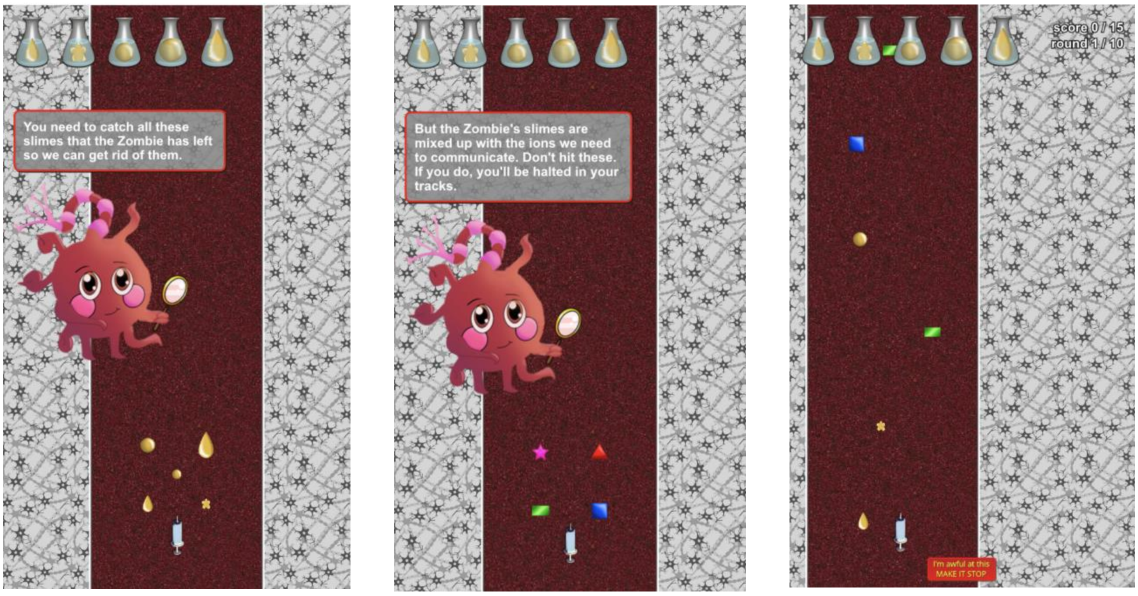
When users entered a mini-game, they were presented with (1) a welcome and description of damage done by the zombie to set the scene and maintain engagement, as informed by discovery phase ER digital intervention and collaborative, interdisciplinary design literature (e.g., Reynard et al., 2022; Bevan Jones et al., 2020; Fleming et al., 2019; Scholten & Granic, 2019); (2) an overview of the ER strategy and mini-game aims in terms of fixing the network to gradually introduce the user to the psychoeducation and gameplay rules as informed by discovery phase learning in digital environments literature (e.g., Reynard et al., 2022; Sweller et al., 2011; Wouters et al., 2008) and codesign workshops; (3) level one explicit psychoeducation, to impart the knowledge required to engage with the mini-game and learn about the specific ER strategy; (4) specific gameplay instructions with visuals, to promote understanding, autonomy and enjoyment, as informed by codesign workshops. Information was delivered by the respective network's brain cell character with supporting animated visuals (see Graphics and Illustrations section).

When BRAINZ was initially conceptualised, users were given the *option* of engaging in explicit psychoeducation before practicing the ER strategy in the mini-game rounds (i.e., they could just engage in an overview before practicing). However, following further interdisciplinary discussion, it was decided that psychoeducation should be mandatory, and be provided incrementally by the brain cell character over levels (see Figures 4.3 and 4.6). In keeping with this, after playing 8-10 rounds in each level, users answered MCQs in relation to the ER strategy psychoeducation, to promote the understanding and internalisation of information (see Figure 4.5 for a screengrab). To maintain flow and engagement, MCQs focused on the context of the game. To increase engagement and interest, users were presented with brain facts pseudorandomly across the MCQ presentation. Following the successful completion of mini-game rounds and MCQs in a given level, users were able to choose to re-do the level or move onto the next level. Psychoeducative MCQs were re-attempted if answered incorrectly before the next level could begin. Users could return to the network screen or control screen at any time by tapping an exit button. See Pedagogical Approach and Considerations section for details of psychoeducation content and theory across levels in different mini games.

Keep Focused Network Mini-Game. Within the Keep Focused network, one action, top-down perspective mini-game allows users to practice mindful distraction in a fun and safe context via a sustained attention task. Following psychoeducation, in each round users must focus on collecting different golden zombie slime droplets with a pipette. Across increasing levels of difficulty, electrically charged brain ions (that must be avoided) become increasingly like zombie slime droplets (in shape and colour). At the same time, users must try to keep the pipette on a moving brain cell axon. If the pipette falls off the axon or gets hit by an ion the user loses a life. The brain cell character provides encouragement and reminders of the psychoeducation learning throughout (see Figure 4.4 for associated screengrabs of level one). This mini-game is called *Slime Collector.*

Figure 4.4

Slime Collector level one mini-game screengrabs.

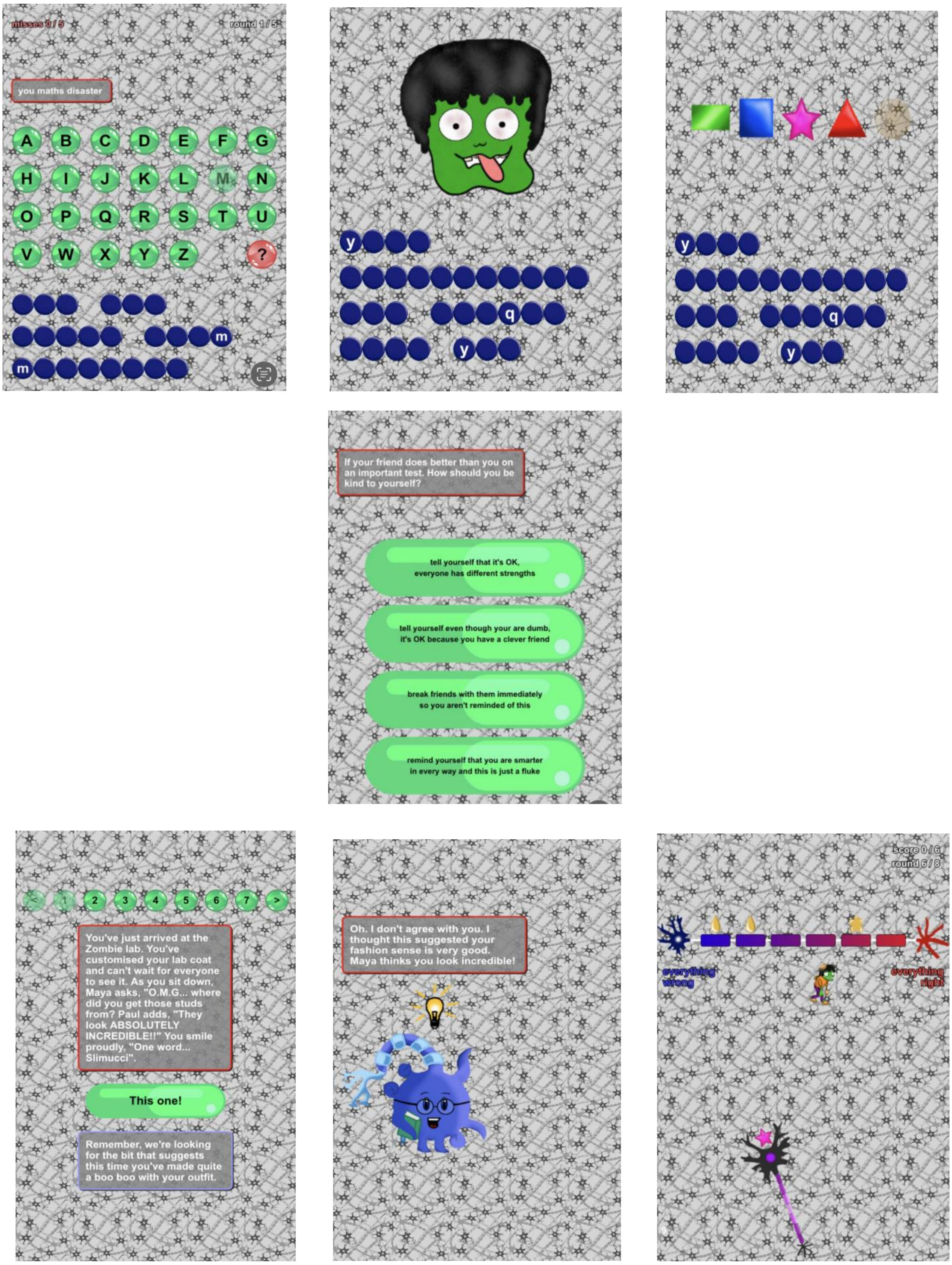


Think Differently Network Mini-Games. Within the Think Differently network, we developed two mini-games. One puzzle, top-down perspective mini-game allows users to practice positive self-talk in a fun and safe context via a hangman-style task. Following psychoeducation, in each round users read a story about a difficult situation that they experienced whilst working in the zombie slime lab. They then transform an associated negative self-talk statement into a positive one by moving and dropping letters encased in brain cells from a green slime damaged brain cell letter network to a new blue 'fixed' one. If the user attempts to make an incorrect letter move the zombie appears on the screen and blows a raspberry, and the user loses a life, denoted by vanishing brain ions (see Figure 4.5 for associated screengrabs). This mini game is called *Sensational Statements*.

One puzzle-action, first-person-style perspective mini-game allows users to practice scaling of thoughts in a fun and safe context via a sorting and shooting task. Following psychoeducation, in each round users read a story about a difficult situation that they experienced whilst working in the zombie slime lab. They then rank parts of each story out of seven based on how good or bad they are, receiving feedback and help from the brain cell character during and after each ranking. After a correct ranking, users shoot zombie slime droplets assigned to the ranking at the top of the screen by tapping on a synapse-ion shooter positioned at the bottom of the screen. They must also avoid hitting the zombie, who will eat the ion and cause a lost life if it hits them (see Figure 4.5 for associated screengrabs). This mini game is called *Slime Shooter*.

Figure 4.5

Sensational Statements mini-game screengrabs (top); example MCQ screen grab (middle); Slime Shooter mini-game screengrabs (bottom).



The Kindness network did not contain mini games in the initial prototype.

Figure 4.6

Development of BRAINZ psychoeducation structure. Initial concept of users choosing whether to engage in psychoeducation (left); automatic presentation of psychoeducation before playing mini-game rounds in each level (right).

Note. Users tapped on the screen to move to the next section of text. The name of the Slime Shooter mini-game was originally conceptualised as Brain Cell Fire, in which the fun element of the mini-game involved users shooting slime-damaged brain cells. However, this was altered to focus on shooting zombie slime due to participants reporting a dislike of shooting involving cells in the human body, and to simplify the mini-game concept, which was identified as too complex in interdisciplinary team discussions.

SR created specification documents for the mini-games and the wider meta-game in 2020, following initial ideas generation, storyboards and conceptual refinement of each mini-game and the meta-game. In 2021, these were reviewed and refined in online interdisciplinary team specification meetings.

Mini-Game Short Stories. The short stories used in the *Sensational Statements* (positive self-talk) and *Slime Shooter* (scaling of thoughts) early-stage prototype mini games were created iteratively in collaboration with young adults and a professional storyteller (AB). The purpose of the stories were to provide information for the user to complete the mini-games. Informed by the online feedback study, short stories were set in and around the zombie slime lab and focused on difficult situations around *peer victimisation* (from other Trainee Scientists), *feeling alone*, *authority victimisation* (from a lab manager) or *academic failure*. As participants identified most with difficulties around peer victimisation, we placed greater weighting on this. Ideas for short stories were created by SR and young adults and refined and amended by SR. They were created to be fun and immersive, with sufficient detail to promote engagement. AB reviewed drafts iteratively and provided feedback in terms of style, structure, and language.

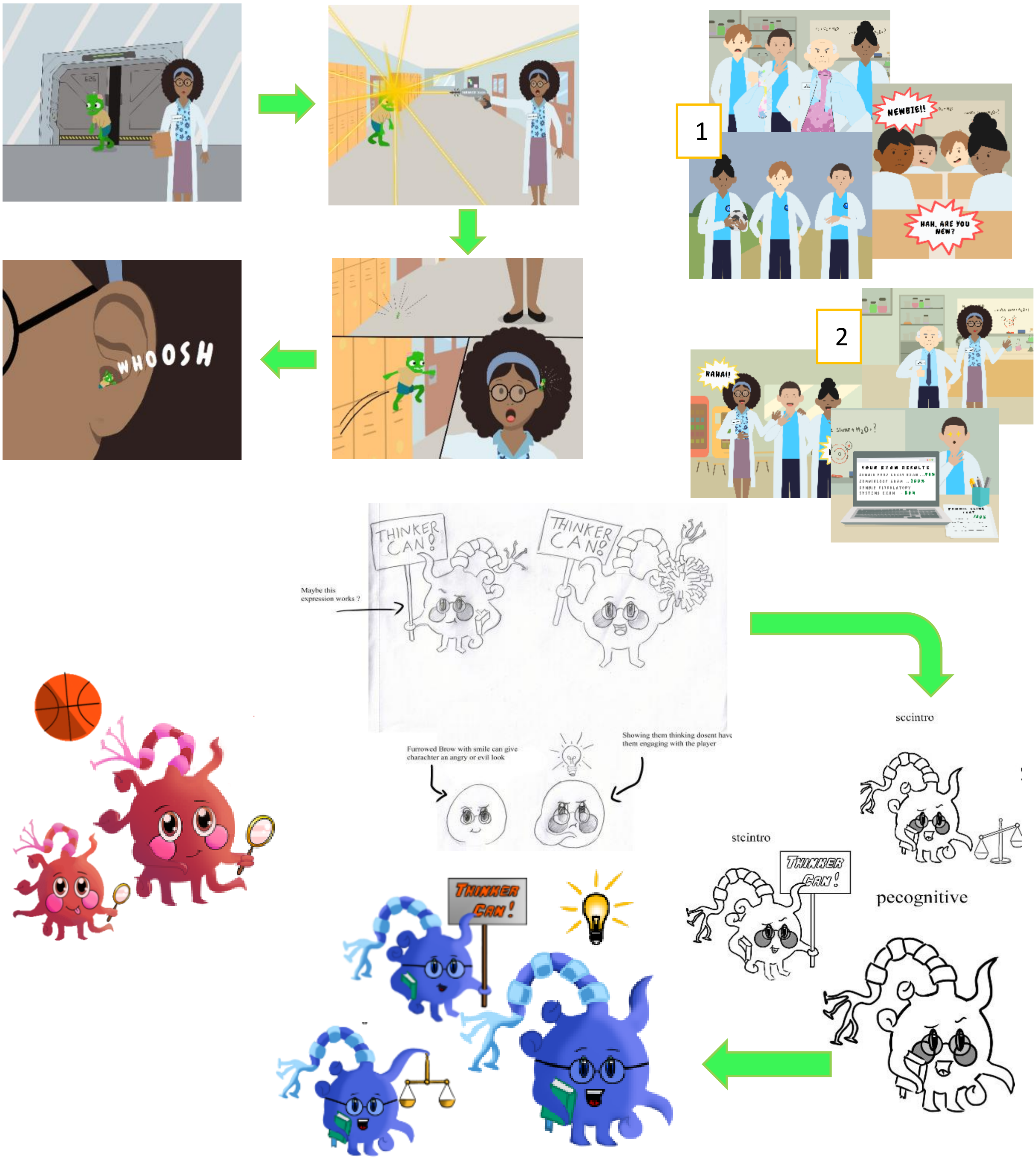
Each *Slime Shooter* short story was designed to contain different segments that could be ranked in terms of how good or bad they were. As the intensity of the short stories were not perceived similarly across participants, we based the correct rankings on the brain cell character's opinion, to demonstrate that thoughts can be perceived across a breadth of good and bad intensities.

In addition, we used a web-based reading age calculator to ensure that short stories were age-appropriate in terms of language. See Appendix 3, "Short Story Examples" for examples of short stories from mini-games.

Graphics and Illustrations. Informed by the codesign workshops, we aimed for the broad aesthetic design to be simple, colourful and appealing. Digital artwork designed for the prototype (professor character, lab manager character, short stories illustrations, brain cell characters and animations) upheld these principles. Where possible, placeholders, accessed via open source and royalty free websites, also adhered to the aforementioned principles. The background to all screens other than mini-game short stories was a silver brain cell network (Figure 4.6), to emphasise the overarching human brain setting. Each ER strategy network door and screen was assigned a colour (Figure 4.3); this was also used in the associated brain cell character in each ER strategy network. This aimed to facilitate flow and clarity in the navigation within and across networks. Further, the colours aimed to reflect the ER network strategies. The colours chosen (bright blue for Think Differently and bright red for Keep Focused) were informed by the graphic design hackathon consultations with young people. In addition, the features of the brain cell characters were designed to correspond to the ER network strategy cluster (see Figure 5 below). The graphic design hackathon consultations indicated that focus could be shown by large eyes and pupils, and a magnifying glass in the Keep Focused brain cell character.

Figure 4.7

Opening sequence illustrations with Prof. Zed and Zombie characters (top left); selection of negative (top right 1) and positive (top right 2) short story visuals from Slime Shooter mini-game; Keep Focused network brain cell character (bottom left); iterative development of Think Differently network brain cell character (bottom right).



Further, the Keep Focused network was largely informed by DBT, in which mindfulness and acceptance are key features of ER strategies. We aimed for the brain cell character to reflect this by making them appear gentle and ‘cute’, using pink cheeks, glossy eyes and round body. The Think Differently network was largely informed by CBT-based approaches, in which cognitive ER strategies are the focus. Graphic design hackathon consultations indicated that this can be shown by glasses and book features in the Think Differently brain cell character. In addition, the interdisciplinary team integrated a lightbulb, and aimed to integrate a ‘thinking’ facial expression. However, as indicated in Figure 4.7, this was not included in the final version, as it appeared slightly hostile. The brain cell characters were created iteratively with a graphic designer (JC) (see Figure 4.7). Here, SR discussed ideas with the interdisciplinary team and reviewed with the graphic designer, who provided pencil drafts, then digital black and white drafts, and then colour versions. At each stage, drafts were reviewed with the team and issues were discussed and highlighted to the graphic designer. Engaging features were added to the brain cell characters for the mini-game welcome and level one psychoeducation overview. For example, in Sensational Statements, the Think Differently brain cell character, named ‘Thinker’, is holding a self-affirmative cheerleading sign. Psychoeducation and game instructions were delivered by the ‘standard’ brain cell character version in each network (the enlarged brain cell characters in Figure 4.7).

Figure 4.7 also displays the opening sequence story illustrations, inclusive of the professor character. These were created by AM, based on graphic design hackathon consultations, and discussions and iterative feedback from SR, KW, and the wider interdisciplinary team. Graphic design hackathons indicated that a young, professional, and female professor character was preferred, and classic ‘crazy scientist’ professor characters look too unprofessional to lead a zombie slime lab.

Pedagogical Approach and Considerations

Scaffolding

As indicated via discovery phase evidence (Reynard et al., 2022; Scholten & Granic, 2019; Sweller et al., 2011; Wouters et al., 2008), and codesign workshops, system- and user-led scaffolding strategies in digital tools promote active learning, better understanding of material, acceptability, flow, and autonomy. Scaffolding, defined as a "process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (Wood et al., 1976, p. 90), was incorporated into the design of the prototype game via a system- and user-led approach. Example strategies are (1) user taps on the phone screen to move to the next part of text at their chosen pace, (2) three levels per mini-game that provide increasing psychoeducative information and difficulty, (3) dynamic difficulty adjustment, (4) simple, user-friendly interface, (5) ER strategy groups in separate locations, (6) each mini-game focuses on one ER strategy, (7) fun brain cell characters in each network represent that network, (8) brain cell characters provide psychoeducation, (9) modelling of ER strategy implementation by brain cell characters, (10) MCQs after each level in each mini-game, (11) text-based feedback when user makes incorrect move or answers question incorrectly, (12) use of topics relevant to users (victimisation, academic failure, feeling alone).

Psychoeducation Content

Informed by the discovery phase therapeutic-empirical ER strategy synthesis and ongoing review of scientific literature, psychoeducation across the prototype was informed by CBT and DBT (inclusive of mindfulness) based therapeutic and literature-based ER strategy information, with up-to-date strategy and early adolescent specific empirical research findings. For example, the Sensational Statements mini-game self-talk psychoeducation was based on positive self-talk information detailed in youth-focused CBT manuals and relevant literature, with specific features (e.g., linguistic, self-distancing, decentering; focus on effort rather than ability in academic situations) drawn from recent empirical research (Nook et al., 2020; Kross & Ayduk, 2017; Bennett et al., 2021; Thomaes et al., 2020).

The information drawn from the evidence described above was grouped into self-talk ‘clusters’ through iterative feedback and discussion within the interdisciplinary team. Clusters were added and delivered incrementally over the three mini-game levels using child-friendly language. The clusters were ‘being truthful’, ‘being kind’ and ‘being helpful’. Social cognition psychoeducation was included within the being helpful cluster, which was integrated in level three, based on conceptual and empirical evidence linking cognitive ER to social cognitive abilities in adolescence (e.g., McRae et al., 2012; Thompson et al., 2019).

We did not focus on emotion naming or differentiation within the current prototype, (although this is the norm in extant universal mental health interventions, traditional therapies, and lay theories). This is because there is no direct evidence in developmental samples aged <14 years to suggest that it supports successful ER, or shares clear links to psychopathology (Nook, 2021). Although there is some broad evidence in older youths, this is limited and may be challenged somewhat by methodological issues around potential omitted third variables (e.g., IQ, personality traits, mean negative affect), and lack of consistent emotion differentiation terminology and valid measurement (Nook et al., 2018; Nook, 2021). Further, emerging empirical research suggests that emotion naming may in fact crystalise emotional experiences in youth, causing them to be harder to regulate via cognitive- and mindfulness-based strategies (Nook et al., 2021).

Findings from the online focus group with young adults with lived experience of early disadvantage indicated that the psychoeducation information should be more concise and clear. Psychoeducation scripts were amended accordingly, with iterative review, discussion, and feedback from the interdisciplinary team.

Beta Testing

Through beta testing with adolescents, issues concerning themes of clarity, bugs, general gameplay, aesthetics, and text were identified and highlighted prior to initial evaluation. Issues around clarity focused on some inconsistencies and inaccuracies found in the information, rules, and stories across and within mini games. Bugs were largely due to the game being played via a webpage, rather than app. General gameplay issues were linked to excessive difficulty adaptation in the Slime Shooter mini-game and mini-game length in Slime Collector. Aesthetic issues focused on small text size and graphical inconsistencies between some graphic placeholders and graphics and illustrations designed specifically for the game. Most text-based issues centered on typos and grammatical errors, however this also encompassed young people not reading the text-based information. This was most problematic in parts of the game where processes and mechanics were not intuitive.

PICO(T) Framework Informed Statement

To provide clarity, below we present a working PICO(T)-informed statement regarding the intervention that is being developed. This will be refined throughout ongoing iterative codesign and evaluation work and will include the comparison/control and time components and additional outcomes when appropriate.

P: Early adolescents aged 10-12 who are transitioning to secondary school.

I: Smartphone-based psychoeducation ER game.

C:

O: Improvement in ER strategy knowledge.

T:

Discussion

We present the collaborative, iterative design, and development of the early-stage prototype of BRAINZ, a universal ER psychoeducation smartphone game for early adolescents aged 10-12. BRAINZ is set inside a professor's brain and zombie slime lab and aims to train specific ER strategies via psychoeducation and fun mini games.

Initial Prototype Development

As highlighted previously, digital interventions may often become 'stuck' at the development and early evaluation phase due to a misalignment between funding opportunities and required flexibility and rigour in collaborative intervention development. This is evidenced by an extant lack of large-scale randomised control trials (RCTs) of ER digital games (Reynard et al., 2022). Further, limited early-stage development and evaluation studies of digital games for ER before RCT and large-scale evaluation may indicate a lack of adherence to recommended guidelines (Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021) through development, which is essential to promote optimal efficacy and engagement. Additionally, the recent COVID-19 pandemic has demanded adaptability and refinement of digital intervention creation approaches, adding a further barrier to reaching RCT readiness, which is important to acknowledge. In this context, it is strongly recommended that researchers adhere to recent development guidelines (e.g., Bevan Jones et al., 2018, 2020; Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021) and report this work in published development studies, before conducting large-scale evaluation studies. Akin to Bevan Jones digital intervention development work for a depression-focused app for youth (Bevan Jones et al., 2018); the current study demonstrates the collaborative, cross-national interdisciplinary methods necessary to develop a potentially efficacious and acceptable ER strategy digital game for early adolescents. Hence, this study may be a particularly helpful resource for psychoeducative ER digital game researchers to use to demonstrate early, iterative collaboration with early adolescents and other stakeholders before initial evaluation and large-scale evaluation.

Psychoeducation Codesign

A key finding that was pertinent to the development of the current BRAINZ prototype was that the transfer of knowledge appears to be optimal in digital approaches when information is presented explicitly. This was demonstrated within the codesign workshops, where participants engaged with different digital learning methods. Recent digital game research echoes this finding. Sakkal and Martin (2019), found that after controlling for in-game performance, youth who received brief explicit instruction before engaging with a music-based videogame performed better in a subsequent real-world musical task. This also suggests that explicit instruction may lead to better real-world generalisability, further emphasising the importance of assessing generalisability of learnt skills in ER digital games, which was identified in our discovery phase systematic review and meta-analysis (see chapter 3, Reynard et al., 2022).

The usefulness of explicit psychoeducation in preventative intervention is supported by a recent meta-analysis, which examined universal and selective interventions in youth (de Pablo et al., 2021). Here, psychoeducation information was found to demonstrate the largest effect size for affective symptoms in youth, and also for interpersonal violence. This was over and above that of broad psychotherapy. Hence, here we demonstrate a convergence of findings from collaborative and iterative digital intervention development, with emerging digital game research findings and universal preventative intervention evidence.

Therefore, it may be beneficial for future ER digital interventions for early adolescents to incorporate explicit psychoeducation before engagement with fun and implicit elements to promote the successful transfer of knowledge, and potentially generalisability and preventative action. Further empirical research examining explicitly provided information in an ER digital game context is also required to extend the findings discussed above.

Other ER Digital Games

To the best of our knowledge, this is the first study to present the development of a prototype universal ER psychoeducation smartphone game for early adolescents, in line with guidance and information on the collaborative development of complex and digital interventions (Craig et al., 2008; Craig & Petticrew, 2013; Bevan Jones et al., 2018, 2020). In addition, extant ER digital games or digital interventions that include ER game components for children and early adolescents (e.g. Reynard et al., 2022; Moltrecht et al., 2021; Saleme et al., 2021; de la Barrera et al., 2021; David et al., 2022; Tsui et al., 2021; Wijnhoven et al., 2022; Schuurmans et al., 2020; Schuurmans et al., 2021) tend to use evidence only from traditional therapeutic approaches, such as CBT, or conceptual models, in the design of ER training, or assess commercial videogames. However, we integrated up-to-date empirical evidence into the design and development of the BRAINZ prototype, which challenged and built upon some extant ER therapeutic practices. The careful integration and application of empirical research findings may help to drive the field forwards and strengthen the credibility of ER digital tools, because it may support the creation of novel, applied and timely early evaluation research questions; and potentially increase the likelihood that the resultant intervention is efficacious (e.g., O'Cathain et al., 2019).

Next Steps

We endeavor to detail the early-evaluation methods and findings, and subsequent codevelopment steps in a further study. Indeed, the early prototype was evaluated in UK schools and online. Following data synthesis, presentation and dissemination, further iterative, collaborative development of BRAINZ will be conducted to optimise acceptability and feasibility, prior to larger scale trials.

Strengths and Limitations

Throughout the early development of the BRAINZ initial prototype, we demonstrated a methodological approach that adhered to established guidelines and approaches to complex intervention development (Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021) and psychological digital intervention development in adolescents (Bevan Jones et al., 2018, 2020). In addition, the integration of recent empirical evidence, including advances in understanding ER and ER strategies helped to drive the ER digital intervention field forward, which thus far has largely relied upon traditional therapeutic theory and approaches. Further, collaboration and consultation took place with a broad range of future users and other stakeholders, inclusive of multiple nationalities, and a range of socio-economic backgrounds, ethnicities, disadvantage, and cognitive ability. This was essential to ensure that the intervention could have the potential to be implemented universally in the future, as is intended. Interdisciplinary and expert collaboration also strengthened the development of the early prototype as it permitted a broad range of experience, and knowledge to promote optimal ideas generation, problem solving and iterative feedback and discussion. Collaborators and experts within the interdisciplinary team included psychologists, psychiatrists, engineers and computer programmers, a playwright, older adolescents and young adults, graphic designers, and gamers.

Considering the limitations, it is essential to acknowledge that the personal views of the interdisciplinary team may have influenced the development of the BRAINZ prototype. Although, this potential source of bias was somewhat addressed via the broad nature of the interdisciplinary team; and discussions were informed by information from both the evidence and codesign prototype intervention development phases (Bevan

Jones et al., 2018). Indeed, a common difficulty that is often recognised in digital and behavioural intervention development is the difficulty involved in balancing feedback received from a relatively limited group of broad future users, with input via expert opinion (e.g., Lyon & Koerner, 2016; Mullane et al., 2019). Digital intervention researchers should seek to publish specific practical guidelines concerning this issue to ensure that the user is at the forefront of decision making in codesign activities.

Related to the above point, the COVID-19 pandemic significantly limited the scope of iterative codesign phase work with the target users. We had planned to engage with early adolescents at schools within the UK following the codesign workshops in Austria to support the iterative refinement of the game content and prototype development. To counter the negative impact of the COVID-19 pandemic on the codesign of BRAINZ, we engaged in remote, iterative codesign and feedback tasks and activities with a small sample of early adolescents and young people, representing diverse countries and cultures, socio-economic backgrounds, disadvantage, and cognitive ability.

Conclusion

A prototype psychoeducation smartphone game for training ER strategies was codesigned with early adolescents and other stakeholders. Methods that adhered to established complex and digital intervention development guidelines were employed to produce the prototype. This was inclusive of workshops, questionnaires, meta-analyses, a systematic overview of ER strategies, a feedback task and further codesign consultations with interdisciplinary experts and collaborators. An early evaluation of the BRAINZ prototype has been carried out to assess acceptability and feasibility, to inform further development prior to further feasibility testing that places a greater focus on contextual and individual difference factors. Following its dissemination, further refinement will take place before conducting a randomised control trial, as indicated via recent MRC guidelines (Skivington et al., 2021). Should the further development and testing of

BRAINZ prove to be successful (i.e., demonstrate high acceptability, feasibility, and effectiveness), we aim to make it freely accessible via smartphone application download and promote its uptake via charities, local authorities, and government channels.

List of BRAINZ Interdisciplinary Collaborators Initials and Companies Included in the Chapter

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AZ: Alex Zylberberg (Computer Engineer)

IP: Isabella Pollak (Psychology PhD student)

IK: Ina Krammer (Psychology PhD student)

GM: Gloria Mittmann (Psychology PhD student and gamer)

JR: Justyna Rauch (Researcher and gamer)

AF: Alison Fulop (Youth Outreach Project Coordinator/Researcher)

ST: Sarah Turner (Clinical Psychology MRes student)

AB: Adam Barnard (Playwright)

MP: Michaela Pawley (Clinical Psychology MRes student)

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GB: Grace Burden (Undergraduate Research Intern)

AT: Alexander Topic (Undergraduate Research Intern)

AM: Awatif Mohamad (Undergraduate Research Intern and digital art creator)

SS: Saraah Shah (Undergraduate Research Intern)

CM: Callum Miley (Undergraduate Research Intern)

MC: Min Chuan Lee (Undergraduate Research Intern)

JP: Jannine Pagador (Undergraduate Research Intern and digital art creator)

AK: Amira Koya (Undergraduate Research Intern)

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CHAPTER 5,

GENERAL DISCUSSION

This thesis had the broad aim of adding to the extant evidence base concerning the link between ER and negative social experiences in childhood and adolescence; and the development and use of digital preventative intervention for training adaptive ER in early adolescence. Using quantitative and qualitative methodological approaches, the importance of adaptive ER and related individual difference factors in childhood and adolescence; and the consequent need for *novel, digital ER intervention*, codeveloped iteratively with the target user, was highlighted.

Building upon the extant literature, and seeking to address the limits and constraints of current knowledge and practice, the specific aims of the thesis were:

1. To examine the associations between cognitive reappraisal and expressive suppression ER strategy use, cognitive and affective empathy, and callous-unemotional traits with the experience of peer victimisation, in children and adolescents.
2. To synthesise the existing evidence on the efficacy, feasibility, and acceptability of ER digital interventions in children and early adolescents, using a systematic review and meta-analytic approach.
3. To detail the early interdisciplinary and international development of BRAINZ—an early prototype-stage, universal ER psychoeducation smartphone game for early adolescents aged 10-12 years.

In this final chapter, key findings across chapters 2 to 4 will be converged with the main implications, recommendations and strengths and limitations that have arisen from this thesis. First, the rationale and aims of each study—and importantly—how these were linked, will be summarised before comprehensive summaries of the findings and implications of each chapter are provided in tabular form.

Chapter 2: Study 1

Informed by the EPM (Gross, 2015), the Integrative Account of Empathy and Emotion Regulation, (Thompson et al., 2019) and emerging research findings, a cross-sectional approach was taken to understand the correlational links between ER, affective and cognitive empathy, callous-unemotional traits, and the experience of peer victimisation in children and early adolescents in chapter 2. The main aim was to clarify and further the existing evidence concerning the cross-sectional association between habitual ER strategy use (cognitive reappraisal and expressive suppression) and peer victimisation in broad youth samples, which thus far has been mixed (Chervonsky & Hunt, 2019; Larsen et al., 2012; Vranjes et al., 2018; Platt et al., 2015; Miller et al., 2019). Further, the potential dimensional, interactive nature of the individual difference factors had so far remained unexamined.

Chapter 3: Study 2

The findings of chapter 2 (that the habitual use of cognitive reappraisal and expressive suppression ER strategies, and linked individual difference factors share important associations with the frequency of adverse interpersonal experiences in childhood and adolescence) indicated a need for ER to be targeted via preventative intervention in early development, to promote adaptive coping and positive interpersonal outcomes. Following PRISMA guidelines (Moher et al., 2015; recently updated, Page et al., 2021) the second study (chapter 3) applied the findings and implications of chapter 2 by synthesising the extant data on the efficacy, feasibility, and acceptability of *digital* approaches to training adaptive ER in wide-ranging samples of children and adolescents. This was conducted via meta-analytic and systematic review (see Reynard et al., 2022). The focus on digital intervention was indicated via resource (Chiles et al., 1999; Fusar-Poli, 2019), engagement, acceptability, and stigma (Fusar-Poli, 2019, Radez et al., 2021; Becker et al., 2017; de Haan et al., 2013; Moses, 2014), and access (Fusar-Poli, 2019;

Radez et al., 2021; Keppens & Spruyt, 2018) issues in extant traditional and wider-reaching ER-based interventions for children and adolescents.

Chapter 4: Study 3

Chapters 2 and 3 indicated that the habitual use of ER strategies and other linked individual difference factors share important associations with the frequency of adverse interpersonal experiences (i.e., peer victimisation) in broad child and adolescent samples; and adaptive ER may be trained successfully in broad child and adolescent samples via digital game intervention. Further, as highlighted in chapter 3 and other recent research, issues pertaining to the need to involve the end user and other stakeholders actively and iteratively in intervention development to promote acceptability and feasibility remain (Reynard et al., 2022; Bevan Jones et al., 2020; Thabrew et al., 2018; Fleming et al., 2019). Moreover, both ER and measures of interpersonal experience (i.e., peer victimisation, peer relationship quality, quantity, and availability) share prospective and longitudinal associations with resilience and psychopathology from early adolescence (Lamblin et al., 2017; Stewart-Tufescu et al., 2021; van Harmelen et al., 2017; Schriber & Guyer, 2016), and ER is a transdiagnostic risk marker for psychopathology (Aldao et al., 2016; Cludius et al., 2020). Therefore, successfully training adaptive ER universally in early adolescence may serve as a buffer against poor psychosocial outcomes.

Informed by chapters 2 and 3 and adhering to guidance on the development of complex (Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021) and digital (Bevan Jones et al., 2018, 2020) interventions to address extant acceptability- and feasibility-related issues, chapter 4 detailed the early interdisciplinary and international development of a smartphone game for ER in early adolescence.

See Table 5.1 for a comprehensive summary of the research findings and implications of each chapter.

Table 5.1

Comprehensive summary of research findings and implications

Chapter	Summary of findings	Summary of implications
Chapter 2	Zero-order correlations between variables revealed significant, although small, negative associations between habitual cognitive reappraisal use and peer victimisation frequency, and cognitive empathy and peer victimisation frequency in children and adolescents. Furthermore, significant, small, positive associations were found between habitual expressive suppression use and peer victimisation frequency, and CU traits and peer victimisation frequency. CU traits shared the strongest association with victimisation.	Consistent with ER conceptual accounts and wider research findings (McRae & Gross, 2020; Ahmed et al., 2015; Feldman, 2021; Davis & Levine, 2013; English et al., 2021), in which cognitive reappraisal is considered more adaptive than expressive suppression across several domains, the findings described in chapter 2 contribute to the emerging evidence base pertaining specifically to ER strategy use and peer victimisation experience in children and adolescents. In addition, this indicates that ER is an appropriate target for improving the quality of peer relationships and linked psychological outcomes in childhood and adolescence. The lack of a significant link between affective empathy and peer victimisation in children and adolescents was in line with recent meta-analytic findings (Zych et al., 2019). However, in contrast to these

In addition, CU traits shared a significant, moderate, negative, association with cognitive empathy, and a significant, but small, negative association with affective empathy. Furthermore, significant, small, negative, and positive associations were found between habitual cognitive reappraisal use and CU traits, and habitual expressive suppression use and CU traits, respectively. Finally, there were further significant, small associations between habitual cognitive reappraisal use and cognitive empathy and habitual expressive suppression use and cognitive empathy. These were positive, and negative, respectively.

findings, cognitive empathy shared a negative association with peer victimisation. Taking the results on face value, it is unsurprising that the ability to understand others' feelings (and respond adaptively and appropriately, given contextual demands and considerations) may support optimal navigation of increasing social networks through childhood and adolescence (e.g., Portt et al., 2020). The inconsistent findings in comparison to previous meta-analytic evidence may be partially explained via differential methodological approaches across relevant studies.

The association between CU traits and victimisation was consistent with prior meta-analytic evidence (Zych et al., 2019). This may be explained via the tendency for individuals who demonstrate high CU traits to be more likely to behave in an aggressive manner, and for their relational networks to be formed of deviant peers, (i.e., those who engage in violent or property crime, delinquency, and drug and/or substance-related crime or abuse) (Barker & Salekin, 2012). Hence, these factors may lead to increased experiences of peer victimisation.

		The previously unexplored associations between ER strategies and cognitive and affective empathy, and ER strategies and CU traits are important to highlight. Here, it was shown that there are significant links between these variables, and this may have implications for the development of future ER interventions in child and adolescent samples. Indeed, the association between CU traits and expressive suppression in the current study, and potential link to early adversity (Ford et al., 2006; Bennett & Kerig, 2014), in which expressive suppression may serve an adaptive function (Gee et al., 2013; Gross & Cassidy, 2019) indicates a need for individualising targeted, preventative ER interventions in samples at-risk of early adversity.
Chapter 3	Findings showed that digital games present the highest proportion of ER digital interventions (69% of the total included studies) developed for children and early adolescents. The included samples were classified as diagnosed, at risk, healthy, or universal. Digital games significantly	The main findings indicated that digital games may be the most appropriate mode of training ER in diverse samples of children and adolescents, over virtual or augmented reality, biofeedback, and program and multimedia-based interventions. It is important to acknowledge that the apparent success and appropriateness of digital games may be challenged by changes to digital intervention

reduced negative emotional experience, with a small effect.

In addition, there were limited measurement of ER (change in ability, difficulties and/or use following intervention engagement) within the included studies.

Further, most identified feasibility issues were in studies sampling those diagnosed with a neurodevelopmental disorder or mental health difficulties. Acceptability was generally high across the digital interventions included in the meta-analysis and systematic review.

approaches in the future, as accessible digital media and technology, and the way in which youth interact with it, inevitably changes.

Findings concerning the limited measurement of ER (change in ability, difficulties and/or use following intervention engagement) indicated a need for future intervention evaluation studies to prioritise the assessment of ER at pre-, post-, and consistent follow up time intervals, and for ER researchers to create valid and reliable ER measures for children and adolescents. Considerations around methodological issues will be further explored within the Strengths and Limitations section of this chapter.

Specific feasibility and acceptability factors including adherence and dropout, generalisability, content relevance, difficulty and difficulty adaptation, likeability and flow were identified as important to consider and address in future ER digital game intervention development for children and adolescents via appropriate engagement with the target end user, and other relevant stakeholders.This was consistent with existing guidance on the development of both complex interventions

		(Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021) and psychological digital interventions for youth (Bevan Jones et al., 2020), in which researchers are urged to consider such factors and contextual dynamics to address known feasibility and acceptability issues, and ultimately promote the effective training of ER.
Chapter 4	Key findings throughout the different stages of game development documented in chapter 4 (discovery phase and codesign phase) related to intervention mode, interpersonal stressors, and ER strategy awareness vs. use throughout secondary school transition, optimal understanding when information is presented explicitly, preference for simple, bright graphical content, and a need for relatable and engaging text-based content. The interdisciplinary, iterative feedback and discussion culminated in the creation of an early-	Emerging empirical research supports the notion that explicitly presented information supports effective in-game learning and transference to out-of-game knowledge application in youth (Sakkal & Martin, 2019). Further, a recent meta-analysis showed that explicit psychoeducation may be the most efficacious approach for improving affective symptomatology via universal and selective preventative intervention in youth (de Pablo et al., 2021). Hence, future ER digital games for broad early adolescent samples should include explicit psychoeducation before users engage in entertaining and implicit components of the intervention. This may stimulate optimal

stage prototype of BRAINZ, a universal ER psychoeducation smartphone game for early adolescents aged 10-12 years. This was the first study to present the early development of a universal ER psychoeducation smartphone game for early adolescents, informed by appropriate intervention development guidance.	knowledge transfer, and potentially improve knowledge generalisability and use, and preventative ER action.

Strengths and Limitations, Implications and Considerations for Future Research

This thesis provides evidence for the cross-sectional link between ER strategies and individual difference factors and the experience of peer victimisation in childhood and adolescence (chapter 2); and the potential for novel digital technology, specifically, digital games, for training ER strategies in early adolescence (chapters 3 and 4). When considering the conclusions to be drawn in the current thesis, it is important to consider its broad strengths and limitations. Indeed, the research detailed here, and its inherent strengths and limitations, influence the overarching implications and how future research should seek to increase knowledge in the field of ER, peer victimisation and digital game intervention, in child and adolescent samples. Chapters 2-4 discuss in detail the strengths, limitations, implications and linked future directions.

Here, some overarching and cross-study strengths and limitations, implications and future directions and considerations will be highlighted and described prior to drawing a conclusive statement.

Strengths and Limitations

Mixed Methods Approach. A significant strength of the thesis is in the use of a mixed methods approach (Creswell & Plano Clarke 2017; Almalki, 2016; Guetterman et al., 2019). Specifically, a convergent mixed methods approach, with a pragmatism-based research philosophy was adopted across the thesis. Here, the separate collection and examination of both quantitative (correlational study – chapter 2; meta-analysis – chapter 3) and qualitative (systematic review – chapter 3; collaborative codesign – chapter 4) information, and the combination of their complementary findings allowed the creation of a prototype smartphone game for training ER in early adolescence. The use of divergent quantitative and qualitative methodological approaches provided both depth and breadth of evidence for the rational and holistic development of a potentially efficacious ER smartphone game; which could not have been facilitated through the use of one isolated method (e.g., Almalki, 2016). Further, the convergence of differentially derived findings may allow more robust inferences and recommendations to be made for future research (Guetterman et al., 2019). Consequently, this may support the rigorous progression of the ER digital intervention research field, allowing researchers to develop more effective and appropriate tools to train adaptive ER safely in adolescence.

Impact of the COVID-19 Pandemic. The COVID-19 pandemic had a significant impact upon the completion of this thesis overall. Most prominent was the difficulty in recruiting UK schools and other relevant organisations to take part in codesign activities for the development of BRAINZ within the UK. This limited the ability to sufficiently consider broad and potentially unexpected and important contextual factors implicated in training ER via a smartphone game at the time of transition to secondary school (Skivington et al., 2021; Craig et al., 2008; Craig & Petticrew, 2013). However, this was countered by sourcing codesign phase feedback online via several stakeholders; and at alternate locations and settings when restrictions began to lift.

The need to adapt the work conducted for the thesis permitted the increased empirical focus on the assessment of ER and negative relational outcomes in broad samples of children and adolescents (see study 1, chapter 2). On reflection, this generated a stronger narrative within this thesis around the vital importance of adaptive ER strategy development, and the importance of previously unexplored linked personality factors and social cognitive skills.

Measures. Across this thesis, a noteworthy limitation and consideration for future research was issues around measurement of target constructs and other outcomes. Most notable is that of ER measurement, which was a focus of both chapters 2 (correlational study) and 3 (meta-analysis and systematic review). Although the field of ER has shone a light on the importance of adaptive ER development through early adolescence (Ahmed et al., 2015; Feldman, 2021; Davis & Levine, 2013; English et al., 2021) and the various factors that are linked to this (Adrian et al., 2019; Mitic et al., 2021; Cludius et al., 2020; Aldao et al., 2016; England-Mason & Gonzalez, 2020; Herd & Kim-Spoon, 2021), the availability of ER assessment tools designed for use in diverse samples of children and adolescents, as represented in the research presented across this thesis, remains an extant issue (e.g., Zhou et al., 2020). This somewhat limits the ability to inform ER digital intervention for broad samples. For example, the Emotion Regulation Questionnaire (Gross & John, 2003), which is a measure of the frequency of cognitive reappraisal and expressive suppression habitual use, is commonly used in child and adolescent samples to provide an index of ER functioning. Although the measure has been validated in some youth samples (e.g., Gómez-Ortiz et al., 2016), it was created for use in adult samples, and it does not measure the ability to reach an emotional goal via the habitual use of a specific ER strategy (Gross & John, 2003).

Further, considering ER digital intervention development and evaluation as examined in chapters 3 and 4 of the thesis, the assessment of ER is surprisingly lacking (Reynard et al., 2022). Specifically, although researchers are harnessing the potential of digital tools to train ER in children and early adolescents, currently the change in the ability and/or use of ER is not routinely measured (Reynard et al., 2022). This may be a reflection of the lack of reliable and valid ER measures for use in broad child and adolescent samples, and the early stage of the ER digital intervention field. The digital tools for ER that have proved most successful in terms of the extent of their empirical evaluation (e.g., Mindlight digital game: Schoneveld et al., 2016; Schoneveld et al., 2020; Wijnhoven et al., 2022) largely assess improvements in emotional experience, as the intervention targets samples at-risk of anxiety. Although this offers insight and promise into the success of ER intervention tools in at-risk child and adolescent samples, a better understanding of the mechanistic action of the digital game, purporting to changes and improvements in all stages of the ER Extended Process Model, remains unclear. To further the fields of ER and ER digital intervention in child and adolescent samples, future research should place a focus on the creation, validation, and routine use of ER measures in diverse child and adolescent samples that reflect all stages of the EPM (Gross, 2015).

To counter issues around the extant lack of valid and reliable ER measures for diverse child and adolescent samples, within study 3 of this thesis (chapter 4), qualitative information about early adolescents' experiences of ER was used to inform the development of BRAINZ—an early-stage prototype of an ER smartphone game. Through the qualitative evidence gathering approach, the nuances and contextual factors that may surround and mediate ER strategy use in early adolescence were observed and used to inform game design. This adheres to recent MRC complex intervention guidelines in which context is considered as both a dynamic and multi-dimensional factor; and importantly, is likely to be highly influential in intervention effectiveness (Skivington et al., 2021). Hence, in addition to the need to develop ER measures to permit the valid and reliable assessment of efficacy in early-stage evaluation studies and large-scale RCT trials, future ER digital intervention research should seek to integrate appropriate qualitative approaches to address the importance of contextual factors.

Theoretical and Clinical Implications

Targeted vs. Universal Intervention. Findings from this thesis concerning the differential associations between ER, empathy, CU traits and victimisation when split by group (chapter 2) bring about the consideration of wider theoretical and clinical implications relating to ER digital intervention development. Specifically, when participants with a diagnosis of Conduct Disorder (CD) and those who were typically developing were examined separately, CU traits was the only variable to correlate significantly with peer victimisation in children and adolescents, and this was evident within the typically developing sample only. In addition, significant correlations between empathy and ER, and between CU traits and ER, were only evident in the typically developing sample. Possible reasons for this include correlated group mean differences and range restriction within the CD sample. Importantly, this suggests that future research examining ER and its associations should explore the variables using a person-centered approach as well as dimensionally when including heterogeneous groups. This is because it may provide vital evidence to inform ER intervention by demonstrating in what context(s) targeted, preventative intervention may supplement appropriate universal approaches, and how this might look. In addition, as evidenced within the meta-analysis and systematic review study (chapter 3; Reynard et al., 2022), within samples diagnosed with neurodevelopmental disorders such as ASD and ADHD, there are increased feasibility and acceptability related difficulties in ER digital intervention engagement—likely due to interindividual differences in ER processes and related constructs (Reynard et al., 2020; Jouen et al., 2017). Consequently, this may also offer an awareness into the necessity and appropriateness of *individualisation* in ER digital intervention.

Related to this, recent insight pieces highlight the need to exercise caution around the impact of universal mental health preventative intervention (e.g., Cuijpers, 2022; Arango & Fusar-Poli, 2022). Specifically, Cuijpers discusses the often-limited attention to methodological rigour in some universal and selective prevention intervention evaluations. It is argued that a proportion of the effect of such interventions may be indicative of a post-intervention reduction in symptoms within individual participants who report relatively increased clinical symptomology (e.g., anxiety) at baseline (Cuijpers, 2022). Further, work by Foulkes and Stapley highlights that universal classroom based preventative interventions, which are increasingly implemented, are not suitable for all children and adolescents, or in all contexts (Foulkes & Stapley, 2022). For example, mindfulness-based group practical exercises and group activities that encourage open discussion and/or self-disclosure may cause some individuals to use maladaptive ER strategies, such as rumination, or co-rumination; or to feel uncomfortable, vulnerable, or judged; and may generate particular difficulties for those who are victimised by their peers (Foulkes & Stapley, 2022; Hailwood, 2020; Lindholm & Zetterqvist Nelson, 2015).

Moreover, a recent large-scale RCT (*N* = 8,376) examining universal mindfulness school-based intervention, 'My Resilience in Adolescence', found no evidence for superiority over TAU at 1-year follow-up (Montero-Marin et al., 2022). Further, higher-dose intervention was associated with lower wellbeing and higher risk for depression at post-intervention; and importantly, in participants at-risk of mental ill-health, the intervention condition resulted in lower wellbeing and higher risk for depression at post-intervention and follow-up, although this effect was noted as small (Montero-Marin et al., 2022). In addition, a recent meta-analysis of school-based anxiety and depression prevention interventions found small effects of universal interventions immediately post-intervention, with little evidence of follow-up maintenance, but slightly larger effects for those that are targeted, and delivered by external professionals, rather than school staff (Werner-Seidler et al., 2021). This suggests that the approach to universal prevention requires recalibration to better consider potential adverse effects, and ensure that individuals most in need can be reached and supported in the most appropriate way.

Following a comprehensive review of recent evidence supporting the use of primary prevention to address the incidence of specific psychopathology and promote mental wellbeing in young people, Fusar-Poli and colleagues propose increased nuance, and decreased fragmentation across approaches and sectors (Fusar-Poli et al., 2021). It is suggested that the integration of evidence-based universal and targeted preventative intervention approaches, combined with a governmental drive to reduce broad social inequalities and determinants that are key drivers of mental distress is required to reduce population-level clinical risk profiles, and address the burden of mental-ill health in youth

(Fusar-Poli et al., 2021). Within the context of universal digital ER interventions for early adolescents, through appropriate iterative codevelopment and early evaluation, researchers can and must theorise how best to address potential issues arising from an often over reliance on a one-size-fits-all, universal approach.

Individualisation of Digital Preventative Intervention. A need for privacy, wide-reach, individualisation and a deep understanding of specific peer dynamics and complex contextual factors in school-based universal preventative intervention is indicated via the research discussed above (Foulkes & Stapley, 2022; Hailwood, 2020; Lindholm & Zetterqvist Nelson, 2015; Montero-Marin et al., 2022). Codesigned digital ER-focused technologies that can be engaged with individually in broad settings, such as BRAINZ, inherently offer privacy and a means of appropriately reaching and engaging marginalised, diverse, and disadvantaged early adolescents. In addition, digital technology offers an opportunity to codesign and evaluate universal ER interventions that can be tailored dynamically to an individuals' unique needs, across both clinical and typically developing samples (e.g., Reynard et al., 2022). Hence, it may be possible to promote the integration of universal and targeted prevention science theoretical frameworks (Fusar-Poli et al., 2021) whilst adhering to complex and digital intervention development guidelines (Craig et al., 2008; Craig & Petticrew, 2013; Skivington et al., 2021).

Future Research Directions

Considerations for future individualisation capabilities of the BRAINZ prototype and other ER digital games may include a strengths-based capitalisation approach. For example, researchers may codesign ER games that train and promote the safe practice of adaptive ER strategies that an individual already has a pre-defined level of competence in, in given situations and/or contexts where they are most beneficial and appropriate (e.g., Doré et al., 2016; Saleme et al., 2021). Alternatively, placing a focus on training adaptive ER strategies that an individual *believes* they are good at may be explored. Indeed, recent research suggests that adolescents who believe that they have effective ER capabilities demonstrate stronger future connection to peers and family (Demkowicz et al., 2023); and being advised that an intervention focuses on one's strengths may lead to improved emotional experience following emotion induction in universal adolescent samples (e.g., Murphy et al., 2022). In addition, an individual's beliefs about their broad ER capabilities may be trained alongside such individualisation, to further capitalise on improvements in specific ER strategy knowledge and ability (e.g., Smith et al., 2018).

It is also important to acknowledge that typical universal prevention perspectives suggest an essential requirement of face-to-face expert and professional contact, for example from therapists or school staff (e.g., Werner-Seidler et al., 2021). This may be considered contrary to intervening with a digital game, as identified barriers to the access to expert face-to-face input are key to their development. Although, in line with MRC complex intervention (Skivington et al., 2021) and digital intervention (Bevan Jones et al., 2020) development guidelines and perspectives, such interventions are developed with significant input from relevant experts and relevant up-to-date empirical evidence (see chapter 4). In addition, emerging findings from one study within the meta-analysis and systematic review in this thesis (chapter 3) suggest that digital games may be non-inferior to face-to-face CBT in an indicated prevention context (Schoneveld et al., 2018; Reynard et al., 2022). Although, additional face-to-face input may be successfully included in some ER digital games and other digital intervention types (e.g., biofeedback)—and this may be of particular benefit in certain populations, for example those with ASD (Reynard et al., 2022). Hence, researchers examining the *individualisation* of ER digital preventative intervention may consider the potential for a blended approach where it is feasible and contextually appropriate.

Conclusion

Within the general discussion chapter, key findings from this thesis are highlighted and discussed. Collectively, the findings demonstrate the importance of the development and use of good ER skills through childhood and adolescence within the context of psychosocial functioning, and that such skills may be trained via appropriately codesigned digital games. Prior research suggests that the use of digital technology, in particular digital games, offer a promising way of addressing disparities in access to and engagement with appropriate ER-focused prevention approaches across diverse early adolescent samples. By adhering to extant complex and digital intervention development guidelines and linked approaches, novel digital games for training ER in early adolescence may be created. BRAINZ—a psychoeducation ER strategy smartphone game prototype presented within this thesis—has the potential to successfully promote ER knowledge and abilities and linked positive psychosocial outcomes within diverse samples of early adolescents.

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APPENDICES

Page number

APPENDIX 1

Imputation of Missing Data

Imputation of items of the following questionnaires: ERQ, IRI, YPI, RPQ, ICU parent and ICU child, RAQ, Maysi, APQ parent and APQ child, CECA-Q

Project: FemNAT-CD

Author: Dr. Marietta Kirchner, IMBI Heidelberg, Germany

Date: 04.10.2017 - Version 1.0

Missing values of the respective questionnaire scores (subscale or total) were imputed based on the whole FemNAT sample. It has been shown that missing data in a multi-item instrument is best handled by imputation at the item level (Eekhout et al., 2014). Thus, missing values of the single items were imputed first and the scores were calculated based on the imputed items. The imputation was done in SAS version 9.4 using the procedure PROC MI. Imputation by fully conditional specification (FCS) is used which offers a flexible method to specify the multivariate imputation model for arbitrary missing patterns including both categorical and continuous variables (Liu & De, 2015). As the items are measured at an ordinal level, the logistic regression method is specified in the FCS statement. The following variables were included in the imputation model: all items of the respective questionnaire, age, IQ, group (case/control), gender (male/female), site, comorbidities (PTSD, ADHD, ODD 1/0, Depression, Anxiety), items of other questionnaires if correlated with at least one of the items with ≥0.4. For imputation diagnostics, distribution of the observed and imputed items and scores were checked.

Shapiro-Wilks Normality Test and Normality Plots

Table 1.1

Shapiro-Wilk Normality Test for all included variables (N=969)

	Shapiro-Wilk Normality Test
Victimisation	W = 0.77, *P* = < 2.2e-16***
Cognitive reappraisal	W = 0.99, *P* = 7.821e-08***
Expressive suppression	W = 0.98, *P* = 1.997e-08***
Cognitive empathy	W = 0.97, *P* = 5.75e-12***
Affective empathy	W = 0.99, *P* = 0.0001442***
CU traits	W = 0.95613, *P* = < 2.2e-16***

****p < .001.*

Histograms

Figure 1.1

Poisson distribution (positively skewed) victimisation frequency variable (N = 969).

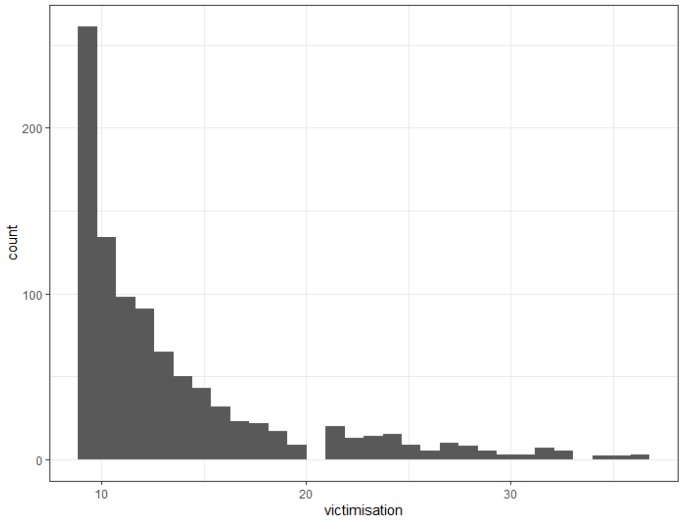


Figure 1.2

Negatively skewed cognitive reappraisal use variable (N = 969).

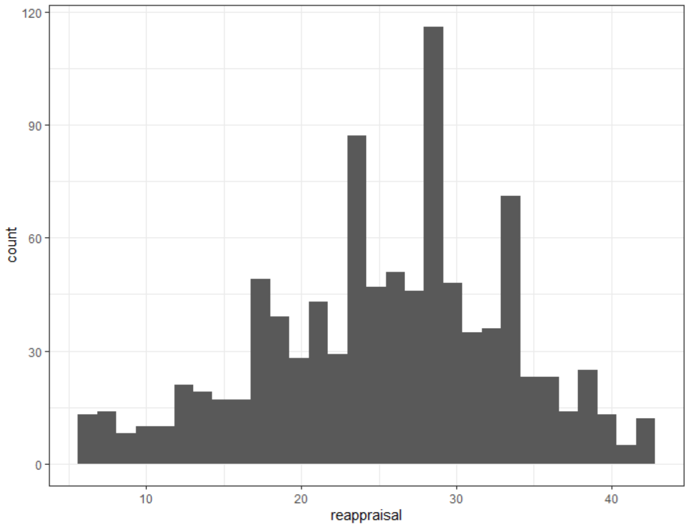


Figure 1.3

Positively skewed expressive suppression use variable (N = 969).

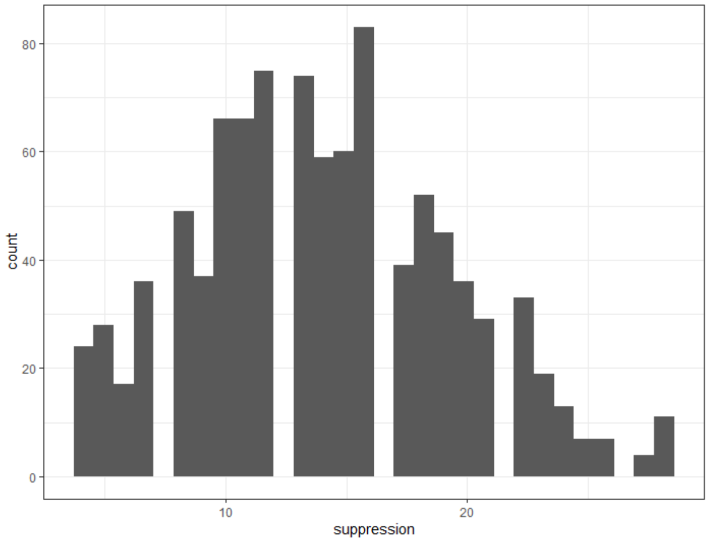


Figure 1.4

Positively skewed CU traits variable (N = 969).

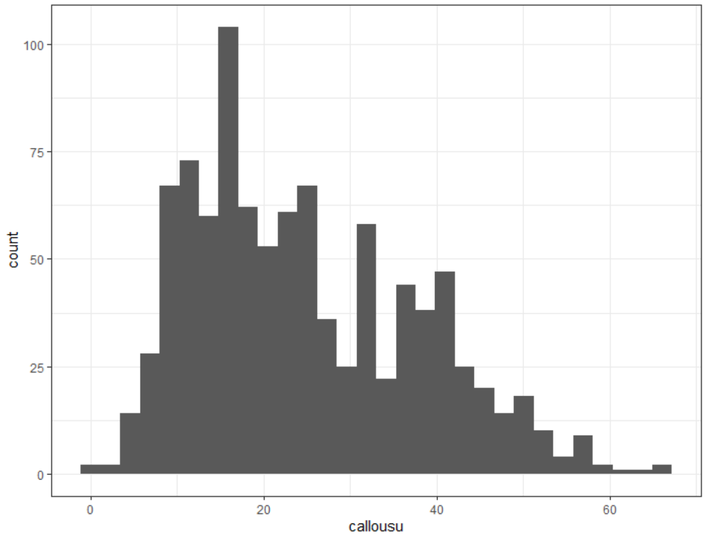


Figure 1.5

Negatively skewed cognitive empathy variable (N = 969).

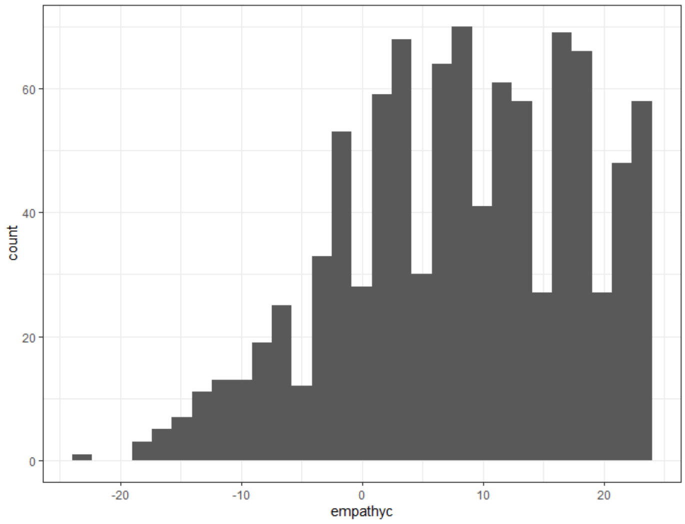
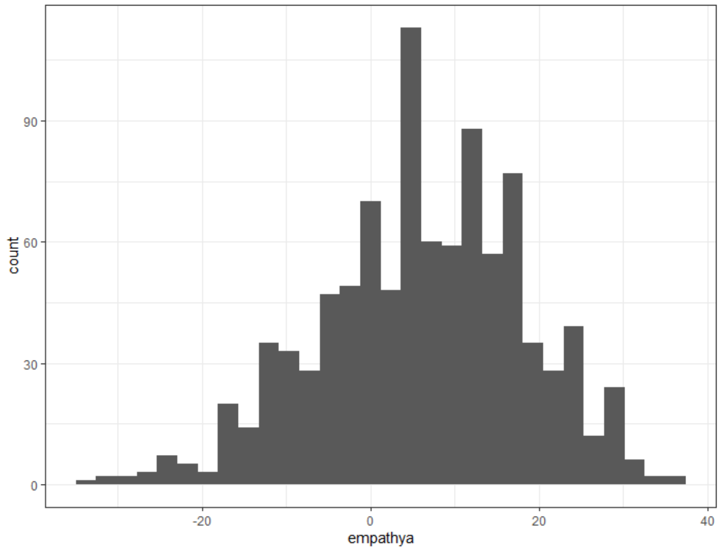


Figure 1.6

Negatively skewed affective empathy variable (N = 969).



QQ plots

Figure 1.7

Non-normal (Poisson) distribution of victimisation frequency variable (N = 969).

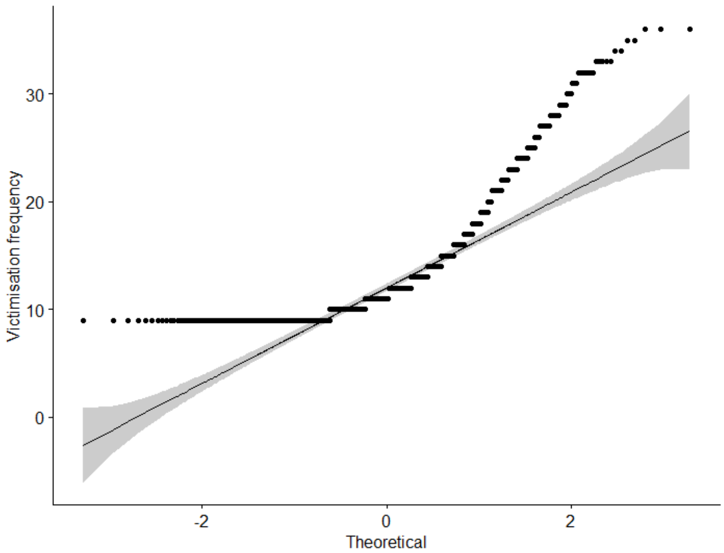


Figure 1.8

Normal distribution of cognitive reappraisal use variable (N = 969).

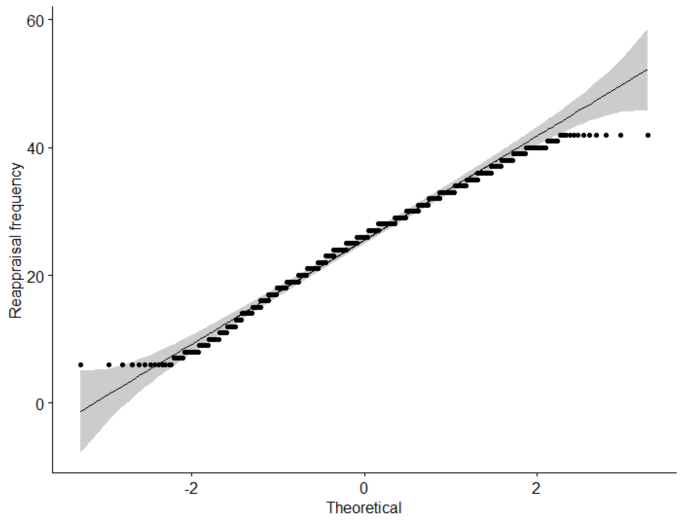


Figure 1.9

Normal distribution of expressive suppression use variable (N = 969).

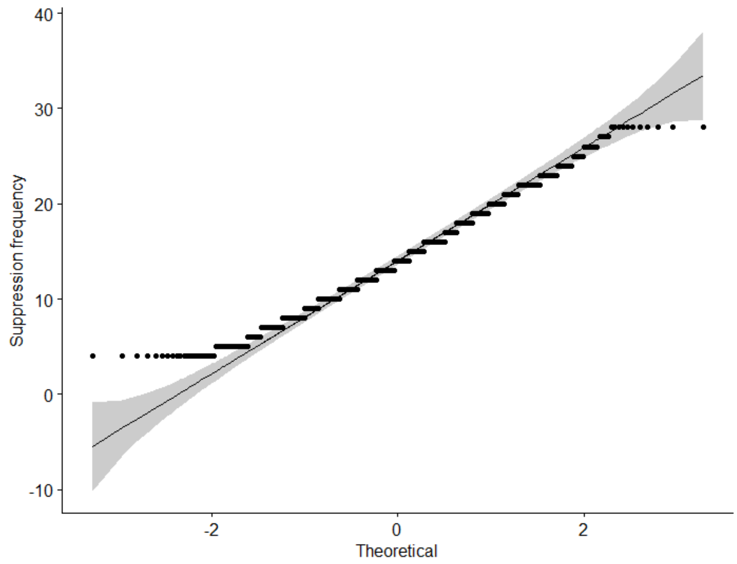


Figure 1.10

Normal distribution of CU traits variable (N = 969).

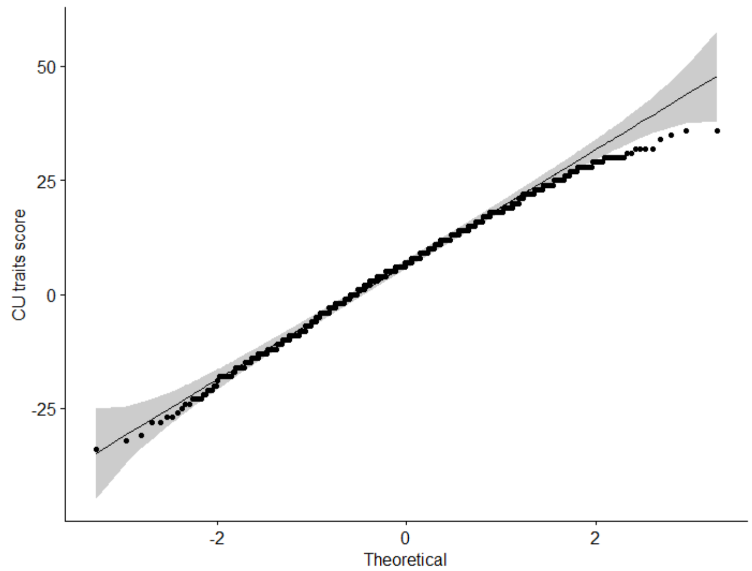


Figure 1.11

Normal distribution of cognitive empathy variable (N = 969).

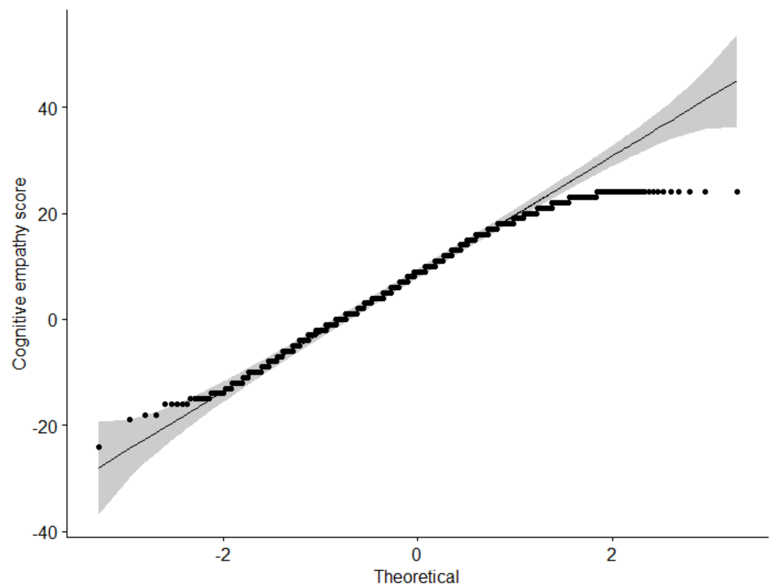
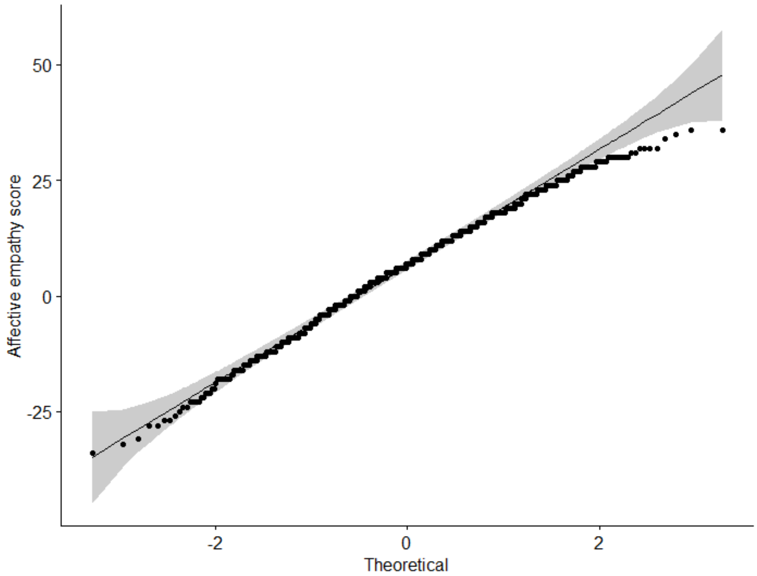


Figure 1.12

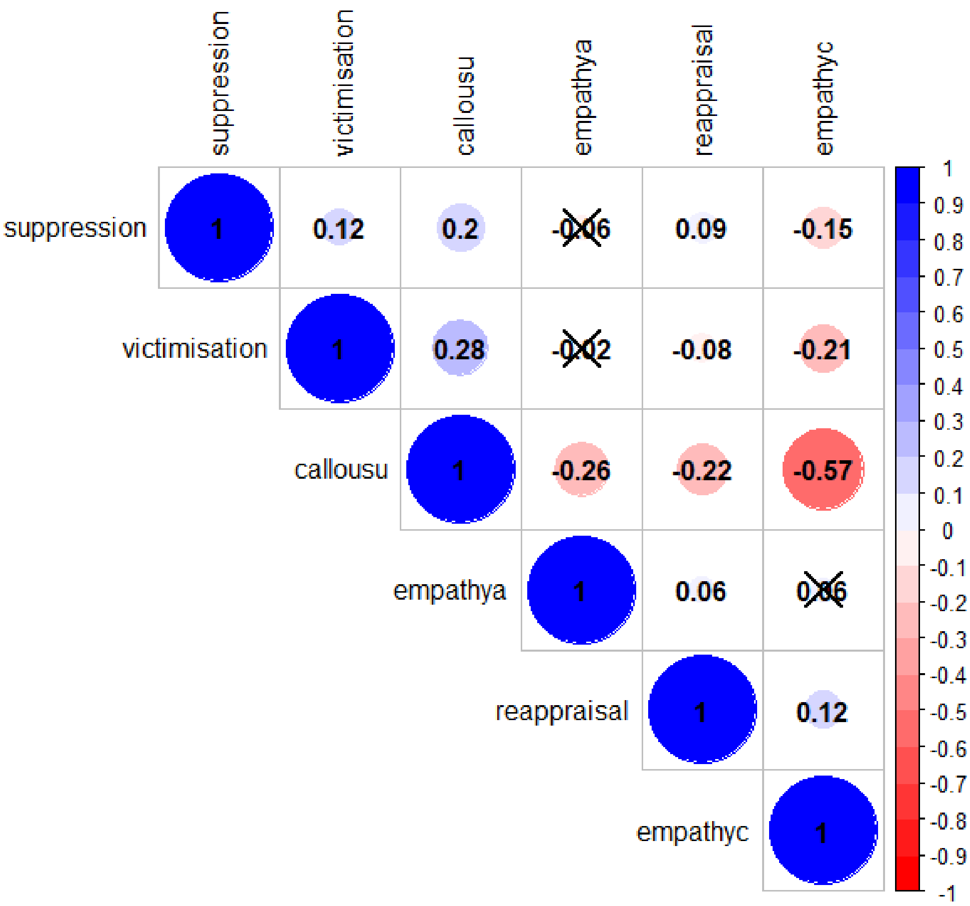
Normal distribution of affective empathy variable (N = 969).



Correlogram

Figure 1.13

Spearman correlation coefficients between victimisation frequency, cognitive reappraisal use, expressive suppression use, CU traits, and cognitive and affective empathy ordered in a hierarchical cluster correlogram (upper split). Red shade indicates negative correlations; blue shade indicates positive correlations. Darker shades indicate larger correlations (see shade indicator on right panel). Non-significant coefficients (p = >.05) are indicated by a black cross ×.



Descriptive Statistics

Table 1.2

Descriptive statistics for all included variables (N=969).

	M	SD	SE	Median	Mode	Range
Victimisation	13.47	5.63	.18	16	9	27
Cognitive reappraisal	25.49	7.86	.25	26	28	36
Expressive suppression	14.08	5.31	.17	19	16	24
Cognitive empathy	8.05	9.87	.32	9	9	48
Affective empathy	6.29	12.17	.39	14	6	70
CU traits	24.74	12.96	.42	22	12	66

Quasi-Poisson Regression Plots

Figure 1.14

Quasi-Poisson regression model 1 (cognitive reappraisal) residual normal distribution plot (A), residual QQ plot (B) and model fit residual plot (C).

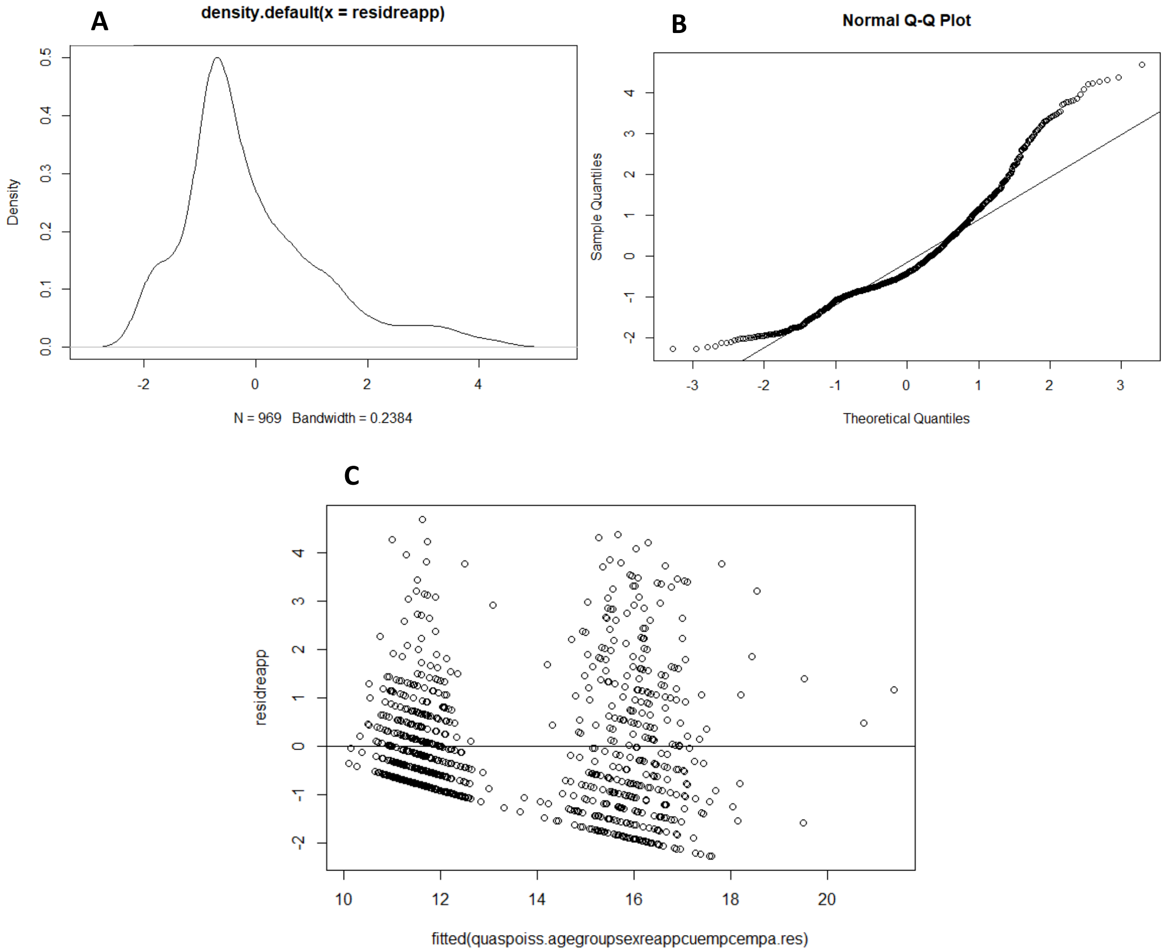
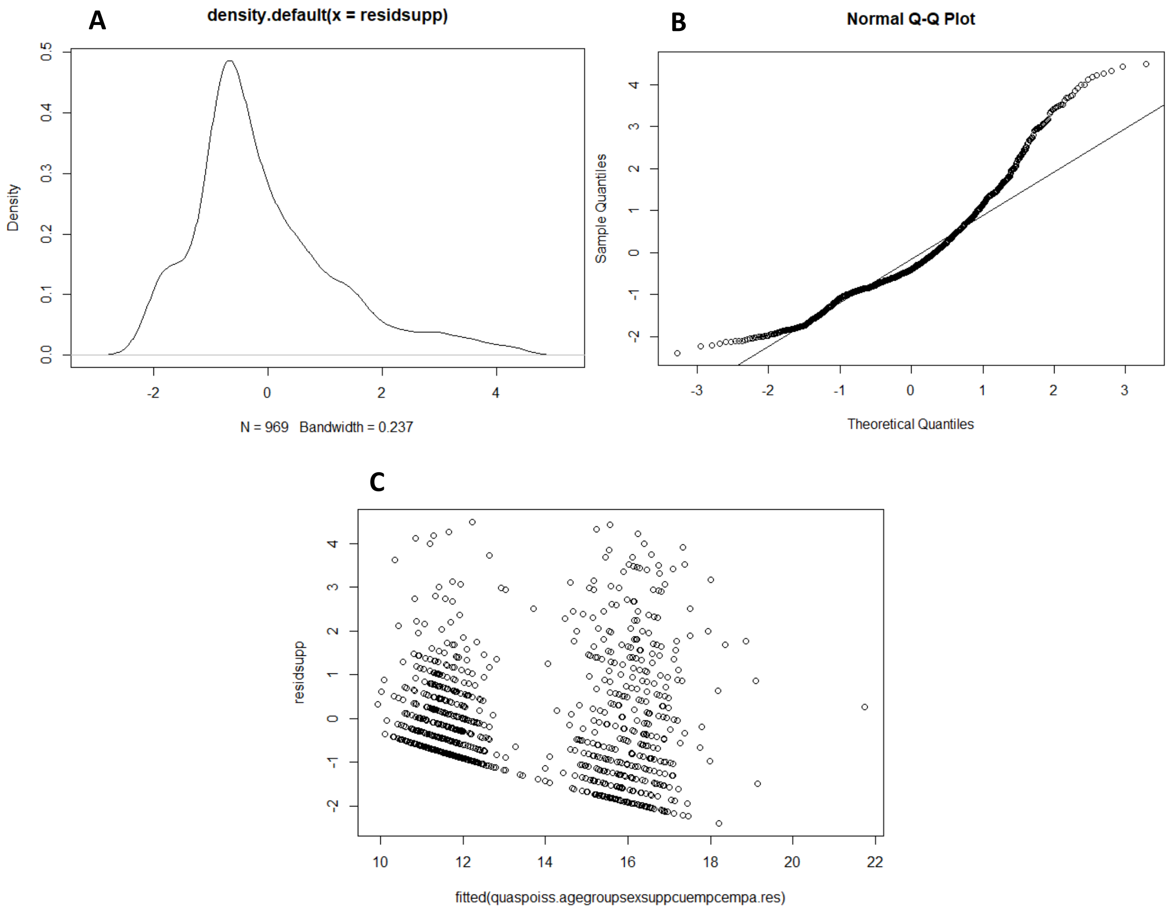


Figure 1.15

Quasi-Poisson regression model 2 (expressive suppression) residual normal distribution plot (A), residual QQ plot (B) and model fit residual plot (C).



APPENDIX 2

Full Search Strings

Database	Search string
Web of Science	(child* OR adoles* OR teenage* OR youth) AND (intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat*) AND (digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR “digital portal” OR “web based portal” OR “online portal” OR e-platform OR “online platform” OR “web based platform” OR “digital platform” OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR “artificial intelligence” OR AI OR “augmented reality” OR AR OR e-health OR web OR cyber OR multimedia OR remote* OR app OR application OR “mobile technology” OR “mobile device” OR “mobile platform” OR smartphone OR phone OR “handheld device” OR “handheld application” OR interactive OR “digital device”) AND (“emotion* regulation” OR “emotion* management” OR “affect regulation” OR “self control” OR “self regulation” OR “emotion* control” OR “affective self control” OR "social cognition" OR "perspective taking" OR “metacognition” OR “mentalis*” OR “mentaliz*” OR “TOM” OR "theory of mind")
PsychINFO	child* OR adoles* OR teenage* OR youth AND intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat* AND digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR digital portal OR web based portal OR online portal OR e-platform OR online platform OR web based platform OR digital platform OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR artificial intelligence OR AI OR augmented reality OR AR OR e-

	health OR web OR cyber OR multimedia OR remote* OR app OR application OR mobile technology OR mobile device OR mobile platform OR smartphone OR phone OR handheld device OR handheld application OR interactive OR digital device AND emotion* regulation OR emotion* management OR affect regulation OR self control OR self regulation OR emotion* control OR affective self control OR social cognition OR perspective taking OR metacognition OR mentalis* OR mentaliz* OR TOM OR theory of mind
Medline	child* OR adoles* OR teenage* OR youth AND intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat* AND digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR digital portal OR web based portal OR online portal OR e-platform OR online platform OR web based platform OR digital platform OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR artificial intelligence OR AI OR augmented reality OR AR OR e-health OR web OR cyber OR multimedia OR remote* OR app OR application OR mobile technology OR mobile device OR mobile platform OR smartphone OR phone OR handheld device OR handheld application OR interactive OR digital device AND emotion* regulation OR emotion* management OR affect regulation OR self control OR self regulation OR emotion* control OR affective self control OR social cognition OR perspective taking OR metacognition OR mentalis* OR mentaliz* OR TOM OR theory of mind
EMBASE	child* OR adoles* OR teenage* OR youth AND intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat* AND digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR digital portal OR web based portal OR online portal OR e-platform OR online platform OR web

	based platform OR digital platform OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR artificial intelligence OR AI OR augmented reality OR AR OR e-health OR web OR cyber OR multimedia OR remote* OR app OR application OR mobile technology OR mobile device OR mobile platform OR smartphone OR phone OR handheld device OR handheld application OR interactive OR digital device AND emotion* regulation OR emotion* management OR affect regulation OR self control OR self regulation OR emotion* control OR affective self control OR social cognition OR perspective taking OR metacognition OR mentalis* OR mentaliz* OR TOM OR theory of mind
Education Resources Information Centre	child* OR adoles* OR teenage* OR youth AND intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat* AND digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR digital portal OR web based portal OR online portal OR e-platform OR online platform OR web based platform OR digital platform OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR artificial intelligence OR AI OR augmented reality OR AR OR e-health OR web OR cyber OR multimedia OR remote* OR app OR application OR mobile technology OR mobile device OR mobile platform OR smartphone OR phone OR handheld device OR handheld application OR interactive OR digital device AND emotion* regulation OR emotion* management OR affect regulation OR self control OR self regulation OR emotion* control OR affective self control OR social cognition OR perspective taking OR metacognition OR mentalis* OR mentaliz* OR TOM OR theory of mind
ACM Digital Library	child* OR adoles* OR teenage* OR youth AND intervention* OR placebo* OR train* OR program* OR teach OR prevent* OR therap* OR strateg* OR treat* AND

	digit* OR technolog* OR internet OR virtual OR VR OR online OR neurofeedback OR portal OR e-portal OR “digital portal” OR “web based portal” OR “online portal” OR e-platform OR “online platform” OR “web based platform” OR “digital platform” OR wearable OR biofeedback OR comput* OR gamification OR game* OR gaming OR videogame OR “artificial intelligence” OR AI OR “augmented reality” OR AR OR e-health OR web OR cyber OR multimedia OR remote* OR app OR application OR “mobile technology” OR “mobile device” OR “mobile platform” OR smartphone OR phone OR “handheld device” OR “handheld application” OR interactive OR “digital device” AND “emotion* regulation” OR “emotion* management” OR “affect regulation” OR “self control” OR “self regulation” OR “emotion* control” OR “affective self control” OR social cognition OR perspective taking OR metacognition OR mentalis* OR mentaliz* OR TOM OR theory of mind
IEEE Xplore	:(("emotion regulation" OR "emotional regulation" OR "emotional management" OR "emotion management" OR "affect regulation" OR "self control" OR "self regulation" OR "emotion control" OR "emotional control" OR "affective self control" OR "social cognition" OR "perspective taking" OR “metacognition” OR “mentalis*” OR “mentaliz*” OR “TOM” OR "theory of mind") AND (adolescent OR adolescence OR child OR children OR teenage OR teenager OR teenagers OR youth OR youths) AND (intervention OR interventions OR strategy OR strategies OR train OR training OR trained OR teach OR placebo OR placebos OR programme OR program OR programs OR programmes OR prevent OR preventative OR therapy OR therapeutic OR treatment OR treat OR treated) AND (internet OR virtual OR online OR neurofeedback OR portal OR "e portal" OR "digital portal" OR "web based portal" OR "online portal" OR "e platform" OR "online platform" OR "digital platform" OR "web based platform" OR wearable OR biofeedback OR technology OR computer* OR gamification OR game OR videogame OR "artificial intelligence" OR "augmented reality" OR "e health" OR digit* OR web OR cyber OR multimedia OR remote OR remotely OR application OR app OR "mobile technology" OR "mobile device" OR "mobile platform" OR smartphone OR phone OR "handheld device" OR "handheld application" OR interactive OR "digital device*"))

Risk-of-Bias Tool Domains

RoB domain	RoB source	Low risk of bias definition for review	Yes, no, unclear or N/A with example of associated extraction table statement
Selection bias	1. Random sequence generation	Randomisation was employed to allocate participants to intervention and the random sequence generation method was clearly explained (where, using what method, with what software).	Yes: Randomisation was employed to allocate participants to intervention and the randomisation lists were obtained using x procedure (explain this clearly), at x location. No: Randomisation was not employed to allocate participants to intervention or randomisation was used BUT evidence for generation of a randomised sequence was not provided. Unclear: The randomisation lists were created at x but further details were not provided. N/A: The study design employed was not relevant to random sequence generation selection bias, e.g. single case study or feasibility study.
	2. Allocation concealment	Randomisation was employed to allocate participants to intervention and the method used to conceal the allocation sequence from the	Yes: Randomisation was employed to allocate participants to intervention and x method was used to conceal the allocation sequence (explain this clearly); this was implemented by x. No: Randomisation was not employed to allocate participants to intervention or the allocation to intervention was not concealed before intervention assignment. Unclear: The allocation sequence was concealed but further details were not provided.

		researcher was explained clearly.	N/A: The study design employed was not relevant to allocation concealment selection bias, e.g. single group repeated measures study.
	3. Population representation	It was clear from the recruitment method that participants recruited for the study were representative of the population from which they were drawn.	Yes: Participants recruited for the study were representative of the population from which they were drawn, (e.g. five randomly selected children's homes from a whole population of children's homes in Scotland were included in the study or stratified sampling or systematic sampling). No: Participants recruited for the study were not representative of the population from which they were drawn (e.g. opportunistic/convenience sampling at a youth wellbeing drop-in group in x city suburb used to recruit a looked-after children population or self-selecting sample). Unclear: Recruitment method is unclear, or participants are fairly typical of the average in the population from which they were drawn (e.g. looked-after children population). N/A: The study design employed was not relevant to population representation selection bias, e.g. RCT.
Performance bias	4. Blinding of participants, <u>raters</u> and intervention deliverer*	Measures are used to blind participants, <u>raters</u> and intervention deliverer(s) from knowledge of which intervention participants received and these	Yes: Participants, <u>raters</u> and intervention deliverer(s) taking part in the feasibility study were advised they would be taking part in research on x but full aim of the study (i.e. to find out if a part of an intervention was satisfactory) was not divulged (clearly explain the relevance of the type of study in relation to the definition). The efficacy data showed x. No: Participants and/or <u>raters</u> and/or intervention deliverer(s) were not blinded from knowledge of which intervention participants received

		were explained; or (measures were used to blind participants from knowing that the authors wished to create a satisfactory intervention/assess part of an intervention *applicable to feasibility/acceptability type studies only) and information relating to whether the intended blinding was effective was provided.	in the RCT (clearly explain the relevance of the type of study in relation to the definition). Unclear: The blinding measures were unclear.
5.	Acquiescence	In studies examining new interventions or components of interventions, methods taken to ensure that outcome assessments objectively seek opinions rather	Yes: X procedure was used in the case study to ensure that participants did not feel pressured into giving certain responses (explain this clearly). The efficacy data showed x. No: A procedure was not put in place to ensure that participants did not feel pressured into giving certain responses in the acceptability single group study. Unclear: It is not clear how effective the measures used to ensure that participants did not feel pressured into giving certain responses were as efficacy data was not provided. N/A: The study design employed was not relevant to acquiescence performance bias, e.g. RCT.

			than suggesting that that one answer is desirable are described clearly and Information pertaining to whether these measures were effective is also provided.	
Detection bias	6.	Blinding/objectivity of outcome measures*	The person(s) interpreting the data was not aware of the hypotheses and aims; information was not accessible to them to allow them to be able to foresee the outcome (e.g. group affiliation data) and information concerning whether this was effective was provided or the outcomes were objective e.g. time taken to maintain an oscillatory	Yes: The methods used to blind the person(s) interpreting the data from knowledge of the study hypotheses, aims and information pertaining to likely outcome of participants result were x (clearly explain this). The efficacy data showed x. No: The person(s) interpreting the data were not blinded from knowledge of the hypotheses and aims and which intervention participants received. Unclear: The blinding (and/or) objectivity of all outcome measures were unclear.

		frequency above a specified threshold.	
Attrition bias	7. Incomplete outcome data*	Data was provided for all outcome variables. For each outcome measure, attrition (<15% total across all available data) and exclusions from analysis data was provided with reasons or ITT was used (including the numbers in each intervention group (compared with total participants), and any re-inclusions in analyses for the review; or the study design employed resulted in complete outcome data e.g. single case study.	Yes: Data was provided for all outcome variables and <15% attrition (give specific %). This was due to x. *n* = x lost in x group, *n* = x lost in x group; total participants = x. No: Data was not provided for all outcome variables and/or >15% attrition (give specific %). No information regarding exclusions provided and no information provided related to reasons, or breakdown for each intervention group. Unclear: The attrition data was not provided or was unclear. N/A: The study design employed was not relevant to attrition bias, e.g. a study examining a component part of an intervention.

Reporting bias	8. Selective reporting*	Selective outcome reporting was documented and the findings were presented.	Yes: There are no discrepancies between measures used and outcome data; or any discrepancies between the measures and outcome data are clearly justified (document justification). No: There are discrepancies between measures used and outcome data and justification information in relation to selective outcome reporting was not provided.
	9. Baseline outcome measurements similar*	Performance or clinical outcomes were measured before the intervention in non-randomised trials, and there were no significant differences across groups, or there were differences across groups in randomised trials but this was taken into account in the analysis (e.g. ANCOVA).	Yes: Performance in x and x were measured at baseline in the non-randomised trial and there were no significant differences between groups; or performance in x and x were measured at baseline in the randomised trial and significant differences observed between groups was taken into account in the statistical analysis (report statistical method used). No: Important differences were found in baseline performance scores in the non-randomised trial; or there were differences between groups in the randomised trial and this was not taken into account in the analysis. Unclear: Baseline performance was measured, however data was not provided. N/A: The study design employed was not relevant to baseline outcome measurements similar reporting bias, e.g. single group repeated measures design.
	10. Validation and reliability of outcome measures*	All outcome measures were validated and/or reliable, as evidenced in the text or through further	Yes: All outcomes measures were validated and/or reliable (report validity and reliability data for each outcome measure); for example: acceptable factor analysis loading values for validity and/or Cronbach's α values for reliability. No: Some, but not all outcome measures were validated and/or reliable (report available validity and reliability data for each

		investigation into the outcome measure(s).	outcome measure); for example: acceptable factor analysis loading values for validity and/or Cronbach's α values for reliability.
	11. Full-scale study criteria transparency	The criteria used in feasibility, pilot or single case studies to determine whether to conduct a full-scale study were provided (as well as results of all outcome measures) and the outcome and implications of this were clearly documented.	Yes: The criteria that was employed to determine whether to take the current study to a full-scale study were: x, x and x. The outcome of this was: x, the implication of this was: x. No: Criteria used to determine whether to take the current study to a full-scale study was not provided. Unclear: The criteria that was used to determine whether to take the current study to a full-scale study were: x, x and x, however the outcome of this was not provided or were unclear. N/A: The study design employed was not relevant to future research criteria transparency, e.g. RCT.
Other bias(s)	12. e.g. Seasonality, time of measurement, maturation, mortality, intervention setting differences, extreme high or low score at baseline (regression	There was no evidence of other sources of bias (i.e. caused by an extraneous variable) not accounted for by clearly described, specific methods, not previously covered in the other 5 domains.	Yes: There was no evidence of other sources of bias. No: A spurious effect may have been caused, e.g. by seasonal differences; the baseline measures were completed in January and the post intervention measures were completed in August. Unclear: There were potential spurious effects of x and x, however these were unclear.

	to mean effects), measurement differences (different outcome measure for different type of intervention).		
13.	Competing interest and source of support	The author clearly stated that there were no competing interests and documented any sources of support (i.e. funding).	Yes: There were no competing interests and the source(s) of support are documented. Partial: Only the competing interest information or only the source of support was documented by the author. No: The competing interest and source of support was not documented by the author.

*=To assess each main outcome or class of outcomes.

Scoring

- Yes = 2 points
- No = 0 points
- Unclear/partial = 1 point
- N/A = 2 points

Max quality score = 26

>80% (>21) = high quality

>60% (>16) = moderate quality

<59% (<15) = low quality

Study Characteristic Matrix

Study & intervention type	Digital intervention	Additional component	*M* age	Sample	*N* (Intervention/control/ additional control)	Theory & intervention description	Setting	Length/ session *N*
Cohen Kadosh 2016	fMRI NF		11.6	Healthy	19	Increase or decrease anterior insular fMRI amplitude/thermometer dial via thinking happy thoughts or relaxing.	University research centre	One day/ four 3-min sessions
Torrado 2017	LG Watch Urbane HR BF[c]	Caregiver support & computer	10	ASD (low function)	2	Reduce HR below threshold during emotional outburst via alert and caregiver-designed personalised ER prompt.	School class	Nine days/ nine 4-hr sessions
[a]Lackner 2016	EEG NF[d]		-	Anorexia Nervosa	20 (10/ 10)	*Theory of operant conditioning of brain oscillations.* Maintain EEG α above threshold to raise ball over line via self-chosen cognitive strategies.	Hospital therapy room	Five weeks/ ten 20-min sessions
[b]Goodman 2018	Thought Technology HR BF & EEG NF[c]	Researcher strategy modelling	12.4	ASD (mixed function)	15	*Operant conditioning of brain oscillations & BCI.* Maintain EEG α-mu power above and breathing rate below thresholds to play DVD via diaphragmatic breathing.	Unspecified clinical setting	Six weeks/ twelve 80-min max. sessions

[b]Heinrich 2020	SAM[e]	Real-life strategy practice	9.8	ADHD	48 (30/ 18)	*Neurobehavioural approach.* EEG NF. Maintain relative θ/β or SCP to win games via self-chosen cognitive strategies.	Unspecified clinical setting	Four weeks/ 36 50-min sessions
[ab]Rogel 2020	EEGer4 & Zukor Interactive[d]		9.6	PTSD	32 (16/ 16)	*BCI.* EEG NF. Maintain posterior α to win audio/visual rewards via passive game interaction.	Therapy centre	Twelve weeks/24 18-min max. sessions
Filella 2016	Happy 8–12[c]		10.5	Universal	574 (351/ 223)	*Modal model of emotion.* RPG. Resolve conflicts by choosing correct assertive response from list.	-	30 1-hr sessions
Filella 2018	Happy 12–16[c]		12.6	Universal	903 (472/ 431)	*Modal model of emotion.* RPG. Resolve conflicts by choosing correct assertive response from list.	School tutor sessions	30 1-hr sessions
David 2018	ReThink mini-game	Therapist REBT description	13	Healthy	25	*REBT.* 2D. Learn about and practice differentiating between emotions to win keys and territories.	Unspecified group setting	One day/ one 30-min session
[a]David 2019	ReThink		12.9	Healthy	142 (48/ 48/ 46)	*REBT.* 2D. Learn about and practice REBT-based strategies to win keys and territories.	School class	Four weeks/ seven 50-min sessions
[a]David 2020	ReThink		12.9	Healthy	134 (47/ 42/ 45)	*REBT.* 2D. Learn about and practice REBT-based	School class	Four weeks/ seven

						strategies to win keys and territories.		50-min sessions
Rodriguez 2015	Game-Teen System	Bluetooth therapist monitoring	-	Healthy	52	*Theory of embodied cognition.* VR-enabled 3D frustration induction. Breathe with undulating feather & identify incorrect numbers in sequence.	-	One day/ one 45-min session
Vara 2016a	Game-Teen System		13	Healthy	61	*Theory of embodied cognition.* VR-enabled 3D frustration induction. Breathe with undulating feather.	School	One day/ one 20-min session
Vara 2016b	Game-Teen System		13.6	Healthy	63	*Theory of embodied cognition.* VR-enabled 3D joy induction. Breathe with undulating feather.	-	One day/ one 20-min session
[b]Antle 2018	Mind-Full[c]	Bluetooth therapist monitoring / support	-	Living in poverty	21 (9/ 12)	*MCT.* EEG NF 2D. Maintain α/θ or β above threshold to control pinwheel and paraglider or build stone stack via body relaxation/deep breathing or sustained attention.	School counsellor sessions	Six weeks/ 24 15-min sessions
Kahn 2013	RAGE-Control[d]	ACT & therapist support	-	Elevated anger/ aggression	37 (18/ 19)	*CBT & ACT.* BF 2D. Maintain HR below threshold to navigate spaceship and shoot aliens via deep breathing.	Inpatient psychiatric unit	Five days/ five 30-min sessions

Lutz 2014	HeartMath HRV[d]	Therapist support	-	Emotionally disturbed offenders	-	BF 2D. Maintain high cardiac coherence to make rainbow drop coins into vessel via positive focus and rhythmic breathing.	Psychiatric unit	-
[a]Schuurmans 2018	Dojo[d]		13.9	Anxiety with/ without ID	37 (18/ 19)	*CBT.* Immersive BF 3D fear, frustration & anger induction with character-led tutorials. Maintain HR below threshold to win mini-games via deep breathing, PMR, positive thinking, guided imagery.	Residential home	Four weeks/ eight 30-min sessions
[a]Scholten 2016	Dojo[e]		13.3	Elevated anxiety	138 (70/ 68)	*CBT.* Immersive BF 3D fear, frustration & anger induction with character-led tutorials. Maintain HR below threshold to win mini-games via deep breathing, PMR, positive thinking, guided imagery.	School & home	Three weeks/six 1-hr sessions
[a]Schoneveld 2016	Mindlight[e]		9.9	Elevated anxiety	136 (69/ 67)	*CBT.* Immersive, EEG-NF 3D anxiety induction with guidance. Maintain high β below and α above threshold to navigate scenarios in old mansion via deep breathing, self-talk and ABM.	School	Three weeks/five 1-hr sessions
[a]Schoneveld 2018	Mindlight[e]		9.9	Elevated anxiety	174 (86/ 88)	*CBT.* Immersive, EEG-NF 3D anxiety induction with guidance. Maintain high β below and α above threshold to navigate scenarios in old	School	Six weeks/ six 1-hr sessions

						mansion via deep breathing, self-talk and ABM.		
[a]Schoneveld 2020	Mindlight[e]		9.9	Elevated anxiety	174 (86/ 88)	*CBT.* Immersive, EEG-NF 3D anxiety induction with guidance. Maintain high β below and α above threshold to navigate scenarios in old mansion via deep breathing, self-talk and ABM.	School	Six weeks/ six 1-hr sessions
[a]Wijnhoven 2020	Mindlight[d]	Therapist psychoeducation and support	11.1	ASD (high function) elevated anxiety	109 (53/ 56)	*CBT.* Immersive, EEG-NF 3D anxiety induction with guidance. Maintain high β below and α above threshold to navigate scenarios in old mansion via deep breathing, self-talk and ABM.	School individual session	Six weeks/ six 1-hr sessions
[b]Beaumont 2008	Secret Agent Society[c]	Homework, group work, parent training	9.7	ASD (high function)	49 (26/ 23)	*Optimising ASD SS Programmes.* 3D RPG with character-led guidance. Decode feelings, complete social problem solving missions, choose correct defeat strategy to graduate spy school.	University research centre	Seven weeks/eight 2-hr sessions + booster & parent sessions
[b]Beaumont 2015	Secret Agent Society[d]	Homework, classwork	9.5	ASD (high function)	69	*Optimising ASD SS Programmes.* 3D RPG with character-led guidance. Decode feelings, complete social problem solving missions, choose correct	School	Ten weeks/ ten 90-min sessions

						defeat strategy to graduate spy school.		
[b]Sofronoff 2017	Secret Agent Society[c]	Delivered by parents. Homework, parent training	9.6	ASD (high function)	41	*Optimising ASD SS Programmes.* 3D RPG with character-led guidance. Decode feelings, complete social problem solving missions, choose correct defeat strategy to graduate spy school.	Home	12-18 weeks/ten 90-min sessions
[b]Einfeld 2018	Secret Agent Society[c]	Homework, classwork, parent training	10.7	ASD (mixed function)	84 (26/ 58)	*Optimising ASD SS Programmes.* 3D RPG with character-led guidance. Decode feelings, complete social problem solving missions, choose correct defeat strategy to graduate spy school.	School	10-13 weeks/ten 90-min sessions + booster & parent sessions
[b]Beaumont 2019	Secret Agent Society[e]	Homework, group work, parent training	9.8	Peer difficulties/social anxiety	27	*Optimising ASD SS Programmes.* 3D RPG with character-led guidance. Decode feelings, complete social problem solving missions, choose correct defeat strategy to graduate spy school.	University research centre	Nine weeks/ nine 90-min sessions + booster & parent sessions
[b]Shum 2019	Adventures of DoReMiFa[c]	Classwork	9.5	Universal	332 (220/ 112)	*CBT & positive psychology.* 2D modules with characters representing skills/deficits. Read stories and win	School classes	4–6 months/ eleven

							challenges to find hidden book.		20-min sessions
Carlier 2020	New Horizon[c]	Tracking & supportive parent app	8	ASD (high function)	3		*NICE modified CBT for children with ASD.* 2D. Collect stardust and snacks via guided imagery, visualisation and deep breathing. Supplemented with non-therapeutic mini-games	Home	Two weeks/no set sessions
Amon 2008	Journey to Wild Divine[d]	Researcher motivation & guidance	9.5	ADHD	24		*BF therapy.* BF, GSR commercial with character-led tutorials. Maintain HR below threshold to navigate island via breathing techniques.	University research centre	Twelve weeks/12, 18 or 24 45-min sessions
			8.8	Healthy control	12		*BF therapy.* BF, GSR commercial with character-led tutorials. Maintain HR below threshold to navigate island via breathing techniques.	University research centre	Twelve weeks/12, 18 or 24 45-min sessions
Wrzesien 2015	3DMeNow Pro™		13	Healthy		-	*Modelling therapy*. Immersive VR. Watch self-representing avatar become frustrated with computer and use focused breathing strategy.	School	One day/ one 30-min session

[b]Ruiz-Ariza 2018	Pokémon GO		13.3	Healthy	190 (87/ 103)	Commercial AR outdoor quest. Catch Pokémon and us them to fight other players.	Outside (e.g. parks)	Eight weeks/ no set sessions
[b]Yuan 2018	CAVE[c]	Trainer guidance/ debrief	8.9	ASD (high function)	72 (36/ 36)	*Cognitive theory of multimedia learning & group therapy.* Immersive VR. Navigate group control, relaxation and social scenarios via adaptive emotional and behavioural responses.	University research centre	Weeks unspecified/twelve 1-hr sessions
[b]Ip 2018	Half-CAVE[c]	Observation, trainer guidance/ debrief & worksheets	9	ASD (high function)	72 (36/ 36)	*Cognitive theory of multimedia learning & group therapy.* Immersive VR. Navigate control, relaxation and social scenarios via adaptive emotional and behavioural responses.	-	Fourteen weeks/28 1-hr sessions
[b]Carroll 2017	KOOL-Kids[c]	Classwork, homework & finale celebration	8.9	Suspended/at risk of school suspension	49	*CBT model of aggressive and antisocial behaviour.* Multimedia modular programme. Learn about emotions, identity, social skills and strategies with animated stories.	School	Twelve weeks/ thirteen 1-hr sessions
[b]Houghton 2017	KOOL-Kids[c]	Classwork, homework & finale	10	Excluded / suspended from school	13	*CBT model of aggressive and antisocial behaviour.* Multimedia modular programme. Learn about emotions, identity, social	School	Twelve weeks/ thirteen 1-hr sessions

		celebration				skills and strategies with animated stories.		
[b]Carroll 2020	KOOL-Kids[c]	Classwork, homework & finale celebration	9.7	Universal	854 (562/ 292)	*CBT model of aggressive and antisocial behaviour.* Multimedia modular programme. Learn about emotions, identity, social skills and strategies with animated stories.	School	Twelve weeks/ thirteen 1-hr sessions
[ab]Smith 2018	Emotion Theorie[d]		-	Universal	1645 (831/ 814)	*Implicit theories of emotion.* Online programme. Learn about emotions, beliefs about the nature/malleability of them and ER strategies, with scenarios and questions.	School	2-4 weeks/ two 45-min sessions

Note. Studies presented based on intervention type: = biofeedback; = digital game; = virtual and augmented reality; = programme and multimedia. Comparison information for studies included in meta-analytic component only. TAU= treatment as usual control; WL=waitlist control. Where a study reported on multiple samples, characteristics for each sample are presented separately. EEG α/θ frequency associated with relaxation; EEG β frequency associated with focus; EEG high β frequency associated with anxiety; HR, HRV and cardiac coherence associated with emotional arousal; SCP=slow cortical potential; RPG=role player game; ER=emotion regulation; PTSD=post-traumatic stress disorder; ADHD=attention deficit hyperactivity disorder; ASD=autism spectrum disorder; VR=virtual reality; AR=augmented reality. ABM=attention bias modification; PMR=progressive muscle relaxation; CBT=cognitive behavioural therapy; ACT=anger control therapy; REBT=rational emotive behaviour therapy; MCT=mindfulness cognitive therapy; BCI=brain computer interaction; HR=heart rate; GSR=galvanic skin response. NF=neurofeedback; BF=biofeedback. **-**=not reported. [a]=included in meta-analysis. **[b]**=intervention also trained other skill(s). [c]=continuance of existing treatment unclear. [d]=continuance of existing treatment permitted. [e]=continuance of existing treatment not permitted.

Intervention Descriptions

Biofeedback

LG Watch Urbane Heart rate biofeedback (*n* = 1), with an unspecified theoretical or therapeutic basis, was used to train ER in youth with low functioning ASD. It was engaged with in school on a smartwatch over 9 days for 4 hours a day. Participants reduced their heart rate during emotional outbursts by using caregiver led personalised calming strategies (e.g., counting, asking for hugs) with assets such as music and animations. Caregiver-led behavioural intervention and computer for strategy engagement was also provided.

Thought Technology Heart rate biofeedback and EEG neurofeedback (*n* = 1), informed by the theory of operant conditioning of brain oscillations and BCI was used to train ER, social cognition, social skills and address other specific ASD symptomatology in youth with mixed functioning ASD. It was engaged with in a clinical setting on a computer over 6 weeks, with two 80-minute (maximum length) sessions per week. Participants made a DVD play by maintaining alpha-mu power above, and breathing rate below, a specific threshold via diaphragmatic breathing. Researcher-led modelling of diaphragmatic breathing was also provided.

EEG neurofeedback (*n* = 1), informed by the theory of operant conditioning of brain oscillations was used to train ER and address low mood and specific AN symptomatology in youth with AN. It was engaged with in a clinical setting on a computer over 5 weeks, with two 20-minute sessions per week. Participants raised a ball over a line and changed its colour by maintaining alpha power above a specific threshold via undefined self-chosen cognitive strategies. No additional support or non-digital delivery was provided.

fMRI neurofeedback (*n* = 1), with an unspecified theoretical or therapeutic basis, was used to train ER and ER network connectivity in healthy youth. It was engaged with in a research institute on a computer over four 3-minute sessions in one day. Each session consisted of 5 20-second down-regulation blocks and 4 20-second up-regulation blocks. Participants increased and decreased the dial on a thermometer by increasing and decreasing the amplitude of the fMRI signal in the right anterior insular by thinking happy thoughts, and relaxing, respectively. No additional support or non-digital delivery was provided.

Digital Games

Twenty-seven studies assessed 15 different digital game interventions for ER. *Secret Agent Society* (*n* = 5), an intervention package including an immersive, ASD social skills programme-informed, 3D role play video game trained ER, social skills and social cognition in youth with ASD or peer relationship difficulties/social anxiety. It was engaged with in a research institute, special ASD class, at home or school on a computer over 7 – 13 weeks, with one 2-hour session a week. With guidance from a game character, participants learnt about and practiced detecting emotions in themselves and others; emotion intensity classification; detecting unhelpful cognitions; cognitive reframing; coping with emotionally difficult everyday scenarios; perspective-taking; conversation skills; social consequences, as a junior detective in a spy school. However, game mechanics were undefined. Class sessions, parent training and homework with digital journal notes were also included.

Mindlight (*n* = 4), an immersive, CBT-informed, 3D video game with EEG neurofeedback and anxiety induction trained ER for anxiety prevention in youth with and without ASD and elevated anxiety. It was played in school and after school on an Xbox 360 or computer over three weeks, with two sessions per week, or over six weeks, with one session per week. With in-game instruction, participants learnt about and practiced deep breathing, self-talk and attention bias modification in various anxiety-inducing scenarios in an old mansion. The player's ability to control their relative beta and alpha frequency power via a 1-channel EEG dictated their ability to win the game. Therapist anxiety psychoeducation and support was only provided in one study that targeted youth with ASD.

Game-Teen System (*n* = 3), a virtual reality enabled, theory of embodied cognition informed, 3D video game with emotion induction trained ER in healthy youth. It was played in school or unspecified location on a computer, smartphone or RGB-camera over one 20-minute or 45-minute session. In one study, participants engaged in a joy induction challenge where they pricked balloons with ammunition whilst receiving encouraging messages. Next, they played a deep breathing mini-game in which they breathed in and out in time with an undulating feather. In two studies, participants first engaged in a frustration induction challenge where they hit a mole whilst receiving antagonising messages. In one of these studies participants played the deep breathing mini-game only and in the other, participants played a second mini-game in which focused attention was used to identify incorrect numbers in a sequence. This study also reported the provision of Bluetooth enabled therapist monitoring.

ReThink (*n* = 2) and *ReThink Feeling Better mini game* (*n* = 1), 2D, REBT-informed video game trained ER for emotional resilience in healthy youth. ReThink was played in school on an Apple iPad over 4 weeks, with seven sessions. The Feeling Better mini-game was played in an unspecified group setting on a computer over one 30-minute session. In the Feeling Better mini-game, participants learned about and practiced identifying and differentiating between basic/complex/functional/dysfunctional emotions to win earth territory keys. However, game mechanics were undefined. In the full ReThink game, participants engaged in the Feeling Better mini-game, as well as playing other mini-games based on understanding cognitive processes and their relationship with emotions/behaviour; cognitive reframing; problem-solving; relaxation, to win earth territory keys. Again, game mechanics were undefined. No additional support or non-digital delivery was provided in the full ReThink game, but therapist description of REBT was provided in the Feeling Better mini-game.

Dojo (*n* = 2), an immersive, CBT-informed, 3D video game with heart rate biofeedback and emotion induction trained ER for anxiety reduction or prevention and externalising problems in youth with anxiety with/without ID, or elevated anxiety. It was played in school and after school, or at a residential home, on a PC or laptop over 3–4 weeks, with two sessions per week. Participants learnt about skills in game character led tutorials. In an anger mini-game, participants learnt about and used positive self-talk and guided imagery in a hand-slapping contest whilst negative sentences popped up. In a frustration mini-game, participants learnt about and used muscle relaxation to maneuver a ball through a maze. In a fear mini-game, participants learnt about and practiced deep breathing to collect bones whilst evading a ghost. The player's ability to control their heart rate dictated their ability to win the game. No additional support or non-digital delivery was provided.

Happy 8–12 (*n* = 1) and *Happy 12–16* (*n* = 1), a Modal Model of Emotion informed role-play video game trained ER for conflict resolution in universal youth. Both Happy 8–12 and Happy 12–16 were played in school on an unspecified device for 30-hours over an unspecified period. Participants resolved 25 school and family based conflicts by choosing a correct assertive response from a list. No additional support or non-digital delivery was provided.

The Adventures of DoReMiFa (*n* = 1), a CBT and positive psychology informed modular video game trained ER, mental health knowledge, social cognition, social skills and self-esteem in universal youth. It was played in school on an unspecified device in 11 20 minutes lessons, over 4–6 months. Participants helped monsters that represented socio-emotional skills and deficits to find a mental health book in a school by winning undefined mini-games, and reading stories and dialogues dedicated to different skills. Eight classroom lessons were also provided.

RAGE-Control (*n* = 1), an anger control therapy and CBT informed 2D demanding task-based video game with heart rate biofeedback trained ER for anger and aggression in an elevated anger and aggression sample. It was played in a clinical setting on an unspecified device over five daily 30-minute sessions. Participants navigated a space ship and shot aliens by using deep breathing to maintain their heart rate within a specific threshold. Anger control therapy and therapist support was also provided.

Mind-Full (*n* = 1), a mindfulness cognitive therapy informed simple challenge video game with neurofeedback trained ER and attention in youth living in poverty. It was played in school on a computer in 24 15-minute sessions over 6-weeks. Participants played two relaxation mini-games in which they controlled a pinwheel or paraglider by relaxing their body and using breathing techniques. Participants played one attention mini-game in which they built a stone stack by maintaining sustained attention on moving stones. The player’s ability to control their alpha and theta, or beta frequency power via a 1-channel EEG dictated their ability to win the game. Networked therapist monitoring and support was also provided.

SAM (*n* = 1), neurobehavioural approach informed unspecified video games with neurofeedback trained ER and self-regulation for dysregulation in youth with ADHD. It was played in a clinical setting on a computer in 36 50-minute sessions within two 18-session blocks, over 4 weeks (with a 2–3 week break between session blocks). Participants played games and won points by maintaining a relaxed state through using undefined self-chosen mental strategies. The player’s ability to control their relative beta and theta frequency power via an unspecified number of EEG channels dictated their ability to win games. Real life strategy practice and documentation was also included.

EEGer4 and *Zukor Interactive* (*n* = 1), BCI informed unspecified commercial video games with neurofeedback trained ER, executive function and addressed externalising, low mood and PTSD specific symptomatology in youth with PTSD. It was played in a clinical setting on a computer, twice a week in 24 18-minute (maximum) sessions over 12 weeks. Participants passively watched video games that reflected their EEG activity via an unspecified number of EEG channels. They won audio and visual rewards when the EEG was in their personalised posterior dominant rhythm (PDR) 3-Hz band. No additional support or non-digital delivery was provided.

New Horizon (*n* = 1), a modified CBT for children with ASD informed 2D exploration and puzzle video game trained ER for anxiety in youth with high functioning ASD. It was played daily at home on a smartphone for 2 weeks. Participants played two relaxation mini-games, one focused on guided imagery and visualisation – participants popped bubbles of specific colours within a time limit to collect stardust. One focused on relaxation – participants inhaled and exhaled at the correct time to win snacks for a space whale. Participants also played two non-therapeutic mini-games in which they recreated a sequence of stars, and, explored a new territory whilst avoiding hazards. A tracking and supportive application for parents called Space Control, and parental encouragement, were also provided.

HeartMath HRV (*n* = 1), a simple challenge video game with biofeedback with an unspecified theoretical or therapeutic basis trained ER in a young offender sample with unspecified emotional disturbance. It was played in a clinical setting on a computer over an unspecified period. Participants made a rainbow drop coins into a vessel by using positive focus and rhythmic breathing to maintain high cardiac coherence. The participant’s ability to maintain high cardiac coherence dictated their ability to win the game. Clinician support was also provided.

Journey to Wild Divine (*n* = 1), a biofeedback therapy informed commercial video game with biofeedback and galvanic skin response (GSR) trained ER for emotional symptoms and addressed specific ADHD symptomatology in healthy youth and those with ADHD. It was played for 45-minutes in a research institute on a computer once a week, twice a week or three times a week over 12 weeks. Participants learnt breathing techniques via a game character and practised them to win activities, (e.g. creating a pathway across an island). The participant’s ability to control their heart rate dictated their ability to win the game. Researcher motivation and guidance was also provided.

Virtual Reality and Augmented Reality

CAVE (*n* = 1) and *Half-CAVE* (*n* = 1), cognitive theory of multimedia learning and group therapy informed immersive virtual environments trained ER, social cognition and social skills in youth with high functioning ASD. CAVE was engaged with in a research institute in twelve 1-hour sessions over an unspecified period. In groups, participants navigated control/relaxation and social scenarios by practising adaptive emotional and behavioural responses. Half-CAVE was engaged with in an unspecified location twice a week in 28 sessions over 14 weeks. Participants were guided through the virtual environment individually in turn for 10 minutes whilst other participants observed. Within the CAVE study, trainer guidance and support were also provided; in addition, the Half-CAVE study provided observation/reflection worksheets.

Pokémon GO (*n* = 1), a commercial, augmented reality quest with an unspecified theoretical or therapeutic basis trained ER, executive function, and social skills in healthy youth. It was engaged with outside environment (e.g. parks) on a smartphone over 8 weeks. Participants caught Pokémon characters superimposed to the outside environment and used them to battle other players. Higher levels were accessed by walking greater distances. No additional support or non-digital delivery was provided.

3DMeNow Pro™ (*n* = 1), a modelling therapy informed immersive virtual environment with a self-representing avatar trained ER in healthy youth. It was engaged with in school on a computer in one 30-minute session. Participants watched a self-representing avatar become very frustrated with a computer then implement a focused breathing strategy. No additional support or non-digital delivery was provided.

Programme and Multimedia

KOOL-Kids (*n* = 3), a CBT model of aggressive and antisocial behaviour informed multimedia, modular school programme trained ER, social skills and social cognition and addressed externalising in universal youth and youth at risk of or suspended/excluded from school. It was engaged with at school on an unspecified device in 13 one-hour weekly sessions over 12 weeks. Participants engaged in four modules within five whole-of-class sessions, based on: K = know yourself; O = our needs/emotions; O = others' needs/emotions; L = living well with others. Individual referred child sessions used eight sequentially linked animated stories in which character 'Okki Octopus' had difficulty managing emotions and experienced frequent peer/teacher conflicts. Here, participants learnt key strategies via Okki and explored *their* individual difficulties. Facilitator- and teacher-led sessions, homework and a finale celebration were also provided.

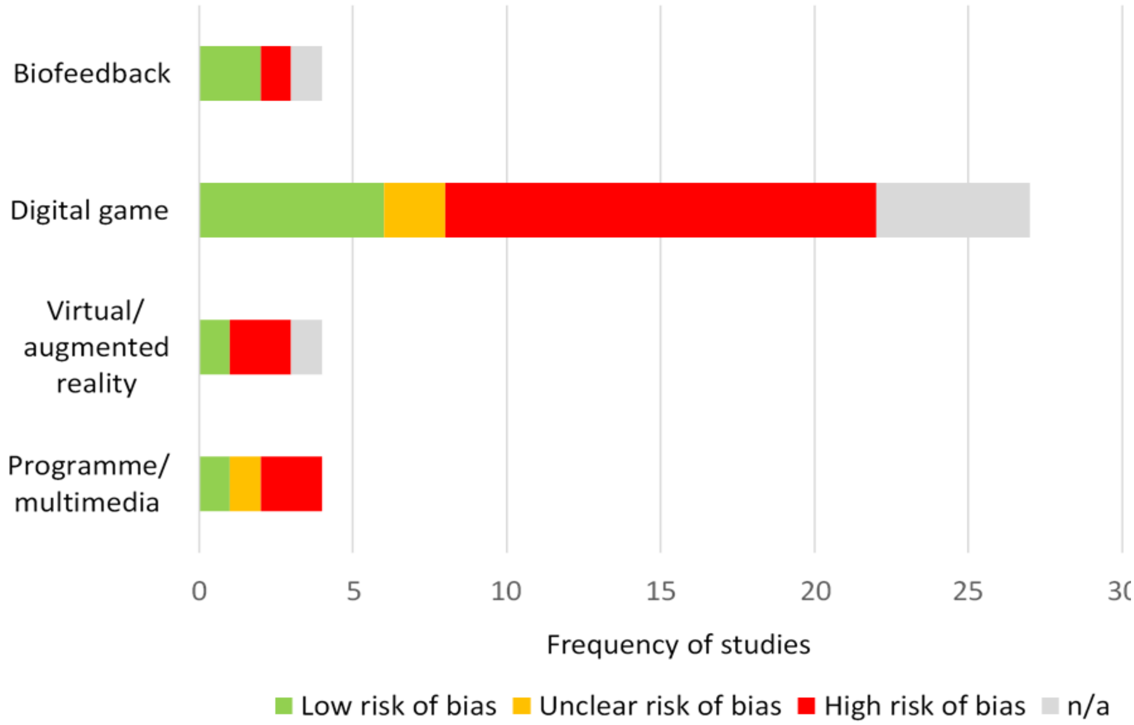
Emotion Theories (*n* = 1), an implicit theories of emotion informed online school programme trained ER and beliefs about the nature and malleability of emotions in a universal sample. It was engaged with at school on a computer in two 45-minute sessions over 2–4 weeks. Participants read/listened to information about what emotions are and how they form, the recognition of emotional experiences, and normalisation of ER difficulties in session one. In session two, participants read/listened to information about adaptive emotion theories and ER strategies. Common school-based emotionally difficult experiences (e.g., bullying) were the example scenarios. Interactive components (e.g., questions) allowed the practising of learnt material. No additional support or non-digital delivery was provided.

Risk-of-Bias Findings Summary

Of the 27/39 (69%) studies that were applicable to *random sequence generation and allocation concealment* (selection bias), most (18/27, 67%) did not apply randomisation or a random component in the sequence generation, or there was not sufficient information to make a judgment. Of those that did (9/27, 33%), most were produced using an independent researcher and computer-based random number generator. However, only 3/9 (33%) also described appropriate allocation concealment. Of the 27/39 (69%) studies that were applicable to *population representation* (selection bias), most (26/27, 96%) either did not provide adequate information to make a judgment or used recruitment methods that resulted in an inadequately representative sample. Hence, the risk of selection bias was high. The risk of performance bias *(blinding of participants, raters and study personnel, and acquiescence)* was high – all studies were unable to perform blinding in relation to knowledge of which intervention participants received; or that the authors wished to create a satisfactory intervention, or assess part of an intervention. Similarly, all studies were unable to ensure that the personnel interpreting and analysing data were unaware of the associated hypotheses and aims; or that all outcomes were objective. Therefore, the risk of detection bias was high. As shown in Figure 2.1, there was variability across studies and clusters in review authors' judgments about *incomplete outcome data* (attrition bias). The biofeedback cluster presented the lowest risk of attrition bias, with 50% (n = 2) of studies judged low risk. Most studies (4/6, 67%) judged low risk within the digital games cluster in this domain targeted at-risk populations.

Figure 2.1

Review authors judgements about incomplete outcome data risk of bias (attrition bias) in intervention clusters.



The risk of reporting bias was variable across studies. The majority of studies (36, 92%) presented no discrepancies between measures used and outcome data. However, of the 29/39 (74%) studies that were applicable to *baseline outcome measurements similar*, less than half (12, 41%) clearly demonstrated no significant differences in outcomes across groups at pre-test where the study was non-randomised; or differences across groups were taken into account where the study was randomised. The majority of these studies were in the digital game cluster. Further, the *validity and reliability* reporting bias source was deemed high risk, with less than a third 10/39 (26%) of included studies' using only valid and reliable outcome measures in the targeted sample. In early stage studies that were applicable to *full-scale study criteria transparency* (reporting bias) (*n* = 10), all were high risk. That is, they did not report the criteria that would determine whether a subsequent full-scale study should be conducted, with associated outcomes. Finally, over half (23/39, 59%) of the studies appeared to demonstrate a high risk of gender bias within the other bias domain. This was evident across all intervention clusters, but largely within studies targeting at risk and diagnosed populations. The risk of bias scores were re-calculated after removing gender bias to consider whether this influenced overall quality ratings. Three studies from the digital game (*n* = 1), biofeedback (*n* = 1) and programme/multimedia (*n* = 1) clusters improved, moving from low quality to moderate quality overall ratings. The supplementary materials contain the Risk of Bias Matrix.

Influence Analysis

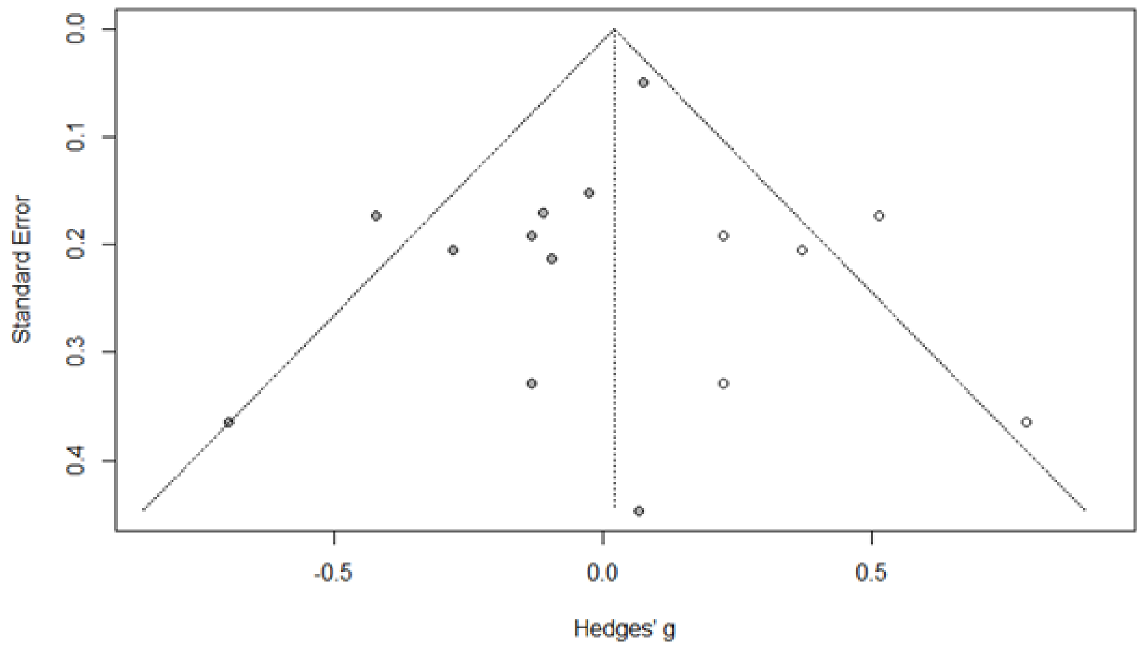
The examination of influence analysis subplots indicated that two studies, (Smith et al., 2018; Schoneveld et al., 2016) presented extreme values in the emotion experience meta-analysis according to Viechtbauer and Cheung's (2010) threshold and author visual inspection. This indicates that they may have biased the pooled effect estimate and caused some of the between-group heterogeneity. The Baujat plot indicated that the significant effect of Schoneveld et al., (2016) contributed greatly in terms of observed heterogeneity, yet its influence on the pooled effect was very small in comparison to Smith et al., 2018, which was a comparatively very large study (N = 1645) and was the only study to assess positive emotion experience. This was further corroborated within the Leave-One-Out forest plots in which the emotion experience negative pooled effect was slightly greater (g = -0.18) and significant (owing to non-overlapping confidence intervals) and I^2 was at its lowest (I^2 = 0%) when Smith et al., (2018) was removed. Of note is the non-validated and unreliable positive emotion experience measure used by Smith et al., (2018).

Considering the ER meta-analysis, examination of the influence analysis subplots indicated that Schoneveld et al., (2020) presented extreme values, according to Viechtbauer and Cheung's (2010) threshold and author visual inspection. This study may have biased the pooled effect estimate and caused some of the between-group heterogeneity. Of note is the unexpected effect observed in Schoneveld et al., (2020) (in which ER was greater in the control group post-intervention). Further, this was the only non-inferiority study, and the only study that did not permit ongoing usual treatment. The extreme values observed in influence analysis subplots is supported by the Baujat plot, in which Schoneveld et al., (2020) was highly influential in terms of between-study heterogeneity. Additionally, Smith et al., (2018) was highly influential in the pooled effect, yet again, this was obtained from a non-validated and non-reliable measure. This is further corroborated within the Leave-One-Out forest plots, in which the positive pooled effect was greater (g = 0.27) and significant (owing to non-overlapping confidence intervals) and I^2 was at its lowest ($I^2 = 0\%$) when Schoneveld et al., (2020) was removed.

Trim and Fill Analysis

Figure 2.2

Trim and fill analysis funnel plot.



Intervention Efficacy Matrix

Study & intervention type	ER	Emotion experience	Physiological regulation	Outcome summary	Additional mode/*skill*	Dropout %
	Outcome (report type) & ROB					
Cohen Kadosh 2016	Cognitive ER scale (self)		fMRI ER brain network connectivity	ER: In fMRI-NF relaxation & positive thinking, only left insula up-regulation *(increased activity)* correlated significantly with cognitive ER, with a large effect (*g* = 1.26). Physiological regulation: ER network connectivity increased significantly in upregulation only, with a medium effect (*g* = 0.52).		9.5%
Torrado 2017			HR	Physiological regulation: In HR threshold alert & personalised ER prompt providing smartwatch, HR reduced below threshold in less than half of alerts.	Caregiver support & use of computer for strategies	-
[a]Goodman 2018	ER scale (parent)	1. Anxiety scale (parent) 2. Lability/ negativity scale (parent)	1. HRV (3 distinct indices) 4. Resting EEG α/θ	ER: In HR-BF & HR-BF+EEG-NF threshold-based diaphragmatic breathing, ER increased significantly in HR-BF group only, with a large effect (*g* = 1.25). Emotion experience: Anxiety decreased non-significantly in both groups & lability/negativity decreased significantly in HR-BF+NF group only, with a large effect (*g* = -0.81).	Researcher strategy modelling/ *Social cognition*	-

				Physiological regulation: Significant HRV improvements in vagal tone & RMSSD in HR BF+EEG NF group only. Resting α/θ changed non-significantly in both groups.		
[b]Heinrich 2020		Emotional symptom scale (parent)	Resting EEG α	Emotion experience: In SCP & θ/β EEG-NF game with self-chosen cognitive strategies, emotional symptoms decreased significantly in SCP-NF only, with a small effect (g = -0.41). *Change scores only.* Physiological regulation: No association between resting α & reduction in emotional symptoms.	Real-life strategy practice/*Self regulation*	-
[a]Filella 2016	Emotional competence scale (self)	State anxiety scale (self)		ER: In a conflict solving RPG game, emotional competence increased. Emotion experience: State anxiety decreased.		-
[a]Filella 2018	Emotional competence scale (self)	State anxiety scale (self)		ER: In a conflict solving RPG game, emotional competence increased. *Change scores only.* Emotion experience: State anxiety decreased. *Change scores only.*		-
David 2018	Emotion Understanding			ER: In 2D REBT emotion differentiation mini-game, collection of functional emotions increased significantly after third gameplay period, with a large effect (g = 1.77). This diminished by the seventh period of game play.	Therapist REBT description	-

	game data					
Rodriguez 2015		Frustration scale (self)	HR	Emotion experience: In VR 3D frustration induction & deep breathing/focused attention ER game, frustration increased significantly in high & low ER difficulty groups after induction, with a very large effect (*g* = 4.56). Frustration reduced by 72.5% across both groups after ER. Physiological regulation: HR increased significantly in both groups after induction, with a very large effect (*g* = 2.29). Non-significant decrease in HR in both groups after ER.	Bluetooth therapist monitoring	-
Vara 2016a		1. Frustration scale (self) 2. Relaxation scale (self) 3. Emotional arousal scale (self)		Emotion experience: In VR 3D frustration induction & deep breathing ER game using different devices, frustration increased & decreased significantly after induction & ER in phone & computer groups, respectively. But in camera group frustration decreased significantly after induction, with a large effect (*g* = -1.2) & this was maintained after ER. Arousal increased & decreased significantly after induction & ER across all groups, respectively. Relaxation decreased & increased significantly after induction & ER across all groups, respectively.		-
Vara 2016b		1. Joy scale (self) 2. Emotional arousal scale (self)		Emotion experience: In VR 3D joy induction & deep breathing ER game using different devices, joy increased & decreased non-significantly after induction & ER across all device groups, respectively. Arousal increased &		-

				decreased significantly after induction & ER across all groups, respectively.		
[a]Antle 2018		Calm scale with open questions (school staff)	EEG α/θ	Emotion experience: In a MCT EEG-NF body relaxation/deep breathing ER game, feelings of calm increased significantly, with a large effect (*g* = 1.98). Reports of reduction in tearfulness, anxiety & shyness. Physiological regulation: Time spent above EEG threshold increased significantly from first 3 sessions to last 3 sessions of 2 ER games (large effect, *g* = 1.01; small effect, *g* = 0.39).	Bluetooth therapist monitoring & support/ *Attention*	9%
[c]Kahn 2013		1. State anger scale (self) 2. Trait anger scale (self)	HR	Emotion experience: In 2D HR BF deep breathing ER game, state & trait anger decreased significantly. Physiological regulation: Time spent below heart rate threshold increased significantly.	ACT & therapist support	-
[c]Lutz 2014		Verbal feedback (self)	Cardiac coherence	Emotion experience: In 2D HRV BF deep breathing & positive focus ER game, reports of feeling calmed. Physiological regulation: Medium or high cardiac coherence usually achieved. *Unexpected ability noted in some highly dysregulated youth.*	Therapist support	-
[a]Beaumont 2008	1. ER knowledge 2. ER knowledge			ER: In 3D ER, social cognition & social skill RPG with allied group-based learning sessions, anger & anxiety ER knowledge increased significantly, with large effects (*g* = 1.06; *g* = 1.51), respectively. ER & social skills improved significantly, with a very large effect (*g* = 2.22).	Homework group work & parent training/ *Social*	-

	3. ER & social skills scale (parent)				*cognition, social skills*	
[c]Beaumont 2015	1. ER knowledge 2. ER knowledge 3. ER & social skills scale (parent) 4. ER & social skills scale (teacher)	Anxiety scale (parent)		ER: In 3D ER, social cognition & social skill RPG with allied structured or unstructured class-based learning sessions, anxiety ER knowledge improved significantly in structured & unstructured groups & maintained at follow-up, with large (*g* = 1.5) & medium (*g* = 0.74) effects, respectively. Anger ER knowledge improved significantly in structured group only & maintained at follow-up, with a large effect (*g* = 1.47). ER & social skills improved significantly in both groups & maintained at follow-up, with medium & large effects for structured group (*g* = 0.75; *g* = 0.82) & small effects for unstructured group (*g* = 0.39; *g* = 0.45). Emotion experience: Anxiety decreased significantly in structured group only & maintained at follow-up, with a small effect (*g* = -0.36).	Homework classwork/ *Social cognition, social skills*	1.4%
[a]Sofronoff 2017	1. ER knowledge 2. ER knowledge	Anxiety scale (parent)		ER: In 3D ER, social cognition & social skill RPG with allied home-based learning sessions, only anger ER knowledge improved significantly, but by follow-up both anger & anxiety had improved significantly, with large effects (*g* = 0.92; *g* = 1.19), respectively. ER & social skills improved	Delivered by parents. Homework & parent training/ *Social*	32%

	3. ER & social skills scale (parent)		significantly & maintained at follow-up, with a large effect (g = 1.36). Emotion experience: Anxiety decreased significantly & maintained at follow-up, with a small effect (g = -0.48).	*cognition, social skills*	
[a]Einfeld 2018	1. ER knowledge 2. ER knowledge 3. ER & social skills scale (parent) 4. ER & social skills scale (teacher)		ER: In 3D ER, social cognition & social skill RPG with allied class-based learning sessions, anger & anxiety ER knowledge improved significantly, with medium effects (g = 0.65; g = 0.55), respectively & maintained at follow-up. Parent-report ER & social skills improved significantly with a large effect (g = 1.03) & maintained at follow-up. Teacher report significant at follow-up only. *Follow-up mean/SD data unclear therefore g reported at post-intervention only.*	Homework classwork & parent training/ *Social cognition, social skills*	-
[b]Beaumont 2019	1. ER Knowledge 2. ER Knowledge	1. Anxiety scale (self) 2. Anxiety scale (parent)	ER: In 3D ER, social cognition & social skill RPG with allied group-based learning sessions, anger & anxiety ER knowledge improved significantly, with large effects (g = 1.81; g = 2.01), respectively & maintained at follow-up. ER & social skills increased significantly & maintained	Homework group work & parent training/ *Social*	-

	3. ER & social skills scale (parent)	at follow-up, with a large effect (*g* = 1.47). Emotion experience: Only parent-report anxiety decreased significantly & maintained at follow-up, with a large effect (*g* = -0.88).	*cognition, social skills*	
[a]Shum 2019	1. Anxiety scale (self) 2. Negative Thinking scale (self)	Emotion experience: In 2D modular ER, social cognition, social skill & mental health game with allied class-based learning, anxiety did not decrease & negative thinking decreased non-significantly.	Classwork/ *Social cognition, social skills, self-esteem, mental health knowledge*	29.2%
[a]Carlier 2020	1. Anxiety scale (self)	Emotion experience: In 2D guided imagery & deep breathing ER & non-therapeutic game, anxiety decreased in 2/3 youth.	Tracking & supportive parent app	40%
	2. Anxiety scale (parent)			
[c]Amon 2008	Emotional, social & behavioural symptom scale (parent)	Emotion experience: In HR & GSR BF breathing strategy ER game (ADHD sample), symptoms decreased significantly in once-a-week group with a large effect (*g* = -1.25) & non-significantly in more than once-a-week group.	Researcher motivation & guidance	-
	Emotional, social & behavioural symptom	Emotion experience: In HR & GSR BF breathing strategy ER game (healthy sample), symptoms decreased non-significantly in both groups.	Researcher motivation & guidance	-

		scale (parent)				
Wrzesien 2015		1. Frustration scale (self) 2. Relaxation scale (self) 3. Valence scale (self) 4. Arousal scale (self) 5. Dominance scale (self)	EEG activity source	Emotion experience: In immersive VR frustration induction with self-representing (VRS group) or neutral (VRN group) avatar that modelled emotions, behaviours & ER, frustration increased & decreased non-significantly after induction & ER in VRS & VRN groups, respectively. Relaxation decreased & increased after induction & ER significantly in VRS group, respectively. Negative valence increased significantly after induction in VRS group only. Arousal decreased significantly in VRS group only, after ER only. Dominance decreased & increased non-significantly after induction & ER in both groups, respectively. Physiological regulation: Θ activation in brain regions associated with emotion processing increased significantly only in VRS group. No association in other EEG frequencies.		-
Ruiz-Ariza 2018	1. Self-control scale (self) 2. Emotional intelligence scale (self)			ER: In AR outdoor quest, self-control decreased & emotional intelligence increased non-significantly.	*Social skills, executive function*	5.4%

[a]Yuan 2018	ER & expression test (parent)			ER: In immersive group VR emotion & social skill practice scenarios, ER & expression increased non-significantly.	Trainer guidance & debrief/*Social cognition, social skills*	-
[a]Ip 2018	ER & expression test (parent)			ER: In immersive individual VR emotion & social skill practice scenarios, ER & expression increased significantly, with a small effect (*g* = 0.38).	Observation, trainer guidance, debrief & worksheets/ *Social cognition, social skills*	2.25%
[a]Carroll 2017		1. Positive emotion scale (self) 2. Negative emotion scale (self)		Emotion experience: In multimedia modular programme, intensity of positive & negative emotions decreased significantly, with small effects (*g* = -0.47; *g* = -0.43), respectively.	Classwork, homework & finale celebration/ *Social cognition, social skills*	3.4%
[a]Houghton 2017		1. Positive emotion scale (self) 2. Negative emotion scale (self)		Emotion experience: In multimedia modular programme, intensity of positive emotions decreased significantly, with a large effect (*g* = -1.39). Intensity of negative emotions decreased non-significantly.	Classwork, homework & finale celebration/ *Social cognition, social skills*	-
[a]Carroll 2020	Socio-emotional compet	Internalising scale (teacher)		ER: In multimedia modular programme, socio-emotional competence increased significantly, with a small effect (*g* = 0.17).	Classwork, homework & finale celebration/	-

	ence scale (teacher)		Emotion experience: Internalising decreased non-significantly.	*Social cognition, social skills*

Note. This table includes efficacy outcome summaries for all studies included in the systematic review not suitable for meta-analysis. =biofeedback; =digital game; =virtual reality/augmented reality; =programme/multimedia. ER=emotion regulation. EEG α/θ frequency associated with relaxation; EEG β frequency associated with focus; SCP=slow cortical potential. Green shading=low ROB; red shading=high ROB. -=not reported. ADHD=attention deficit hyperactivity disorder; RPG=role player game; REBT=rational emotive behaviour therapy; ACT=anger control therapy; MCT=mindfulness cognitive therapy; VR=virtual reality; AR=augmented reality. HR=heart rate; GSR=galvanic skin response. NF=neurofeedback; BF=biofeedback. See Appendix 2 'Measures Matrix' for details of efficacy measures.

Measures Matrix

First author with year of publication	Effectiveness, efficacy, feasibility outcome measure(s)	Acceptability outcome measure(s)
Cohen Kadosh, 2016	1. Cognitive Emotion Regulation Questionnaire (Garnefski et al., 2001) (self-report) 2. fMRI Granger information flow during NFT	-
Torrado, 2017	1. Heart rate (LG Watch Urbane™) 2. Evaluator field notes inclusive of caregiver comments	
Lackner, 2016	1. Eyes Closed and Open Resting State EEG Band Power **2. Regulating and Controlling Own Emotions subscale of Emotional Competence Questionnaire (Rindermann 2009) (self-report)** 3. Recognising and Understanding Own Emotions subscale of Emotional Competence Questionnaire (Rindermann 2009) (self-report) 4. General Emotionality subscale of Emotional Competence Questionnaire (Rindermann 2009) (self-report) **5. Anxiety subscale of Brief Symptom Inventory shortened from Symptom Checklist-90-Revised (Franke & Derogatis, 2002; Frank 2000) (self-report)**	-
Goodman, 2018	1. Standard Deviation of Normal-to-Normal Wave Intervals (Thought Technology Ltd) 2. Square Root of the Mean Squared Difference of Successive Normal-to-Normal Intervals (Thought Technology	-

	Ltd) 3. Vagal tone (Thought Technology Ltd) 4. Alpha and Theta activity in resting state EEG 5. Lability/Negativity subscale of Emotion Regulation Checklist (Shields & Cicchetti, 1997) (parent-report) 6. Emotion Regulation subscale of Emotion Regulation Checklist (Shields & Cicchetti, 1997) (parent-report) 7. Children's Anxiety Scale (Nauta et al., 2004; Spence, 1998) (parent-report)	
Heinrich, 2020	1. Alpha Activity in Eyes Closed and Open Resting State EEG 2. Emotional Symptoms subscale of the Strengths and Difficulties Questionnaire (Goodman 1997) (parent report)	-
Rogel, 2020	1. Internalising scale of Child Behaviour Checklist (Achenbach & Rescorla, 2001) (self-report) **2. Anxiety scale of Trauma Symptom Checklist for Young Children (Briere, 2005) (self-report)**	-
Filella, 2016	1. Emotional Development Questionnaire (López & Pérez, 2010) (self-report) 2. State subscale of Anxiety Inventory for Children (Seisdedos, 1990; Spielberger, 1973) (self-report)	-
Filella, 2018	1. Emotional Development Questionnaire (López & Pérez, 2010) (self-report) 2. State subscale of Anxiety Inventory for Children (Seisdedos, 1990; Spielberger, 1973) (self-report)	-

David, 2018	1. In game performance (developed by study authors)	-
David, 2019	1. Awareness subscale of Emotion Regulation Index for Children and Adolescents (MacDermott et al., 2010) (self-report) **2. Control subscale of Emotion Regulation Index for Children and Adolescents (MacDermott et al., 2010) (self-report)** 3. Fear subscale of Early Adolescent Temperament Questionnaire—Revised (Ellis & Rothbart 1999) (self-report) **4. Emotional Symptoms subscale of the Strengths and Difficulties Questionnaire – Child Version (Goodman 1997) (self-report)**	-
David, 2020	1. Portable EEG (Emotiv EPOC 14-channel Headset, Emotiv Systems, Inc., San Francisco, CA) frontal alpha asymmetry **2. Concern and Anxiety subscale of Profile of Affective Distress (Opris & Macavei 2007) (self-report)**	-
Rodriguez, 2015	1. ECG heart rate pre-post breathing strategy 2. Thermometers scale (author unclear) (self-report)	-

Vara, 2016a	1. Frustration Visual Analogue Scale (adapted from Stern et al., 1997) (self-report) 2. Relax Visual Analogue Scale (adapted from Stern et al., 1997) (self-report) 3. Felt Arousal Scale (adapted from Hulley et al., 2008) (self-report)	1. Participants Report on the GT-System Scale (self-report; developed by study authors)
Vara, 2016b	1. Joy Visual Analogue Scale (Stern et al., 1997) (self-report) 2. Felt Arousal Scale (Hulley et al., 2008) (self-report)	-
Antle, 2018	1. Portable EEG (Neurosky Mindwave Headset™) mean % time spent above 70% threshold 2. Calm instrument including open questions (developed by study authors, school counsellors and school) (school staff-report) 3. Behavioural assessment survey including open questions (developed by study authors, school counsellors and school staff) 4. Counsellor written reports and follow up emails (developed by study authors) 5. Teacher written reports (developed by study authors) 6. Observations (study authors and school staff)	1. Counsellor written reports and follow up emails (developed by study authors) 2. Teacher written reports (developed by study authors) 3. Observations (study authors and school staff) 4. Focus groups (school staff)

Kahn, 2013	1. State Anger subscale of State and Trait Anger Expression Inventory—Child and Adolescent (Spielberger 1996) (self-report) 2. Trait Anger subscale of State and Trait Anger Expression Inventory—Child and Adolescent (Spielberger 1996) (self-report) 3. Heart rate first-last session (author unclear)	1. Therapeutic Helpfulness Questionnaire (self-report; author unclear)
Lutz, 2014	1. Medium and high cardiac coherence during video game (emWave2™) 2. Participant verbal feedback 3. Clinician verbal feedback and observations	1. Clinician verbal feedback and observations 2. Participant verbal feedback
Schuurmans, 2018	**1. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)** 2. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (mentor report) 3. Compliance scale (developed by study authors) (self-report)	1. User Evaluation Scale (self-report; developed by study authors)
Scholten, 2016	**1. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)** 2. Game Expectations – dichotomous responses (developed by study authors) (self-report)	-
Schoneveld, 2016	**1. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)** 2. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (parent report) 3. Game Evaluations Scale (self-report; developed by study authors) 4. Game Expectations – dichotomous response	1. Game Evaluations Scale (self-report; developed by study authors)

	(developed by study authors) (self-report)	
Schoneveld, 2018	**1. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)** 2. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (parent report) 3. Children's Program Ratings Scale (self-report; developed by study authors) 4. Expectations Scale (developed by study authors) (self-report)	1. Children's Program Ratings Scale (self-report; developed by study authors)
Schoneveld, 2020	1. Internalising subscale of Strengths and Difficulties Questionnaire – Mother Version (Goodman 1997; Stone et al. 2010) (parent report) **2. Emotion Self-Efficacy scale from Self-Efficacy Questionnaire for Children (Muris 2001) (self-report)**	-
Wijnhoven, 2020	**1. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)** 2. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (parent report) 3. The Anxiety Disorders Interview Schedule for DSM-IV, Parent version (Silverman et al., 2001) (data not provided) 4/5. Parent Expectancies for Therapy Scale (PETS; Kazdin & Holland, 1991) (self- and parent report)	-

Beaumont, 2008	1. James and the Maths Test (Attwood, 2004a) 2. Dylan is Being Teased (Attwood, 2004b) 3. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (parent report)	-
Beaumont, 2015	1. James and the Maths Test (Attwood, 2004a) 2. Dylan is Being Teased (Attwood, 2004b) 3. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (parent report) 4. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (teacher report) 5. Spence Children's Anxiety Scale (Spence 1998) (parent report)	-
Sofronoff, 2017	1. James and the Maths Test (Attwood, 2004a) 2. Dylan is Being Teased (Attwood, 2004b) 3. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (parent report) 4. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (parent report)	
Einfeld, 2018	1. James and the Maths Test (Attwood, 2004a) 2. Dylan is Being Teased (Attwood, 2004b) 3. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (parent report) 4. Emotion Regulation and Social Skills Questionnaire (Butterworth et al., 2014) (teacher report)	-
Beaumont, 2019	1. James and the Maths Test (Attwood, 2004a) 2. Dylan is Being Teased (Attwood, 2004b) 3. Emotion Regulation and Social Skills Questionnaire	-

	(Butterworth et al., 2014) (parent report) 4. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (parent report) 5. Spence Children's Anxiety Scale (Dutch version) (Spence 1998) (self-report)	
Shum, 2019	1. Chinese version of 9 items from Screen for Child Anxiety – Related Emotional Disorders (Birmaher 1997) (self-report) 2. Chinese version of Personal Failure subscale of Children’s Automatic Thoughts Scale-Negative or Positive, with another 10 positive items added to facilitate calculation of the state-of-mind ratios (Schniering 2002) (self-report)	-
Carlier, 2020	1. Spence Children’s Anxiety Scale (Spence, 1998) (self-report) 2. Spence Children’s Anxiety Scale (Spence, 1998) (parent report) 3. Parent Interview	1. Parent Interview 2. In Game Mood Likert Scale (self-report; developed by study authors)
Amon, 2008	1. Strengths and Difficulties Questionnaire – composite score only (Goodman, 1997) (parent report) 2. Parent Diary 3. Game Experience Questionnaire scale (created by study authors) (parent report)	-

Wrzesien, 2015	1. EEG (Emotiv EPOC device™) activity across phases 2. Frustration Visual analogue scale (Adapted) (Stern et al., 1997) (self-report) 3. Relaxation Visual analogue scale (Adapted) (Stern et al., 1997) (self-report) 4. Valence subscale of Self-assessment manikin scale (Lang, 1980) (self-report) 5. Arousal subscale of Self-assessment manikin scale (Lang, 1980) (self-report) 6. Dominance subscale of Self-assessment manikin scale (Lang, 1980) (self-report) 7. Presence self-assessment manikin (author unclear) (self-report) 8. Identification with avatar questionnaire (author unclear) (self-report)	1. Appeal Questionnaire Scale (self-report; developed by study authors)
Ruiz-Ariza, 2018	1. Self-Control subscale of Trait and Emotional Intelligence Questionnaire, Short Form (Petrides, 2009) (self-report) 2. Emotionality subscale of Trait and Emotional Intelligence Questionnaire, Short Form (Petrides, 2009) (self-report)	1. Satisfaction Level with Pokemon GO: Ad-Hoc Questionnaire – dichotomous response (self-report; author unclear)
Yuan, 2018	1. Affective Expressions Subtest of Psychoeducational Profile, Third Edition (Schopler et al., 2005) (parent report) 2. Ongoing Qualitative Communication Log with Parents and Teachers (Description; developed by study authors)	-

Ip, 2018	1. Affective Expressions Subtest of Psychoeducational Profile, Third Edition (Schopler et al., 2005) (parent report)	-
Carroll, 2017	1. Positive Emotions subscale of Emotional Intensity Scale for Children (Braaten & Rosén, 2000) (self-report) 2. Negative Emotions subscale of Emotional Intensity Scale for Children (Braaten & Rosén, 2000) (self-report) 3. Facilitator feedback (based on Corner et al., 2013)	1. Acceptability Assessments Scale (self-report; developed by study authors) 2. Facilitator feedback (based on Corner et al., 2013)
Houghton, 2017	1. Positive Emotions subscale of Emotional Intensity Scale for Children (Braaten & Rosén, 2000) (self-report) 2. Negative Emotions subscale of Emotional Intensity Scale for Children (Braaten & Rosén, 2000) (self-report) 3. Facilitator feedback (based on Corner et al., 2013)	1. Acceptability Assessments Scale (self-report; developed by study authors) 2. Facilitator feedback (based on Corner et al., 2013) 3. Acceptability Assessments Scale (facilitator report; developed by study authors)
Carroll, 2020	1. Social and Emotional Competence Questionnaire (CASEL & AIR 2013) (teacher report) 2. Internalising subscale of Strengths and Difficulties Questionnaire – Teacher Version (Goodman 1997) (teacher report)	-

Smith, 2018	**1. Adaptive Theories of Emotions Scale – based on Implicit Theory of Emotion Items (Tamir et al., 2007**) & Emotion Regulation Questionnaire (Gross & John, 2003) (self-report) **2. Emotional Well-Being in School Scale (developed by study authors) (self-report)** 3. Emotional Well-Being in Life Scale (developed by study authors) (self-report)	-

Note. All data from the measures used within the included studies were collected between 2008 – 2019. Therefore, the evidence for the efficacy, feasibility, and acceptability of digital games for ER presented within this review reflects this time only, and it is important to note that this was pre-COVID-19. Measures used in the meta-analysis are in bold.

Intervention Feasibility Matrix

ID	Dropout % & reasons	Measure & ROB	Report	Outcome summary & additional information
Cohen Kadosh 2016	9.5%			
Torrado 2017	-	Field notes & comments	Researcher/caregiver	In HR threshold alert & personalised ER prompt providing smartwatch, one participant demonstrated 20/30 unsuccessful uses due to ignoring alert when in difficult situation & not knowing how to use watch on days 1-3. High level of support required on days 1-3 to use watch & ER. Activated alerts due to excessive excitement–caregiver noted helpful as excessive excitement caused emotional outbursts. Ongoing support required to associate prompts to music video ER strategy on computer. One participant who experienced light/sound sensitivity activated 54 ER prompts. 31/54 unsuccessful uses due to not knowing how to use watch on days 1-4 & unable to use due to high level of distress. High level of support required on days 1-4. Lowered hands from ears on days 6, 7 & 9 when noticed alert (hands on ears a lot due to loud noises from classmates). Both participants able to interact successfully & autonomously with watch by end of intervention. Also acted as distractor when in difficult situation.
Lackner 2016	9%			
[a]Rogel 2020	22% ITT: Personal/family/communication issue, group			

	assignment displeasure			
David 2019	7%: Withdrew			In 2D ER game, maximum 50min completion time per mini-game determined in pre-study testing with *N* = 5 youths. Missed levels played in next session in current study.
David 2020	18.8%: Did not complete first intervention task			In 2D ER game, wireless Emotiv EPOC 14-channel EEG technical issues severely affected EEG signal quality.
Rodriguez 2015	-			In VR 3D frustration induction & deep breathing/focused attention ER game, X3 engagements required to determine stability of ER ability.
[a]Antle 2018	9%: Left participating school	Behavioral assessment scale & open questions	School staff	In a EEG-NF, body relaxation/deep-breathing ER game, learnt skills used in classroom & playground.
Lutz 2014	-	Verbal feedback	Clinician	In 2D HRV BF deep breathing & positive focus ER game, easy integration in therapy sessions but some reports of BF set-up & explanation difficulties.
		Observations	Clinician	No real-life practice of learnt ER strategies when ER strategy/game novelty declined.
Schuurmans 2018	34% ITT: Discharged from participating clinic, re-placed, behavioural	Game tutorial compliance scale	Self	In 3D immersive HR BF fear, frustration & anger induction ER game, high compliance in anger: positive self-talk (*M* = 5.76/7) & guided imagery (*M* = 5.95), frustration: muscle relaxation (*M* = 6.12/7), fear: deep-breathing (*M* = 6.06/7) mini-game tutorials.
		Open-answer question on skill use	Self	Deep breathing & positive thinking strategies were used most in real-life.

	improvement/ decline, refused treatment		
Scholten 2016	8.7% ITT		
Schoneveld 2016	25.7% ITT		
Schoneveld 2018	12% ITT: Time issues in control group		87% (*n* = 64) intervention group & 91% (*n* = 66) control group attended at least 5 or 7 sessions, respectively.
Schoneveld 2020	*See Schoneveld 2018*		
Wijnhoven 2020	32%		73% (*n* = 39/53) intervention group & 80% (*n* = 45/56) control group attended 6 sessions.
[a]Beaumont 2008	-		In 3D ER, social cognition & social skill RPG with allied group-based learning sessions, pre-study testing conducted with 8 ASD/healthy youth to check engagement & difficultly.
[a]Beaumont 2015	1.4%: Left participating school		

[a]Sofronoff 2017	32%: Personal/family issue, time constraints, engagement/motivation issues			In 3D ER, social cognition & social skill RPG with allied home-based learning sessions delivered by parents, dropout parents younger with lower education level & higher ASD traits than non-dropouts. 10-week program took parents 12-18 weeks to deliver.
[a]Shum 2019	29.2%			In 2D modular ER, social cognition, social skill & mental health game with allied class-based learning, 68.9% (*n* = 182/264) participants reached intervention completion rate of >50%.
Carlier 2020	40%: Illness, game too easy	Engagement game data		In 2D guided imagery & deep breathing ER & non-therapeutic game, platformer non-therapeutic mini-game was most played in 2/3 participants (44% & 92% gameplay), but 0% completion. Memory non-therapeutic mini-game was most played in 1/3 participants (41% gameplay) & second in 2/3 participants (23% & 4% gameplay). Guided imagery & breathing therapeutic mini-games were least played in all participants.
		Interview	Parent	Distracted by ‘owning’ smartphone device on which intervention played (2 youths given smartphone by parents–parents did not use parent tracking app). WIFI issues prevented synchronisation of parent tracking app data in one parent. Parents did not track non-spontaneous engagement. Engagement encouraged by parents only when participant calm. High engagement in platformer mini-game in one participant attributed to potential provocation of repetitive behaviour. Anxiety measures completed incorrectly.
Amon 2008	-	Diary	Parent	In HR & GSR BF breathing strategy ER game, dizziness, emotional outbursts, tiredness, low appetite & hyperactivity experienced by 8-25% (*n* = 2-6/24) youths diagnosed with ADHD did not change significantly over intervention. No symptoms in healthy youth.
		Game experience scale	Parent	54%, (*n* = 13/24) diagnosed youths practiced breathing technique in real-life by end of intervention.

Wrzesien 2015	-	VR avatar identification scale	Self	In immersive VR frustration induction with avatar that modelled emotions, behaviours & ER, youth did not identify physically/behaviourally with self-representing (*M* = 3.47/8; 3.17/8) or neutral (*M* = 2.02/8; 2.39/8) avatar. Did not identify emotionally with self-representing (*M* = 3.39/8) but did somewhat with neutral (*M* = 3.42/8) avatar.
		VR presence scale	Self	No/neutral presence in self-representing (*M* = 5.83/9) & neutral (*M* = 5.09/9) VR.
[a]Ruiz-Ariza 2018	5.4%: Stopped using application			
[a]Yuan 2018	-	Communication log	Parents & teachers	In immersive group VR emotion & social skill practice scenarios, trainer facilitated understanding of audio/visual aids. Trainer provided behavioural/emotional support that permitted use of VR goggles successfully & without distress after 3/12 sessions. Briefing & debriefing sessions essential to generalise learnt skills to real-life.
[a]Ip 2018	2.25%: Expectations not met, time issues			
[a]Carroll 2017	3.4%: Left participating school, withdrew	Verbal feedback	Facilitator	In multimedia modular programme, literacy requirement/content complexity too high for <8 years. Time constraints negatively affected delivery. Recommendations: Teachers to have formal intervention training. Make contingency plans for absentees. Reduce text in manual. Stories promoted engagement & should involve whole-class.
[a]Houghton 2017	-	Verbal feedback	Facilitator	In multimedia modular programme, literacy requirement/content complexity too high. Time constraints negatively affected delivery. Manual detailed & easy to follow.
[a]Smith 2018	0 reported			In online programme, due to minimal time available to fill in scales, authors created short scales.

Note. This table includes the feasibility outcome summaries for all included studies, where feasibility data is available. In studies included in the meta-analytic component, between group feasibility data presented if available, with significance information. =biofeedback; =digital game; =virtual reality/augmented reality; =programme/ multimedia. ER=emotion regulation. -=not reported. Red shading=high ROB. RPG=role player game; ADHD=attention deficit hyperactivity disorder; VR=virtual reality; AR=augmented reality. HR=heart rate; GSR=galvanic skin response. NF=neurofeedback; BF=biofeedback. Additional feasibility information provided below information borne out of feasibility measures. See appendix 2 ‘Measures Matrix’ for details of feasibility measures.

Intervention Acceptability Matrix

ID	Measure & ROB	Report	Outcome summary
Vara 2016a	Game likeability & usefulness scale	Self	In VR 3D frustration induction & deep breathing ER game using different devices, higher induction likeability in smartphone (*M* = 4.19/5) & camera (*M* = 4.3/5) device than computer (*M* = 2.88/5). Device type did not affect breathing mini-game likeability (*M* = 3.6-3.9/5). Higher usefulness of breathing strategy in smartphone device (*M* = 3.85/5) than camera (*M* = 3.7/5) & computer (*M* = 3.12/5).
[a]Antle 2018	Focus group, observations, written reports & email updates	School staff	In an EEG-NF, body relaxation/deep-breathing ER game, no usability issues. All participants easily learned to use their bodies to implement strategies & successfully play all mini-games. Real-time calibration (making game easier by lowering relaxation threshold/decreasing hold time) required in 1/2 ER mini-games.
Kahn 2013	Game helpfulness scale	Self	In a 2D HR BF deep breathing ER game, high helpfulness (*Median* = 5-6/7).
Lutz 2014	Verbal feedback	Self	In 2D HRV BF deep breathing & positive focus ER game, repeat game sessions requested.
	Verbal feedback	Clinician	Clinicians inspired to expand on strategies dependent on needs, preferences & treatment style. Created vibrant learning community.
	Observations	Clinician	Some performance anxiety, especially when losing previously won rewards.
Schuurmans 2018	Game appeal, usefulness & likeability scale	Self	In 3D immersive HR BF fear, frustration & anger induction ER game (*intervention group only)*, *h*igh appeal to oneself (*M* = 4.53/5) & other children (*M* = 4/5). Liked that a digital game is an intervention (*M* = 3.88/5) & very useful in daily life (*M* = 4.53/5).
Schoneveld 2016	Game difficulty, flow, appeal	Self	In 3D immersive EEG NF anxiety induction ER game, moderate difficulty (*M* = 2/4), flow (*M* = 1.94/4), appeal (*M* = 1.9/4) & appeal to other children (*M* = 2.29/4). Low relevance (*M* = 1.68/4). Non-significant difference in difficulty, relevance & appeal to other children.

	& relevance scale		Significant difference in appeal & flow. *Higher rating in commercial control game relative to intervention.*
Schoneveld 2018	Game difficulty, fun & relevance scale	Self	In 3D immersive EEG NF anxiety induction ER game, moderately fun (*M* = 2.35/5) & fun for other children (*M* = 2.61/5). Low difficulty (*M* = 1.85/5) & relevance (*M* = 2.13/5). Non-significant difference in difficulty, fun & fun to other children. Significant difference in relevance. *Higher rating in control group CBT relative to intervention.*
Carlier 2020	Game emotion scale	Self	In 2D guided imagery & deep breathing ER & non-therapeutic game, mainly happy in non-therapeutic mini-games. One participant very angry in platformer non-therapeutic mini-game.
	Interview	Parent	Breathing mini game boring & difficult. One participant refused to play platformer non-therapeutic mini game as too difficult. One parent reported platformer non-therapeutic mini-game too difficult in lowest difficulty level & guided imagery mini-game became too easy. Manually switching between difficulty levels reported as a nuisance.
Amon 2008	Game experience scale	Parent	In HR & GSR BF breathing strategy ER game, most ADHD (70.8%, *n* = 17/24) & healthy (83.3%, *n* = 10/12) youths experienced moderate difficultly & just over half of ADHD youths (58.3%, *n* = 14/24) still found game difficult by end of intervention. Most healthy youths experienced low difficulty by end of intervention (58.3%, *n* = 7/12). *Benefit of using techniques in real-life unclear.*
Wrzesien 2015	VR education & fun scale	Self	In immersive VR frustration induction with avatar that modelled emotions, behaviours & ER, youths reported moderate fun & educational impact. Self-representing & neutral avatar likeable.
[a]Ruiz-Ariza 2018	AR happiness, danger, helpfulness, motivation, satisfaction & further play dichotomous questions	Self	In AR outdoor quest, youths felt happy (54.5%, *n* = 48/87), motivated to go out (56.8%, *n* = 50/87), intervention is dangerous (72.7%, *n* = 64/87) helped to make friends (52.3%, *n* = 46/87). Willing to keep playing (63.6%, *n* = 56/87) & test new versions (77.3%). Males played to have fun, females played due to boredom. Males reported greater satisfaction than females.

[a]Carroll 2017	Education & likeability scale	Self	In multimedia modular programme, youths liked the programme ‘A lot’ or ‘Very, very much’. Learned ‘A lot’ or ‘Very, very much’.
	Verbal feedback	Facilitator	Stories promoted enjoyment - they should involve the whole-class. Content relevant & had positive impact.
[a]Houghton 2017	Education & likeability scale	Self	In multimedia modular programme, youths liked the programme ‘Very much’ or ‘Quite a lot’. Learned ‘Very much’, ‘Quite a lot’ or ‘Some things’.
	Verbal feedback	Facilitator	Programme flowed well. Materials acceptable to youths; used each week & had positive impact.
	Programme quality scale	Facilitator	High quality programme.

Note. This table includes the acceptability outcome summaries for all included studies, where acceptability data is available. In studies included in the meta-analytic component, between group acceptability data presented if available, with significance information. =digital game; =virtual reality/augmented reality; =programme/multimedia. ER=emotion regulation. Green shading=low ROB; red shading=high ROB. ADHD=attention deficit hyperactivity disorder; CBT=cognitive behavioural therapy; VR=virtual reality; AR=augmented reality. HR=heart rate; GSR= galvanic skin response. NF=neurofeedback; BF=biofeedback. See appendix 2 ‘Measures Matrix’ for details of acceptability measures.

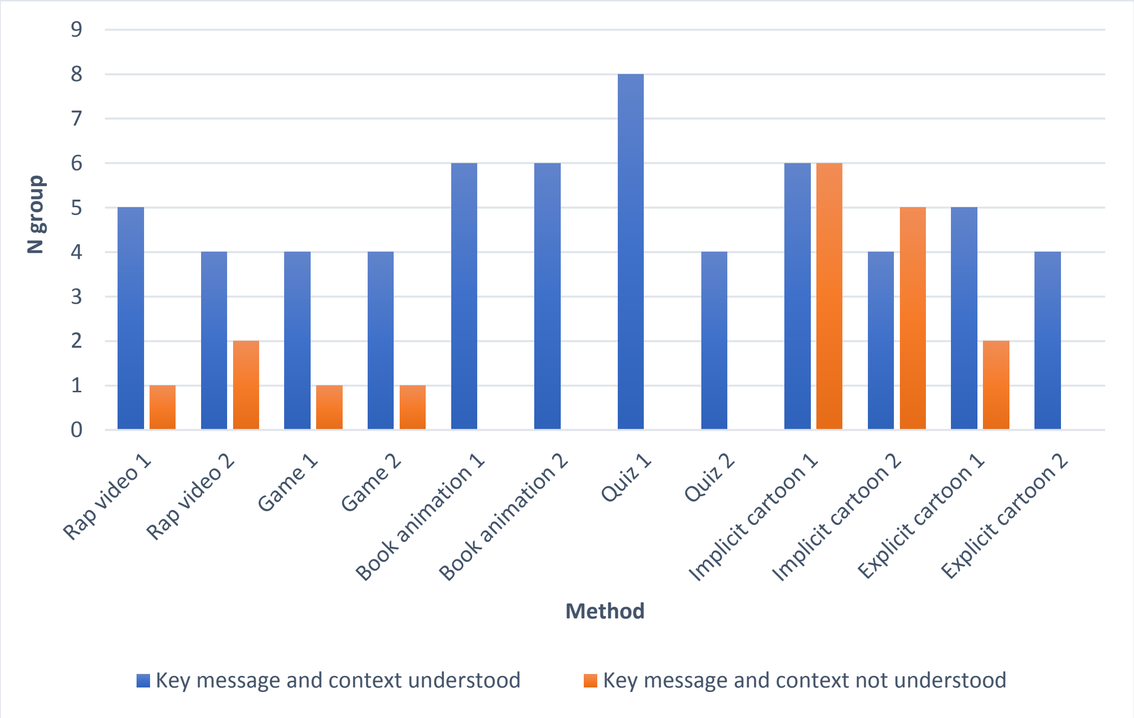
APPENDIX 3

Codesign Workshop Code Frequencies

Understanding

Figure 3.1

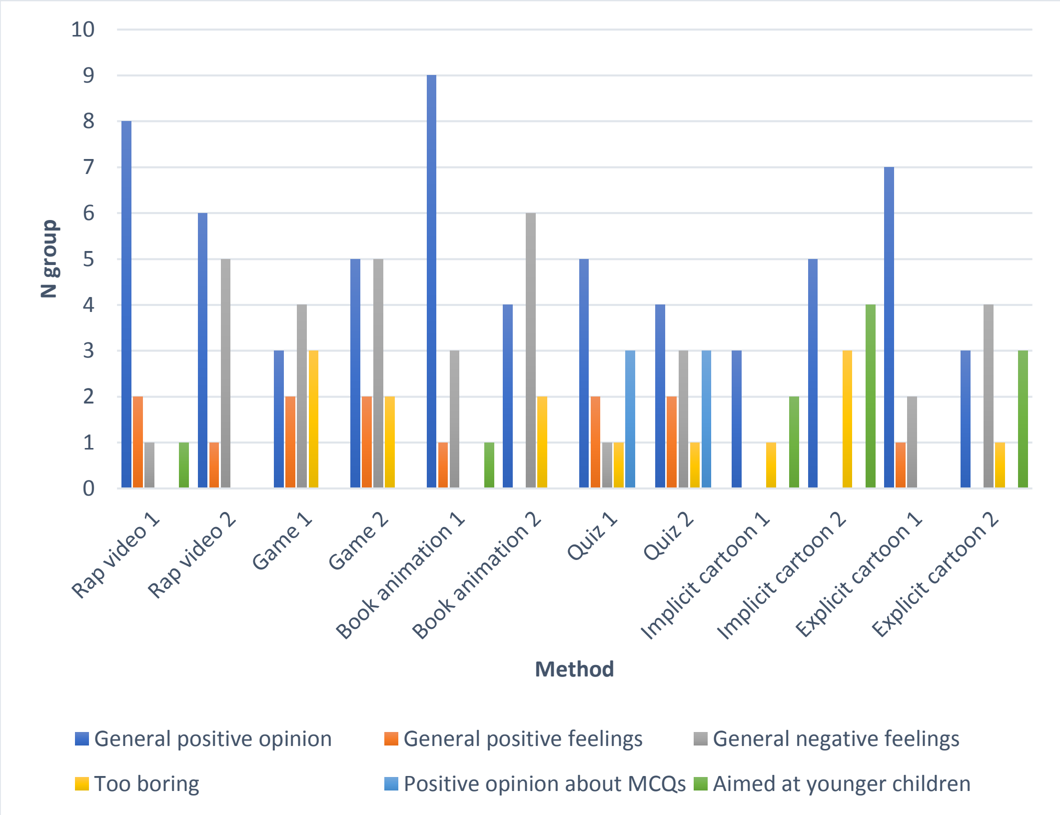
Frequency of understanding code counts per digital learning method at the n group level.



General acceptability

Figure 3.2

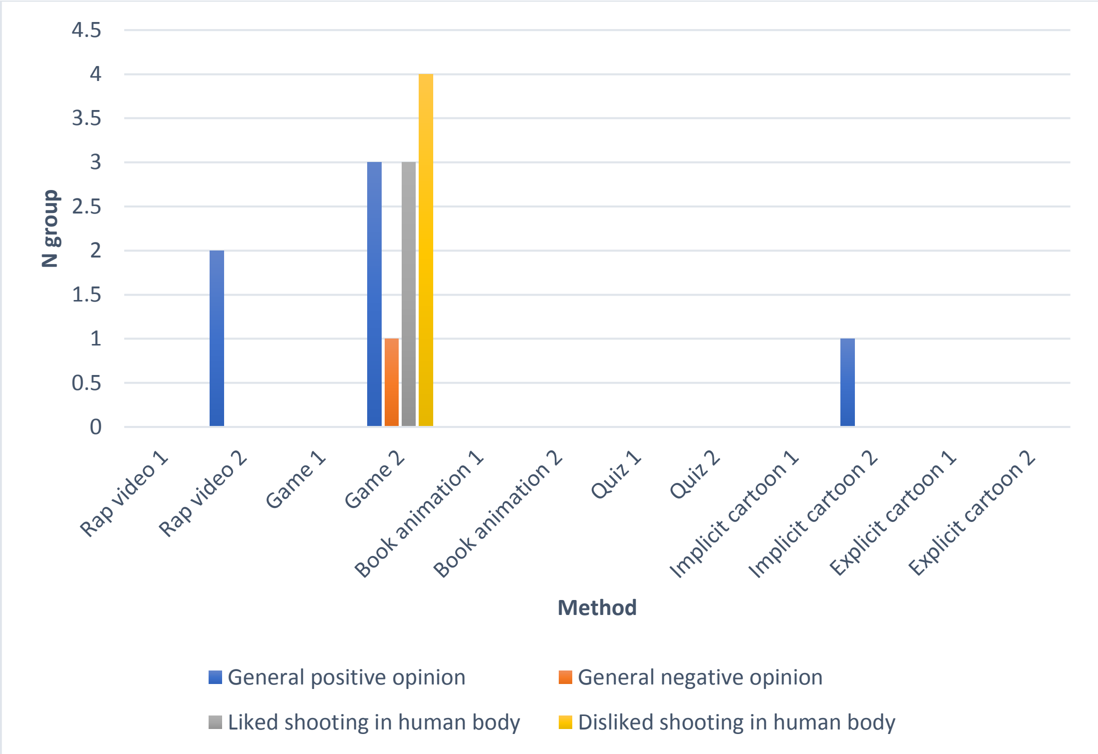
Frequency of general acceptability code counts per digital learning method at the n group level.



Setting

Figure 3.3

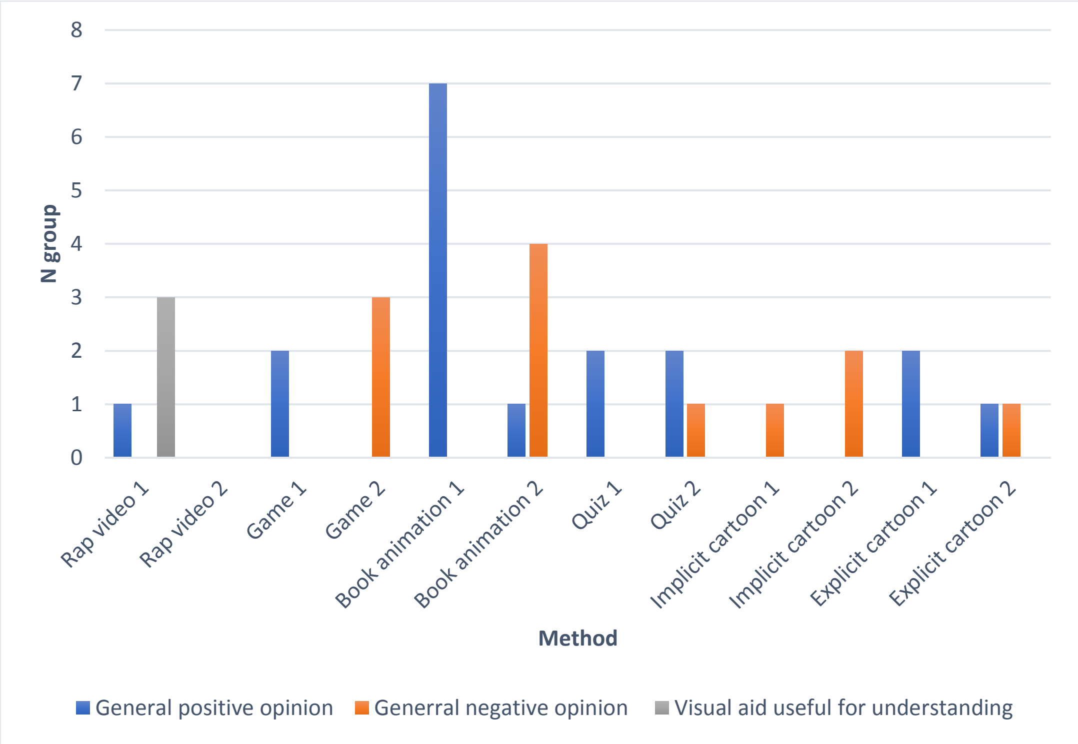
Frequency of setting code counts per digital learning method at the n group level.



Graphics

Figure 3.4

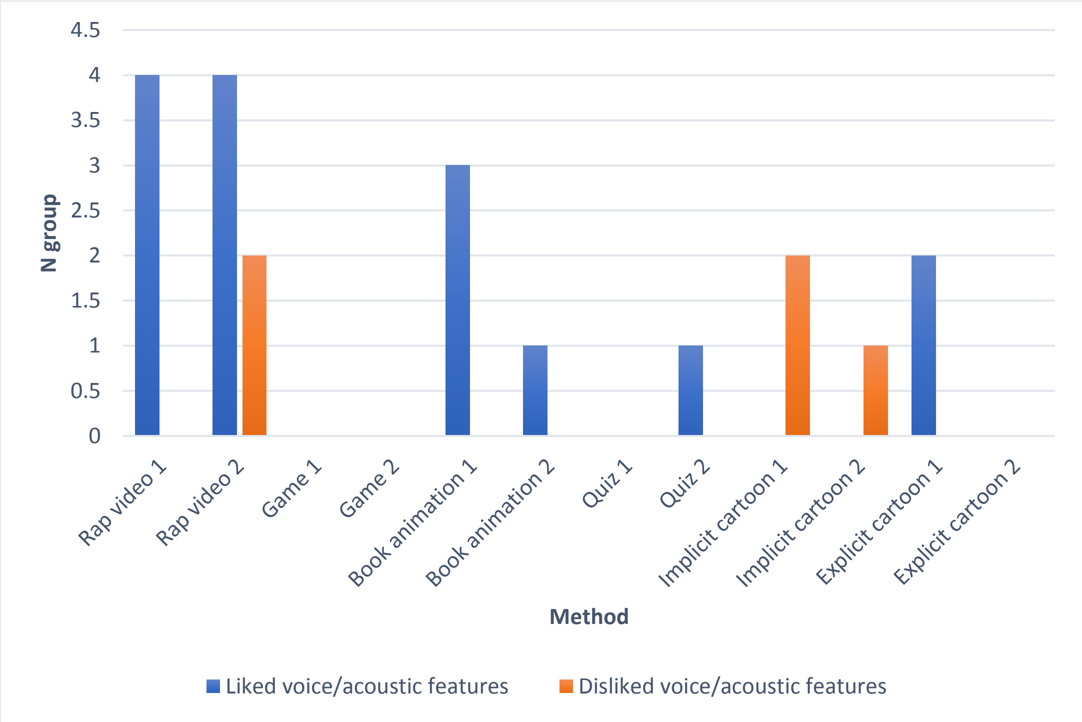
Frequency of graphics code counts per digital learning method at the n group level.



Sound

Figure 3.5

Frequency of sound code counts per digital learning method at the n group level.



Short Story Examples

Below is an example of a story from the *Slime Shooter* BRAINZ mini-game. The stories are used to provide material to be ranked on a scale based on an overall context (e.g., clothes and fashion sense); stories contain different segments that are ranked differentially in terms of how good or bad they are. Each story segment is represented by a slime droplet that must be shot at in the next phase of the game.

You've just arrived at the zombie lab. You've customized your lab coat and can't wait for everyone to see it. As you sit down, Maya asks, "O.M.G… where did you get those studs from?" Paul adds, "They look ABSOLUTELY INCREDIBLE!!" You smile proudly, "One word… Slimucci".

The lab manager calls you over. "This is the second warning this week. You look RIDICULOUS! You will be cleaning the zombie toilets for two weeks if you don't smarten up". You return sheepishly to your bench.

Bart approaches you and says, "That lab coat is a bit much". You smirk, "Actually, I have a fashion vlog with 5,000 followers – some are famous designers…"

The weekend comes and you head to Maya's birthday party.

When you arrive, Maya and Bart greet you. Bart exclaims, "You look awesome! Let me find your vlog… by tomorrow you'll have one more follower!"

Jaz overhears and shouts, "WHO IS THAT CLOWN? EVEN THE LAB MANAGER TRIED TO GIVE THEM FASHION ADVICE!!"

Maya whispers, "Take no notice of them, but you have gone a wee bit overboard".

Below are three examples of stories from the *Sensational Statements* BRAINZ mini-game. The stories are used to provide context to a negative self-talk statement that is presented subsequently on the screen. The negative self-talk statement must be turned into a positive self-talk statement by moving and dropping letters encased in brain cells from a damaged brain cell letter network to a new ‘fixed’ one.

Example 1.

You pick up your lab coat from your locker for zombie care training, only to notice it is creased!

As you walk into the lab, you see a couple of stares before someone bursts into a fit of giggles.

“HAHAHA OH MY GOSH, LOOK AT YOUR LAB COAT”, Bart squeals… “Honestly, looking like that, you really bring down the prestige of our lab”.

Example 2.

It’s time for an experiment on Zombie #389. You are preparing the Bunsen burners when a hideous odour wafts from the zombie enclosures.

“EWWWW! Who farted?” Jaz exclaims, wrinkling her nose… “I BET IT WAS YOU!” Bart shouts, pointing at you.

IT SMELLS LIKE ROTTEN EGGS, YOU’RE TOTALLY RIGHT!” Jaz exclaims.

Example 3.

You are relaxing at home after finishing work at the lab. Suddenly, you remember that results from the weekly test will be released at 8pm.

You quickly log in to the online portal. You scroll down the page until you see your result. 6 out of 10.

You open the group chat with your lab mates. Lots of people are saying they got 10 out of 10.