HOW CAN THE SOCIAL BEHAVIOR OF CHILDREN ON THE AUTISM SPECTRUM BE COMPREHENSIVELY UNDERSTOOD AND TREATED MORE EFFECTIVELY? INSIGHTS FROM MECHANISTIC AND DIGITAL INTERVENTION APPROACHES

DISSERTATION

zur Erlangung des akademischen Grades
Doktor rerum naturalium (Dr. rer. nat)
im Fach Psychologie

eingereicht an der
Lebenswissenschaftlichen Fakultät
der Humboldt-Universität zu Berlin

von
SIMONE KIRST, M.A.

Präsidentin der Humboldt-Universität zu Berlin
Prof. Dr. Julia von Blumenthal

Dekan der Lebenswissenschaftlichen Fakultät
Prof. Dr. Dr. Christian Ulrichs

Gutachter/innen

1. Prof. Dr. Isabel Dziobek
2. Prof. Dr. Julia Asbrand
3. Prof. Dr. Christine Knaevelsrud

Tag der mündlichen Prüfung: 09.11.2022

DISSERTATION

How can the social behavior of children on the autism spectrum be comprehensively understood and treated more effectively? Insights from mechanistic and digital intervention approaches

Simone Kirst

Eidesstattliche Erklärung

Ich erkläre hiermit an Eides statt, dass ich die vorliegende Dissertation selbständig verfasst, mich außer der angegebenen keiner weiteren Hilfsmittel bedient und alle Erkenntnisse, die aus dem Schrifttum ganz oder annähernd übernommen sind, als solche kenntlich gemacht und nach ihrer Herkunft unter Bezeichnung der Fundstelle einzeln nachgewiesen habe.

Ich erkläre des Weiteren, dass die hier vorgelegte Dissertation nicht in gleicher oder in ähnlicher Form bei einer anderen Stelle zur Erlangung eines akademischen Grades eingereicht wurde.

I hereby declare in lieu of oath that I have written this dissertation myself, that I have not used any aids other than the ones indicated and that all knowledge that has been taken from the literature has been identified as such and according to its origin referenced to the source.

I also declare that the dissertation presented here has not been submitted in the same or a similar form to another institution for the purpose of obtaining an academic degree.

Berlin, 09.11.2022

Acknowledgments

I would like to take this opportunity to thank all of those who made it possible for me to complete this dissertation. First of all, I could not have undertaken this long journey without my first supervisor Prof. Dr. Isabel Dziobek, who always provided me with great trust and support, and who continuously inspired me as a person and as a researcher. It was a great pleasure working with her, and she deserves my deepest thanks. I further would like to express my great gratitude to Prof. Dr. Matthias Ziegler and Katharina Bögl for their cooperation and expertise in the data analysis. It was also a pleasure to work with my other coauthors, Dr. Robert Diehm, Verena Gross, Prof. Dr. Ulrike Lucke, Dr. Dietmar Zoerner, Jan Schütze, Dr. Sabine Wilde-Etzold, Dr. Christiane Bach, Prof. Dr. Michele Noterdaeme, and Prof. Dr. Luise Poustka. I sincerely thank my second and third supervisors Prof. Dr. Julia Asbrand and Prof. Dr. Christine Knaevelsrud, and Prof. Dr. Ursula Hess and Dr. Charlotte Küpper for joining the defense committee.I am also very grateful to Annika Hamann, Simon Könneke, Cristina Amate, and Lars Weström for creating Zirkus Empathico, and to my friend Johannes Dach for setting up the Zirkus Empathico website. This endeavor would also not have been possible without the financial support of the Stiftung Irene, the Berlin School of Mind and Brain, and the many children, families, and autism professionals who supported the studies, as well as my students and interns, who contributed with great enthusiasm and engagement. Many thanks to Lutz W., whose unique personality gave rise to the initial idea of Zirkus Empathico. Special thanks belong to my colleagues and friends in my working group for always providing me with a motivating, warm, and enjoyable working environment. For their inspiration, feedback, and moral support regarding this dissertation, I am especially thankful to Silke Lipinski, Dr. Renata Wacker, and Dr. Simón Guendelman. Last but not least, I am deeply thankful to my family, especially Hannelore and Johanna Kirst, and my many dear friends for offering practical and moral support, encouragement, trust, and a rich and joyful life apart from my dissertation. From the bottom of my heart, I want to thank my love and husband Nabil, and the joy of my life, my children, Adam, Anna Luise, and my bonus child Yara for constantly reminding me through their lively and enjoyable presence, why it is truly worth bringing this dissertation to a good conclusion.

Abstract

Children with an autism spectrum (AS) diagnosis are characterized by deviations in their socio-cognitive and emotional competencies, which increase their overall risk for antisocial behavior and decrease their likelihood of prosocial behavior. This can significantly limit such children's integration into social and school contexts. Therefore, it is crucial to understand the causes of maladaptive social responses and provide effective and accessible interventions to strengthen socio-emotional skills. However, established models of social information processing, which explain social responses in terms of a variety of interacting cognitive and emotional processes, are rarely applied to social behavior research in autism. Similarly, while digital interventions may have great potential to address the existing gap between the support needs and the actual provision of support, the existing approaches usually target single socio-emotional skills, e.g., emotion recognition. This isolated training approach could be one of the causes of the often limited transfer of learning outcomes to real-world social behavior.

The overall aim of this dissertation was therefore to provide a more comprehensive insight into the causes of disturbed social behavior as well as a more effective digital training approach to strengthen prosocial behavior in children on the AS. ***Study 1*** examined the impact of reduced emotion recognition and impaired emotion regulation on the tendency to attribute hostile intentions to others (*hostile attribution bias*) and the presence of aggressive social behaviors. Better emotion recognition was found to be associated with enhanced hostile attribution biases. These, in turn, increased verbal and covert but not physical forms of aggression. Finally, stronger emotion dysregulation directly favored the occurrence of aggressive behaviors as well as indirectly through the reinforcement of the hostile attribution bias. ***Study 2*** evaluated the effectiveness, acceptability, and feasibility of the manualized, parent-guided eLearning program "*Zirkus Empathico*" (***Technical Report***) in a real-world application setting. The digital intervention is based on the assumption that an increase in the actual social behavior of autistic children can be achieved by holistically promoting different facets of empathy and their underlying competencies. The six-week, multicenter, randomized controlled trial found satisfactory acceptability and feasibility, and moderate

intervention effects for parent-rated empathy and behaviorally assessed emotion recognition as primary outcomes. While these effects were no longer detectable three months after completion of the intervention, there were moderate improvements in emotional awareness and emotion regulation and reductions in social characteristics associated with autism. This appears to indicate sustained changes in socio-emotional skills and a real transfer to social behavior.

In summary, this dissertation contributes to a more comprehensive understanding and more holistic training of impaired social behavior in autistic children, which underscores the validity of established and comprehensive models of social information processing, and the relevance of basing them on future research and intervention approaches. Furthermore, the digital intervention Zirkus Empathico appears suitable to feasibly and effectively strengthen the prosocial behavior of autistic children. From a transdiagnostic perspective, Zirkus Empathico might also have great potential for promoting social behavior and mental health in children suffering from other conditions. Basic prerequisites for ensuring an actual clinical benefit for children with special needs are a more systematic investigation of the feasibility and acceptability of digital approaches, and facilitation of their transfer from academic contexts to practice.

Kurzfassung

Kinder mit einer Diagnose aus dem Autismus-Spektrum (AS) sind durch Abweichungen in sozio-kognitiven und emotionalen Kompetenzen charakterisiert, welche insgesamt das Risiko für antisoziales Verhalten erhöhen und die Wahrscheinlichkeit für prosoziales Verhalten verringern. Dies kann die Integration der Kinder in soziale und schulische Kontexte erheblich einschränken. Von daher ist es notwendig, die Ursachen maladaptiver sozialer Reaktionen zu verstehen und eine wirksame sowie leicht zugängliche Förderung des Sozialverhaltens anzubieten. Etablierte Modelle der sozialen Informationsverarbeitung, welche soziale Reaktionen anhand einer Vielzahl von miteinander interagierenden kognitiven und emotionalen Prozessen erklären, werden jedoch nur selten zur Erklärung des Sozialverhaltens autistischer Kinder angewandt. Digitale Interventionen, welche hinsichtlich der bestehenden Lücke zwischen Unterstützungsbedarf und tatsächlichem Förderangebot ein großes Potenzial haben, adressieren ebenso oftmals einzelne sozio-emotionale Fähigkeiten, z. B. Emotionserkennung. Eine solch isolierte Förderung könnte eine der Ursachen für die oft begrenzte Übertragung von Lernerfolgen auf das reale Sozialverhalten sein.

Die vorliegende Dissertation möchte von daher einen umfassenderen Einblick in die Ursachen gestörten Sozialverhaltens sowie einen effektiven digitalen Trainingsansatz zur Stärkung prosozialer Verhaltensweisen für Kinder im AS bieten. ***Studie 1*** untersuchte dementsprechend die Auswirkung von reduzierter Emotionserkennung und beeinträchtigter Emotionsregulation auf die Tendenz, anderen feindselige Absichten zuzuschreiben (feindseliger Attributionsstil) und die Präsenz aggressiven Sozialverhaltens. Es zeigte sich, dass eine bessere Emotionserkennung mit stärkerem feindseligen Attributionsstil assoziiert war. Dieser erhöhte wiederrum das Auftreten verbaler und verdeckter Aggressionen, nicht jedoch physischer Aggressionsformen. Stärkere Emotionsdysregulation begünstige schließlich das Auftreten aggressiven Verhaltens direkt sowie indirekt durch die Verstärkung des feindseligen Attributionsstils. ***Studie 2*** evaluierte die Wirksamkeit, Akzeptanz und Durchführbarkeit des manualisierten, eltern-begleiteten eLearningprogramms „*Zirkus Empathico*“ (***Technischer Bericht)*** im realen Anwendungskontext. Die digitale

Intervention basiert auf der Annahme, dass durch eine ganzheitliche Förderung verschiedener Facetten der Empathie und deren zugrundeliegende Kompetenzen eine Steigerung des tatsächlichen Sozialverhaltens autistischer Kinder erreicht werden kann. Die sechswöchige, multizentrische, randomisiert kontrollierte Studie ergab eine zufriedenstellende Akzeptanz und Durchführbarkeit sowie moderate Interventionseffekte für die von den Eltern bewertete Empathie und die im Verhaltenstest erfasste Emotionserkennung als primäre Endpunkte. Während diese Effekte drei Monate nach Abschluss der Intervention nicht mehr nachweisbar waren, zeigten sich moderate Verbesserungen der emotionalen Bewusstheit und der Emotionsregulation sowie eine Reduktion der mit Autismus assoziierten sozialen Charakteristika. Dies deutet auf eine nachhaltige Stärkung sozio-emotionaler Kompetenzen und eine tatsächliche Übertragung auf das Sozialverhalten hin.

Zusammenfassend leistet die vorliegende Dissertation einen Beitrag zu einem umfassenderen Verständnis und einer ganzheitlicheren Förderung des beeinträchtigten Sozialverhaltens autistischer Kinder. Dies unterstreicht die Validität etablierter und umfassender Modelle der sozialen Informationsverarbeitung sowie die Relevanz, diese zukünftigen Forschungs- und Interventionsansätzen zugrunde zu legen. Darüber hinaus erscheint die digitale Intervention Zirkus Empathico geeignet, prosoziales Verhalten autistischer Kinder auf effektive und praktikable Weise zu stärken. Transdiagnostisch betrachtet könnte Zirkus Empathico ein großes Potenzial zur Förderung des Sozialverhaltens und der psychischen Gesundheit von Kindern mit anderen Störungsbildern haben. Die Gewährleistung eines tatsächlichen klinischen Nutzens für Kinder mit besonderen Bedürfnissen erfordert jedoch eine systematischere Untersuchung der Machbarkeit und Akzeptanz digitaler Ansätze sowie eine Erleichterung ihres Transfers von akademischen Kontexten in die Anwendungspraxis.

List of Original Publications

This dissertation is based on two studies and a technical report that have been published in peer-reviewed journals, or, respectively, in peer-reviewed conference proceedings.

Study 1

Kirst, S., Bögl, K., Gross, V.L., Diehm, R., Poustka, L., Dziobek, I. (2021). Subtypes of Aggressive Behavior in Children with Autism in the Context of Emotion Recognition, Hostile Attribution Bias, and Dysfunctional Emotion Regulation. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-021-05387-w

Technical Report

Zoerner, D. Schütze, J., **Kirst, S**., Dziobek, I., Lucke, U. (2016) Zirkus Empathico: Mobile Training of Socio-Emotional Competences for Children with Autism," 2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT), 2016, pp. 448-452, https://doi:10.1109/ICALT.2016.146

Study 2

Kirst, **S**., Diehm, R., Bögl, K., Wilde-Etzold, S., Bach, C., Noterdaeme, M., Ziegler, M., & Dziobek, I. (2022). Fostering socio-emotional competencies in children on the autism spectrum using a parent-assisted serious game: A multicenter randomized controlled trial. *Behaviour Research and Therapy*, 104068. https://doi.org/10.1016/j.brat.2022.104068

EIDESSTATTLICHE ERKLÄRUNG **I**

ACKNOWLEDGMENTS **II**

ABSTRACT **III**

KURZFASSUNG **V**

LIST OF ORIGINAL PUBLICATIONS **VII**

1 GENERAL INTRODUCTION **1**

1.1 Relevant Constructs and Their Impact on Social Information Processing **6**

1.1.1 Emotion Regulation and Emotional Awareness 6

1.1.2 Empathy, a Multifaceted Construct 8

1.1.3 Linking Empathy to Social Behavior through Empathic Concern 10

1.1.4 Mutually Interacting Processes Determining Social Responses 13

1.1.5 A Brief Insight into the Development of Socio-Emotional Competencies 14

1.2 A Summary of Socio-Emotional Deviations in Autistic Individuals **16**

1.2.1 Alexithymia and Emotion Regulation Difficulties 16

1.2.2 Problems in Facial Emotion Recognition 18

1.2.3 Differences in Theory of Mind, Empathy, and Empathic Concern 19

1.2.4 Differences in Social Behavior under the Perspective of the Social Cognitive Information Processing Models 21

1.3 The Potential and Limitations of Digital Interventions **22**

1.3.1 The Severe Gap between Intervention Needs and Supply 23

1.3.2 The Potential of Digital Interventions for Autistic Children 24

1.3.3 Limited Maintenance and Real-Life Transfer of Digital Interventions 25

1.3.4 Limitations of Past Studies on Digital Approaches 26

2 SUMMARY AND AIMS OF THE DISSERTATION **28**

3 SUBTYPES OF AGGRESSIVE BEHAVIOR IN CHILDREN WITH AUTISM IN THE CONTEXT OF EMOTION RECOGNITION, HOSTILE ATTRIBUTION BIAS, AND DYSFUNCTIONAL EMOTION REGULATION **31**

4 ZIRKUS EMPATHICO. MOBILE TRAINING OF SOCIO-EMOTIONAL COMPETENCIES FOR CHILDREN WITH AUTISM **55**

5 FOSTERING SOCIO-EMOTIONAL COMPETENCIES IN CHILDREN ON THE AUTISM SPECTRUM USING A PARENT-ASSISTED SERIOUS GAME: A MULTICENTER RANDOMIZED CONTROLLED TRIAL **65**

6 GENERAL DISCUSSION **96**

6.1.1 Motivating Comprehensive Approaches for Research and Intervention in Autism And Beyond 99

6.1.2 The Relevance of Holistic Frameworks Integrating Socio-Cognitive and Emotional Processes 99
6.1.3 The Profound Impact of Emotion Dysregulation on Social Behavior 100
6.1.4 The Need for Comprehensive, Transdiagnostic Approaches to Disentangle Complex Interplays and to Design Effective Interventions 102
6.2 Identifying Future Perspectives for Zirkus Empathico 104
6.2.1 Potential Transdiagnostic Application Fields 104
6.2.2 A Modified Version Targeting Maladaptive Behaviors under Consideration of the Social Cognitive Information Processing Models 106
6.2.3 A Communication Context to Foster Mutual Empathy 108
6.3 Addressing the Challenging Real-Life Application of Digital Interventions 110
6.3.1 Possibilities to Enhance Maintenance and Generalization 110
6.3.2 The Importance of Using Participation Research Approaches 113
6.3.3 Ways to Strengthen Acceptability and Feasibility 114
6.3.4 Challenges in the Academic Development of Digital Solutions 116
6.4 Limitations and Further Directions 119
6.4.1 Practical Restrictions Potentially Biasing the Results 119
6.4.2 Limited Mechanistic Understanding 122
6.4.3 Future Directions: Studying Additional Influences 123
6.4.4 Future Directions: Systematically Assessing Feasibility and Acceptability 124
6.4.5 Outlook: Suggestions for Innovative and Feasible Study Designs 125
7 SUMMARY AND CONCLUSIONS 126
LIST OF ABBREVIATIONS 129
LIST OF FIGURES 132
LIST OF TABLES 133
SUPPLEMENT OF STUDY 2 134
REFERENCES 155

1 General Introduction

According to the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, American Psychiatric Association, 2013), "Autism Spectrum Disorder"[1] is an umbrella term for several persuasive neurodevelopmental conditions, formerly diagnosed as autistic disorder/childhood autism, pervasive developmental disorder not otherwise specified (PDD-NOS), and Asperger Syndrome (International Statistical Classification of Diseases and Related Health Problems, 10th revision, ICD-10; WHO, 1994a). Even though the expression of autism characteristics varies significantly across individuals (Lord & Risi, 1998), persons on the autism spectrum (AS) are characterized by an early onset of special, thorough, or intense patterns of behavior, interests, or activities, and persistent qualitative differences in social communication and social interaction across multiple contexts (American Psychiatric Association, 2013). The reported prevalence of autism in Western countries ranges from 0.6% to 2.2% (Elsabbagh et al., 2012; Zablotsky et al., 2015), with up to 1% of the population being affected when the new DSM-5 diagnostic criteria are applied (Maenner et al., 2014). The male-to-female ratio is 3:1 (Loomes et al., 2017). Generally, autism is broadly considered to be caused multi-factorially as a result of genetic and non-genetic factors and their interaction (Park et al., 2016). Thirty percent of persons on the AS qualify for developmental disability services (Baio et al., 2018), and 30% percent are only minimally verbal (Tager-Flusberg & Kasari, 2013). Other co-occurring conditions include medical conditions (e.g., sleep disorders, seizures) and developmental or behavioral diagnoses such as attention-deficit/hyperactivity disorder (ADHD), anxiety, mood disorders, and self-injury (Coury, 2010).

[1] This dissertation respects the language preferences of the autism community, which are summarized by recent publications. e.g., Bury et al. (2020); Kenny et al. (2016); Bottema-Beutel, Kapp, et al. (2021) and recommended by the German Autismus-Forschungs-Kooperation (AFK; unpublished). The term "Autism Spectrum Disorder" is therefore only used when specifically discussing autism diagnoses in the context of the DSM-V or the ICD-10. Since the terms "persons on the autism spectrum" and "autistic persons" were voted as being the least offensive and most accepted by the community, they are applied here. Moreover, medicalized and value-laden terms are avoided, and strengths-based language instead of deficits-based language is used. Please note that these standards have not yet been used within the publication of Study 1 and the Technical Report.

Autism-related characteristics in the social domain refer to differences in social-emotional reciprocity (e.g., few or unusual social approaches, reduced turn-taking and joint attention, and reduced sharing of interests and emotions), difficulties in verbal and nonverbal communication (e.g., diminished interactive eye contact, difficulties in understanding and using gestures, fewer facial expressions, and less nonverbal communication), and difficulties in developing, maintaining, and understanding relationships (e.g., difficulties in adjusting behavior to suit various social contexts, in sharing imaginative play, or in making friends, and diminished interest in peers; American Psychiatric Association, 2013). In sum, these differences express themselves in social behavior, which is perceived as unusual, different, or abnormal by their social surroundings. One example of this is absent, reduced, or divergent reactions towards others' emotions, which are frequently reported in clinical observations and parent reports, and observed in laboratory investigations (e.g., Begeer et al., 2006; Yirmiya et al., 1989). A large body of research and autism theory explain these reactions by underlying differences in perspective-taking (using a theory of mind; ToM), or, respectively, empathy difficulties in children on the AS (E. L. Hill & Frith, 2003).

Empathy is an umbrella term summarizing understanding and sharing of others' emotions (Hodges & Myers, 2007). It is closely related to ToM (Healey & Grossman, 2018) and skills such as recognition and differentiation of one's own and others' emotions, which were found to represent leverages to empathic understanding and sharing (Bird et al., 2010; Israelashvili et al., 2020; Israelashvili, Oosterwijk, et al., 2019; Moriguchi et al., 2006; Moriguchi et al., 2007). Empathy is thought to be a prominent precursor of social behavior, since it may evoke feelings of emotional concern which contain positive feelings of empathic care and a prosocial motivation to care for or to help someone in need (Decety & Lamm, 2009). However, when empathic resonance to others' feelings is not regulated adequately, empathy may also result in personal distress, which culminates in feelings of stress and anxiety that rather motivate withdrawal instead of prosocial behavior (Klimecki & Singer, 2013).

In persons on the AS, emotional resonance to others' emotions seems to be intact or even enhanced (Dziobek et al., 2008; Smith, 2009c; Song et al., 2019), while difficulties in comprehending others' mental and emotional states through perspective-taking (ToM) diminishes the understanding of their emotions (cognitive empathy; Baron-Cohen & Wheelwright, 2004; Song et al., 2019). Furthermore, children and

adults on the AS were found to have difficulties in recognizing others' emotions (e.g., through facial expressions; see Lozier et al., 2014; Uljarević & Hamilton, 2013) and in being aware of, and distinguishing their own emotions (Giannotti et al., 2020; Griffin et al., 2016; Milosavljevic et al., 2016). As a consequence, emotional resonance to others' emotions often seems to result in experiences of personal distress instead of emotional concern (Song et al., 2019). This pattern might partly be due to problems in regulating emotions (Decety & Lamm, 2009; e.g., using maladaptive emotion regulation strategies such as rumination or shutting down; Mazefksy et al., 2013; Samson et al., 2014), which are highly prevalent in individuals on the AS and which might generally enhance the experiences of intensive (negative) emotions (Bos et al., 2018; Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015).

Together with problems in interpreting social intent (ToM) and tendencies to attribute hostile intentions to others (Mazza et al., 2017; Ziv et al., 2014), difficulties in emotion regulation might further trigger aggressive responses in children on the AS in social situations. Here, parent-reported prevalence rates range from 35–50% (Farmer & Aman, 2011b; Kanne & Mazurek, 2011), while more standardized measurement results in lower rates (19–22.5%) of clinically relevant aggression (Hartley et al., 2008). Aggressive behavior in children on the AS was often found to persist in a serious form over an extended period, is observable in different settings and in more than one relationship, and endangers the mastery of developmental steps (Hodgetts et al., 2013). As such, it exceeds the temporary, unstable, and unproblematic forms of aggressive or oppositional behavior that are exhibited by most non-autistic children in their early lives (Petermann & Koglin, 2015).

Taken together, autism research over the past decades has generated evidence for both difficulties in cognitive (e.g., reduced ToM, cognitive empathy, emotion recognition, and differentiation of own and others' emotions) and in emotional processes and responses (e.g., problems in emotion regulation, high emotionality, reduced empathic concern, and enhanced personal distress). These difficulties might in sum increase the risk for antisocial behavior such as aggression on the one hand, and decrease the likelihood of prosocial behavior on the other. In turn, the children's unusual and sometimes maladaptive social behaviors and responses might impede their ability to develop satisfactory social relations throughout their entire life span (E. L. Hill & Frith, 2003), hinder appropriate education and support, and cause high levels of stress

in parents and educators (Chalfant et al., 2007; Hodgetts et al., 2013; Kanne & Mazurek, 2011; Otero-López et al., 2009)(Chalfant et al., 2007; Hodgetts et al., 2013; Kanne & Mazurek, 2011; Otero-López et al.; Otero-López et al., 2009). Therefore, understanding the causes and mechanisms of divergent social interaction in children and adolescents on the AS is of great importance for providing customized and effective early interventions with good outcomes (Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015; Simonoff et al., 2008). Indeed, it has been shown that i.a. group-based social skills training or individual treatment based on cognitive behavioral therapy (CBT) are effective for improving socio-emotional competencies in children and adolescents on the AS (Darling et al., 2021; Wang et al., 2021). Nevertheless, the current supply situation in Germany and other countries is insufficient since there is a large gap between the intervention needs and available autism services. In this context, digital interventions targeting social behavior (e.g., "*Mindreading*," Baron-Cohen et al., 2004; "*The Secret Agent Society*," Beaumont & Sofronoff, 2008) might be promising means for complementing standard therapy (Andersson et al., 2014; Hollis et al., 2017; Sandgreen et al., 2021).

Given that social behavior is the result of a very complex interplay between cognitive and emotional processes, comprehensive perspectives are lacking for both understanding deviant social behavior in autistic children and digital interventions aiming at enhancing prosocial skills in these children. For example, although non-autistic children's maladaptive social responses such as aggression have been frequently explained based on models integrating cognitive and emotional factors and their interrelations (e.g., "*Social Cognitive Information Processing*" [SCIP] models; Crick & Dodge, 1994, 1996; Lemerise & Arsenio, 2000), similarly holistic approaches were rarely applied to explain aggressive behaviors in autistic children. Similarly, most of the existing digital approaches focus on emotion recognition and mentalizing as cognitive correlates of prosocial behavior, while emotional facets of empathy and its foundations have rarely been targeted. It might be speculated that this limited scope partly explains the limited transfer effects of past approaches on the children's real-life social behaviors (Grynszpan et al., 2014). Moreover, only a few digital interventions were rigorously evaluated by conducting randomized controlled trials (RCT) on their effectiveness, acceptability, and feasibility (Berggren et al., 2017).

Therefore, the overall aim of this dissertation was therefore to provide a more comprehensive insight into the causes of disturbed social behavior as well as a more effective digital training approach to strengthen prosocial behavior for children on the AS. First, the possible interplay between aggression-prone cognitions and disturbed emotional processes (emotion recognition, emotion regulation), and its effect on different forms of maladaptive social behaviors (e.g., physical, verbal, and covert aggression) was investigated based on the SCIP models (***Study 1***). Second, it was explored how a holistic digital intervention aimed at improving adaptive social behavior should be designed to provide an actual clinical benefit for the children and their families. As a first step, the manualized, parent-assisted digital intervention "*Zirkus Empathico – Mobile Training of Socio-Emotional Competencies*" focusing on different facets of empathy and its foundations was therefore developed in the form of a serious game (***Technical Report***). Subsequently, it was investigated whether the Zirkus Empathico training results in improvements in empathy and emotion recognition and whether such training transfers to real-life social behavior. Thus, the effectiveness, acceptability, and feasibility of the serious game were evaluated by conducting a six-week multicenter RCT with 82 primary and preschool children on the AS who were randomized into an intervention group and an active control group (***Study 2***).

To explain the rationale for these two main studies more thoroughly, Chapter 1.1 defines and summarizes past research on all relevant social-cognitive and emotional constructs. In addition, two central models for this dissertation are introduced: the "*Self to Other Model of Empathy"* (SOME; Bird & Viding, 2014) provides an understanding of the multifaceted nature of empathy, while the "*Social Cognitive Information Processing"* (SCIP) model by Crick & Dodge (1994, 1996) and the modified version of the model by Lemerise and Arsensio (2000) explain the interrelations between the introduced constructs and, specifically, their contribution to socially aggressive behavior. Subsequently, deviations in the previously introduced socio-emotional competencies in individuals on the AS are summarized (Chapter 1.2). In Chapter 1.3, the current supply situation is described and a brief introduction to past digital intervention approaches targeting social behaviors in children on the AS and their potential is given. Both chapters identify current research gaps concerning the general claim that comprehensive perspectives on social behavior are largely absent in past behavior research and intervention to provide the foundation for the rationale and research aims of this dissertation (Chapter 2).

1.1 Relevant Constructs and Their Impact on Social Information Processing

In the following, definitions and research on the central constructs and models of this dissertation in non-autistic individuals are summarized to provide a common ground for the reader. First, *emotional awareness*, the process of identifying, explaining, and discerning own and others' emotional experiences (Lane & Schwartz, 1987), and *emotion regulation* involving goal-directed monitoring and modification of emotional responses (Eisenberg & Spinrad, 2004) are introduced (Chapter 1.1.1). This is followed by an explanation of the multifaceted construct of *empathy*, which is the ability to understand and share the emotions of other people (Dziobek et al., 2006). In this section, the SOME (Bird & Viding, 2014) provides an understanding of how different encoding and representational systems contribute to sharing feelings empathically between two persons (Chapter 1.1.2). Next, the link between empathy and social behavior is explained, by introducing *empathic concern* (feelings of affective care and a motivational, prosocial component to support/help; Decety et al., 2018) and its counterpart *personal distress* (feelings of discomfort and anxiety; M. Davis, 1983) as different consequences of empathy (Chapter 1.1.3). By integrating different socio-cognitive and emotional factors beyond empathy, the SCIP models (Crick & Dodge, 1994, 1996; Lemerise & Arsenio, 2000) explain how an individual's response to a social situation is determined. The models are introduced in the next section to provide a comprehensive understanding of adaptive and maladaptive social behaviors (Chapter 1.1.4). Finally, the development of the introduced competencies in non-autistic children is briefly summarized (Chapter 1.1.5).

1.1.1 Emotion Regulation and Emotional Awareness

Emotion regulation involves goal-directed monitoring and modification of emotional responses (Eisenberg & Spinrad, 2004) aimed at modifying the intensity, duration, and types of emotions experienced (Thompson, 1991). The first step of emotion regulation requires identifying emotions that need regulating (Gross, 2015), which is dependent on functional *emotional awareness* (McRae et al., 2012). The construct, which is conceptualized as a cognitive skill (Lane & Schwartz, 1987), is characterized by attentional and interpretative processes through which the process of identifying, explaining, and discerning own as well as others' emotional experiences occurs (Lane & Schwartz, 1987). It comprises meta-knowledge about emotional states and experiences (Boden & Thompson, 2015). In contrast, reduced emotional awareness

and differentiation have been summarized under the concept of *alexithymia*. Alexithymia is a subclinical condition that refers to individual difficulties in identifying, describing, and distinguishing one's own feelings, which are often accompanied by externally oriented thinking instead of a focus on internal experience (Nemiah & Sifneos, 1970). For example, an alexithymic individual still knows that they are experiencing an emotion, but is unaware whether they are experiencing sadness, anger, or fear (Bird & Cook, 2013).

When an individual became aware of their current emotional state, the implementation of emotion regulation strategies is triggered, which aim to either increase or decrease the emotion in question (Gross, 2015). Generally, healthy emotion regulation is characterized by the successful up-regulation of positive emotions and down-regulation of negative emotions (Giuliani et al., 2008; Gross, 2002, 2015). The most influential and widely known model is Gross' process model of emotion regulation, which understands emotion regulation as a multicomponent and dynamic process between the individual and their context (Gross, 1998). The model defines five families of emotion regulation strategies, which are either adaptive or maladaptive to physical and mental health and general wellbeing (Gross & John, 2003): selection (e.g., avoiding or approaching specific situations), situation modification (e.g., problem-solving), attentional deployment (e.g., paying attention toward or away from information), cognitive change (e.g., modifying appraisals of a situation), and response modulation (e.g., modulating the extent to which an emotion is expressed outwardly (Gross, 1998). The acquisition of emotion regulation represents one of the key developmental tasks in early childhood (Kopp, 1989), with inappropriately and ineffectively regulated emotions manifesting themselves in negative affectivity or irritability (Cai et al., 2018). Therefore, emotion dysregulation was shown to be a transdiagnostic risk factor for mental health conditions in the general population (Aldao et al., 2016; Gross & John, 2003). Specifically, the habitual use of maladaptive emotion regulation strategies such as avoidance, denial, or negative rumination is associated with more negative emotions, disrupted relationship formation, and internalizing symptoms such as anxiety and depression (Cai et al., 2018). In addition, maladaptive strategies have more strongly been associated with psychopathology than adaptive strategies (e.g., cognitive reappraisal, problem-solving, and acceptance; Aldao et al., 2016).

1.1.2 Empathy, a Multifaceted Construct

Empathy, which corresponds to the German term "*Einfühlung*" (Titchener, 1909), can be defined as the ability to understand and share the emotions of other people (Dziobek et al., 2006). Empathy allows people to create connections, develop bonds of trust, and gain insights into the actions of others (Eisenberg & Miller, 1987). It not only informs an individual of another's subjective experience but also serves as a sort of social glue among dyads and groups (Decety & Lamm, 2006). Hence, empathy is proposed to play a crucial role in moral development and navigating social interactions (Decety et al., 2018) and is therefore regarded as an essential component of human society (Harmsen, 2019). Empathy is understood as a multi-dimensional construct comprising cognitive and affective aspects as separate, but interrelated components (M. Davis, 1980). *Cognitive empathy* refers to the capacity to engage in the cognitive process of adopting another's psychological point of view (Frith & Singer, 2008), and it contains contextual appraisal and an understanding of what caused the other person's emotion (Waal, 2008). As such, cognitive empathy may involve making inferences regarding the other's affective and cognitive mental states, in a process which has been referred to as the *theory of mind* (ToM, Astington et al., 1990). Using ToM or "mindreading" requires putting aside one's current perspective and tapping into the mental state of the other based on their experience (Baron-Cohen & Wheelwright, 2004). Inferring others' thoughts, beliefs, and intentions has been labeled cognitive ToM, while affective ToM (which is very closely related to cognitive empathy; Healey & Grossman, 2018) refers to making inferences or predictions about other people's emotions and feelings (Shamay-Tsoory et al., 2009; Shamay-Tsoory et al., 2010). From cognitive empathy, but also bottom-up processes (Decety, 2011) such as mirroring mechanisms (Bird & Viding, 2014), may arise feelings of *emotional resonance* to others' emotions, which forms the emotional component of empathy (Decety, 2011). Thus, emotional resonance refers to the conscious or subconscious process by which emotions in one agent trigger isomorphic emotions in another agent (Bird & Viding, 2014; Eisenberg, 2000; Healey & Grossman, 2018). Finally, empathy arises when the perceived affective state is explicitly "tagged" as being experienced by the other person (Bird & Viding, 2014; see below).

Findings in social neuroscience show that the systems processing emotional and cognitive facets of empathy operate as separate, albeit interacting, brain networks (Decety et al., 2018). When a cognitive empathic response is generated, the cognitive

ToM network (i.e., medial prefrontal cortex, superior temporal sulcus, temporal poles) and the affective ToM network (mainly involving the ventromedial prefrontal cortex) are both activated. In contrast, emotional resonance to others' feelings involves regions that mediate emotional experiences (i.e. amygdala, anterior insula, anterior cingulate cortex; Lamm et al., 2011), which suggests that the emotional facets of empathy are mainly driven by simulating the other's emotional state through mirroring mechanisms (Bird & Viding, 2014; Keysers & Gazzola, 2009). Indeed, current neurobiological evidence shows that the same neural circuit that is stimulated when experiencing emotions is activated when perceiving others expressing emotions (Decety & Lamm, 2009; T. Singer et al., 2004).

Based on these findings, Bird and Viding (2014) proposed the SOME as an information processing model to explain *how* feelings are shared empathically between two persons (see Figure 1.1). The SOME proposes that empathy relies on the activation and interaction of the same neural systems that are involved when processing own emotions: The first input system is the "*situation understanding system*," which estimates emotional states based on information within the actual situation by comparing it with previously learned socioemotional knowledge as represented in social scripts. The second input system, the "*the affective cue classification system*," performs low-level perceptual categorization of person-level cues such as facial expressions, tone of voice, or biological motion signaling affective states. Both systems might produce emotional resonance by influencing the affective state of the self in the "*affective representation system*," which represents interoceptive cues and the internal representation of these in emotions. An indirect link between the affective cue classification system and the affective representation system is provided by the "*mirror neuron system*,*"* which associates action perception with action production (Cook et al., 2014). Without being a necessary requirement for empathy, emotional resonance might occur when the facial expressions of another person are automatically imitated. The second representational system, the "*ToM system*," produces inferences about beliefs and desires that are used to infer own and others' affective states. While the cognitive ToM process is affectively neutral, its outcome is likely to provoke affective reactions. Within an interpersonal situation, the proposed "*self/other switch*" allows a person to actively switch their attention from its default mode "self" to the other person to process this person's situational and emotional cues instead of one's own. As a result, the

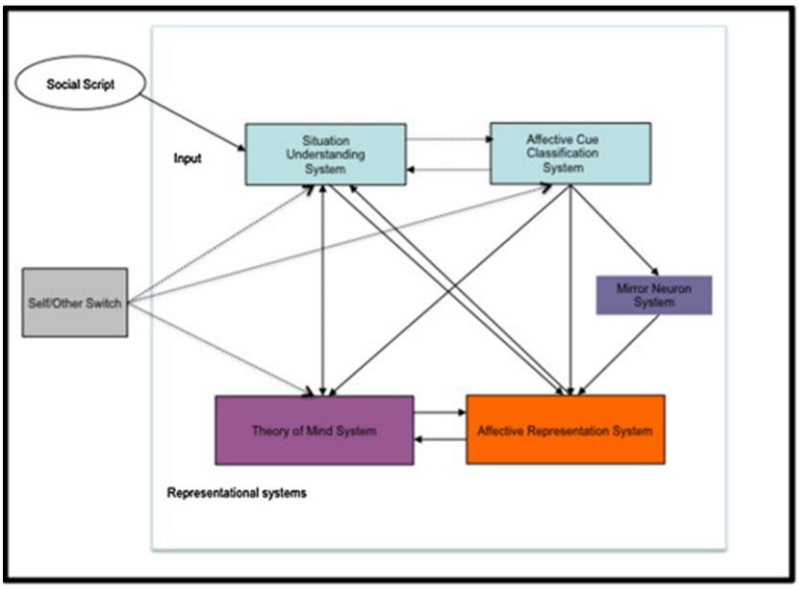
affective state as represented in the affective representation system is now appropriate to the other person's situation/state ("simulation" of another's state). In the ToM system, the self/other switch tags that the person's current affective state is appropriate for the other (Bird & Viding, 2014).

Beyond neurobiological findings, behavioral results seem to support the central assumption of the SOME that the awareness of emotional states in the self is a prerequisite for empathically processing others' emotions (Bird & Viding, 2014 and compare Moriguchi et al., 2007). For example, processes associated with the perception and understanding of own emotional experiences (e.g., interoception, emotion differentiation) were found to represent leverages to the understanding and sharing of others' emotions (e.g., Israelashvili, Sauter, & Fischer, 2019; Reniers et al., 2011). On the other hand, problems in differentiating own emotions were associated with cognitive and affective facets of empathy such as lower mentalizing abilities (Moriguchi et al., 2006; but see Di Tella et al., 2020; Milosavljevic et al., 2016 for different results) and reduced affect sharing with others (e.g., Di Tella et al., 2020; Grynberg et al., 2010; Moriguchi et al., 2007). Beyond this, alexithymia was associated with poorer emotion recognition skills and emotion regulation difficulties (Di Tella et al., 2020), which was also – in anticipation of Chapter 1.2 – reported for individuals on the AS (Gormley et al., 2022; Milosavljevic et al., 2016).

1.1.3 Linking Empathy to Social Behavior through Empathic Concern

In general, evidence for a direct link between empathy and prosocial behavior is lacking (T. Singer & Lamm, 2009). However, empathic experiences may evoke *empathic concern* (Klimecki & Singer, 2013), which is understood as feelings of affective care and a motivational, prosocial component to support or help someone in need (German: "*Mitgefühl*"; Decety et al., 2018); compare the related terms *compassion* and *sympathy*; T. Singer, 2012; T. Singer & Lamm, 2009). While empathy refers to the aspect of "feeling *as* the other person," thus, an isomorphic state, empathic concern is conceptualized as containing inherently other-oriented "feelings *for* the other person" (T. Singer, 2012, p. 442), and subsequently, it has different goals and consequences (e.g., helping, supporting) than empathy (Decety & Meyer, 2008). Crucially, empathic concern depends on functional emotion regulation to modulate empathic resonance in a top-down fashion and to allow a successful differentiation between one's own and other's perspectives and states (Decety & Lamm, 2009; Simantov et al., 2021). When

the empathic resonance to another person's state, specifically if induced by distressed states, is not regulated adequately, *personal distress* instead of empathic concern might be evoked (Decety & Meyer, 2008; Klimecki & Singer, 2013). Under personal distress, feelings of discomfort and anxiety (M. Davis, 1983), or the experience of the pain of the other as one's own (Decety & Lamm, 2009; Simantov et al., 2021) are summarized. Experiences of personal distress might promote rather aversive, self-focused emotional reactions geared towards relieving the individual's own distress and not that of the other, such as a desire to escape the aversive arousal (Decety & Lamm, 2009; Decety & Meyer, 2008; Simantov et al., 2021). Indeed, while empathic concern has been demonstrated to be linked to approaching and prosocial behavior by many studies (see Eisenberg et al., 2010 for a review), personal distress tends to either be negatively related or unrelated to prosocial behaviors (Eisenberg et al., 2010). Hence, as proposed in the model by Klimecki & Singer (2013), empathic concern links empathy to prosocial behavior.



Within the SOME (Bird & Viding, 2014), the "*empathy system*" is proposed to be formed by mutually interacting input (*situation understanding system, affective cue classification system*) and representational systems (*affective cue classification system, ToM system*), which are thought to be located in different areas of the brain. The *mirror neuron system* provides an indirect link between affective cue classification and their representation in emotions. The *self/other switch* allows actively switching the perceiver's attention to the other person and tags the affective state to be appropriate for the other in the ToM system, which is necessary for experiencing empathy. Original figure by Bird and Viding (2014), *Neuroscience & Biobehavioral Reviews*, 47, p. 522, Copyright c2014, Elsevier. Reprinted with permission.

Figure 1.1 The Self to Other Model of Empathy

1.1.4 Mutually Interacting Processes Determining Social Responses

Within reciprocal social interactions, the processes introduced in the previous chapters contribute either directly or indirectly to the enactment of social actions. In this context, the multifaceted SCIP models (originally developed by Crick & Dodge, 1994, 1996; Huesmann, 1998; modified by Lemerise & Arsenio, 2000) explain how an individual's response to a social situation is determined by mutual interactions between cognitive and emotional processes (e.g., emotion recognition, intent attribution, arousal regulation, response evaluation, and selection). These processes are thought to operate on a sequence of six mental steps that are processed rapidly with numerous feedback loops (see Figure 3.1; Study 1, Chapter 3). Broadly speaking, individuals encode incoming information (e.g., socio-emotional and situative cues), interpret this information within the particular social context, which results in causal or intent attributions, clarify their goals for the interaction, search for possible responses, evaluate the possible outcomes of these responses, and finally select a response for enactment (van Nieuwenhuijzen et al., 2004). The mental operations are further mediated by stable and circumstantial personal dimensions (e.g., temperament, mood, emotion regulation capacity; see the modified model by Lemerise & Arsenio, 2000), and are affected by (and in turn affect) a database of memorized experiences, acquired rules, social schemas, social knowledge, and affect-event links (Crick & Dodge, 1994, 1996; Lemerise & Arsenio, 2000; Ziv et al., 2014). According to Lemerise and Arsensio (2000), emotion recognition, emotion awareness, and communication may significantly contribute to the SCIP encoding and interpretation steps. Since these capacities provide ongoing information about how an encounter is proceeding, they allow sensitive behavior adjustments. Thus, own and others' affective cues have a mutual regulatory function, and when these competencies are deficient, behavior problems may result (Lemerise & Arsenio, 2000).

The SCIP models were shown to be effective in identifying different SCIP patterns of prosocial children, who were reported to be highly competent in each mental operation (e.g., (Mayeux & Cillessen, 2003; Nelson & Crick, 1999). However, most studies used the SCIP models to examine how different factors interact and culminate in aberrant or maladjusted social responses such as engaging in aggressive social responses toward others (Smeijers et al., 2020; van Nieuwenhuijzen et al., 2004). Under the perspective of the SCIP models, aggressive behaviors can be understood as a

consequence of incorrect or biased social information processing, which is caused by an aggression-supporting cognitive style that is acquired and maintained through the interaction of environmental socializers (e.g., exposure to aggressive models; see Bandura, 1973), biological predispositions (e.g., anger proneness), and situational instigators (e.g., provocation). Thus, the style refers to a tendency to interpret situations or the intentions and behavior of others as hostile, even when there is conflicting, lacking, or ambiguous information (Guy et al., 2017) and to construct and evaluate aggressive responses as adequate reactions (Görtz-Dorten & Döpfner, 2010, 2010; in the ff. "*hostile attribution bias*"). In aggression-provoking situations, the presence of hostile attribution bias can lead to the selection of aggressive responses and thus provoke the development of a stable pattern of aggressive behavior (Musher-Eizenman et al., 2004). The crucial role of hostile attribution bias in the development and maintenance of aggression in children has been supported by several investigations (see Martinelli et al., 2018; Verhoef et al., 2019 for recent meta-analyses).

In addition, diminished cognitive and affective empathy (Euler et al., 2017; Petermann & Koglin, 2015; Pouw et al., 2013), reduced emotion knowledge/awareness (Trentacosta & Fine, 2010), and dysfunctional emotion regulation (Röll et al., 2012) have frequently been linked to aggressive behaviors while emotion dysregulation was found to predict aggressive behavior from early to middle childhood (but not vice-versa; Blandon et al., 2010; Halligan et al., 2013). These findings contribute to the modified version of the SCIP models by Lemerise and Arsenio (2000), who claimed that dysfunctionalities in emotional processes might further enhance and maintain hostile attribution biases and influence later SCIP operations (see Helmsen et al., 2012). This view is supported by the studies reviewed by Smeijers and colleagues (2020), which tentatively suggest that impairments in emotional functions such as emotion recognition and emotion regulation have distinct influences at different stages of SCIP, all having direct or indirect relations to aggressive responses.

1.1.5 A Brief Insight into the Development of Socio-Emotional Competencies

In non-autistic and healthy children, the development of the different socio-emotional competencies introduced in the previous sections already starts shortly after birth. For example, the ability to discern others' emotions from their facial expressions is already present in three to four-month-old infants, who are able to discriminate between static displays of happy, sad, and surprised faces. Four-year-old children already freely label

prototypical (full or exaggerated) displays of happiness, sadness, and anger with almost perfect accuracy. Emotion recognition accuracy and speed further improve during childhood with positive emotions preceding negative emotions and basic emotions being recognized as complex emotions at an earlier stage. By the age of 10, emotion recognition abilities reach adult levels (for an overview, see Juen et al., 2012; Rump et al., 2009).

In parallel, the awareness of one's own emotional experiences becomes more differentiated and integrated with increasing age as the representations of emotional states move from implicit to explicit forms (Lane, 2000) with young children experiencing affective arousal as bodily sensations, action tendencies, or global states of positive/negative tension followed by growing conscious awareness of distinct emotional states and their potential co-occurrence (compare Lane & Schwartz, 1987). This contributes to the development of functional emotion regulation, which matures during the first years of life from external (e.g., parental regulation) to internal sources of emotional control (Eisenberg & Morris, 2002). At the age of approximately two years, toddlers are taught behavioral self-regulation by their caregivers, while the ability to inhibit reactions increases during their third year along with the continuous development of executive functions (Muralidharan et al., 2010). Children in preschool and school develop internal cognitive coping strategies (e.g., distraction, and positive thinking; (Eisenberg & Morris, 2002) and learn to assess their effectiveness and situative appropriateness, which are key developmental tasks within early and middle childhood (Morris et al., 2011). In sum, knowledge about one's own and others' emotions, emotion regulation, and emotional expressiveness, as the three central elements of emotional competence, each contribute to the successful development of social competencies in childhood (S. Denham et al., 2003).

Concerning empathic abilities, the mechanism subserving emotion sharing in the sense of emotional contagion is immediately present from birth, representing an instrument of social learning (Decety & Meyer, 2008). Expressions of empathic concern manifest in facial and vocal expressions of prosocial actions (Davidov et al., 2013) and cognitive awareness of the other's emotional experiences during the first and second years of life (Zahn-Waxler et al., 1992). At two years of age, children's prosocial behaviors (e.g., helping or comforting) better match the other person's needs, they are

less self-centered, and appear more regulated (Decety & Meyer, 2008). Cognitive empathy was shown to develop along with ToM, whose precursors already appear in the first 18 months of life (Imuta et al., 2016). ToM develops through the maturation of self-other differentiation until about four years of age (Decety, 2010).

1.2 A Summary of Socio-Emotional Deviations in Autistic Individuals

In contrast to non-autistic children, children on the AS display various differences in their development of emotional and socio-cognitive competencies, which are summarized in this chapter. The deviations manifest as reduced emotional awareness and differentiation, alexithymia, problems in developing mature emotion regulation capacities (Chapter 1.2.1), and difficulties in recognizing others' emotions (Chapter 1.2.2). Furthermore, individuals on the AS were reported to show deviances in the development of ToM, empathy, and empathic concern (Chapter 1.2.3). The final part of this chapter relates these peculiarities—in reference to the previously introduced SCIP models—to differences in social interaction behaviors, with a special focus on aggressive social responses (Chapter1.2.4).

1.2.1 Alexithymia and Emotion Regulation Difficulties

Alexithymia is found to co-occur with autism with prevalence rates of 40–65% (Berthoz & Hill, 2005; E. L. Hill et al., 2004; Lombardo et al., 2007; Samson et al., 2012), and elevated levels of alexithymia in adults on the AS when compared to non-autistic individuals were reported regardless of their level of intellectual ability (Griffin et al., 2016; E. L. Hill et al., 2004; Lombardo et al., 2007) as well as above the clinical level (Bird & Cook, 2013). Importantly, while the awareness and expression of conscious feelings (emotions with cognitive content and meaning) might be reduced and an overall trend towards reduced interoception (the sense of the physiological state of the body; A. D. Craig, 2002) was reported (see review by DuBois et al., 2016), physiological emotions (e.g., heart rate, skin conductance reactions) seem to be close to those of comparison groups (Ben Shalom et al., 2006). Despite its clinical relevance and high prevalence in adults on the AS, alexithymia in autistic children has rarely been investigated. As one of the first researchers in this area, Griffin and colleagues (2016) found substantially elevated levels of self- and parent-reported alexithymia in children on the AS, with parent-rated alexithymia being associated with increasing levels of

autistic traits. Similarly, when compared to their peers, more difficulties in describing feelings and inner states were reported, with approximately 21% of the researched children (Giannotti et al., 2020) and 55% of the adolescents (Milosavljevic et al., 2016) scoring above the cut-off for alexithymia, with age and verbal IQ having no significant effect (Giannotti et al., 2020).

Beyond this, there is growing awareness of serious emotion dysregulation in individuals on the AS (Laurent & Rubin, 2004; Mazefksy et al., 2012; Samson et al., 2012), although emotional difficulties are not considered to be a core deficit. However, since problems in emotion regulation were observed to share underlying clinical and biological mechanisms with autism-related social impairments (e.g., the prefrontal and ventromedial prefrontal cortex, including the amygdala; see Mazefksy et al., 2013), Mazefsky and colleagues (2013; 2014) suggested that impaired emotion regulation is inherently rooted in the core characteristics of autism. Specifically, they hypothesized that challenges with social communication (e.g., perspective taking, describing emotional states, socio-emotional cue perception) interfere with regulation, resulting in high levels of emotional dysregulation (Mazefksy & White, 2014). Further, a tendency to rely more on others to regulate their emotions than non-autistic peers was reported for autistic children (Cibralic et al., 2019), while, on the other hand, they were found to be less willing and able to respond to emotion regulation cues from caregivers, which impairs emotion regulation development (Jahromi et al., 2012). Evidence from various studies suggests that difficulties in using adaptive emotion regulation strategies (e.g., cognitive reappraisal) tend to persist over the lifetime (Cai et al., 2018; Reyes et al., 2019) and autistic adolescents and adults were shown to experience emotion regulation failures such as not engaging in, or being less effective in regulating emotions in comparison to non-autistic individuals. Furthermore, the use of adaptive strategies was observed less frequently, while maladaptive emotion regulation strategies such as defense, avoidance, crying, suppression, rumination, or shutting down were applied to a greater extent (see Cibralic et al., 2019 and Cai et al., 2018 for recent reviews, and a summary of mixed results).

Emotion dysregulation may both reduce the ability to stop unfavorable behaviors and negative emotions and promote perseveration (Mazefksy et al., 2012) which thus could result in anger or anxiety being experienced more intensively and frequently by children on the spectrum as compared to non-autistic children. Indeed,

high and negative emotionality is often documented in children on the AS (Mazefksy et al., 2013; Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015) which is expressed in maladaptive emotional responses, such as irritability, poor anger control, anger outbursts, tantrums, meltdowns, self-injurious behavior, and, finally, aggression (Bos et al., 2018; Capps et al., 1993; Mazefksy et al., 2012; Samson et al., 2012). Preliminary evidence suggests that adverse emotional reactions impair levels of functioning in everyday life (Jahromi et al., 2013) and emotion dysregulation is associated with greater social difficulties (Gotham et al., 2015).

1.2.2 Problems in Facial Emotion Recognition

Along with problems in recognizing emotional cues in other modalities (e.g., from voices, postures, or body movements), diminished facial emotion recognition skills are repeatedly reported in children, juveniles, and adults on the AS (see reviews by Bons et al., 2013; Gaigg, 2012; Harms et al., 2010; meta-analysis by Uljarević & Hamilton, 2013). Several behavioral studies with this target group showed that they have difficulties in performing explicit tasks requiring them to label emotional states that were presented in static pictures of facial expressions (Bons et al., 2013), the eye region (Baron-Cohen et al., 2001), or in dynamic videos (Tardif et al., 2007). In their meta-analysis, Uljarevic and Hamilton (2013) reported that the general disability in emotion recognition was apparent even after correcting for publication bias. Moreover, emotion recognition difficulties might be due to a general impairment in emotion processing and not to linguistic or perceptual task demands because performance on both emotion labeling and emotion matching tasks was reduced in persons on the AS (Uljarević & Hamilton, 2013). However, despite extensive research, the results are inconsistent with one in every four (Harms et al., 2010) or every two studies (Bons et al., 2013) failing to demonstrate divergent emotion recognition in persons on the AS. Here, a combination of several methodological factors (e.g., sample characteristics, matching, or the specific experimental design) is thought to account for some of the mixed results because nearly all the eye-tracking, neuroimaging, and studies on event-related potentials found a difference between the results of non-autistic and autistic individuals (see Harms et al., 2010 for a discussion; and Gaigg, 2012). Equally, difficulties in autistic children and adolescents seem to be made more pronounced by enhancing the task difficulty (e.g., by using blended emotions or emotions of low intensity; Bons et al., 2013; Harms et al., 2010), using dynamic, more ecologically valid facial stimuli instead of static, prototypical stimuli (Sato et al., 2012), or response times

instead of accuracy (Sucksmith et al., 2013). The latter result points to prolonged processing of social information in autism (Sucksmith et al., 2013). Finally, while the recognition of basic emotions (e.g., fear, joy, surprise) seems to be intact in adolescents and adults on the AS without intellectual disability (IQ > 85), they still have difficulties in recognizing complex emotions such as guilt, shame, and envy (Harms et al., 2010).

1.2.3 Differences in Theory of Mind, Empathy, and Empathic Concern

In the past, empathy difficulties were suggested to be a core feature of autism (e.g., Hobson, 1986) and reduced emotional reciprocity was considered to be a clinically significant indicator of autism (Lord et al., 2000). However, while some clinical observations, parent reports, or studies using vignettes pointed towards absent, reduced, or divergent responses towards others' emotions in autistic children (e.g., Begeer et al., 2008; Yirmiya et al., 1989), other studies pointed to equal or even super-normal degrees of empathy and typical emotional responses during social interactions (e.g., Capps et al., 1992). Overall, empirical evidence on empathy deficits and their underlying competencies in individuals on the AS is inconsistent (e.g., Begeer et al., 2008; Harms et al., 2010; Song et al., 2019; Uljarević & Hamilton, 2013), and consequently, the general claim that individuals on the AS lack empathy has been questioned (e.g., Bird & Cook, 2013; Smith, 2009a, 2009b). Recent research rather points to a dissociation between impaired cognitive empathy/ToM and relatively intact emotional facets of empathy (Baron-Cohen & Wheelwright, 2004; Dziobek et al., 2008; Song et al., 2019).

First, difficulties in the ability to conceive mental states and to use mental state concepts to interpret and predict one's own and other people's behavior have been considered to be a central factor in explaining autism and autism-related social impairments (see "*mentalizing account*" or "*theory of mind hypothesis,*" e.g., Baron-Cohen et al., 1985; E. L. Hill & Frith, 2003). Indeed, a large body of research points to stable deficits in the cognitive ToM component, for example, difficulties in attributing mental states to others and failing on complex ToM tests (for review, see Boucher, 2012). In addition, problems in the affective ToM component, or respectively, cognitive empathy (Healey & Grossman, 2018) have been observed in autistic individuals without intellectual disabilities and in different age groups in some studies (e.g., Dziobek et al., 2006; Dziobek et al., 2008; Mazza et al., 2017; Mul et al., 2018; Poustka et al., 2010; Pouw et al., 2013) although other studies found no impairment in cognitive empathy (e.g., Bird et al., 2010; Chung et al., 2016). Concerning the emotional facets of empathy

(including empathic concern), numerous studies using self-reports have not found an impairment (e.g., Bird et al., 2010; A. P. Jones et al., 2010; Lockwood et al., 2013; Rogers et al., 2007), while others pointed to reduced empathic concern and enhanced personal distress (e.g., Baron-Cohen & Wheelwright, 2004; Johnson et al., 2009; Minio-Paluello et al., 2009). Studies using functional neuroimaging found both atypical (Greimel et al., 2010; Schulte-Rüther et al., 2011) and similar (Hadjikhani et al., 2014) neural responses to emotional stimuli in brain regions which are thought to mediate empathy in autistic individuals when being compared to non-autistic groups.

As pointed out by Song and colleagues (2019), these mixed results might be due to different measures and paradigms, as well as to various definitions of empathy and related constructs. In their meta-analysis, the findings of 51 studies were classified according to the main components of empathy: cognitive empathy, emotional resonance, and empathic concern. Further, studies were differentiated by either assessing the empathy components on a trait level (a general, relatively stable, and invariant ability to understand and share others' feelings measured through offline, self-reported methods) or on a state level (a short-term interpersonal psychological process/state induced/motivated by a specific situation/stimulus measured through online, performance-based methods). Through applying this procedure, cognitive empathy and other-oriented empathic concern were found to be impaired on the trait *and* the state level. Self-oriented emotional resonance – the process of sharing others' feelings – was reported to be intact on the state level. However, on the trait level, emotional resonance was even found to be enhanced when compared to non-autistic comparison groups, which might lead to enhanced experiences of personal distress, in turn disrupting empathic concern and prosocial actions (Song et al., 2019; compare as well Rogers et al., 2007).

Finally, in reference to the SOME model introduced in Chapter 1.1, it should be mentioned that differences in empathy might stem from problems processing own and others' emotions in individuals on the AS (see Chapter 1.2.1 and 1.2.2). Indeed, difficulties in differentiating own emotions were associated with differences in cognitive and affective facets of empathy (e.g., Bird et al., 2010) and higher levels of alexithymia were found to predict empathy significantly better than autistic traits (see e.g., Bird & Cook, 2013; Speyer et al., 2022, Fletcher-Watson & Bird, 2020 for the "*alexithymia hypothesis of empathy in autism*" which states that alexithymia and not

autism per se underlies the abnormalities in the cognitive and emotional domain of empathy in persons on the AS). In addition, as proposed by Bird & Viding (2014), the manifestation of difficulties in differentiating between perspectives of self and others across the sensory, cognitive, and affective domains in autistic persons might be explained by inadequate control over the self/other switch, which has been suggested to be a core deficit in autism (Simantov et al., 2021).

1.2.4 Differences in Social Behavior under the Perspective of the Social Cognitive Information Processing Models

As mentioned initially, autistic individuals are characterized by differences in the social interaction domain (American Psychiatric Association, 2013). According to Kasari and Patterson, (2012), they specifically have two key problems: difficulties in their ability to engage jointly with others and differences in the amount and quality of interactive skills with peers (e.g., showing fewer, extensive, or qualitatively unusual social approaches and reactions or egocentric responses in social situations; Kasari & Patterson, 2012; or absent, reduced, or divergent responses towards others' emotions, Begeer et al., 2008; Yirmiya et al., 1989). In sum, such behavioral patterns interfere with their often cited goal of developing friendships (Kasari & Patterson, 2012; Orsmond et al., 2004), and these impairments in social interaction skills are thought to be underpinned by the range of socio-cognitive and emotional difficulties that were summarized in the previous sections. However, while a large body of past research focused on investigating specific difficulties (especially the ToM impairment), only a few studies so far examined patterns of social-cognitive information processing based on the established SCIP models (see Chapter 1.1.4), even though this might be fruitful for studying the social cognitive mechanisms guiding social behaviors (Ziv et al., 2014). The initial studies applying the SCIP models found difficulties in all SCIP operations in preschool children (Mazza et al., 2017; Ziv et al., 2014) and adolescents (Bauminger et al., 2005; Channon et al., 2001; Embregts & van Nieuwenhuijzen, 2009; Flood et al., 2011; Meyer et al., 2006) when compared with non-autistic comparison groups. For example, autistic boys with mild to borderline intellectual disability were shown to focus on negative aspects of social situations, thereby resulting in a failure to accurately encode social information, and subsequently to evaluate socially unacceptable (i.e., aggressive) responses to these situations more positively (Embregts & van Nieuwenhuijzen, 2009). Less competent ways of social information processing were

further related to poor psychosocial adjustment (Meyer et al., 2006), and autistic children were more likely than non-autistic children to display difficulties in interpreting social situations in the sense of intent attribution to others, and their generation and evaluation of responses to social situations (Flood et al., 2011). Ziv and colleagues (2014) reported a diminished capacity to efficiently encode social information in preschool children on the AS. They were more likely to attribute hostile intentions to others in benign social situations, to construct and evaluate aggressive responses more positively, to construct more avoidant responses, and display more externalizing behaviors. Additionally, two studies reported a positive relationship between the ToM capacities and better performance on SCIP operations in autistic children (Russo-Ponsaran et al., 2015; Ziv et al., 2014; but see Flood et al., 2011; Mazza et al., 2017 for different results). Finally, Russo-Ponsaran and colleagues (2015) showed that better abilities to recognize emotions from postures and gait, but not from facial expressions, were positively associated with better social problem identification and goal generation in autistic children.

As claimed by Lemerise and Arsensio (2000), the mental SCIP operations determining social behavior are likely influenced by emotional processes. However, despite dysfunctional emotion regulation and abnormalities in emotion expression and appraisal being frequently reported to have a strong impact on aberrant social responses such as reactive aggression in children on the AS (Mazefksy & White, 2014; Politte et al., 2019; Pouw et al., 2013; Samson, Hardan, Lee, et al., 2015; Trentacosta & Fine, 2010) their additional impact on SCIP have rarely been investigated in this population. In sum, grounding future studies on the SCIP models and integrating different predictors of deviant social behavior might be very informative for gaining more profound insights and for developing more effective and customized intervention approaches targeting disturbed social interaction in children on the AS (Ziv et al., 2014).

1.3 The Potential and Limitations of Digital Interventions

The previous chapter illustrated that various socio-cognitive and emotional processes influencing social cognitive information processing and underlying social interaction behavior are disturbed in individuals on the AS across age groups. This points to a great need for offering early and easily accessible interventions to ensure a good outcome in terms of satisfying social inclusion, education, mental health, and

integration in the workforce, among others. However, the current supply situation in Germany and other countries is highly insufficient, resulting i.a. in long waiting times for therapy and long distances to travel to the next provider, especially in rural areas, which causes a high burden and stress for families (Chapter 1.3.1). Here, digital approaches might have a great potential for easing the path to social interventions as a complement to standard therapies (Chapter 1.3.2). However, with few exceptions, current digital solutions aiming at fostering social behavior lack the integration of emotional skills beyond socio-cognitive competencies, which potentially limits their transfer to real-life social behavior (Chapter 1.3.3). Furthermore, a rigorous evaluation of the effectiveness of such approaches is lacking and aspects of usability, acceptability, and feasibility are not sufficiently investigated (Chapter 1.3.4).

1.3.1 The Severe Gap between Intervention Needs and Supply

Several studies in recent years showed that considerable improvements in socio-emotional competencies can be reached through providing early social interventions such as social skills groups or individual therapy (e.g., CBT) to children and adolescents on the AS (Darling et al., 2021; Wang et al., 2021). However, given that there are only 2,260 child and adolescent psychotherapists for approximately 887,700 children with various psychiatric conditions in Germany (Bundesärztekammer, 2020) and 149 autism care units[2] providing support for around 67,000 children with a possible autism diagnosis[3], psychotherapeutic and social care for children and adolescents with special needs is highly insufficient. The resulting long waiting times (sometimes > 1 year) for therapy and in some cases limited geographical accessibility, especially in structurally weaker regions, cause great distress for families with affected children. In addition, insufficiently treated conditions might create a long-term burden for society (e.g., by causing direct and indirect costs for long-term treatment of chronic/co-morbid conditions, or failures of integrating people into the workforce; Olesen et al., 2012). This problematic situation has been further significantly exacerbated by the COVID-19 pandemic (see Brakemeier et al., 2020 for reporting an increase in waiting times for

[2] The number refers to the number of facilities providing autism therapy, which are listed on the website of the Bundesverband zur Förderung von Menschen mit Autismus (German Federal Association for the Support of People with Autism; https://www.autismus.de).

[3] Since there is no statistical information on the number of actually assigned autism diagnoses in Germany, the prevalence of 1% estimated by Maenner et al. (2014) was used to calculate the number of potentially affected children belonging to the biggest age group of 6–14 year-old children (Statistisches Bundesamt , 2020).

psychotherapy, and Ravens-Sieberer et al., 2022; Ravens-Sieberer, Kaman, Erhart, et al., 2021; Ravens-Sieberer, Kaman, Otto, et al., 2021 reporting an increase in psychosocial problems among children in Germany, and Colizzi et al., 2020 for the negative impact of the pandemic on autistic children and their families). As stated by the Leopoldina in June 2021 (Leopoldina, 2021), this emergency affects various areas of life, which urgently requires taking countermeasures to prevent further aggravation and long-term consequences.

1.3.2 The Potential of Digital Interventions for Autistic Children

In the context of the existing gap between treatment needs and actual supply, evidence-based digital applications, either as fully automated intervention programs or in combination with traditional therapies, can be important means to ease the treatment-supply gap in a low-threshold way (compare Andersson et al., 2014; Olesen et al., 2012; Sandgreen et al., 2021), especially as supporting tools during a pandemic. In addition to improving coverage (greater reach to geographically isolated populations, flexible access, bridging waiting times), the benefits of digital interventions include improved treatment fidelity, rapid scalability, cost-effective delivery (Grist et al., 2019), and reducing other barriers to conventional psychotherapy (e.g., stigma) through greater anonymity/privacy (Halldorsson et al., 2021). Since many children and adolescents have grown up with digital devices as an integral part of their lives, modern digital interventions may have a particular appeal and usefulness for this population. Furthermore, individuals who would not seek help through traditional mental health services can also be reached using this approach (Halldorsson et al., 2021). Concerning children on the AS, digital means often meet the children's high interest in technology and fulfill their desire for structure, repetition, and predictability, while reducing stress by limiting social demands (Bölte et al., 2010; Golan & Baron-Cohen, 2006). Thus, while addressing the gap between treatment needs and supply and providing cost-effective solutions (Casale et al., 2015), digital interventions might also increase therapy acceptance, compliance, and motivation in children on the AS (Bölte et al., 2010; Golan & Baron-Cohen, 2006). Indeed, recent reviews of digital social intervention point to enhanced attention and motivation and positive intervention effects in children on the AS (see Kouo & Egel, 2016; Mazon et al., 2019). For example, after the 12-week program "*Mind Reading"* (Baron-Cohen et al., 2004), emotion decoding and encoding skills were significantly improved in short- and medium-term assessments (Thomeer et al., 2015). Other programs such as "*Let's Face It!"* (Tanaka et al., 2010), "*FaceSay*^{TM}"

(Hopkins et al., 2011), or "*Emotiplay*" (Fridenson-Hayo et al., 2017) resulted in improvements in facial recognition and processing skills (Tanaka et al., 2010), affect recognition, mentalizing, and social skills (Hopkins et al., 2011; Rice et al., 2015, or respectively, on facial, vocal, body, and integrative emotion recognition tasks, Fridenson-Hayo et al., 2017). Similarly, treatment gains in social skills, emotion regulation, and child anxiety reduction were shown for "*The Secret Agent Society*" (SAS) by Beaumont and Sofronoff (2008) after 7–8 weeks of treatment, and at follow-up (Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017).

1.3.3 Limited Maintenance and Real-Life Transfer of Digital Interventions

Despite these promising results, the few studies assessing the generalization and maintenance of trained skills (e.g., emotion recognition) in real-life social behavior mostly reported low achievement (see Grynszpan et al., 2014 and Zhang et al., 2021 for recent meta-analysis) and even if, in the case of some approaches, significant improvements were still present at follow-up as compared to control groups (Gev et al., 2017; Russo-Ponsaran et al., 2015), the magnitude of the intervention effect was lower than immediately after the training (Zhang et al., 2021). Overall, the poor results concerning the maintenance and generalization of targeted skills question the genuine therapeutic value of digital interventions (Fletcher-Watson, 2014; Fletcher-Watson et al., 2016).

However, in comparison to digital interventions primarily focusing on mentalizing and emotion recognition skills (e.g., *Mind Reading*, *Let's Face it*), more pronounced transfer effects on social behavior were reported for approaches that targeted socio-cognitive skills *together* with emotional competencies such as emotion regulation (Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017; see review by Zhang et al., 2021). An example to be mentioned here is SAS by Beaumont and Sofronoff (2008), which is explicitly aimed at training real-life social behavior through teaching emotion recognition in self and others, emotion regulation, social skills, and problem-solving skills (Beaumont & Sofronoff, 2008). In its first evaluation study, the authors reported that the children in the intervention group showed greater parent- and teacher-reported improvements in social skills and an increase in the suggestion of appropriate emotion-management strategies for story characters. While these gains were maintained at the 5-months follow-up, there was no difference between

the intervention and the comparison group in the improvements in recognizing facial expression and body postures (Beaumont & Sofronoff, 2008).

Since this program targets children older than eight years of age and, like most of these past digital approaches, it has been tested and made available in English-speaking countries only, a comparably holistic approach is lacking for German-speaking and younger children on the AS. In the light of empathy models such as the SOME and past research results, it might be speculated that targeting empathy in all of its facets while additionally focusing on its underlying competencies (e.g., emotion recognition, emotional awareness) as well as on its consequences (empathic concern/personal distress), might, in sum, result in enhanced and maintained changes in real-life social behaviors (compare Eisenberg et al., 2010).

1.3.4 Limitations of Past Studies on Digital Approaches

The evaluation of the past digital approaches aiming to improve social skills in children on the AS have several methodological limitations and blind spots to be addressed by further research. First, although randomized controlled trials (RCTs) have become more common in recent years (Fletcher-Watson, 2014), few studies on the effectiveness of the solutions have incorporated active control groups to account for the amount of time spent playing on the computer and social interactions with the training facilitators during training (Hopkins et al., 2011; Rice et al., 2015; Young & Posselt, 2012). Moreover, despite it being widely acknowledged that difficulty with generalizing skills to other contexts (e.g., other persons, situations, tasks) is part of autism (Happé & Frith, 2006), maintenance and generalization effects were rarely addressed by using follow-up assessments (Berggren et al., 2017) and performance tests of social skills (Mazon et al., 2019).

In addition to evaluating the effectiveness of novel interventions, research is also needed to examine their *acceptability*, namely the perception among users and stakeholders that a given treatment is satisfactory (Proctor et al., 2011). Together with *usability* ("the capability of a software product to enable specified users to achieve specified goals with effectiveness, productivity, safety, and satisfaction in specified contexts"; Yen & Bakken, 2012: p.414), and *feasibility* (the extent to which a new treatment can be successfully carried out within a given setting; Proctor et al., 2011), *acceptability* is an important implementation outcome for predicting the later use and sustainability of a digital intervention in real-life settings (Drotar & Lemanek, 2001).

However, questions of acceptability and feasibility are rarely addressed systematically in the evaluation of technology-based interventions for individuals on the AS (see Valentine et al., 2020 for a recent meta-analysis).

2 Summary and Aims of the Dissertation

In summary, a large body of research shows that individuals on the AS exhibit various cognitive and socio-emotional differences in comparison to non-autistic persons such as difficulties in recognizing, describing, and labeling own and others' emotions, difficulties in inferring others' intentions, desires, and emotions through perspective taking, reduced empathic concern but enhanced personal distress and problems in adequately regulating their emotions. In sum, these characteristics might reduce the likelihood of prosocial behavior and enhance the risk of engaging in maladaptive behaviors, which might have serious consequences for the affected children and their families' lives and health. Gaining a comprehensive understanding of the pattern of disturbed social behaviors is therefore of great importance for providing adequate socio-emotional interventions. In this context, and given the current serious gap between intervention needs and supply, digital approaches seem to be promising means for skills development, which are also thought to fulfill the needs and interests of most autistic children. However, even though there are established frameworks such as the modified SCIP models (Lemerise & Arsenio, 2000) that integrate emotional factors beyond cognitive factors to explain social information processing from cue encoding to behavior enactment, these models are only rarely applied to investigate social interaction in children on the AS. Second, current digital interventions aiming at fostering autistic children's social skills mostly focus on emotion recognition and mentalizing, without targeting their emotional problems (e.g., reduced emotional awareness, personal distress in response to others' feelings). Recent meta-analyses, however, suggest that digital approaches that integrate socio-cognitive *and* emotional competencies achieve better transfer effects on the children's actual social behavior. Another point is that further studies on digital social interventions that use rigorous methodologies are needed and – beyond effectiveness – assess the maintenance and generalization of skills as well as the acceptability and feasibility of the interventions more systematically.

Hence, the overall aim of this dissertation was to provide a more multifaceted and comprehensive insight into the causes of disturbed social behavior as well as a more effective digital training approach to strengthen prosocial behavior for children on the AS. In this context, the interplay between these factors as predictors of various forms of maladaptive social responses was first investigated before the overall objective was pursued by developing and testing a holistic digital intervention to promote empathic

and prosocial behavior in a clinically meaningful way. Concretely, the dissertation pursued the following research questions (RQ):

RQ 1: What is the additional impact of symptoms of dysfunctional emotion regulation on maladaptive social behaviors in children on the AS? The question was targeted by **Study 1** (Chapter 3), which applied the established SCIP models to different forms of socially aggressive behaviors in children on the AS. Based on the assumption that a hostile attribution bias mediates the relation between misinterpretation of emotional expressions and aggressive behaviors (classical SCIP model; Crick & Dodge, 1994, 1996), it was hypothesized that lability-negativity would predict hostile attribution bias and also would have a direct, and positive impact on the presence of aggressive behaviors (modified SCIP model by Lemerise & Arsenio, 2000).

RQ 2: How can a holistic, digital intervention aiming at fostering empathy as a precursor of prosocial behavior in pre- and primary school children on the AS be designed? Based on the theoretical assumptions of the SOME (Bird & Viding, 2014) the digital intervention "*Zirkus Empathico*" – which fosters the cognitive *and* emotional facets of empathy together with their underlying competencies (*here:* emotional awareness, emotion recognition) and prosocial acts of empathic concern – was developed as a serious game for children on the AS with a developmental age between 5 and 10 years (**Technical Report**; Chapter 4). Additional information can be found in the Online Supplementary of Study 2.

RQ 3: Is the novel digital intervention accepted by autistic children and their caregivers and is its application in real-life settings perceived as being feasible? To answer this question, aspects of acceptability and feasibility were investigated in an exploratory manner within a multicenter randomized-controlled trial in Germany and Austria **(Study 2**, Chapter 5) testing Zirkus Empathico in 82 children on the AS aged 5 to 10 years and without intellectual disabilities (IQ > 70) and sufficiently receptive language.

RQ 4: What are the short- and medium-term effects of the digital intervention Zirkus Empathico on empathy and emotion recognition in children on the AS? The evaluation of the effectiveness of Zirkus Empathico was addressed in **Study 2** (Chapter 5). It was hypothesized that the six-week training would result in improvements in empathy and emotion recognition as primary outcomes at both the

post-intervention assessment and three-month follow-up measurement. Additionally, training effects on emotional awareness and transfer effects on emotion regulation, callous and unemotional traits, real-life social behavior (i.e., autistic social symptomatology), and well-being were quantified. Finally, changes in emotional awareness/emotion regulation over the course of the training and changes in emotion recognition/empathy three months after the intervention were explored.

Original Research Articles

Published in *Journal of Autism and Developmental Disorders*, *Online Publication. (2021)*

3 Subtypes of Aggressive Behavior in Children with Autism in the Context of Emotion Recognition, Hostile Attribution Bias, and Dysfunctional Emotion Regulation

Simone Kirst[1], Katharina Bögl[1], Verena Loraine Gross[2], Robert Diehm[3], Luise Poustka[4] and Isabel Dziobek[1]

[1] *Clinical Psychology of Social Interaction, Berlin School of Mind and Brain, Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany*
[2] *Berlin, Germany*
[3] *Department of Child and Adolescent Medicine, Medical University of Vienna, Vienna, Austria*
[4] *Department of Child and Adolescent Psychiatry and Psychotherapy, University Medicine, Georg-August Universität Göttingen, Göttingen, Germany*

The causes of aggressive behavior in children with autism are poorly understood, which limits treatment options. Therefore, this study used behavioral testing and parent reports of 60 children with autism to investigate the interplay of emotion misinterpretation and hostile attribution bias in the prediction of different aggressive behaviors. Further, the additional impact of dysfunctional emotion regulation was examined. Path analyses indicated that hostile attribution bias increased verbal and covert aggression but not physical aggression and bullying. Dysfunctional emotion regulation had an additional impact on bullying, verbal aggression, and covert aggression. Emotion recognition was positively associated with hostile attribution bias. These findings provide a first insight into a complex interplay of socio-emotional variables; longitudinal studies are needed to examine causal relationships.

Introduction

Beyond the core symptoms of autism spectrum conditions (ASC), diverse comorbid behavioral symptoms can hinder the accomplishment of important developmental milestones in children with the diagnosis, with challenging and aggressive behaviors being particularly impactful and limiting (Sullivan et al., 2019). These behaviors considerably restrict school education and treatment, reduce opportunities for interpersonal relationships, and cause feelings of social isolation and stigmatization in parents (Hodgetts et al., 2013). Since 35–50% of children in the autism spectrum show comorbid aggression (Farmer & Aman, 2011a; Mazurek et al., 2013), and with aggression being one of the strongest predictors of parental stress (Baker et al., 2002; Hodgetts et al., 2013), it is one of the key factors for seeking treatment (Robb, 2010). It is thus crucial to gain a better understanding of predictors of aggression in children with autism to provide effective prevention and intervention with positive outcomes (Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015). However, possible causes and correlates are still poorly understood (A. P. Hill et al., 2014). Neither autism-related factors (e.g., ASC symptom severity, adaptive behavior) nor autism-unrelated factors (e.g., low IQ, harsh parental practices; Kanne & Mazurek, 2011; Sullivan et al., 2019) seem to be strong and consistent explanatory factors.

Deficits in socio-emotional functions such as diminished empathy (Euler et al., 2017; Pouw et al., 2013), reduced emotion knowledge (Trentacosta & Fine, 2010), and dysfunctional emotion regulation (Röll et al., 2012) have frequently been linked to aggressive behavior in typically developed (TD) children. Dysfunctional emotion regulation was primarily associated with spontaneous reactions to a real or perceived threat (Kaartinen et al., 2014) without any identifiable goal (Blair, 2016) resulting from anger, frustration, or provocation (Crick & Dodge, 1996). Deficits in emotion regulation (e.g., using maladaptive emotion regulation strategies such as rumination or shutting down; Samson et al., 2014) are highly prevalent in children with autism and may result in anger or anxiety being experienced more intensively and frequently than in TD children (Mazefksy et al., 2013; Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015). In turn, these intensive emotions can cause aggressive behaviors (Bos et al., 2018; Samson, Hardan, Lee, et al., 2015; Samson, Hardan, Podell, et al., 2015), especially in social situations (Laurent & Rubin, 2004). Additionally, social cognition impairments such as inaccurate interpretations of social intent were found to promote aggressive behaviors (Politte et al., 2019). Thus, it seems plausible that both

impaired social-cognitive abilities and emotional functions might explain aggressive behaviors in autistic children.

Even though there is quality research providing empirical support for individual risk factors and predictors of aggression in children with autism, it largely lacks integration, which hinders the effective understanding, prevention, and treatment of aggressive behavior (Chester & Langdon, 2016). The present work is based on the multifaceted Social Cognitive Information-Processing models (SCIP models; Crick & Dodge, 1994, 1996; Huesmann, 1998; Lemerise & Arsenio, 2000) because they are to date the most influential and comprehensive frameworks, which are most widely applied to explain aggressive behavior (see reviews Fontaine, 2008; Larkin et al., 2013; Smeijers et al., 2020). When trying to understand the psychosocial sources of aggression in TD children, the SCIP models have proven to be of very good use (van Nieuwenhuijzen et al., 2004) for "developing an integrated picture of how different factors interact and culminate in aggression" (Smeijers et al., 2020).

In the classical version of the SCIP models (Crick & Dodge, 1994, 1996; Huesmann, 1998), aggressive behavior is understood as a consequence of incorrect or biased information processing, especially in social situations. The models posit that the interaction of environmental socializers (e.g., exposure to aggressive models; see as well Bandura, 1973), biological predispositions (e.g., anger proneness), and situational instigators (e.g., provocation) activate an aggression-supporting cognitive style. This style refers to a tendency to interpret situations or the intentions and behavior of others as hostile, even when there is conflicting, missing, or ambiguous information (Guy et al., 2017) and to construct and evaluate aggressive responses as adequate reactions (Görtz-Dorten & Döpfner, 2010). We will hereafter refer to this construct as the "hostile attribution bias". In aggression-provoking situations, hostile attribution bias can lead to the selection of aggressive responses and thus provoke the development of a stable pattern of aggressive behavior (Musher-Eizenman et al., 2004). The crucial role of hostile attribution bias in the development and maintenance of aggression in TD children has been supported by several investigations (see Martinelli et al., 2018; Verhoef et al., 2019 for recent meta-analyses).

Lemerise and Arsenio (2000) proposed a revised version of the classical SCIP model by including emotion processes (e.g., emotionality/temperament, emotion regulation, and moods, hereinafter: emotion model, depicted in

Figure 3.1). According to this revised model, dysfunctional emotion regulation causes intensive negative experiences of aversive emotions (e.g., anger, anxiety) and general lability, which further enhance and maintain hostile attribution biases and influence later SCIP operations (problem identification and solution, goal clarification, response selection; Helmsen et al., 2012). Empirically, the studies reviewed by Smeijers et al., 2020) tentatively suggest that emotional functions such as emotion recognition and emotion regulation may have distinct influences at different stages of SIP, all having direct or indirect relations to aggressive responses.

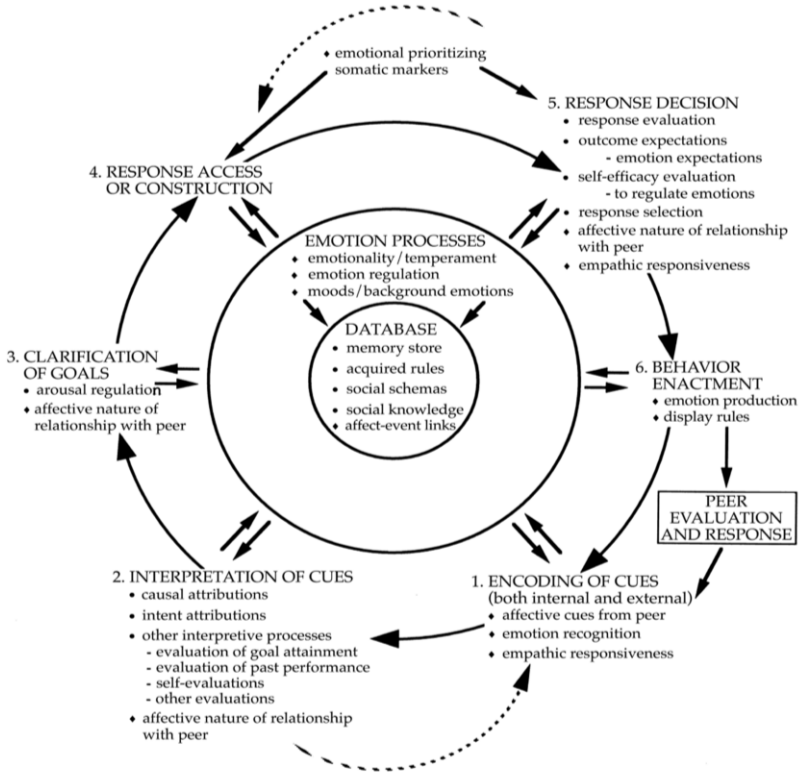
Although the SCIP framework promises to be useful in strengthening the theoretical foundations of research on aggression in children with ASC (Ziv et al., 2014), it is rarely applied. Current evidence in children with autism points to difficulties in all SCIP operations when being compared to TD children, including a diminished capacity to efficiently encode socio-emotional information and the existence of hostile attribution biases (Embregts & van Nieuwenhuijzen, 2009; Flood et al., 2011; Mazza et al., 2017; Meyer et al., 2006; Ziv et al., 2014). Ziv et al. (2014) associated hostile attribution bias with a higher frequency of externalizing behaviors.

However, similar to research in TD (see Fontaine, 2008; Smeijers et al., 2020), the integration of cognition and emotion in the understanding of social information processing in aggression is rarely focused on, and studies that investigate whether hostile attribution bias mediates the relationship between deficient emotion processing and aggressive behavior in autism are currently lacking.

The Present Study

Based on the assumption that a hostile attribution bias mediates the relation between misinterpretation of emotional expressions and aggressive behavior (classical model; Crick & Dodge, 1994, 1996), the present study aimed at identifying the additional impact of dysfunctional emotion regulation expressed as lability and negativity in children with autism spectrum conditions. In reference to the modified SCIP models by Lemerise and Arsensio (2000), we hypothesized (H1) that lability-negativity would predict hostile attribution bias and also would have a direct, and

positive impact on the presence of aggressive behaviors (emotion model; compare Figure 3.2). In alignment with Farmer and colleagues (2016; 2009), we view aggression as a multifaceted phenomenon expressed by different subtypes of aggression, which potentially have different responses to treatment and prognoses (Connor et al., 1998). We, therefore, aimed to explore interrelated predictors in physical acts of aggression and more complex forms (verbal aggression and covert aggression, see Table 3.1 for examples) separately in preschool and primary school children with autism and normal intellectual functioning (IQ≥70). Finally, due to the importance of facial expressions as a modality of social judgment (Frith, 2009) and social-cognitive information processing, we used diminished facial emotion recognition as a potential predictor of hostile attribution bias (compare Lemerise & Arsenio, 2000; Russo-Ponsaran et al., 2015). The present study was part of a registered six-week multicenter, randomized, pragmatic clinical trial testing a tablet-based intervention in children with autism (Kirst et al., 2020; DRKS-ID: DRKS00009337; Universal Trial Number (UTN): U1111-1175–5451). Since no TD children participated in the trial, no comparison group was available for the current study.



In the revised SCIP models (Lemerise & Arsenio, 2000), aggression is understood as a function of biased social information processing in six mental operations, which are processed rapidly with numerous feedback loops in response to socially challenging situations. Individuals encode incoming information, interpret this information within the particular social context resulting in causal/intent attributions, clarify goals for the interaction, search for possible responses, evaluate possible outcomes for these responses, and then select a response for enactment (van Nieuwenhuijzen et al., 2004). The mental operations are influenced by a database of memorized experiences, acquired rules, social schemas, social knowledge (Crick & Dodge, 1994, 1996), and affect-event links (Lemerise & Arsenio, 2000). Original figure by Crick and Dodge (1994), *Psychological Bulletin*, 115, p. 74, adapted by Lemerise & Arsenio, 2000, p. 113). Copyright c1994, American Psychological Association. Reprinted with permission.

Figure 3.1 The revised Social Cognitive Information-Processing model.

Methods

Participants

Out of 184 screened children with ASC, 82 children were eligible for the RCT trial, from which 60 children (50 males) between 5.0 and 10.11 years (M = 8.0 years, SD = 1.6) fulfilled the sample inclusion criteria. A power analysis revealed that this sample size is sufficient to detect an expected effect size of hostile attribution bias on children's aggressive behavior of Cohen's d=0.33 (see meta-analysis by Verhoef et al., 2019) with 80% power (1- β) at a two-sided 5% α level and emotion regulation as an additional predictor. The inclusion criteria were (1) complete testing data in predictor variables (emotion recognition, emotion dysregulation, hostile attribution bias), (2) intellectual functioning within the normal range (IQ≥70) as assessed by a composite score of the Raven's Colored Progressive Matrices intelligence test (2002) and by the

Peabody Picture Vocabulary Test, 4th revision (Dunn & Dunn, 2015), and (3) a clinical consensus ICD-10 (WHO, 1994b) diagnosis of childhood autism, Asperger syndrome, atypical autism or pervasive developmental disorder not otherwise specified (PDD-NOS). Diagnosis was established by specialized and experienced multi-professional teams using a variety of measures and clinical judgment. Results of the Autism Diagnostic Observation Schedule (ADOS-G/ADOS-2; Lord et al., 2000; Lord et al., 2015; Merkle et al., 2016) were provided by caregivers or clinicians for 53 participants, who were eligible for the present study. To confirm the ASC diagnosis, the Autism Diagnostic Interview-Revised (ADI-R) short version (Hoffmann et al., 2015) was administered to all participants, and autism symptomatology was further assessed by using the Social Communication Questionnaire (Rutter et al., 2006). Interfering neurological/medical conditions (except for well-treated epilepsy) were ruled out by parental report. The subscale "Aggressive Behavior" of the Child Behavior Checklist (CBCL 4/18; German version; Döpfner & Arbeitsgruppe Deutsche Child Behavior Checklist, 2003) was used to assess clinical severity by age-group comparisons according to gender. Additionally, the frequency of aggressive and auto-aggressive behaviors ranging from 1: "never" to 4: "several times a week" was rated by parents in an unstandardized report.

Procedure

The children were assessed at three study centers. These were based at Humboldt–Universität zu Berlin, Germany (HU) and at two University Departments of Child and Adolescent Psychiatry and Psychotherapy with specialized outpatient clinics for children/adolescents with ASC in Augsburg (KJPP AUG), Germany, and Vienna (MedUni Wien), Austria. Additional participants were recruited through autism care units and parent organizations in Germany and Austria, as well as through a study website (www.zirkus-empathico.de). The assessment of the data reported here took place before the main intervention of the RCT. The questionnaires for parents were provided online on the SoSci-Survey platform (Leiner, 2014) and Lime Survey (Limesurvey GmbH, 2016). The RCT trial received ethical approval from the Ethics Committee at HU (2015/10/07) and the clinical authorities in the two outpatient clinics. Written informed consent was obtained from the children's legal guardians after receiving a detailed study description. Families received €7/hour as compensation.

Measures

Facial Emotion Recognition

We tested facial emotion recognition accuracy by using a series of 28 pictures of facial affect by Ekman and Friesen (1976). Pictures were presented on a computer screen and participants had to choose the correct emotion label out of a wordlist of six basic emotional states (happiness, sadness, fear, disgust, anger, surprise), intermixed with the word "neutral". Labels were displayed in random order. Each correctly identified emotion label scored one point, and the total sum comprised the accuracy score of the participant. Children with sufficient reading skills (7-10y) read by themselves. For younger/non-literate children, labels were read aloud and keys were pressed by the testing operator according to the child's verbal answer. Analyses with 73 children of the total RCT sample with valid data at baseline and 64 additionally measured TD children revealed good reliability of the Ekman & Friesen picture set (McDonald's Omega=0.97).

Emotion Dysregulation: Lability-Negativity

Dysfunctional emotion regulation was assessed by the "lability-negativity" subscale of the 15-item Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997), which measures lack of flexibility, anger dysregulation, and mood lability on a four-point rating scale (1: "never"; 2: "sometimes"; 3: "often"; 4: "almost always"). The ERC is a parent questionnaire, which is suitable for children aged 6–12 years. The second subscale ("emotion regulation", 8 items), which targets the expression of emotions, empathy, and constructive emotional self-awareness was not included in the present study because it was shown to be more strongly correlated with functional social skills, while the lability-negativity subscale was positively associated with hyperactive, externalizing, and internalizing behavior (Henriques Reis et al., 2016). The ERC shows good convergent validity with similar instruments and an adequate internal consistency (LabNeg: α=0.96; ER: α=0.83; Shields & Cicchetti, 1997).

Hostile Attribution Bias

The subscale "Disturbances in social information processing" (see Table 3.1) of the German Inventory of Aggressive Behavior in Children (FAVK; Görtz-Dorten & Döpfner, 2010) was used to assess hostile attribution bias. The scale targets aggression-

promoting attitudes, thought patterns, and response tendencies towards others as summarized under the concept of an aggression-supporting cognitive style by the SCIP models (Görtz-Dorten & Döpfner, 2010) in children between 4–14 years. It is rated separately with regard to aggressive tendencies (a) towards peers, and (b) towards adults on a four-point-rating scale ranging from 0: "not at all true" to 3: "definitely true." Ratings are subsequently summed up to two total scores with higher scores corresponding to more severe dysfunction. For the present study, we used the parent-report form and calculated a mean score of the peer and adult subscales to collapse both scores into one. The FAVK showed satisfactory internal consistency in non-referred samples as well as good discriminative validity and high internal consistency in a clinical sample (Cronbach's α=0.95; Benesch et al., 2013; Görtz-Dorten & Döpfner, 2010).

Subtypes of Aggressive Behavior

The parent questionnaire C-SHARP ("Children's scale of hostility and aggression: Reactive/Proactive"; Farmer & Aman, 2009, 2010) records aggressive behaviors and hostility in children with developmental disorders (such as ADHD and ASC) in 48 items (short–version) on five subscales: verbal aggression, bullying, covert aggression, physical aggression, and hostility (Table 3.1). In the current study, the hostility subscale was excluded from analyses because its items are similar to those of the ERC lability-negativity subscale (e.g., reacts suddenly or impulsively to minor provocations; shouts at others in anger). Each item of the C-SHARP is rated on a problem and a provocation dimension. The problem dimension assesses the frequency and severity of aggressive behavior in the last month on a scale ranging from 0: "does not occur" to 3: "severe and/or frequent problem". Higher sum scores describe more severe behaviors in the respective aggression subscale. The reliability and validity of the five problem scales of the English original version were shown to be sufficient, and the coefficient alpha ranged from moderate (0.74, physical aggression) to high (0.92, verbal aggression). Behaviors that were classified as present in the problem scale (≥1) were rated on the provocation dimension as either being a response to external circumstances (provoked; reactive, score: -2 to -1), or as being a planned action (not-provoked; proactive; score: +1 to+2), with zero being neutral. Following Farmer et al. (2015), the provocation scores were summed up for each subscale and categorized into one out of

three categories: “reactive” (sum less than zero), “neutral” (sum of zero; similar rates of reactive and proactive behavior), or “proactive” (sum greater than zero).

Table 3.1 Examples of items of the selected FAVK subscale as a measure of hostile attribution bias, ERC subscale lability-negativity, and C-SHARP subscales measuring subtypes of aggressive behavior.

FAVK: Disorder of Social-Cognitive Information Processing ***Here: Hostile attribution bias***	● If someone steps on his/her foot, he/she insinuates malicious intent. ● Feels annoyed or provoked by others when they look at him/her funny in his/her opinion. ● Thinks that many people do not like him/her and have a hostile attitude towards him/her. ● Often feels unfairly treated.
ERC: Lability-Negativity ***Here: Dysfunctional emotion regulation***	● Is easily frustrated. ● Is easily prone to angry outbursts/tantrums. ● Displays flat affect (expression is vacant and inexpressive; the child seems emotionally absent).
C-SHARP: Verbal Aggression	● Calls others insulting names in their absence. ● Calls others insulting names to their faces. ● Says ‘‘I hate [someone]’’ or other hurtful things.
C-SHARP: Bullying	● Breaks others’ things. ● Throws objects at others. ● Crowds others (invades their personal space)
C-SHARP: Covert Aggression	● Sneers, ‘‘makes faces’’ at others. ● Tickles or otherwise physically teases others, even after being asked to stop. ● If caught, denies having behaved badly.
C-SHARP: Physical Aggression	● Bites others. ● Pulls others’ hair. ● Pinches others.

***Note*: C-SHARP = Children’s scale of hostility and aggression: Reactive/Proactive; ERC = Emotion Regulation Checklist; FAVK = German Inventory of Aggressive Behavior in Children, Subscale: Disorder of Social-Cognitive Information Processing**

The internal consistency for this approach was acceptable (verbal aggression: α=0.81, bullying: α=0.81, covert aggression: α=0.72, physical aggression: α=0.68; Farmer et al., 2015). For the current study, the English original of the questionnaire was translated into German and back-translated into English in cooperation with the authors of the questionnaire. Cronbach's alpha for the four problem scales was good for verbal aggression (α=0.90), bullying (α=0.85), and covert aggression (α=0.83), but not for physical aggression (α=0.65).

Statistical Analyses

Pearson's correlation analyses were calculated to examine the links between aggression subtypes and demographic/ clinical characteristics (age, nonverbal/verbal IQ, autism social symptoms [SCQ]). All statistical tests were two-tailed and were conducted pairwise. The Bonferroni–Holm procedure was applied to correct significance thresholds to account for the accumulation of *type I error* due to multiple comparisons. Reports include corrected significance values (p), and r statistics for Pearson's r.

As proposed in our hypotheses, and in reference to the modified SCIP models (Lemerise & Arsenio, 2000;

Figure 3.1), we specified a path model including dysfunctional emotion processes (*emotion model*), which was compared with the classical version of the SCIP models (*classical model*; Crick & Dodge, 1994, 1996). The model comparison was used to evaluate if the more complex *emotion model* explains aggressive behaviors better than the *classical model*, which only relies on cognitive processes such as emotion recognition and hostile attribution bias. In our specific case, we specified the *classical model* by facial emotion recognition accuracy predicting hostile attribution bias (as assessed through the FAVK score), which in turn predicts different aggression subtypes (physical aggression, bullying, verbal aggression, and covert aggression as measured by the C-SHARP). The *emotion model* includes dysfunctional emotion regulation (as assessed by the ERC subscale lability-negativity) as an additional predictor of hostile attribution bias and aggression subtype with hostile attribution bias mediating the relationship between lability-negativity and aggression. Both models were specified through maximum likelihood estimation with robust standard errors and a Satorra-Bentler scaled test statistic. The MLM estimator was used because multivariate normality could not be assumed for every model. Model fit was validated by using

model fit indices (comparative fit index, *CFI*, root-mean-square-error of approximation, RMSEA, and standardized root-mean-square residual, *SRMR*). The emotion model was compared to the classical model based on *CFI* comparisons (*CFI classical model* minus *CFI emotion model*) with negative delta *CFI* pointing to a better ft of the *emotion model*; the cut-of for a meaningful difference was set to -0.002 (Meade et al., 2008). Additionally, a sample-size adjusted Bayesian information criterion (Adj. *BIC*) and Akaike information criterion (*AIC*) were used for model comparison, with smaller values indicating better model fit (Merkle et al., 2016). All comparisons were run separately for each form of aggressive behavior to explore the predictive value of the two proposed models for the different subtypes of aggression. Significance thresholds were corrected by applying the Bonferroni–Holm procedure to account for the accumulation of *type I error* due to multiple comparisons. Reports include corrected significance values (*p*). All analyses were performed in R (Version 1.3.1073, R Core Team, 2018b).

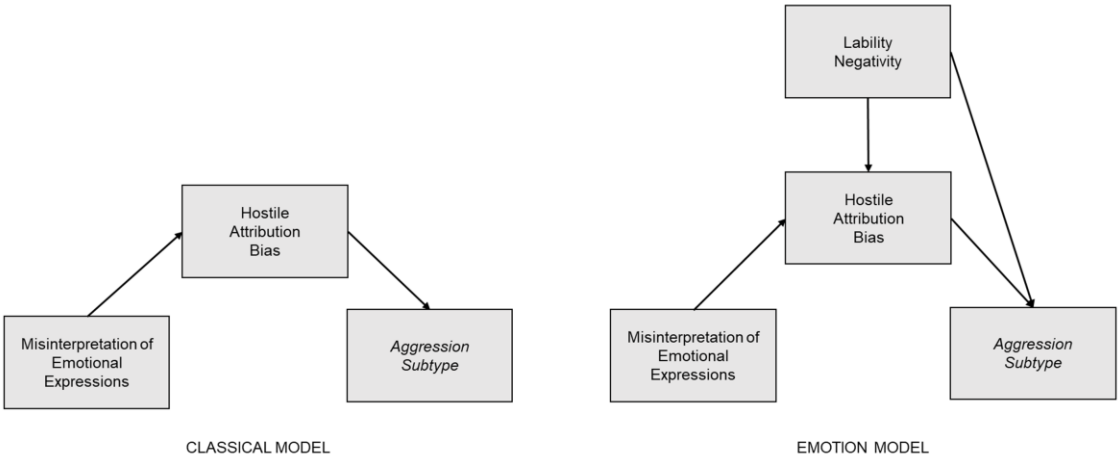


Figure 3.2 Path models testing the emotion model (H1; compare Lemerise & Arsenio, 2000) against the classical model (compare Crick & Dodge, 1994, 1996; Huesmann, 1998)

Results

Sample Characteristics

The demographic and clinical characteristics of n = 60 children are displayed in Table 2. FAVK data was available for 60 participants, and 55 parents rated their child on the C-SHARP aggression assessment. The cut-of (T>70) for clinically significant aggression on the CBCL subscale was met by 55% of the total sample (n=33) with the majority (62%) showing aggressive behaviors several times a month (25%), or several

times a week (37%). The most prevalent subtypes were covert aggression (*M* =9.0, *SD* =5.4), bullying (*M* =8.9, *SD*=6.8), and verbal aggression (*M*=8.7, *SD*=7.8), while physical aggression showed the lowest prevalence (*M*=2.2, *SD* = 2.5). There was no significant difference between boys and girls for all forms of aggressive behavior (verbal aggression: $t(54)=0.99$, $p=0.341$; bullying: $t(54)=0.35$, $p=0.730$; covert aggression: $t(54)=0.62$, $p=0.547$, physical aggression: $t(53)=1.49$, $p=0.154$). Analysis revealed that children were more likely to engage in reactive than proactive aggression as reflected by the C- SHARP provocation dimension (Table 3.2).

Correlation Analyses

After correcting for multiple comparisons, neither age nor nonverbal or verbal IQ or autism social symptomatology (SCQ) correlated significantly with the aggression subtypes or the predictor variables (emotion recognition, hostile attribution bias, lability-negativity) (Table 3.3).

Path Analyses

Path analyses revealed an acceptable to a good fit for the *classical model* in all aggression subtypes (Table 3.4). In favor of H1, model comparisons revealed a better model fit for the *emotion model* when compared to the *classical model* as indicated through *CFI*, *AIC*, and *BIC* values. This means that the predictive power of the models was enhanced when lability-negativity was included as a second predictor of hostile attribution bias and the respective aggression subtypes. By applying the *emotion model*, and after correcting for multiple comparisons (Table 3.4, Figure 3.3), we found hostile attribution bias being positively predicted by emotion recognition accuracy (standardized estimates with confidence intervals, $b=0.283$, $p=0.032$, [0.074, 0.496]) and lability-negativity ($b=0.594$, $p<0.001$, [0.390, 0.797]). Hostile attribution bias was a significant positive predictor of verbal aggression ($b=0.545$, $p<0.001$, [0.375, 0.715]) and covert aggression ($b=0.540$, $p<0.001$, [0.308, 0.772]), but not of bullying ($b=0.332$, $p=0.124$, [0.030, 0.634]) and physical aggression ($b=0.126$, $p=1.00$, [-0.227, 0.478]). Lability-negativity had a direct positive effect on verbal aggression ($b=0.272$, $p=0.004$, [0.113, 0.430]), bullying ($b=0.403$, $p=0.008$, [0.143, 0.662]), and covert aggression ($b=0.356$, $p=0.016$, [0.116, 0.596]), but not on physical aggression ($b=0.321$, $p=0.108$, [0.036, 0.607]). Hostile attribution bias partly mediated the relationship between lability-negativity and verbal, or respectively, covert aggression.

Table 3.2 Demographics and clinical characteristics of the total sample, N = 60

Variable	*M*	*SD*	*Range*
Age (y)	8.0	1.5	5.3 – 10.8
CPM, Nonverbal IQ	105.8	19.1	67.0 – 135.0
PPVT, Verbal IQ	101.7	17.7	65.5 – 134.5
ADOS-G, Total (N = 45)	11.7	4.0	4.0 – 20.0
ADOS-2, Total (N = 8)	10.8	2.9	8.0 – 15.0
SCQ, Total Score	21.2	6.5	3.0 – 35.0
ADI-R short	5.9	5.9	2.0 – 8.0
	N	**%**	
Males	50	83.3	
ASC Diagnosis (ICD-10)			
Childhood Autism	8	13.3	
Asperger Syndrome	34	56.7	
Atypical Autism	4	6.7	
PDD-NOS	14	23.3	
Comorbidity			
None/Unknown	45	75.0	
ADHD/ADD	10	16.7	
Epilepsy	1	1.7	
Other	4	6.7	
CBCL Subscale Aggressive Behavior: Above clinical cut-off (T ≥ 70)	33	55.0	
Parent Report, Frequency of Aggression			
Never	13	22.8	
Infrequent	9	15.8	
Several times per month	14	24.6	
Several times per week	21	36.8	
C-SHARP Provocation Scale: Verbal Aggression			
Reactive	34	28.1	
Reactive-Proactive	5	9.4	
Proactive	7	59.4	
No verbal aggression	4	3.1	
C-SHARP Provocation Scale: Bullying			
Reactive	32	65.3	
Reactive-proactive	10	20.4	
Proactive	7	14.3	
No bullying	0	0.0	
C-SHARP Provocation Scale: Covert Aggression			
Reactive	26	52.0	
Reactive-proactive	6	12.0	
Proactive	16	32.0	
No covert aggression	2	4.0	
C-SHARP Provocation Scale: Physical Aggression			
Reactive	19	35.0	
Reactive-proactive	10	18.9	
Proactive	7	13.2	
No physical aggression	17	32.1	

Note: ADHD/ADD = Attention Deficit Disorder; ADI-R short = Autism Diagnostic Interview-Revised short version; ADOS-G = Autism Diagnostic Observation Scale Generic, overall total (communication + reciprocal social interaction); ADOS-2 = Autism Diagnostic Observation Scale-2, overall total (social affect + restricted and repetitive behavior); ASC = Autism Spectrum Conditions; CBCL = Child Behavior Checklist; CPM = Colored Progressive Matrices; C-SHARP = Children's scale of hostility and aggression: Reactive/Proactive; PPVT = Peabody Picture Vocabulary Test; PDD-NOS = Pervasive developmental disorder not otherwise specified; SCQ = Social Communication Questionnaire.

Table 3.3 Correlation matrix (Pearson's *r*) between demographic variables (age, verbal and nonverbal IQ, autism social symptomatology), predictors (emotion recognition, lability-negativity, hostile attribution bias), and aggression subtypes.

	Age	**CPM**	**PPVT**	**SCQ**	**Emo Rec**	**Lab Neg**	**HAB**	**Verb Aggr**	**Bully**	**Cov Aggr**
Age										
CPM	-.18									
PPVT	-.02	**.47								
SCQ	.27	-.21	-.12							
EmoRec	.35	.33	***.54	-.12						
LabNeg	.03	-.13	.08	.26	-.01					
HAB	.23	.08	.26	.02	.31	***.53				
Verb Aggr	.20	.03	.08	.18	.01	***.59	***.70			
Bully	-.17	.13	.24	-.02	..08	***.59	***.59	***.65		
Cov Aggr	.19	.10	.21	.18	.16	***.67	***.67	***.80	***.76	
Phys Aggr	-.11	.29	.28	.15	.13	.39	.39	.41	***.72	***.54

Note: Bully = bullying; CovAggr = covert aggression; CPM = Colored Progressive Matrices (nonverbal IQ); EmoRec = emotion recognition; HAB = hostile attribution bias; LabNeg = Lability-Negativity; PhysAggr = physical aggression; PPVT = Peabody Picture Vocabulary Test (verbal IQ); SCQ = Social Communication Questionnaire (autism social symptomatology); VerbAggr = verbal aggression;
Significance thresholds were corrected for multiple comparisons by using the Bonferroni-Holm procedure.
*$p < .05$, **$p < .01$, *** $p < .001$

Table 3.4 Model fit indices (*CFI, AIC*/Adj. *BIC*) for the *classical model* and the *emotion model*

	CFI	*AIC*	Adj. *BIC*	*CFI*	*AIC*	Adj. *BIC*	Δ *CFI*
VerbAggr	.95	676.7	672.1	1.00	651.9	645.1	-.05
Bullying	1.00	676.8	672.2	1.00	648.2	642.4	.00
CovAggr	1.00	629.3	624.7	1.00	596.9	590.1	.00
PhysAggr	1.00	570.1	565.5	1.00	550.8	543.8	.00

Note: AIC = Akaike information criterion; Adj. BIC = sample-size adjusted Bayesian information criterion; CFI = comparative fit index; CovAggr = covert aggression; HAB = hostile attribution bias; PhysAggr = physical aggression; Model comparison was done by subtracting fit indices (CFI) of the *emotion model* from those of the *classical model* with negative indices indicating a better fit. Lower AIC and adjusted BIC indicate a better fit of the respective model.

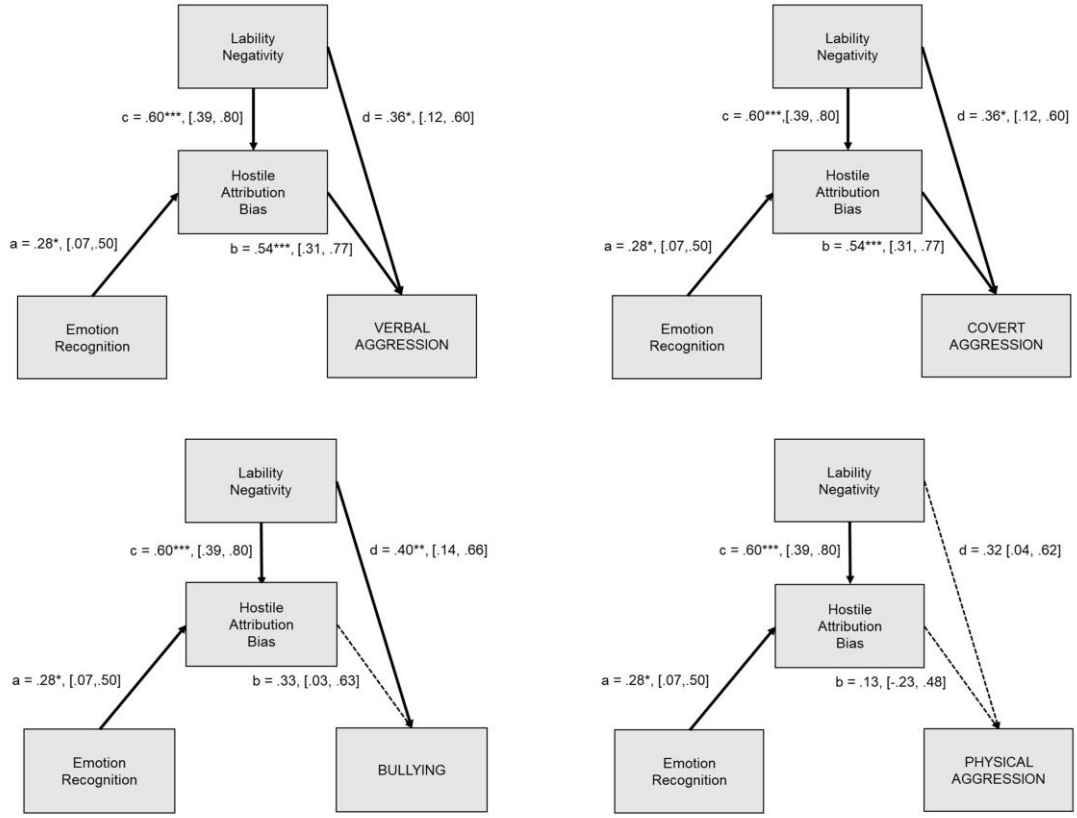


Figure 3.3 Results of the *emotion model.*

Regression coefficients (*β*s) from path models depicting **a** the direct effect of emotion recognition on hostile attribution bias, **b** the direct effect of hostile attribution bias on the respective aggression subtype, **c** the direct effect of lability-negativity on hostile attribution bias, and **d** the direct effect of lability-negativity on aggressive behavior subtype. Standardized estimates and confidence intervals are displayed in parenthesis. **p* < .05, ***p* < .01, *** *p* < .001 (Bonferroni-Holm corrected)

Discussion

We aimed gaining a better understanding of the socio-emotional sources of aggressive behaviors, and specifically the impact of dysfunctional emotion regulation, in pre-and primary school children with autism, hoping to inform the development of customized interventions for target groups and their families. We based our approach on the theoretical considerations of the classical version of the SCIP models (Crick & Dodge, 1994, 1996; Huesmann, 1998) in comparison to its revised version (Lemerise & Arsenio, 2000; here: *emotion model*). Hence, we hypothesized in reference to the *classical model*, that misinterpretation of emotional expressions would predict hostile attribution bias, which in turn, should enhance different aggressive behaviors as measured via the C-SHARP parent questionnaire. In addition – and by referring to the *emotion model* –, we hypothesized that parent-rated lability-negativity, as a symptom of

dysfunctional emotion regulation, should have an additional impact on hostile attribution bias and different aggressive behaviors.

Our results were multifaceted. First, emotion recognition accuracy predicted the tendency to attribute hostile intent positively in all four subtypes of aggression. Second, for all four subtypes of aggression, we found the more complex emotion model including lability-negativity, to describe our data better than the classical model without lability-negativity. Third, lability-negativity was directly related to all aggression subtypes, *except* for physical aggression. Further, the positive impact of lability-negativity on aggressive behavior was partly mediated by hostile attribution bias in the case of verbal and covert aggression, while hostile attribution bias did not affect physical aggression and bullying. Overall, our results confirm our hypothesis for verbal and covert aggression: lability-negativity had a direct influence on the respective aggression subtype as well as an indirect influence via hostile attribution bias. Due to the absent effect of hostile attribution bias on bullying, the hypothesis was not fully confirmed here. No confirmation was found for the influence of lability-negativity and hostile attribution bias on physical aggression. Nevertheless, these findings underline a complex interplay between hostile attribution bias and emotion dysregulation, which differently affects aggression subtypes. In the following, we interpret these findings in the context of past aggression research in children with TD and with ASC.

The Impact of Emotion Recognition on Hostile Attribution Bias

According to the SCIP, the first step of social-cognitive information-processing is the correct encoding and processing of others' emotions to make moral judgments (Chester & Langdon, 2016; Lemerise & Arsenio, 2000). Previous studies identified positive relationships between emotion recognition and later SCIP steps (e.g., problem identification and solution, goal clarification, response selection) in TD children with and without mild intellectual impairments (Bauminger et al., 2005; Meyer et al., 2006; Schultz et al., 2004; van Nieuwenhuijzen & Vriens, 2012) and children with autism (Russo-Ponsaran et al., 2015). In line with this, a lack of cognitive empathy (understanding of others' emotions; Dziobek et al., 2008) was related to higher aggressive tendencies in some studies with TD children (Euler et al., 2017; Mayberry & Espelage, 2007). Hence, it was rather unexpected that children with better emotion recognition skills were rated as having a more pronounced tendency to attribute hostile intent to others in our autistic sample. Interestingly, Pouw et al. (2013) reported a

positive relationship between self-rated cognitive understanding of others' emotions and aggression levels in children with autism but not TD children. They argued that emotional content of any kind, such as when correctly understanding the emotions of others, could activate empathic arousal, which is perceived as aversive (personal distress) due to dysfunctional emotion regulation and therefore triggers aggressive behaviors. However, from a longitudinal perspective, it seems plausible, that the causal relationship between the variables is reversed: a child might have developed a tendency to attribute hostile intent in the first place due to frequent negative social experiences (e.g., being teased, or being excluded because of autism-related social impairments; see Ziv et al., 2014 for further causes). As a consequence, the child might have trained emotion recognition skills/cognitive empathy more intensively to detect potentially hostile or aggressive cues early (compare hypervigilance to hostile cues, Helmsen et al., 2012) to prevent negative experiences. Indeed, Embregts and van Nieuwenhuijzen (2009) found boys with autism and mild intellectual impairment to strongly focus on negative and emotional information in video-presented vignettes of social situations. Longitudinal studies are therefore needed to further disentangle the complex relationship between emotion understanding and aggression (compare Quan et al., 2019).

The Interplay of Hostile Attribution Bias and Lability-Negativity

We observed the proposed interplay between dysfunctional emotion regulation and hostile attribution bias for verbal aggression (e.g., saying hurtful things, insulting others) and covert aggression (e.g., physically teasing others against their will, sneering at others). Thus, the revised SCIP models (here: *emotion model*, Lemerise & Arsenio, 2000) seem to be a valid approach for explaining these more complex aggression subtypes in children with autism. Interestingly, due to the missing impact of hostile attribution bias on bullying and physical aggression in our sample, the revised SCIP models might not be informative for the more physically or overtly expressed aggression subtypes. This is surprising given studies demonstrating significant impairments in SCIP operations in children with autism when compared with TD children including hostile intent attribution in ambiguous situations (e.g., Flood et al., 2011; Russo-Ponsaran et al., 2015; Ziv et al., 2014), and studies demonstrating relations between hostile intent attribution and aggressive behavior in TD children (Martinelli et al., 2018; Verhoef et al., 2019). However, Helmsen et al. (2012) reported no association

between hostile intent attribution and aggression in TD children. A study by Coy et al. (2001) further found that preschool boys with oppositional defiant disorder were no more likely to attribute hostile intentions in ambiguous situations than boys of the control group. Finally, bullying, which is defined as malicious actions to strategically harm another person in order to gain or preserve power or reputation (Volk et al., 2017), is thought to arise from deficiencies, or persistent biases in the early stages of the SCIP (Crick & Dodge, 1999). In contrast to this view, current studies (e.g., Guy et al., 2017) do not support that TD bullies make more hostile attributions in response to ambiguous social information, which would indicate biases in early SCIP operations.

These mixed results might in part be due to differences in methodology such as different measurements of emotion processes, hostile attribution bias, and aggressive behavior (see Helmsen et al., 2012). Furthermore, it may be relevant to operationalize hostile attribution bias analog to the aggression subtype in focus. In their meta-analysis, Martinelli et al. (2018) found *physically* aggressive TD children to attribute hostile intent especially in response to *physically provocative* situations (e.g., when being hit with a ball). In contrast, children engaging in *relational* aggression (infliction of harm via actual or threatened damage to, or control of, relationships; Crick & Grotpeter, 1995) primarily displayed *relational* hostile attribution bias (e.g., in response to vignettes targeting ambiguous social situations like not being invited to a friend's birthday). The items of the FAVK subscale that were used here (e.g., thinks that many people do not like him/her and have a hostile attitude towards him/her; often feels unfairly treated) seem to address hostile intent attributions, which are more closely associated with complex aggression subtypes such as verbal or covert aggression than with physical aggression. Since physical hostile attribution bias was not specifically targeted here, the assumption that a tendency to attribute hostile intent might have an impact on the relationship between lability-negativity and physical aggression in children with autism should be reevaluated with a broader set of hostile attribution bias items.

Furthermore, our results for bullying, with lability-negativity having an impact on this subtype while hostile attribution bias does not, underline the interpretation of the C-SHARP bullying subscale by its authors Farmer and Aman (2010, 2011a). Based on their findings in children with autism, they suggested that the items of the bullying subscale (e.g., throwing objects at others, invading personal space) might not represent

malicious actions intended to harm other persons in this population, but rather impulsive, socially inadequate responses to stressful environmental conditions. More plastically, the "children engage in physical 'communication' when frustrated" (Farmer & Aman, 2010, p.278) because they are incapable of alternative actions (Mazza et al., 2017) due to autism-related social skills impairments (e.g., difficulties to communicate desires, or personal needs in adequate ways). Therefore, we could potentially conclude that our results for the bullying subscale might *generally* account for simple physical acts of aggression towards others, with lability-negativity being a prominent predictor. Additional predictors related to social interaction and communication impairments potentially having an impact on later SCIP operations (e.g., response access/construction; response decision, see

Figure 3.1) should be investigated in future research.

Surprisingly, the C-SHARP subscale, which explicitly targets physical aggression, was not associated with lability-negativity. Besides its questionable reliability in our sample (Cronbach's Alpha=0.65; but 0.74 in Farmer & Aman, 2010), it might be that the low physical aggression rates (M=2.18, SD=0.33), with 17 children (32%) showing no physical aggression at all, resulted in low variance and therefore insufficient statistical power to detect the proposed relations in the rather small sample (n=54). These low physical aggression rates might be due to a low representation of children with intellectual impairment, limited language ability, and low adaptive functioning; factors which are associated with an increased risk for aggressive behavior for individuals with autism (A. P. Hill et al., 2014; Mazefksy et al., 2013). Farmer et al. (2015) found physical aggression being related to lower IQ levels in autistic children, while more complex aggression subtypes (verbal/covert aggression) were associated with higher IQ, better adaptive behavior, and older age. However, we did not observe correlations between demographic/clinical variables (autism symptom severity, age, verbal/nonverbal IQ) and the aggression subtypes in our sample, which shows a relatively narrow age range and (high) IQ level when compared to Farmer et al. (2015). We might conclude that, especially the more physically expressed subtypes (here: bullying and physical aggression), should be targeted with carefully designed longitudinal studies to disentangle a range of different potential predictors (dysfunctional emotion regulation, hostile attribution bias, lack of social skills, etc.) in larger samples under the theoretical perspective of the SCIP models.

Limitations

By using a cross-sectional mediation approach, the developmental trajectories and directionality of the relations between risk factors (here: emotion recognition, hostile attribution bias, lability-negativity) leading to aggressive behaviors cannot be disentangled sufficiently to fully understand causal relationships. According to Cole and Maxwell (2003; 2007) mediation consists of causal processes that unfold over time. Thus, using cross-sectional approaches to mediation typically generate substantially biased estimates of longitudinal parameters (Maxwell & Cole, 2007). As pointed out by Helmsen et al. (2012), it is most likely that the relationship between emotion regulation, social information processing, and aggressive behavior is bidirectional. Therefore, longitudinal studies are needed to investigate the causal direction of these relationships. Second, we can not rule out that observer biases confounded relationships between the different constructs. However, we had to largely rely on parent questionnaires due to the young age of the children. We encourage future studies to use more objective measures to assess emotion regulation abilities and hostile attribution bias (e.g., pictorial interviews using vignettes, compare Helmsen et al., 2012; Mazza et al., 2017; Ziv et al., 2014). Lastly, we have not included a typically developed comparison group, given that we relied on data from an RCT including only children with autism. Thus, we cannot make inferences about the specificity of the reported results. However, much is known about factors predicting aggressive behavior in TD, which we sought to supplement with insights from autism in the current work as a preliminary step. Nevertheless, future research should compare autistic to TD children to investigate between-group differences in the pattern of the interplay of these socio-emotional predictors of aggression.

Implications

Even though our understanding is still limited, the results reported here may have implications for designing and selecting targeted interventions for children with autism and comorbid aggression as well as for future research on the topic. First, our study showed the important role of emotion regulation for verbal and covert aggression as well as for bullying. Thus, emotion regulation competencies (e.g., awareness of own emotions, impulse/anger control, functional emotion regulation strategies) should be given priority in therapy (compare Helmsen et al., 2012; or novel technology-based approaches like “Zirkus Empathico”; Kirst et al., 2020). This might also strengthen

autistic children to better deal with negative arousal potentially induced by others' emotional displays (Kliemann et al., 2013; Pouw et al., 2013) which could, in turn, enable more fruitful training of understanding others' socio-emotional cues. Given our results, emotion regulation competencies may also diminish hostile attribution biases, and thus exert additional beneficial effects on the reduction of externalizing behavior via this indirect route. Since particularly emotionally engaging social situations were found to elicit the automatic and emotional processes that activate hostile attribution bias, interventions should assess and target biases in similar and naturalistic situations (Verhoef et al., 2019). Additionally, the specific pattern of aggressive behavior in children with autism should be carefully identified for each patient to allow individualized interventions. Beyond assessing the most prevalent aggression subtypes and their function for the individual, the nature of hostile attribution biases should be examined to allow customized and effective interventions. Behaviors summarized by the bullying and potentially by the physical subscale might be effectively reduced by strengthening social skills in addition to emotion regulation strategies, while more complex aggression subtypes such as verbal and covert aggression could be targeted by identifying and modifying aggression-promoting attitudes, thought patterns, and response tendencies towards others through cognitive-behavioral approaches. Indeed, interventions modifying SCIP in TD children (e.g., Hudley & Graham, 1993; Lochman & Wells, 2002) have been proven relatively effective (Kazdin, 2003).

Finally, our behavioral findings of the interplay between hostile attribution bias, emotion regulation, and abnormal behavior should be further investigated from different perspectives (e.g., socio-cognitive, developmental, neurobiological) in autism samples. So far, a prominent role of emotion dysregulation and related personal traits such as impulsivity in moderating the relationship between social cognition and aggression has been demonstrated cross-sectionally (e.g., Musher-Eizenman et al., 2004) and longitudinally in TD individuals. For example, Blandon et al. (2010) and Halligan et al. (2013) reported a causal role for problematic regulation of negative emotions at age one and, respectively, two, and the etiology of externalizing psychopathology at age five, and seven. By using a longitudinal approach in a large adolescent sample (N =585), Fite et al. (2008) found impulsivity moderating the relationship between cognitions (here: positive endorsement of aggressive responses in hypothetical, ambiguous situations) at age 11–13 and aggressive behavior at age 14–17. Interestingly, only moderately to highly impulsive individuals showed a significant association between aggression-prone

cognitions and aggressive behavior. Likewise, Goldweber et al. (2011) suggested that individual differences in executive functions (here: inhibiting behavior, shifting attention, and controlling emotions) may account for stability in aggressive social information processing (SIP). They found children aged 7–13 years with a stable aggressive SIP pattern exhibiting more executive function problems than children who showed a decline in aggressive SIP over one year.

From a neurobiological perspective, the medial prefrontal cortex (mPFC) as the "cortical control board" (Xu et al., 2019, page 2), has been found to play an essential role for emotion regulation and, among others, for sociability (Xu et al., 2019). In addition to autism, abnormal activity in the mPFC has been shown for other psychiatric disorders (e.g., depression, anxiety, schizophrenia, addiction; see review by Xu et al., 2019). Identifying the specific pattern of cortical activation in response to emotion regulation processes inherent to autism may help to differentiate between autism and potentially co-occurring psychiatric disorders (e.g., depression, anxiety). Furthermore, localizing distinct cortical areas in the mPFC related to autism-specific deficits in emotion regulation processes (compare findings for major depression, Rive et al., 2013) and studying their connections to regions involved in higher-order socio-cognitive processing may result in a more in-depth understanding of the interrelated abnormalities underlying aggressive behavior in some individuals with autism.

Conclusion

Taken together, the revised SCIP models (Lemerise & Arsenio, 2000) seem to be a promising approach for investigating various risk factors and their interplay for aggressive behaviors in children with autism. It demonstrated a prominent role of dysfunctional emotion regulation in causing different aggression subtypes, which might be differently affected by a tendency to attribute hostile intent to others. By applying the model, future studies with bigger samples, control groups, and longitudinal designs should identify distinct patterns of aggressive behaviors by investigating the interplay of various socio-emotional predictors in children with autism.

Acknowledgments The authors thank the children and their caregivers who made this research possible. We are especially thankful to Prof. Dr. Michele Noterdaeme (KJPP Augsburg) for her collaboration and to Prof. Dr. Birgit Elsner (University of Potsdam) for supervising the third author's Master's thesis, on which the current article is based. We thank Dr. Sabine Wilde-Etzold (KJPP Augsburg) and Mag. Barbara Kainz (MedUni Wien) for data collection. Furthermore, we extend our gratitude to various pediatric services, autism centers, outpatient clin- ics, child psychiatrists, and parent organizations in Germany and

Aus- tria for supporting the recruitment of participants. Finally, the authors direct their sincere thanks to the Stiftung Irene (Hamburg, Germany), the Berlin School of Mind and Brain, and the Medical-Scientific Funds of the Mayor of Vienna (Austria) for financing the first author's PhD scholarships and the fourth author's position.

Funding Open Access funding enabled and organized by Projekt DEAL. Stiftung Irene (Germany), Berlin School of Mind and Brain (Germany), Medical-Scientific funds of the mayor of Vienna (Austria).

Declarations

Conflict of interest The authors declare no conflict of interest.

Published in the conference proceedings of *IEEE 16th International Conference on Advanced Learning Technologies Technologies (ICALT), 2016: 448-452*

4 Zirkus Empathico. Mobile Training of Socio-Emotional Competencies for Children with Autism

Dietmar Zoerner[1], Jan Schütze[1], Simone Kirst[2], Isabel Dziobek[2] and Ulrike Lucke[1]

1 Department of Computer Science, University of Potsdam, Potsdam, Germany

[2] *Clinical Psychology of Social Interaction, Berlin School of Mind and Brain, Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany*

The aim of the mobile app „Zirkus Empathico“ is to strengthen socio-emotional competences in pre- and primary school children. It`s holistic and natural training concept is based on current results of empathy research. Pilot testing of the app revealed it`s good usability and comprehensibility. The effectiveness of “Zirkus Empathico” is currently investigated in a longitudinal clinical study with children aged 5 to 10.

Introduction and Related Work

Empathy is the ability to share the internal feelings of other people (Dziobek et al., 2008)[4] while recognizing that the other person is the source of that shared feeling (Decety & Lamm, 2009). Several studies show that individuals with autism are mainly suffering from reduced cognitive empathy, i.e., the difficulty to recognize emotions of others from their gestures and facial expressions (Bons et al., 2013; Harms et al., 2010). Moreover, current neuro-physiological and behavioural experiments point to a difference in emotional empathy, i.e., the perceived feeling with other people. Effective predictors for reduced empathy seem to be the amount of empathic distress in social interactions (Dziobek et al., 2008; Minio-Paluello et al., 2009; Rogers et al., 2007) as

[4] Note: the original citation style of this article has been changed to the one used in this work (APA) .

well as individual problems in categorizing and verbalizing own emotions (Bird et al., 2011). Thus, individuals with autism often show reduced or unexpected behavior when processing own and other`s emotions (Dziobek et al., 2008), which causes problems in establishing social relationships (Krasny et al., 2003). This results in low quality of life throughout the lifespan. Thus, early training of empathic competences is highly important for children with autism (Herbrecht & Bölte, 2009).

The approach of IT-based training of cognitive empathy, especially regarding the recognition of facial emotions, has provided several successful developments during the last decade (Bölte et al., 2002; Golan et al., 2010; Golan & Baron-Cohen, 2006; Harms et al., 2010; LaCava et al., 2007; LaCava et al., 2010; McHugh et al., 2011; Silver & Oakes, 2001; Tanaka et al., 2010). In general, such IT-based trainings focus mainly on practicing specific skills, ways to act or think in certain situations, rather than on learning abstract facts or procedures. Moreover, different forms of assessment can be found, but usually not with a separation in correct and wrong answers, but rather in more or less appropriate behaviour (short-term) or strategies (mid- to long-term). Such training in simulated scenarios as well as their integration in educational games is an establised approach in e-learning (Rieber, 2012). This experience can be exploited for the development of IT-based training systems in autism. Indeed, as shown in recent studies, IT-based systems are effective especially for individuals with autism. Besides the primary learning goals, a higher level of motivation and attention could be reached (Bölte, 2009). Computers offer an efficient and effective training environment, since they fulfill the needs of people with autism regarding structure, consistency, and predictability. Thus, this group of learners often has an increased interest in technical systems. Furthermore, the limited social demands of computer systems reduce stress and allow for learning in one’s own pace (Bölte et al., 2010; Golan & Baron-Cohen, 2006).

Despite positive results, there is a need for further development: Previous systems are solely focussing on cognitive empathy, leaving problems in emotional empathy and the basal processing and verbalizing of own emotions unsolved. Beyond that, the generalization of skills to everyday life is a severe problem for people with autism (Feineis-Matthews & Schlitt, 2009) that is not targeted by previous trainings. This might explain why studies yielded only limited clinical relevance for general social behaviour (Bölte et al., 2010), which is tightly associated with empathy. Considering

the dynamics of emotions in real-life, the stimuli used in previous trainings (mainly photos of faces showing a certain emotion) are rather artificial, so that generalization isn`t supported effectively. In contrast to this, the software SCOTT (Kliemann et al., 2011) is using natural video stimuli from a variety of persons. However, SCOTT is highly complex and not suited for children. All in all, the development of a naturalistic and age-appropriate software for training empathy in children with autism is highly needed.

Besides a number of IT-based trainings from different fields of psychotherapy (Baños et al., 2011; Köppen et al., 2013) and first frameworks for the development of therapeutic software (Gutschmidt et al., 2013), literature provides some guidelines for digital content creation in psychotherapy (Miclea et al., 2009). Moreover, e-learning research from computer science may contribute to future therapeutic software with design procedures (Lucke & Castro, 2016), architectural patterns, description languages, analytic tools and so on. This article contributes to the field with a description of the therapeutic and gaming concept to train empathy of autistic children (section 0) as well as the resulting approach for the implementation (section 0). The app is briefly presented (section 0), and first results of evaluation are given (section 0). The article concludes with a summary and further work discussed in section 0.

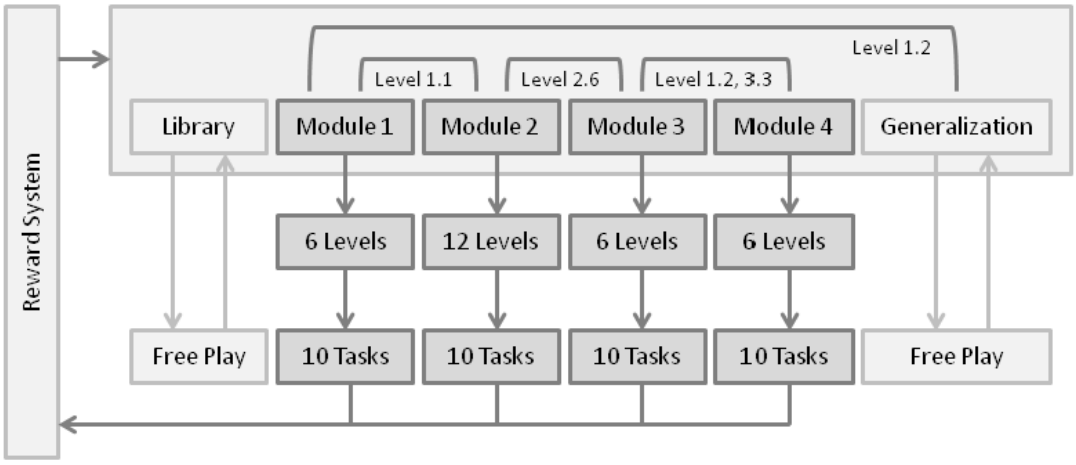


Figure 4.1 The game concept consists of four training modules, a generalization module and a library with information in emotions. The modules and levels are available depending on the learning success in previous tasks

Game Concept

The mobile app „Zirkus Empathico“ presented in this paper is based on a holistic and naturalistic concept to train socio-emotional competences in younger children.

Learning Goals

Following existing guidelines (Miclea et al., 2009), the app consists of four separate training *modules* focussing on different aspects of social cognition as well as a module to generalize the previously learned behaviour into daily life (Figure 4.1). First, the recognition and verbalisation of one`s own emotions (Module 1) is established as a basis of the empathic competencies, which are addressed in the following modules. The two modules focussing on cognitive empathy train the recognition of other`s emotions from videotaped facial expressions (Module 2) as well as from videos showing the emotion triggering context (Module 3). For strengthening emotional empathy, own emotions in reaction to the emotion of another person have to be described (Module 4). Appropriate reactions in response to the other`s emotion are addressed to reduce empathic distress and thus enhances the children`s competence to act prosocially.

The transfer into daily life is supported by the naturalistic *video stimuli* (facial expressions and context videos) in the app. The combination of the visual and auditory input triggers the children`s emotions stronger than it would be the case in using only photographies as stimuli. All video stimuli focus on visual-perceptual aspects of empathy (emotional expressions, emotional sounds like “oh!”), verbal information about the other`s emotional state was left out consciously. Thus, even children with low verbal ability can benefit from the training. Since the children`s parents participate actively in the training as *tutors,* the transfer is further enhanced due to their interaction. First, in demonstrating own emotional and empathic experiences, the tutor functions as role model, which is especially important for the understanding of emotional empathy and the acquisition of empathic acts. Second, the app provides a structured possibility to communicate about each other`s inner life (i.e. visualization of emotions), which enhances the reciprocal understanding and connects the training content to the children`s daily emotional experiences. Building a bridge between the app and the real world, the tutor facilitates the use of the generalization module to establish empathic behaviour in daily routine.

Therapeutic Aspects

The conception of the training app is based on principles of behavioural therapy for individuals with autism (Bernard-Opitz, 2009a). Considering the needs and cognitive capacities of the target group, a clear and unambiguous *design* without distracting details as well as elements to maintain the children`s attention and motivation is required: A fox as a supportive non-player character guides the children through the training, he explains, helps, and motivates the children. The audio examples („fox“) are characterized by precise, non-metaphoric wording and simple grammar. The verbal content is visualized by icons, which allows even pre-school children a self-determined gaming experience. Following principles of behaviour therapy (Bernard-Opitz, 2009a), so called prompts (supportive hints) are implemented in the *feedback system* in order to prohibit frustration: The first incorrect answer leads to a general hint, while the second incorrect answer brings up a hint that is specific to the given emotion and thus leads directly to the adequate solution.

Within the modules, the difficulty of the tasks rises step by step, depending on the previous success of learning. In analogy to the usage of behaviour intensifiers in established approaches in autism therapy, a level-based *reward system* (see Figure 4.1) visualizes achieved goals and keeps the player motivated: Each level consists of ten tasks represented by ten slices of a cake. For each task solved, the children receive one slice of the cake. Finishing a level activates the next one, and the child is automatically taken into a circus scenario (reward system) to select an animated object to complete the circus scenery. The design of the reward items is based on typical preferences of autistic children for certain toys (e.g. spinners, whirligig, toys with audio-visual effects, technical objects).

Implementation

The challenges of the technical realization of the game concept presented above consist of selecting suitable devices, defining an appropriate software technology, and establishing an effective development method for the interdisciplinary team. A suitable *device* must meet the requirements of the scientific intervention study as well as the special needs of the target group. Thus, the most important criteria for “Zirkus Empathico” were a high mechanical robustness, a high usability for children, and a

good handling in the training situation. Mechanical robustness results from the special risks coming from young user groups, i.e. spilling liquids, drops, or hits. Usability for kids comprises a large display and an easy, precise touch input. Appropriateness for the scientific study as well as for later therapeutic use leads to a demand for moderate prices, in order to be affordable for a larger target group. Moreover, high mobility (in terms of accu capacity / duration) and low efforts for network / power connectivity, support, and maintenance are required. This is given by many current tablet-sized devices, whereas Andriod-based ones are generally cheaper than iOS-based tablets. Considering the above-mentioned criteria the Sony Xperia Z2 was selected for the study.

Figure 4.2 Software architecture and technologies are aligned to an easy maintenance and extendability of the app.

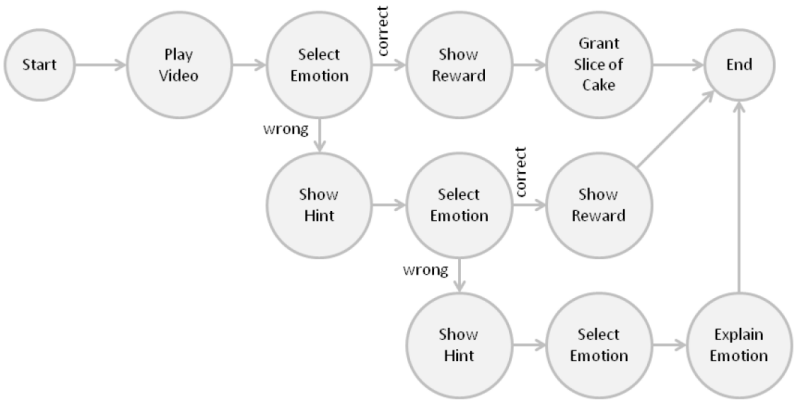


Figure 4.3 Single steps of a task are realized as finite state automata

With that, Android was set as the target platform for the study. Selecting an appropriate *software technology* should also consider the capabilities of current and future developers in order to ensure an effective and sustainable project. That is why developing a hybrid app was favoured over a native app. Aditionally, a hybrid app may run on other platforms and also in regular browsers. Independent of that, the app should also run completely offline since large amounts of data (ca. 2GB of videos) are used and some families participating in the study would not have abroadband internet connection. For these reasons, all necessary data has to be pre-installed on the tablets.

"Zirkus Empathico" originates from an interdisciplinary team of psychologists, computer scientists, and user interface designers. Thus, a *development method* needed to be used to integrate the various competences, disciplinary backgrounds and habits into a sound approach for coordination and cooperation. Project controlling based on the Kanban method (Ōno, 1988) as well as frequent status meetings of all team members was chosen to ensure communicative and successful development.

During the study, quick modifications of the app as a reaction to first experiences would be crucial. Moreover, further development of the software based on the results of the study and the feedback from users shall be easily possible. For instance, single modules or tasks could turn out to be less appropriate and should be modified or replaced for later use, which must be possible even for external developers. This led to a flexible, modular *software architecture* as depicted in Figure 4.2. The hybrid app consists of Cordova[5] plug-ins that extent the native Android app, HTML/CSS/Javascript to implement the internal app logics, as well as media assets (images and videos). For creation of the CSS files SASS[6] with the SCSS dialect was used. Since browsers are not able to interpret SCSS directly, pre-processing was necessary. This was done by means of the JavaScript-based task runner tool grunt[7] and should thus be also re-usable during later development.

The *structure of the app* is determined by the model- view-controller (MVC) paradigm. There are six view- controller combinations (starting screen, module selection, level selection, task, library, reward system), which are associated with single HTML pages. Selection of the current view-controller combination is realized by the Backbone.Router[8] library which interacts as a front controller. The entities of the model layer are realized as require.js[9] modules. Since every task consists of several internal steps (depending on the type of the current module), an additional abstraction layer is used to control task handling. These steps are modeled as a finite state automaton. An

[5] http://cordova.apache.org/
[6] http://sass-lang.com
[7] http://gruntjs.com/
[8] http://backbonejs.org/#Router
[9] http://requirejs.org/

example is presented in Figure 4.3. Every step within a task can be displayed, hidden, or repeated. This architecture provides a solid foundation for later extensions of a module, or for integration of new modules or game elements. For instance, a new view-controller combination can be created to realize new functionality. For modification of existing features, the structured implementation offers sufficient tools on a higher abstraction level. However, for performance reasons (Gutschmidt et al., 2013) we did not use a generic framework for app development.

Current Results

Based on therapeutic principles, the game concept, and the technical concept presented in previous sections, the graphical user interface of the app was designed. In order to align all these aspects with each other, a rapid prototyping approach with functional mock-ups was used. This helped to clarify design issues and to identify potential conflicts with other expert domains, while all teams worked in the project simultaneously. The interface design is realized as a circus scenario. The four training modules and the generalization module have a comparable, stage-like design (see Figure 4.4a). The other game elements (starting screen, home screen with module selection, library, level selection and reward system as depicted in Figure 4.4b) visualize other circus aspects. The user may navigate more or less independently (only limited by minor level restrictions) through the modules and gaming elements of the app.

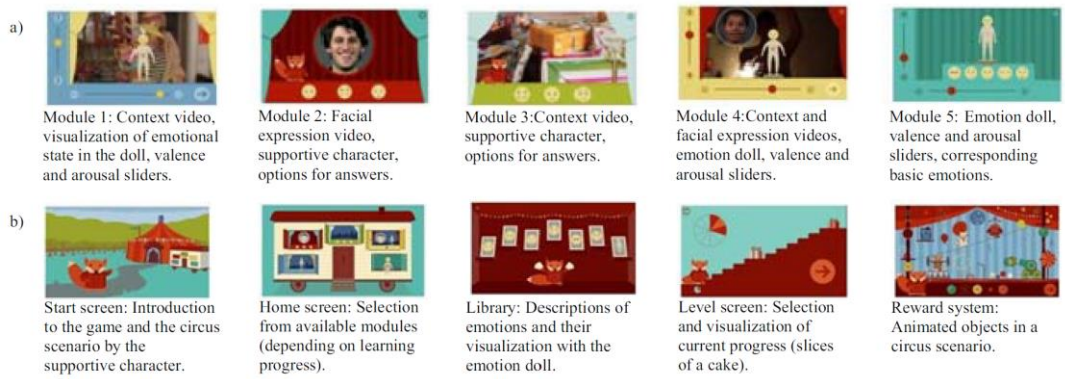


Figure 4.4 Exemplary tasks in modules 1 to 4 and in the generalization module (a) and selected game elements (b)

Special emphasis was given to the generalization of empathic competences into everyday life. Therefore, a so called *emotion doll* was designed. It visualizes the valence of the internal emotional sensation of the user (positive vs. negative; represented in facial changes of the doll) with the current emotional arousal (represented in body movements). The chosen combination of valence and arousal is linked to the corresponding basic emotions, visualized by icons to communicate the actual own emotion as well as these from other people.

Evaluation

To ensure the *general suitability* of the developed app, the video stimuli were validated, and the comprehensibility and usability of the app was tested. The videos with the adult`s facial emotions were taken from the SCOTT software , (Kliemann et al., 2011) their validity regarding precision and reliability was proven by experts in a previous study (Kliemann et al., 2013). A similar study was carried out for the children and context videos produced de novo for "Zirkus Empathico". Hence, all used stimuli were tested as valid. Regarding the app itself, a pilot study with 11 typically developed children and 4 children with autism aged 7 to 12 was carried out. The children were monitored during the game play and answered questions concerning the understanding and liking of the game elements (e.g., buttons, visual feedback, visualization of emotions) and their general motivation to play afterwards. This confirmed an intuitive and self-determined use of the app, a good motivation to play and a sufficient understanding of all relevant elements. Based on these results and on the children`s feedback, an even more precise design of game elements was realized.

Currently, a *clinical intervention study* is carried out to prove the effectiveness of "Zirkus Empathico" as an instrument to strengthen socio-emotional competences in children with autism as a basis to establish the tool`s wider use in therapy. 80 children with autism spectrum disorder aged 5 to 10 participate in the multicentre, randomized controlled trial (RCT). They are randomized to an intervention and a control group. The intervention group (n = 40) trains over six weeks for 100 minutes per week with the Zirkus Empathico app and an adult tutor in their family environment. The tutors are supervised via phone once a week by the principal investigators. To make sure that the expected results can be explained by the empathy training only, the control group (n = 40) uses online games to train self-confident behaviour without social aspects (e.g.

traffic safety) under similar conditions. The socio-emotional competences of both groups are measured with behavioural tests and parent and teacher questionnaires before and after the intervention. As shown in previous studies (Bölte et al., 2002; Golan et al., 2010; Golan & Baron-Cohen, 2006; Harms et al., 2010; LaCava et al., 2007; LaCava et al., 2010; McHugh et al., 2011; Silver & Oakes, 2001; Tanaka et al., 2010), main effects in facial emotion recognition measured by a computerized test are expected. Differences within the ability to verbalize own emotions, in emotional empathy, and in general social behaviour should be measurable as secondary effects after the intervention. Due to the holistic training concept, the assumed learning results are expected to be stable over time as measured in a three-month follow-up assessment.

Conclusion and Further Work

The mobile app “Zirkus Empathico” is the first IT-based realization of a holistic and naturalistic therapeutic concept to strengthen socio-emotional competence of children in pre- and primary school. The tight interdisciplinary cooperation between psychology, computer science, and user interface design along with a mutual exchange of methodology and experience was a valuable basis for developing this well- grounded and applicable prototype. If the ongoing clinical study will elucidate clinical effectiveness, further application in therapeutic practice will be explored.

The technical concept of the app was designed for high adaptivity and extendability. Thus, findings from the studies can be easily transferred into further developments. In a long-term perspective, the prototype shall be established as a sophisticated therapeutic instrument for children with autism. In this context, current work is focused on integration of a tracking mechanism in order to monitor user behavior. The gathered data shall be used to determine the effects of training considering potentially influencing variables, such as intensity of training or preference of certain modules. Moreover, valuable insights for further improvement of the app (e.g., concerning usability) are expected from tracking. The long-term goal is a system that adapts dynamically to the current competence level, behavior, needs, and learning goals of the users.

Published in *Behaviour Research and Therapy, Vol. 152:104068. (2022)*

5 Fostering socio-emotional competencies in children on the autism spectrum using a parent-assisted serious game: A multicenter randomized controlled trial

Simone Kirst[a], Robert Diehm[b], Katharina Bögl[a], Sabine Wilde-Etzold[c], Christiane Bach[d], Michele Noterdaeme[c], Matthias Ziegler[f] and Isabel Dziobek[a]

[a] *Clinical Psychology of Social Interaction, Berlin School of Mind and Brain, Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany*
[b] *Department of Child and Adolescent Medicine, Medical University of Vienna, Vienna, Austria*
[c] *Department of Child and Adolescent Psychiatry and Psychotherapy, Josefinum Augsburg, Augsburg, Germany*
[d] *Department of Psychosomatic Medicine and Psychotherapy, University of Leipzig, Leipzig, Germany*
[e] *Department of Child and Adolescent Psychiatry and Psychotherapy, University Medicine, Georg-August Universität Göttingen, Göttingen, Germany*
[f] *Psychological Diagnostics, Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany*

Objective: Serious games are a promising means of fostering socio-emotional skills in children on the autism spectrum (AS). However, empathy and related constructs have not yet been addressed comprehensively and together with emotion recognition, and there is a lack of randomized controlled trials (RCT) to investigate skill maintenance and the transfer to functional behavior.
Method: The manualized, parent-assisted serious game *Zirkus Empathico* (ZE) was tested against an active control group, in a six-week multicenter RCT. Eighty-two children aged 5–10 years on the AS were assessed at baseline, post-treatment, and three-month follow-up. Empathy and emotion recognition skills were defined as the primary outcomes. The secondary outcomes included measures of emotional awareness, emotion regulation, autism social symptomatology (Social Responsiveness Scale), and subjective therapy goals.
Results: Training effects were observed after the intervention for empathy (d = 0.71) and emotion recognition (d = 0.50), but not at

follow-up. Moderate effects on emotional awareness, emotion regulation, and autism social symptomatology were indicated by the short and mid-term assessments. Parents reported treatment goal attainment and positive training transfer.
Conclusion: While a six-week training with ZE failed to induce lasting changes in empathy and emotion recog- nition, it may be effective for improving emotional awareness and emotion regulation, and mitigate general autism symptomatology. *Clinical trial registration information: Zirkus Empathico* – Promoting socioemotional competencies in 5- to 10-year- old children with autism spectrum conditions using a computer-based training program; https://www.drks.de/; DRKS-ID: DRKS00009337; Universal Trial Number (UTN): U1111-1175-5451.

Introduction

Understanding one's own emotional state and that of others enables us to interact effectively, thus supporting prosocial behavior (Decety & Meyer, 2008). Persons on the autism spectrum (AS)[10] have been shown to exhibit differences in different facets of empathy (Song et al., 2019), which might result in divergent reactions to other people's emotions, peer conflicts, and social exclusion (E. L. Hill & Frith, 2003). As an umbrella term (Hodges & Myers, 2007), empathy comprises emotional resonance to others' emotions (Decety, 2011), which arises from the comprehension of others' emotional states through perspective-taking (cognitive empathy; Baron-Cohen & Wheelwright, 2004), but also bottom-up processes (Decety, 2011) such as mirroring mechanisms (Bird & Viding, 2014). Emotional resonance might either trigger *personal distress,* a self-oriented motivation to reduce stress by withdrawal, or *empathic concern*, a motivation to care for or to help someone in need (Decety & Lamm, 2009).

As suggested by neurobiological models of empathy (e.g., Bird & Viding, 2014; Shamay-Tsoory, 2011), recognizing others' emotions (e. g., through facial expressions) represents leverage to empathic under- standing and sharing others' emotions. Indeed, emotion recognition was found to be positively related to empathic concern, but

[10] To respect the language preferences of the autism community, we use the term "persons on the autism spectrum", which was voted as being least offen- sive and most accepted by the community in recent publications (e.g., Bottema-Beutel, Kapp, et al. (2021); Bury et al. (2020); Kenny et al. (2016)).

negatively to personal distress (Israelashvili et al., 2020). Furthermore, emotion recognition (e.g., Israelashvili, Oosterwijk, et al., 2019), as well as cognitive and affective facets of empathy (e.g., Bird et al., 2010; Moriguchi et al., 2006; Moriguchi et al., 2007), are associated with differentiating own emotions.

As recently reported in a meta-analysis by Song et al. (2019), a large body of research points to difficulties in cognitive empathy and reduced empathic concern in persons on the AS. On the contrary, emotional resonance seems to be intact or even enhanced (Dziobek et al., 2008; Smith, 2009c; Song et al., 2019), which is resulting in higher personal distress compared to non-autistic individuals, partly due to problems in emotion regulation in emotion regulation (goal-directed monitoring and modification of emotional responses; Eisenberg & Spinrad, 2004; Mazefksy et al., 2013). In turn, individuals on the AS might aim to reduce their distress by withdrawal when confronted with feelings of another person, instead of attending to the other person's emotional state, which possibly results in inadequate social behavior (Decety & Lamm, 2009). Beyond that, persons on the AS are reported to show poor recognition of facial emotions (see meta-analyses by Lozier et al., 2014; Uljarevic & Hamilton, 2013) and difficulties in describing their feelings and inner states (e.g., Giannotti et al., 2020; Griffin et al., 2016; Milosavljevic et al., 2016). Taken together, research of the past decades has generated evi- dence for deviations in empathy, which are characterized by difficulties in cognitive empathy, enhanced personal distress, reduced empathic concern, and difficulties in underlying competencies (e.g., emotion recognition, emotional awareness, and emotion regulation), which have a negative impact on prosocial behavior.

In recent years, computerized intervention programs, also known as *serious games*, have been implemented to train social-cognitive skills in children on the AS. Serious games offer a cost-effective solution to bridge the gap between the high need for evidence-based interventions and limited access to specialist autism services (Casale et al., 2015). By fulfilling the desire for structure and predictability while reducing stress through limiting social demands and meeting the interest in technology, serious games are a fruitful complement to face-to-face interventions for children on the AS (Bölte et al., 2010).

Indeed, several studies addressing social-cognitive skills have reported enhanced attention and motivation, as well as positive training results (see Kouo & Egel, 2016;

Mazon et al., 2019 for recent reviews). An RCT, which was conducted in the US, investigated the effectiveness of the 12-weeks program "*Mind Reading"* (Baron-Cohen et al., 2004) in 43 children on the AS aged 7–12 years with normal intelligence (IQ > 85). The study found significantly better emotion decoding and encoding skills (primary outcomes) in the treatment group post-treatment, which were maintained at a five-week follow-up (Thomeer et al., 2015). Tanaka et al. (2010) reported improvements in facial recognition and processing skills in 42 children, adolescents, and young adults on the AS after training 20h with the "*Let's Face It!"* program relative to a matched control group. For the interactive program "*FaceSay*^{TM}", RCTs by Hopkins et al. (2011) and (2015) Rice, Wall, Fogel, and Shic (2015) showed improvements in affect recognition, mentalizing, and social skills in two samples (n = 49; n = 31) of primary-school-aged children on the AS after 6–10 weeks of training. A cross-cultural evaluation in the UK, Israel, and Sweden showed, that 6 to 9-year-old participants on the AS with normal intel- ligence using the serious game "*Emotiplay*" for 8–12 weeks showed significant improvement on facial, vocal, body, and integrative emotion recognition tasks (Fridenson-Hayo et al., 2017). Finally, studies inves- tigating the effectiveness of the Australian serious game (SAS, Beaumont & Sofronoff, 2008) in home- and school-based settings, found treatment gains in social skills, emotion regulation, and child anxiety reduction after 7–8 weeks of treatment, and at follow-up (Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017).

However, most of these serious games have been tested and made available in English-speaking countries only and very few/none integrated persons on the autism spectrum into the design process. Further, they focused predominantly on emotion recognition and mentalizing, while enhanced personal distress and reduced emotional concern (Song et al., 2019) in response to others' feelings have rarely been targeted. Since aberrant social behavior might result from an interplay of cognitive and affective facets of empathy and deficits in underlying compe- tencies (e.g., emotion recognition, emotional awareness), this might partly explain the finding that previous evaluations of serious games showed little evidence of transfer effects to real-world settings (Grynszpan et al., 2014).

Concerning methodology, although randomized controlled trials (RCTs) have become more common in recent years (Fletcher-Watson, 2014)), few studies on the effectiveness of serious games have used follow-up assessment to assess maintenance

and generalization effects (Berggren et al., 2017) or used performance tests of social skills (Mazon et al., 2019). Furthermore, only a few studies (Hopkins et al., 2011; Rice et al., 2015; Young & Posselt, 2012) incorporated active control groups to account for the amount of time spent playing on the computer and social interactions with the training facilitators during training. However, these studies did not address maintenance effects.

To conclude, we aimed to apply a more holistic approach targeting empathy and related constructs here with our newly developed serious game Zirkus Empathico (ZE) for children on the AS. To foster empathic behavior and emotion understanding in real-world settings, ZE focuses in its first modules on foundations of empathy, thus, awareness and differentiation of own emotional states (module I; compare SAS, Beaumont & Sofronoff, 2008) and emotion recognition from facial expres- sions (module II). Next, cognitive empathy is addressed by teaching inferring others' emotions from emotion eliciting contexts (module III; compare Emotiplay; Fridenson-Hayo et al., 2017). Finally, ZE targets dealing with personal distress through conveying that others' emotions can elicit own emotions and through teaching possible options of pro- social and empathic behavior to given contexts (module IV).

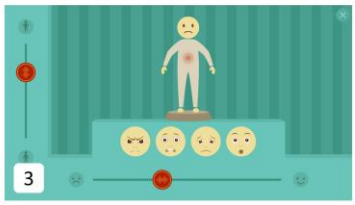
While the comparable SAS program (Beaumont & Sofronoff, 2008) was designed to suit the cognitive profile and needs of children aged from 8 to 12 years old with normal intelligence (IQ > 85), ZE addresses younger children of between 5 and 10 years, with varying intellectual level from low to high (IQ > 70), by using simplified language and age-appropriate, visualized content (e.g., animated emotional states, Figure 5.1). To meet the actual needs of the children and their families, the development of the serious game contained co-design elements. Finally, we integrated naturalistic video-based content and allowed caregivers to assist with the training at home to enhance maintenance and general- ization (compare Sofronoff et al., 2017). We conducted a multicenter RCT in Germany and Austria to test our primary hypothesis (H1) that a six-week training course would result in improvements in emotion recognition and empathy at the end of the training (T2) and at a three-month follow–up (T3). Specifically, we expected empathy, as measured by a parent questionnaire tapping cognitive and affective aspects of empathy, and emotion recognition, which was assessed by a behavioral paradigm, to be enhanced in the ZE training group at T2 and T3. Training effects should be expressed by differences

between the groups' developmental trajectories over time (H1.1) and group differences at post-treatment and follow-up with effect sizes favoring the ZE training group (TG) (H1.2). In addition, we included several secondary outcome measures to quantify effects on emotional awareness and clinically relevant functions and traits, which have been shown to be related to understanding own and others' emotions such as emotion regulation (Kashdan et al., 2015) and callous-unemotional traits (Carter Leno et al., 2015). Further, we explored the transfer of emotion recognition skills to untrained stimulus material, real-life social behavior, i.e. autism social symptomatology, and well-being. Finally, the moderating effects of autism symptomatology, verbal age, and nonverbal IQ were investigated, and the relationships between changes in emotional awareness/emotion regulation over the course of the training and changes in emotion recognition/empathy three months after the intervention were explored. It was hoped that the results would provide important implications for the potential of serious games in teaching socio-emotional skills to children on the AS.

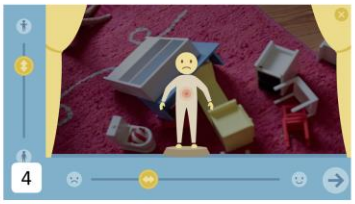
Method

Study design

A six-week multicenter, parallel-group, randomized, pragmatic clinical trial (DRKS-ID: DRKS00009337; Universal Trial Number (UTN): U1111-1175-5451) was conducted at Humboldt–Universität zu Berlin, Germany (HU) and two child and adolescent psychiatry and psycho- therapy university departments with specialized outpatient clinics for children/adolescents on the AS in Augsburg (KJPP AUG), Germany, and Vienna (MedUni Wien), Austria. 82 children aged 5–10 years on the AS participated in the trial between December 2015 and April 2018. The study was registered in the German register for clinical studies and received ethical approval from the Ethics Committee at HU (2015/10/ 07) and the clinical authorities of the two outpatient clinics. The registered study protocol was fulfilled except for one outcome measure being excluded from analysis because the majority of the children did not comprehend task requirements (see below). The coordinating activities, data management, and analysis were conducted at HU. In accordance with the CONSORT 2010 Checklist (Schulz et al., 2010), detailed descriptions of the sample selection, settings, training protocol, and outcome measures are available online (see Table S1 in online supplement).



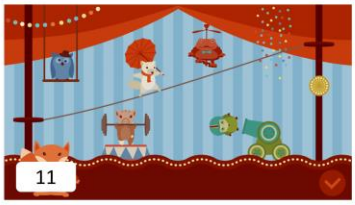
Emotion Library (1,2): The library contains an explanation of the emotion manikin and the 6 emotion cards with definitions and explanations of the basic emotions/neutral states targeted. (1): Characteristic display of emotion in the eye/mouth region, synonyms for the emotion label, examples of emotion triggering contexts, arousal and valence of the emotion indicated by the manikin (2). **Emotion manikin/Transfer module (3):** The interactive manikin is a central element in the game which enables one's own inner emotional states and those of others to be visualized. The child/tutor can use two five-step sliders to indicate a) his/her level of bodily arousal (very calm – calm – neutral – aroused – highly aroused), and b) the valence of his/her feeling (very negative – negative – indifferent/neutral – positive – very positive). The manikin changes its movement and facial expression accordingly.



Module I – Awareness of own emotions (4): By using the emotion manikin, the child specifies its inner emotional state regarding a specific context which is presented using a short emotion-inducing video clip. In a second step, the child describes its inner state by choosing an emotion label. The program provides feedback on whether the inner state and chosen emotion label are matched correctly or incorrectly. **Module II – Emotion recognition in faces (5,6):** The child is asked to identify the correct emotion label for the emotion shown by the facial expression (5). Unsolved tasks are repeated, with correct answers being prompted by visual hints after the first 2 wrong answers and an automatic correction after 3 wrong answers (6).

Module III – Cognitive empathy (7): The module requires the child to identify a specific emotion-eliciting context, in which another person finds him/herself. The child chooses the correct emotion label from 3 options (5). Unsolved tasks are repeated, with correct answers being prompted by verbal hints and a picture of the other person's emotional expression in response to the context (6). **Module IV – Empathy and prosocial action (8,9):** The stimuli show a third person's emotional expression embedded in the emotion triggering context. By using the emotion manikin, the child first evaluates its own emotional state, which may be provoked by the other person's emotional reaction to the given context (8). In a second step (9), the child is asked to choose between (a) approaching the person, (b) leaving the situation, or (c) waiting and seeing. If "approach" is selected, it is presented with a selection of concrete prosocial actions towards the other person (e.g. helping, being friendly, comforting, listening).

Level System (10): The system indicates the child's progress within each module. The modules are comprised of 6 (Mod. I, III, IV) or 12 levels (Mod. II). Each level contains 10 tasks, which are displayed as a pie chart which is completed with the number of solved tasks. When a level has been completed, the child is allowed to choose an animated reward, which is integrated into a circus arena. Extra rewards are hidden in boxes to enhance motivation.



Reward System (11): In total, 30 animated reward elements (e.g. bouncing ball, spinning top) and 5 animated animals can be added to the circus environment with increasing performance.

Figure 5.1 Modules and elements of the serious game *Zirkus Empathico*

Study participants

Children (5 years–10 years, 11 months) with a clinical consensus ICD-10 (WHO, 1994a) diagnosis of childhood autism, Asperger syndrome, atypical autism, or pervasive developmental disorder not otherwise specified (PDD–NOS), were eligible for the study. Diagnosis was established by specialized and experienced multi-professional teams (e.g., child and adolescents psychiatrists, neuropediatrics, psychologists, and other therapists like speech and occupational therapists, rehabilitation educators), using a variety of measures (e.g., parent interviews, patient observation, clinical interviews, basic functional level assessments) and clinical judgment (compare NICE guidelines, German guidelines of DGKJP; see Table S2 for diagnostic institutions). For seventy-three participants, the study operators have been provided with results of the Autism Diagnostic Observation Schedule (ADOS-G/ADOS-2; Lord et al., 2000; Lord et al., 2015) by caregivers or clinicians. Before the trial, the Autism Diagnostic Interview-Revised (ADI-R) short version (Hoffmann et al., 2015) was administered to 80 participants to confirm the autism diag- nosis. Autism symptomatology was further assessed by using the Social Communication Questionnaire (SCQ; Rutter et al., 2006) for 80 participants (see Table S3 for more detailed information on diagnostic scores). Autism symptomatology was further assessed by using the Social Communication Questionnaire (SCQ; Rutter et al., 2006) for 80 participants. Children with a nonverbal IQ below 70, as measured via the Colored Progressive Matrices (CPM) intelligence test (Raven, 2002) and an insufficient receptive German language level (verbal age<5,0; tested by Peabody Picture Vocabulary Test, PPVT, 4th revision, Dunn & Dunn, 2015). The children in the HU sample were recruited through autism care units, parent organizations, and the study-website (www.zirkus-empathico.de). In the KJPP AUG, eligible children were asked to participate after receiving an autism diagnosis. The same procedure was used at the MedUni Wien, with additional children being recruited through parent organizations and autism care units. Written informed consent was obtained from the children's legal guardians. The children were tested in four sessions (diagnostics, T1/T2/T3) at their respective study centers, care unit, or at home. The families received 7 €/hour as compensation.

Intervention

The manualized, tablet-based ZE intervention (Kirst et al., 2015; Zoerner et al., 2016; Figure 5.1, demo video, and further description in Tables S1 and S3, online) was conceptualized by the first and the last author (HU) and developed by a team of independent designers and developers under the supervision of the first author and Potsdam University, Germany. ZE includes four modules that focus on (I) awareness of own emotions, (II) emotion recognition in faces, (III) inferring emotions from emotion-eliciting contexts (cognitive empathy), and (IV) understanding emotional resonance and learning appropriate reactions towards other people's emotions. A fifth module (interactive animation: emotion manikin) is used for emotional communication in family life (real-life transfer). The modules consist of different levels and open up according to the child's progress within the previous module (see Fig. S2, online). Open modules can be selected freely to allow a choice to be provided (compare Whyte et al., 2015). The training is self-explanatory, with a fox character that guides the participants through the training modules by providing instructions, explanations, prompts, and rewards. It is recommended that the training is conducted under a caregiver's guidance to enhance emotional and empathic communication. The training includes video stimuli showing i) 315 adults and children's emotional facial expressions and ii) 62 emotion-eliciting situations filmed in the first-person perspective with an illustrated verbal introduction. Each video addresses a basic emotion (fear, anger, sadness, surprise, joy) or a neutral state. The production of video-taped adult expressions was part of a comprehensive project using 60 actors to produce an ecologically valid set of 40 emotions (Kliemann et al., 2013). In addition, the videos of children's basic emotional expressions and context video stimuli were produced for ZE with help from the HU media services. All the stimuli were validated using expert ratings and showed high average emotion recognition rates and good believability (see S3a). During the serious game development process, children (n = 15), their parents, and adults on the AS (n = 2) repeatedly provided feedback, usability was tested, and the intervention was piloted (see S3b). None of these individuals took part in the RCT.

Training took place in the children's homes with tablets provided by the study centers. One caregiver was instructed to assist each child's training by discussing its content, providing motivation during training, and, importantly, supporting the transfer of skills to everyday life by using module V. The caregiver's involvement was intended

to enable emotional communication within the family's natural home context. The caregivers received on-site instruction and a training manual (see Table S1 for details) and were supervised by training operators during the training period.

In total, the intervention lasted for six weeks with a minimum intensity of 100 min of training per week, to be done in a minimum of two single training sessions. Modules II/III were complemented by the task of analyzing emotional situations in children's movies (e.g. *Pippi Long- stocking*) using the generalization module (40 min/week). In addition, the aim of transfer to contexts outside the ZE environment was addressed by requiring that module V be used for a minimum of 10 min per day for individualized, real-life transfer goals focused on recognizing one's own and other people's emotions and prosocial/empathic acts (e. g., playing a game recognizing emotional expressions in family members, for further examples, see Table S1, online). The transfer was supported by an additional, paper-based reward system (Table S1). The tablets were returned to the study centers at T2 to prevent non-monitored training extension.

Control intervention

The active control training was framed as aiming to foster the children's confidence in their actions/knowledge. It was conducted as parent-assisted computerized training to guarantee a comparable level of motivation, media use, and quantity/quality of parent interaction. The caregivers providing the training received different serious games, which targeted non-social skills/knowledge. Depending on the children's age and interest, the serious games either focused on traffic safety (N = 29), body-related knowledge (N = 3), or school- and nature-related knowledge (N = 8; see Table S1 for additional information). Additionally, caregivers received a reward system for transfer goals, a training manual, and weekly supervision via phone. As in the ZE group, the caregivers were encouraged to teach the training content to their children actively, by using the respective app (e.g., talking about targeted behaviors, serving as role models, ensuring understanding) for 100-min per week in the context of a minimum of two sessions per week plus 10 min daily transfer.

Intervention monitoring: training intensity, treatment fidelity, and motivation

To ensure treatment fidelity, the training was monitored: (1) The caregivers of both groups recorded the training times using a paper-based system, and a tracking

application was used to record training times automatically for ZE. (2) In both groups, the caregivers' commitment to comply with the study conditions was monitored by weekly phone calls from training operators who asked about the prog- ress of training, training transfer, interfering events, and problems (see Table S1). The conversations were protocolled, and the caregivers received weekly emails with a summary of the conversation. After the intervention (T2), treatment fidelity was further assessed using a treat- ment satisfaction parental report (see below). (3) The children's moti- vation to engage in the training was assessed at five time-points during the course of the intervention. The assisting caregivers were asked to rate their child's behavior during gameplay on nine items (e.g., "explores novelty", "stays engaged") by using a four-point scale ranging from engaging in passive (1) to spontaneous (4) behavior. The items were adapted from the *Pediatric Volitional Questionnaire* (PVQ, Basu et al., 2008), an observational assessment tool for children with developmental disorders (note: the instrument was not validated in a parent-sample). The children's motivation and enjoyment were also assessed in the treatment satisfaction report at T2.

Randomization and blinding

Eligible participants were randomized to either the TG or the active control group (CG). Minimization was performed with a randomization ratio of 0.8 and the two three-staged stratification factors verbal age and study center using MinimPy (Saghaei, 2011). Since ZE is an online psychotherapy with a clear focus on socio-emotional skills, blinding children and caretakers was not possible. In addition, for feasibility reasons at the respective sites, only one assistant on each site was responsible for all study-related tasks (e.g. training supervision, recruitment, testing), and thus, blinding of testers was not possible either.

Outcome measures

Primary outcomes

The primary outcomes were changes in the *Griffith Empathy Measure* (GEM, Dadds et al., 2008) total score for parent-rated empathy comprising affective and cognitive aspects. The GEM consists of 23 items for assessing empathy in children using a nine-point-rating scale. Reliability and validity were sufficient (Cronbach's $\alpha = 0.91$, test-retest reliability over 6 months: $r = 0.69$). In addition, the *Kids Emotion Recognition Multiple Images Task* (KERMIT) served as the primary

measure of changes in emotion recognition accuracy (Drimalla & Dziobek, 2019). In this task, 48 naturalistic pictures of adults' basic emotions with varying intensities are presented on a computer. Children must choose the correct emotion label from two options as quickly as possible. Analyses of 73 of the children in the total sample with valid data at baseline plus 64 additionally measured, non-autistic children, revealed that the *KERMIT* had good reliability (McDonald's Omega = 0.91). The test-retest reliability of the KERMIT was not assessed.

Secondary outcomes

Since the *KERMIT* pictures are frames extracted from some of the ZE training video clips, emotion recognition was additionally tested using 28 computer-presented photos of six basic emotions taken from the pictures in a facial affect set (Ekman & Friesen, 1976) to account for more distant generalization effects. The internal consistency in our sample at baseline (N = 73 children on the AS, N = 64 non-autistic children; compare KERMIT) was good (McDonald's Omega = 0.94). Changes in the awareness of one's own emotions were assessed using a modified version of the *Level of Emotional Awareness Scale for Children* (LEAS-C; Bajgar et al., 2005). The children reported their emotional reactions to 12 narratively presented, emotion-eliciting situations. The internal consistency of the LEAS-C subscale referring to own emotions (self-LEAS-C) was sufficient (Cronbach's α. = 0.71). Emotion regulation was tested with the emotion regulation (ERC-ER) and lability/negativity (ERC-LN) subscale of the *Emotion Regulation Checklist* parent questionnaire (ERC; Shields & Cicchetti, 1997). The internal consistency of both scales is adequate (ERC-L/N: α = 0.96; ERC-ER: α = 0.83). Callous-unemotional traits were measured by the *Inventory of Callous-Unemotional Traits* (ICU; Essau et al., 2006), the subscales of which showed acceptable reliability (Cronbach's α = 0.77 - 0.81; test–retest reliability over *M* = 23 days: *r* = 0.84; Moore et al., 2017). To further explore the training's ecological validity, the parents and (kindergarten) teachers/assistants rated changes in general autism social symptomatology using the *Social Responsiveness Scale* (SRS; Constantino & Gruber, 2007). The SRS has demonstrated excellent internal consistency (Cronbach's α = 0.97) and a good test-retest reliability of *r* = 0.77 (for females) to *r* = 0.85 (for males).
The *Kiddy Kindl* (Ravens-Sieberer & Bullinger, 1998) parent questionnaire was used to measure the children's wellbeing. The internal consistency for the whole scale was acceptable, with Cronbach's α = 0.85. The *Multifaceted Empathy Test for*

Adolescents/Children (MET-J/K; Dziobek et al., 2008; Poustka et al., 2010) was excluded from the analyses because the majority of the children did not demonstrate a full understanding of the instructions and the concept of the emotional facets of empathy (e.g., as shown by systematic or repetitive response tendencies; see also Table S1, online).

The assessments took place at baseline (T1), post-treatment (T2), and at the three-month follow-up (T3). T2 was conducted within the first two weeks after the end of the intervention. All the parent/teacher ques- tionnaires were presented online using the SoSci Survey (Leiner, 2014)/Limesurvey platforms (Limesurvey GmbH; MedUni Wien).

Treatment goal achievement and treatment satisfaction

At baseline, we operationalized two individually defined, socio- emotional treatment goals for each child in the TG, using *Goal Attainment Scaling* (GAS; McDougall & King, 2007). At T2, parents were asked to rate their child's level of achievement on a scale from -2 'no change', through 0 'goal achieved', to 2 'change far beyond goal'. Finally, an unstandardized treatment satisfaction questionnaire was used post-treatment in the TG and CG, to target treatment satisfaction, acceptance, feasibility, treatment fidelity, and changes in generalized behavior that had not otherwise been assessed. Where possible, the children were also interviewed using a modified version of the questionnaire.

Statistical analyses

The sample size was planned on the medium effect sizes found in previous serious game interventions targeting emotion recognition (Grynszpan et al., 2014). A total sample of 82 participants was needed to provide 80% power (1- β) at a two-sided 5% α level and 7% attrition. Data from all randomized participants was used for primary and sec- ondary analyses according to the intention-to-treat principle. The training effects were estimated using path analyses with maximum likelihood estimation and robust 'Huber-White' standard errors (MLR). This statistical approach was chosen because it combines several ad- vantages: First, missing data can be handled by using a full information maximum likelihood estimation method (FIML; Enders & Bandalos, 2001). In contrast, classical MANOVA handles missing data by deleting all the individuals with incomplete data (Hox, 2000), resulting in a reduced sample size and

lower statistical power. Second, it is possible to control for differences between groups at baseline, as well as in con- founding variables, such as autism scores. Third, autoregressive ap- proaches are easy to implement. In the context of our study, this means the following: Using path analyses enabled us to keep all the data points collected and adjust our baseline measurements for differences in baseline scores and autism symptomatology (SCQ). These adjusted values were then used as predictors for the subsequent time points, thus leading to less biased estimates for T2 and T3. All the variables were centered to zero (with 0 being the mean and positive scores indicating values above average) to facilitate the interpretation of intercepts.

We specified three different path models to test our two primary hypotheses: First, training effects should be expressed by differences in the two groups' developmental trajectories over time (H1.1). Statistically, this is indicated by different path coefficients between groups, with higher values for regression coefficients indicating higher stability between measured constructs over time, while lower values indicate less stable relationships, i.e. more changes/development over time.

Second, group differences should be indicated by different intercept values at post-treatment and follow-up, with effect sizes favoring the TG (H1.2). H1.1 was tested by comparing the information criteria of a model with freely estimated path coefficients for each group (*unequal model*) with a restricted model with fixed corresponding paths for each group (*equal model*). To test H1.2, the favored model from this first comparison was contrasted with a third model defined by fixed intercepts at post-treatment and follow-up in both groups (*fixed means model*). The model fit indices (*CFI, RMSEA, SRMR*) could not be estimated in the case of saturated models (unequal model), and sample-size adjusted Bayesian information criterion (*BIC ad.*) and Akaike informa- tion criterion (*AIC*) were used for model comparison. Favored models were indicated by lower *BIC ad*. and *AIC* values (Merkle et al., 2016). The model selection for non-saturated models was based on *CFI* comparisons with the fit of the unrestricted model (*CFI* equal model) being subtracted from that of the restricted model (*CFI* fixed means model). Negative *Delta CFI* values suggest the equal model is a better fit (cut-off = .002; Meade et al., 2008). The effect sizes (Cohen's *d*) were calculated by dividing the group difference of least squares mean scores of the favored model by the pooled standard deviation for each time-point.

To inform the ZE training's implementation into autism care, additional moderator analyses were conducted for primary outcome mea- sures in our group of interest, the TG. Autism symptomatology (SCQ), verbal age (VA), and nonverbal IQ were judged to be the most interesting for clinical practice and were therefore included as moderators in a freely estimated model (*main effects only model).* This model was compared to one including the respective moderator's interaction terms and the *GEM/KERMIT* score at baseline (*interaction model*). In the final analysis, we tested whether increases in emotional awareness or emotion regulation in the TG would predict changes in empathy/emotion recognition after training. Therefore, we calculated the *LEAS-C* change score (T2 minus T1), the *ERC-ER* change score (T2 minus T1), and the GEM/KERMIT change scores (T2 minus T1/T3 minus T2) and ran a correlation analysis. Relations between *LEAS-C/ERC-ER* change scores (T2-T1) and KERMIT*/GEM* change scores (T3-T2), were further investigated in a multiple regression analysis. All the analyses were conducted using the RStudio software version 1.3.1073 (RStudio Team, 2015; see Table S1 for R packages and link to data repository and scripted analyzes (R markdowns). IBM SPSS statistics, version 25.0 (2017) was used for the ancillary analyses.

Results

Of the 184 children assessed, 82 (69 boys, 13 girls) (Figure 5.2) met the inclusion criteria and were randomly assigned to ZE (n = 42 children; age range 5.3–10.8 years) or the control condition (n = 40; age range 5.5–10.6 years). There was a significantly larger proportion of females (23%; χ^2 (1) = 4.09, p = .04, φ = 0.22) in the TG than in the CG (7.5%). At baseline, the groups differed significantly in autism symptoms, as measured by SCQ, with the TG showing higher symptomatology (TG: *M* = 22.8, *SD* = 6.2; CG: *M* = 19.5, *SD* = 6.2; *t* (78) = 2.39, *p* = .019, *d* = 0.54). All other major demographic and clinical characteristics were comparable between groups, both for participants (Table 5.1) and caregivers (Table S2). Specific data on race/ethnicity were not recorded, but all the participants were native German speakers. Sample sizes varied across sites, with 37 children being enrolled at the HU, 17 in KJPP AUG, and 28 in MedUni Wien. For differences in baseline characteristics across sites and testing requirements for path analyses, see Table S1.

Attrition and missing data

Two children from the TG (5%) and four from the CG (10%) did not complete the respective training. In all cases, participants dropped out for personal reasons (e.g., death of a grandparent, separation of parents). The only significant difference between completers and non-completers was in nonverbal IQ (t (79) = -2.31, p = .024, d = -0.52), with completers (M = 104.7, SD = 18.8) scoring higher than non-completers (M = 85.0, SD = 10.2). In the TG, parent-rated data for the primary measure (GEM) was missing for 5% participants at baseline, for 26% post-treatment, and 19% at follow-up. For the CG, incomplete GEM data was given in 15% of the cases at baseline, 25% post-treatment, and 25% at follow-up. In total, 40 GEM datasets were missing across all time points (16.7%). In the TG, the KERMIT testing data was missing/invalid for 7% at baseline, 19% at post-treatment, and 24% at follow-up. At baseline, 15% of the participants of the CG had missing or invalid testing data (KERMIT), increasing to 23% at post-treatment, and 33% at follow-up (15.1% overall). Over both groups, all three time points, and all primary and secondary measures, 17.1% of data was missing/invalid (see Table S1).

Intervention monitoring: training intensity, treatment fidelity, and motivation

Training times were reported by caregivers for 59 participants (TG: n = 32; CG: n = 27; for details see Table S3). Overall, the participants trained for an average of 11.3 h (SD = 2.4) during a minimum of four weeks; the 100 min per week training requirement was met in 73% of the cases. The preferred number of training sessions per week was 4–5 for both groups, with an average length of M = 22 min in the TG (SD = 8.5) and M = 30 min in the CG (SD = 11.7). The total training times differed significantly between the groups, with higher intensity (hours) in the CG (TG: M = 9.7, SD = 2.8; CG: M = 13.2, SD = 3.6; t (57) = -4.24, p = .000). There was no significant difference in training intensity between sites (F (2,35) = 2.32, p = .114). Due to technical problems, the use of the ZE transfer module in the TG was only tracked in frequency, but not in duration. This might have caused the difference between the automatically tracked times and the parent-recorded times in the TG, with only the latter including transfer episodes (parent-recorded: M = 9.7, SD = 2.8; tracking: M = 7.34, SD = 2.4, t (29) = 4.81, p = .000). However, the manually and automatically recorded times correlated significantly (r = 0.54, p = .002). To check for treatment fidelity, the caregivers were asked whether they had been motivated to

conduct the training as previously agreed upon, by using a 5-point scale (ranging from 1 'no, never', to 5 'yes, always'). According to the training protocols obtained during weekly supervision, the treatment fidelity was highly rated in both groups (TG: $M = 4.32$, $SD = 0.77$; CG: $M = 4.07$, $SD = 0.87$; $t\,(59) = 1.19$, $p = .240$). The children's motivation for engaging with the apps (volition) over the course of the training was rated as 'involved' for most participants without group differences (see Table S4 for detailed PVQ results). Retrospectively, the caregivers from both groups perceived their chil- dren as having enjoyed the training most of the time and having been mainly motivated (Treatment Satisfaction Report, Table S7a).

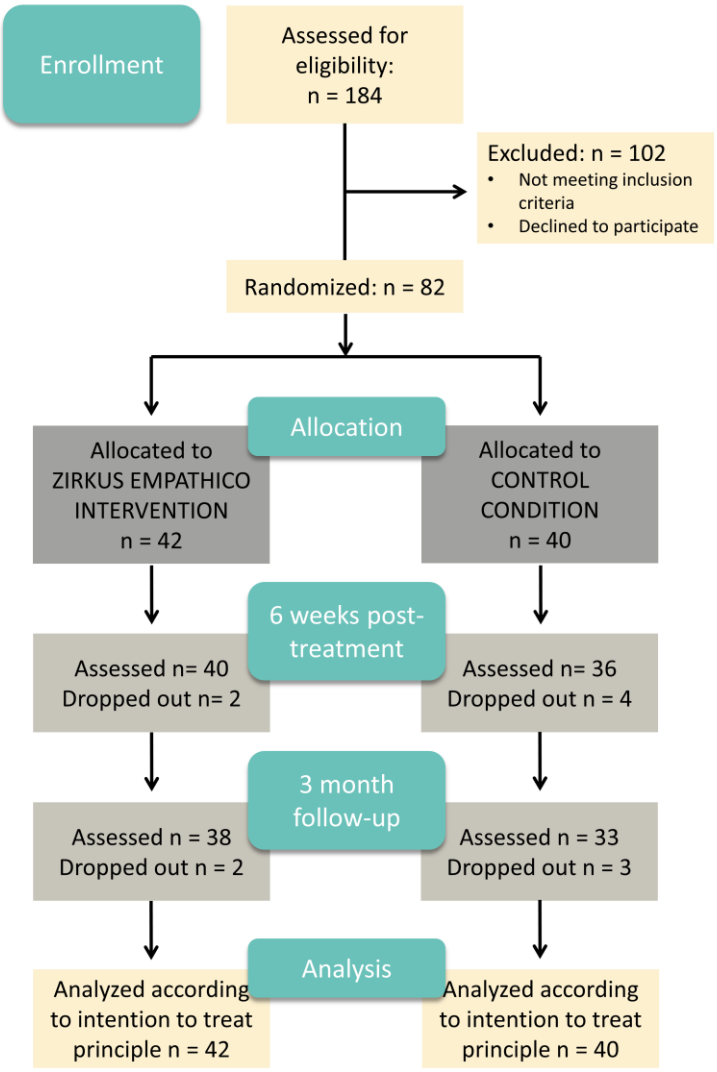


Figure 5.2 Trial time flow.

Table 5.1 Demographic and clinical characteristics of the total sample (n = 82) by training group.

	Zirkus Empathico N = 42			*Control Condition* N = 40			
Variable	***M***	***SD***	***Range***	***M***	***SD***	***Range***	***p***
Age (y)	8.1	1.6	5.3 - 10.8	7.6	1.3	5.5 - 10.6	.143
CPM, Nonverbal IQ	102	19	67 - 135	105	19	72 - 135	.586
PPVT, Verbal IQ	97.6	17	66 - 135	103	18	73 - 135	.196
Verbal age (y)	7.9	2.2	4.7 - 13.8	7.8	2.0	5.1 - 13.0	.814
ADOS-G overall total (n=60)	11.9	4.0	5 - 20	11.9	4.0	4 - 20	.997
ADOS-2 overall total (n=13)	10.6	2.3	8 - 14	11.8	5.2	6 - 20	.600
ADI-R-short total	6.1	1.3	2 - 8	6.0	1.3	3 - 8	.678
SCQ, total score	22.8	6.2	10 - 35	19.5	6.2	3 - 31	.019
Age (y), Caregiver 1[a]	40.5	5.8	29 - 52	41.7	7.3	29 - 54	.446
AQ, Caregiver 1[a], total score	14.9	9.3	3 - 42	17.7	19.7	4 - 132	.410
TAS, Caregiver 1[a], total score	63.2	10.4	34 - 79	61.6	7.0	43 - 73	.414
	N	**%**		**N**	**%**		***p***
Males	32	76.2		37	92.5		.043
Autism diagnosis (ICD-10)							
Childhood autism	9	21.4		4	10.0		.504
Asperger syndrome	19	45.2		21	52.5		
Atypical autism	3	7.1		2	5.0		
PDD-NOS	11	26.2		13	32.5		
Co-occurring conditions							
None/Unknown	31	73.8		30	75.0		.662
ADHD/ADD	6	14.3		8	20.0		
Epilepsy	2	4,8		1	2.5		
Other	3	7.1		1.	2.5		
Pharmacological treatment							
None/unknown	35	83.3		33	82.5		.374
Central stimulants	2	4.8		1	2.5		
Antiepileptics	2	4.8		0	0.0		
Other Psychotropics	2	4.8		1	2.5		
>/= 2 Psychotropics	1	2.4		5	12.5		
Males, Caregiver 1[a]	5	12.2		5	13.2		1.00
Level of education[b], Caregiver 1							
Lower secondary education	1	2.4		1	2.7		.780
Upper secondary education	21	51.2		16	43.2		
Academic education	19	46.3		20	54.1		
Study Center							
HU Berlin	19	45.2		18	45.0		.982
KJPP Augsburg	9	21.4		8	20.0		
UniMed Wien	14	33.3		14	35.0		

Note: ADHD/ADD = Attention Deficit Disorder, ADOS-G = Autism Diagnostic Observation Scale Generic, overall total (communication + reciprocal social interaction); ADOS-2 = Autism Diagnostic Observation Scale-2, overall total (social affect + restricted and repetitive behavior); AQ = Autism Quotient; CPM = Colored Progressive Matrices; PPVT = Peabody Picture Vocabulary Test; PDD_NOS = Pervasive developmental disorder not otherwise specified; SCQ = Social Communication Questionnaire; TAS = Toronto Alexithymia Scale.

[a] Data refers to the primary caregiver who assisted the child's training. For the second caregiver's data, see Table S2, online.

[b] The level of education was determined according to the International Standard Classification of Education (ISCED) applied to the German and Austrian school system: Lower secondary education (ISCED-Level-2); Upper secondary education (ISCED-Level-3); Academic education (ISCED-Level- 6/7).

Primary outcome measures

For the *GEM* total scores, the model comparisons revealed a preference for the equal model (*AIC* = 1781.6; *BIC* = 1765.4; unequal model: *AIC* = 1785.2; *BIC* = 1766.7; Table 5.2) with the same regression coefficients for both groups (Table 5.3). Thus, no differences in the groups' developmental trajectories over time could be inferred (H1.1). Second, the analyses showed a clear preference for the model with freely estimated intercepts in both groups (H1.2): The GEM total scores differed between groups after the training, resulting in a medium effect size in favor of the TG (*difference of intercepts* between groups at T2, *DI* = 17.0;

Cohen's *d* = 0.71; Figure 5.3; Table S5 for means). There was no significant difference between the groups at follow-up (*DI* = -4.7; *d* = -0.17). This was supported by analyses of the accuracy of emotion recognition (*KERMIT* accuracy scores) as a second primary outcome: While the developmental trajectories and regression coefficients (Table 5.3) were comparable between groups (equal model: *AIC* = 1051.3, *BIC ad.* = 1035.1; unequal model: *AIC* = 1054.3, *BIC ad.* = 1035.1), the model with freely estimated intercepts revealed a between-group difference in *KERMIT* accuracy scores, with a medium effect size favoring the TG at post-treatment (*DI* = 2.0; *d* = 0.50, Figure 5.3), but not at follow-up (*DI* = -0.7; *d* = -0.18). The information criteria from the moderator analyses in the TG revealed a preference for the main effects model for both primary measures (Table S9). Hence, the intervention effect was not impacted by any interaction between autism symptomatology, verbal age, or nonverbal IQ and the primary outcomes at baseline. After correcting for multiple comparisons, the correlation analyses (see Table S8 in the supplement) did not reveal significant correlations between the LEAS-C and the ERC-ER change scores from baseline to post-treatment (T2-T1) and the GEM and the KERMIT change scores from post-treatment to follow-up (T3-T2). Although the correlation between the LEAS change score (T2-T1) and the GEM change score (T3-T2) was only trending towards significance, the effect size was large ($r = 0.55$, $p = .061$), which is why a regression analysis was conducted. It showed that the *GEM* change score, from post-treatment to follow-up, was significantly predicted by the *LEAS-C* change score from baseline to post-treatment (F (1,23) = 10.19, $p = .004$, with an adjusted *R2* of 0.28).

Table 5.2 Primary and secondary outcome measures at post-treatment (week 6) and three-month follow-up. Model choice is marked. Smaller AIC/BIC values suggest a better fit, negative CFI Delta values prefer the equal model over the fixed means model (cut-off = 0.002; Meade et al., 2008).

	Model comparison I				**Model comparison II**		
	Unequal Model		Equal Model		Fixed Means Model		
	AIC	*BIC ad.*	*AIC*	*BIC ad.*	*AIC*	*BIC ad.*	*CFI* Delta
GEM	1785.2	1766.7	1781.6	1765.4	1791.9	1777.2	-0.08
KERMIT	1054.3	1035.7	1051.3	1035.1	1052.0	1037.3	-0.08
EKMAN	989.0	970.5	986.4	970.2	994.8	980.1	-0.17
LEAS-C	248.4	229.9	251.4	235.2	256.0	239.0	---
ERC ER	958.1	939.6	954.5	938.3	969.5	954.8	-0.12
ERC N/L	1262.6	1244.0	1256.9	1240.7	1261.9	1247.2	-0.03
SRS parent	1751.7	1733.2	1760.4	1744.2	1769.5	1752.8	---
SRS teacher	1515.8	1497.3	1523.4	1507.2	1517.9	1500.9	---
ICU	1425.5	1407.0	1420.6	1404.4	1425.7	1411.0	-0.04
Kiddy Kindl	1423.9	1405.4	1424.3	1408.1	1422.2	1407.5	---

Note: AIC = Akaike Information Criterion; BIC = Bayesian information criterion, sample size adjusted; CFI Delta = CFI Fixed Means Model – CFI Equal Model; EKMAN = Ekman & Friesen Pictures of Facial Affect Set; ERC ER = Emotion Regulation Checklist - Subscale Emotion Regulation; ERC N/L = ERC Subscale Negativity/Lability; GEM = Griffith Empathy Measure; ICU = Inventory of Callous/Unemotional Traits; KERMIT = Kids Emotion Recognition Multiple Images Tasks; LEAS-C = Level of Emotional Awareness Scale for Children, self-score; SRS = Social Responsiveness Scale.

Secondary outcome measures

When testing if training effects were expressed by differences between the groups' developmental trajectories over time (H1.1), the model comparisons revealed no differences in path coefficients between groups (preference for equal model, Table 5.2) for distant emotion recognition (EKMAN), emotion regulation (ERC-ER), lability/negativity (ERC-NL), and callous-unemotional traits (ICU). Thus, the two groups' developmental trajectories were comparable for these measures. The preferred unequal model indicated different developmental pathways over time between groups for emotional awareness (LEAS-C), parent-, and teacher-rated autism social symptomatology, and well-being (Kiddy-Kindl), (Table 5.2, and Table 5.3 for regression coefficients).

Table 5.3 Standardized regression coefficients.

	Zirkus Empathico N = 42		**Control Condition N = 40**	
Predictor	GEM T2	GEM T3	GEM T2	GEM T3
GEM T1	.59***	---	.69***	---
GEM T2	---	.68***	---	.61***
SCQ	.08	.09	-.26**	-.22*
	KERMIT T2	KERMIT T3	KERMIT T2	KERMIT T3
KERMIT T1	.46***	---	.35***	---
KERMIT T2	---	.56***	---	.65***
SCQ	.11	-.28**	.13	-.04
	EKMAN T2	EKMAN T3	EKMAN T2	EKMAN T3
EKMAN T1	.63***	---	.44***	---
EKMAN T2	---	.23*	---	.20*
SCQ	-.02	-.21	-.20	-.28
	LEAS-C T2	LEAS-C T3	LEAS-C T2	LEAS-C T3
LEAS-C T1	.50**	---	.52***	---
LEAS-C T2	---	.74***	---	.38*
SCQ	.06	.10	.00	.14
	ERC-ER T2	ERC ER T3	ERC ER T2	ERC ER T3
ERC ER T1	.79***	---	.77***	---
ERC ER T2	---	.45***	---	.41***
SCQ	.06	-.17	-.03	-.24
	ERC-N/L T2	ERC N/L T3	ERC N/L T2	ERC N/L T3
ERC N/L T1	.75***	---	.86***	---
ERC N/L T2	---	.55***	---	.66***
SCQ	.01	-.01	-.04	.05
	SRS parent T2	SRS parent T3	SRS parent T2	SRS parent T3
SRS parent T1	.88***	---	.55***	---
SRS parent T2	---	.46*	---	.77***
SCQ	-.05	.18	.34*	.17*
	SRS teacher T2	SRS teacher T3	SRS teacher T2	SRS teacher T3
SRS teacher T1	.65***	---	.89***	---
SRS teacher T2	---	.59***	---	-.74*
SCQ	.13	.17	-0.16	.42
	ICU T2	ICU T3	ICU T2	ICU T3
ICU T1	.64***	---	.68***	---
ICU T2	---	.57***	---	.58***
SCQ	-.13	.06	.36***	.13
	Kiddy Kindl T2	Kiddy Kindl T3	Kiddy Kindl T2	Kiddy Kindl T3
Kiddy Kindl T1	.77***	---	.69***	---
Kiddy Kindl T2	---	.62***	---	.29
SCQ	-.08	-.21**	.13	.07

** p ≤ .05, ** p ≤ .01, *** p≤ .001*

In the case of H1.2 (differences of intercepts between groups), an intervention effect was observed for distant emotion recognition (EKMAN: *DI* at T2 = 2.8, *d* = 0.84), which was not maintained at follow-up (*DI* = -0.1, *d* = -0.03). The same findings were observed for callous-unemotional traits (ICU T2: *DI* = -5.3, *d* = -0.56; T3: *DI* = -0.6, *d* = -0.06), and lability/negativity (ERC-NL T2: *DI* = -3.3, *d* = -0.47; T3: *DI* = 0.2, *d* = 0.03). However, more long-lasting changes were observed in the TG for emotion regulation (ERC-ER T2: *DI* = 2.3, *d* = 0.70; T3: *DI* = 1.2, *d* = 0.33) and

the awareness of their own emotions (LEAS-C T2: *DI* = 0.3, *d* = 0.67; T3: *DI* = 0.1, *d* = 0.24). Importantly, parents and teachers reported a reduction in autism social symptomatology (SRS) directly after training (parents: *DI* = -18.2; *d* = -0.69; teacher: *DI* = -7.0; *d* = -0.28), and at follow-up (parents: *DI* = -7.1; *d* = -0.28; teacher: *DI* = 13.7; *d* = -0.53). Model comparisons with a preference for the unequal model and a rejection of the fixed means model indicate a positive effect on the children's wellbeing (Kiddy Kindl) from the ZE training. However, the effect sizes were too small to be of significance (Cohen's d < 2; Cohen, 1988; T1: *DI* = 2.0, *d* = 0.18; T2: *DI* = 1.5; *d* = 0.14).

Treatment satisfaction and feasibility

As reported in the Treatment Satisfaction Report (online report/interview), treatment satisfaction and acceptance (e.g., enjoyment, motivation to play) were generally high after the intervention in care- givers (TG: n = 34; CG: n = 27) and children (TG: n = 34, CG: n = 22), and did not differ between the groups, except that the caregivers' enjoyment was significantly higher in the TG. Overall, the feasibility of the training, operationalized by compatibility with family life, training-induced stress, quality of supervision, and understanding of training content, was good. Adverse events were not accessed systematically, but caregivers of both groups did not report negative training effects within the weekly training supervision. In the caregiver report at T2, the chil- dren were reported to show low negative emotionality (e.g., stress, frustration) during training and caregivers rated for themselves having been only minimally stressed by the intervention. For a detailed report and the results of the children's interviews, see Table S7a/b.

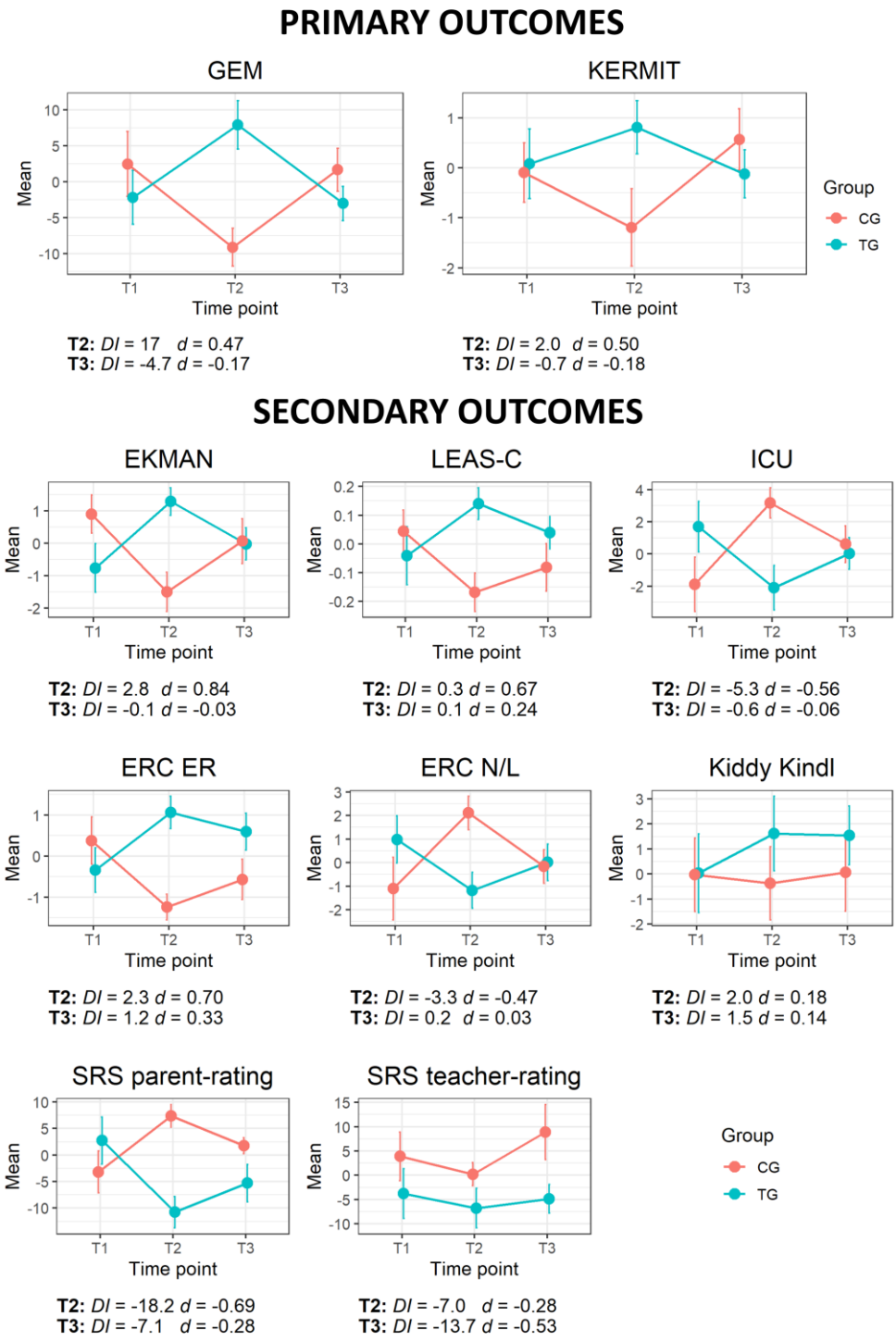


Figure 5.3 Graphs showing group means at baseline (T1) and estimated means (unstandardized intercepts) at post-treatment (T2), and follow-up (T3) for primary and secondary outcomes. The differences in intercepts (DI) and effect sizes (Cohen's d) at T2 and T3 are presented for each outcome

Treatment goal achievement

The caregivers' treatment satisfaction reports for the ZE TG indicated that the majority of participants showed enhanced interest in, and recognition of emotions,

improvements in dealing with, and awareness of their own emotions, and adequate reactions towards other people's emotions. Sixty percent of the caregivers in the TG experienced their child being more sociable than before treatment. The TG and CG differed significantly when caregivers were asked whether their child had changed its behavior, and whether their emotional approach, relation- ship, and/or interaction/communication with their child had improved during the training, with higher values in the TG (see Table S8a/b for details and the results of the children's interviews). In addition, it was possible to interview 30 parents (71%) in the ZE TG (n = 42), post- treatment, concerning treatment goal achievement (GAS; for details Table S9). Parents reported achievement (27%; GAS score = 0) or overachievement (39%; GAS score = 1 or 2) for n = 60 predefined goals. A subtle change in behavior towards the goal (GAS score = -1) was observed in 28% of the goals, while goals were not reached in 6% (GAS score = -2).

Discussion

Although serious games have previously been identified as promising ways of teaching socio-emotional skills to children on the AS, a lack of RCTs investigating the maintenance and transfer of skills to everyday behavior limits the external validity of the findings (Berggren et al., 2017; Grynszpan et al., 2014; Kouo & Egel, 2016). Beyond that, the different facets of empathy have also not yet been adequately addressed in conjunction with emotion recognition. The current RCT addresses these points by testing a parent-assisted serious game about socio-emotional competencies with a follow-up assessment, and quantitative and qualitative generalization measures. In contrast to most previous studies, an active control group was integrated into the study to account for maturation effects and the effects of enhanced parent-child interaction and media use. Furthermore, using path analyses allowed differences in the groups' developmental trajectories over time to be modeled and unbiased changes assessed.

While short-term intervention effects on general empathy and emotion recognition, as primary outcomes, could only be demonstrated directly after training, the training seemed to be effective in the short-, *and* mid-term for skills related to the processing of the participants' *own* emotions, i.e., emotional awareness and regulation. Furthermore, the reduction of autism social symptomatology in parent and teacher reports, the positive results of the parents' and children's treatment satisfaction reports,

and the goal attainment scaling are indicative of a transfer of socio-emotional skills into different, real-life settings (family/ school/kindergarten). Given the high training acceptance, as indicated by parent report, low drop-out rates, and satisfactory treatment fidelity, we conclude that ZE appears to be a promising intervention for children on the AS without severe intellectual impairment. Several interesting observations are relevant to practical implementation and future program development and research.

Empathy and emotion recognition

For the primary outcomes, improvements could be demonstrated in (1) parent-rated empathy and (2) emotion recognition abilities in the TG after six weeks of training, resulting in medium effect sizes (Cohen, 1988). Neither effect was moderated by autism symptomatology (SCQ) or verbal age. These results accord well with previous research on serious games for fostering socio-emotional competencies in children on the AS (Grynszpan et al., 2014). However, no differences between the ZE training and control groups were present, for either construct, three months after the training.

This pattern was replicated by the EKMAN emotion recognition test as a secondary measure: The large post-treatment intervention effect suggests a distant generalization effect to untrained stimuli, but the effect was not maintained three months later. These findings are in contrast to Thomeer and colleagues' (2015) evaluation of the serious game *Mind Reading*, which showed a medium treatment effect for emotion recognition at a five-week follow-up assessment in children on the AS and an IQ > 70, in comparison to waitlist controls. The different results may be because *Mind Reading* focuses exclusively on emotion recognition, with richer content targeting simple and complex emotion recognition in facial and bodily expressions through multiple programs and games, and a higher dose of training (12 weeks).

In contrast, ZE focuses solely on unambiguous basic emotions without the inclusion of progressive levels of difficulty and individualization (e.g., matching the task difficulty to the child's abilities), which may have resulted in insufficient learning trials and early ceiling performance, as outlined by Whyte et al. (2015). Furthermore, the *intrinsic* motivation to acquire emotion recognition skills was not addressed, either during or after the intervention (e.g., through developing individual and significant goals with the children). Thus, the ZE training might have facilitated attentiveness

toward facial emotions during the training, while lacking motivation and refreshment of skills after the end of the intervention, which might have led to reduced maintenance. Finally, the recognition of other people's emotions seems to have been difficult for caregivers and children to generalize: As parents stated during training supervision, naturally occurring emotional expressions are more transient and mixed than those provided in the video content (Riediger et al., 2011), and thus not easy to capture.

Changes in socio-emotional traits and autism social symptomatology

Interestingly, callous-unemotional traits that have been reported to be associated with deficits in fear recognition in typically and atypically developing samples (Carter Leno et al., 2015), only improved in the short-term, similarly to emotion recognition skills. The same was true for lability-negativity (lack of flexibility, anger dysregulation, mood lability), which was reduced only over the training period. We might speculate that more specific content (e.g., different and multimodal fear stimuli, emotion regulation skills for dealing with frustration and anger) and higher intensity training would have resulted in more long-lasting changes.

In contrast to emotion recognition/empathy, our findings indicate mid-term changes in emotional awareness, emotion regulation (measured by expression of emotions, empathy, and constructive emotional self-awareness), and autism social symptomatology, as demonstrated by medium effect sizes after training and, albeit smaller, at follow-up. For emotional awareness and autism social symptomatology, the differences in the groups' developmental pathways over time further emphasized the changes observed in the TG in comparison to the active controls. Furthermore, the increased awareness of their own emotions during the intervention predicted gains in empathy three months after the intervention, which might suggest that the process of differentiating own emotions contributes to empathy (compare Bird & Viding, 2014; Cook et al., 2013; Moriguchi et al., 2006; Moriguchi et al., 2007).

Interestingly, changes in emotional awareness were not associated with improvements in emotion recognition after training, and changes in emotion recognition within training were not related to changes in empathy after training. These findings are in contrast with the results of other studies, for example, Israelashvili et al. (2020; 2019). This might be due to differences in methodology (e.g., tasks targeting complex versus basic emotions, non-autistic adult samples versus children on the AS). To

conclude, future studies should explore whether and how tasks that strengthen the awareness of own emotions/emotion recognition indeed affect different facets of empathy as suggested by models of empathy (e.g., Bird & Viding, 2014; Shamay-Tsoory, 2011).

The positive results for social functioning (here: SRS) and emotion regulation accord well with other studies, e.g., on the effectiveness of the *Secret Agent Society* (Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017), *FaceSay*^{TM} (Hopkins et al., 2011; Rice et al., 2015), and *Emotiplay* (Fridenson-Hayo et al., 2017). Nevertheless, the difference between the more pronounced changes in the participants' processing of their own emotions and social functioning versus only short-term training effects in processing others' emotions warrants further examination. Interestingly, Beaumont and Sofronoff (2008) reported similar results, with improvements in social functioning and emotion regulation, but a lack of training effect on behaviorally assessed emotion recognition, which was explained by ceiling and practice effects in the behavioral measure used.

Another possible explanation of these, and our, results may be that parents perceived interventions that targeted their child's own emotions as being more relevant to their daily family lives and therefore focused specifically on those interventions when working with their children. Indeed, research shows that behavioral and emotional dysfunction, such as anger dysregulation and temper tantrums, interfere greatly with family life and are associated with parental stress, anxiety, and depression, while reduced social competencies have a lesser impact (A. L. Davis & Neece, 2017; Firth & Dryer, 2013). This psychological strain may have resulted in more parental effort and motivation being focused on fostering emotional awareness and regulation during and after training, in comparison to repeatedly focusing on other people's emotional expressions. In addition, the children's social environments may have provided reinforcement, especially for enhanced emotion regulation and communication skills, resulting in better maintenance. Indirect evidence for this hypothesis comes from parents' statements during training supervision and the training goals defined by parents in the goal attainment scaling: In almost half of the cases, the parents wished to improve their children's handling of their own emotions (47%). Finally, because the ZE modules focusing on own emotions (I, IV) used videotaped emotion-eliciting contexts, they were more immersive and contextualized than module II, which presented isolated facial ex-

pressions. According to Whyte et al. (2015), more extensive learning contexts should support the learning of difficult behaviors and skills, as the motivation to learn them is intrinsically enhanced in the children. However, due to the lack of further studies which investigate the maintenance effects of computer-based interventions on emotion recognition (Berggren et al., 2017), empathy and related socio-emotional skills, there is a need for additional RCTs with rigorous methodology (e.g., active controls, long-term assessment, distant generalization measures).

Implications

In view of the generally high acceptance, feasibility, treatment satisfaction, and good ecological transfer of serious game effects to social abilities in daily-life situations (e.g., Beaumont & Sofronoff, 2008; Thomeer et al., 2015), our study's results are promising regarding practical implementation of the serious game *Zirkus Empathico* into current autism interventions, e.g., as a complement to specialized emotional and social skills training, such as that recommended by Berggren et al. (2017). As reported by the parents of our study participants, we see an especially high potential for ZE to serve as a communication context for sharing emotional experiences with peers and family members. In this function, the app facilitates the parents' involvement in the training of socio-emotional skills, which has already been shown to be important for therapy transfer and outcome (McConachie & Diggle, 2007; Sofronoff et al., 2005; Sofronoff et al., 2017). In addition, and considering the "double empathy problem" (Milton, 2012), which posits that non-autistic individuals generally have just as much difficulty in understanding the autistic mind as vice versa, ZE can foster the mutual understanding of emotion processing and thus, can help non-autistic individuals (e.g., caregivers, peers) to empathize more with children on the AS.

While designing the ZE intervention, we respected the importance of embedding serious games into real-life settings in order to enhance generalization, as it has been emphasized by other authors (see Kouo & Egel, 2016). However, as our findings for emotion recognition and empathy are limited, it might be fruitful to give parents more intensive training in providing structured real-life practices, and to incorporate more motivating transfer tasks/materials that are linked to the ZE storyline, for the children (compare Beaumont & Sofronoff, 2008; Whyte et al., 2015). Future research on ZE should investigate whether longer training periods under structured, professional supervision would result in more pronounced treatment effects and whether the content

is more appropriate and effective for younger age groups. Beyond that, and to test the effectiveness of ZE more comprehensively, future studies should investigate if our results apply in other samples with training-assisting caretakers having lower educational or different ethical backgrounds, or less time. Currently, our results do apply for predominantly female caretakers with mostly Caucasian ethnicity, medium to high educational background, who were able to investigate up to 100 min per week in their child's training. Furthermore, the feasibility of using ZE in routine care, as well as for fostering socio-emotional competencies in associated conditions (e.g., ADHD, anxiety disorders), should be ascertained.

Finally, when considering future serious game development, implementation, and research, it might be fruitful to compare the different computer-based interventions with each other to investigate which specific training content, elements, and mechanisms (e.g., various tasks/ materials, individualized/adaptive difficulty, compare Whyte et al., 2015) are most suitable for affecting targeted outcomes for different contexts (e.g., settings, assisting facilitators, target groups). Specifically, factors that support the successful generalization and maintenance of social skills (compare Gunning et al., 2019), should be examined so that they can be carefully incorporated into future serious game design.

Limitations

There are several limitations to the study, which are in part due to the assessment having taken place in the children's natural setting. First, because of structural limitations (e.g. time restrictions), real-life transfer was assessed using parent and teacher reports rather than direct and more objective, behavioral observations. Furthermore, as is common in psychotherapy studies, the observers could not be blinded regarding treatment allocation and therefore, the positive effects could have resulted, at least in part, from observer biases. However, given that the behavioral results from the objective tests support the parents' and teachers' subjective observations, it is unlikely that the effects are solely attributable to observer bias. An active control group was included to account for the potential effects of enhanced parent-child interaction, media use, and professional supervision, which could potentially have driven the results. Although the children were allowed to receive other treatments in parallel with the serious game, no socio-emotional content was allowed, so that a confounding of our results is unlikely.

A future study on parent-assisted serious games should investigate the caregivers' and children's behavior during training (e.g. by filming and analyzing training sessions) to allow insights into learning and other moderators that could potentially drive training effects. Furthermore, adverse events should be assessed more systematically to ensure safe training environment and a more complete picture of the effects of the training. While behavioral paradigms allow measuring direct effects on the children's behavior, they should be piloted beforehand to ensure a sufficient understanding of the task requirements, which was not the case for the MET-J/K in our sample. Finally, about 17% of the data overall participants and time points were missing because the outcome measures depended largely on the caretakers' compliance. This problem could be handled partly by using a full information maximum likelihood estimation method in statistical analyses. Nevertheless, this was not possible for evaluation of the treatment goal achievement (GAS) within the treatment group. To conclude, future studies on serious games should include more direct, behavioral, or observer-based assessments of the targeted competencies and rely less on parental judgment.

Conclusions

This study has shown that the parent-assisted serious game *Zirkus Empathico* has some potential for training socio-emotional skills in children on the autism spectrum. Future research is needed to investi- gate the specific mechanisms, which account for the transfer and maintenance of emotion recognition and empathy. However, the broad approach taken to the own and other people's socio-emotional functioning and the intervention's naturalistic approach seemed to be effective in improving emotional awareness and emotion regulation, as well as general autism symptomatology in the mid-term.

Funding

The study was funded by research funds from the Freie Universität Berlin (Berlin, Germany), the Berlin School of Mind and Brain (HU, Berlin, Germany), and the Stiftung Irene (Hamburg, Germany). The main author received a Ph.D. scholarship from two last institutions. In Austria, the study received funding from the Medical-Scientific Funds of the Mayor of Vienna (Vienna, Austria) (Project-No: 15162) for project funds and the second author's position. The third author was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foun- dation; 337619223/RTG2386). The funding

organizations had no role in the design of the serious game, study design, data acquisition and analysis, review, or approval of the manuscript, or the decision to submit the manuscript for publication.

CRediT authorship contribution statement

Simone Kirst: Conceptualization, Software, Methodology, Funding acquisition, Project administration, Formal analysis, Visualization, Writing – original draft, preparation. **Robert Diehm**: Investigation, Data curation, Writing – review & editing. **Katharina Bögl**: Methodology, Formal analysis, Writing – review & editing. **Sabine Wilde-Etzold**: Investigation**. Christiane Bach**: Methodology, Funding acquisition. **Michele Noterdaeme**: Resources, Supervision. **Luise Poustka**: Resources, Methodology, Supervision. **Matthias Ziegler**: Methodology, Formal analysis, Supervision, Writing – review & editing. **Dziobek Isabel**: Conceptualization, Supervision, Resources, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

The authors thank the children, their caregivers, teachers, and assistants, who made this research possible. We would like to thank Prof. Dr. Ulrike Lucke, Dietmar Zoerner, and Jan Schütze (Department of Computer Science, University of Potsdam, Germany) for the technical design, and Annika Hamann, Simon Könnecke, Lars Weström, and the CMS Video- and Audio Service (HU Berlin) for Zirkus Empathico's development and design. We are especially thankful to Verena Gross for data collection and training supervision at HU, to Mag. Barbara Kainz at MedUni Wien, and to all the other students who were involved in the study. We thank the administrative personnel of the Berlin School of Mind and Brain, and the Department for Child and Adolescent Psychiatry of MedUni Wien, as well as the Autismus Therapie Zentrum Bonn- Siegburg (Bonn, Germany), and the outpatient clinic of the University Clinic Cologne (Germany), and various pediatric services, autism centers, outpatient clinics, child psychiatrists and parent organizations in Germany and Austria for supporting recruitment. Finally, the authors direct their sincere thanks to the Stiftung Irene (Hamburg, Germany), the Berlin School of Mind and Brain, the Medical-Scientific Funds of the Mayor of Vienna (Austria), and the German Research Foundation for their financial support.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi. org/10.1016/j.brat.2022.104068.

6 General Discussion

This dissertation aimed to gain a multifaceted and comprehensive insight into the social behaviors of children on the AS by integrating various associated cognitive and emotional processes into research and intervention models. More specifically, by using path analysis it was first investigated whether symptoms of dysfunctional emotion regulation (*here*: lability-negativity, lack of flexibility, anger dysregulation, and mood lability; Shields & Cicchetti, 1997) have an additional impact on the interplay between the misinterpretation of emotional expressions and tendencies to attribute hostile intent to others (in the ff. hostile attribution bias) as predictors of different forms of maladaptive (here, aggressive) social behaviors in children on the AS (RQ 1). Second, a mechanistic and holistic digital intervention was developed to foster empathy as a precursor of prosocial behaviors in autistic preschool and primary school children through training cognitive and affective facets of empathy, its foundations (*here*: emotional awareness, emotion recognition), and prosocial acts of empathic concern (RQ 2). Third, the acceptability and feasibility of the novel intervention were examined (RQ 3) and the expected short- and medium-term intervention effects on empathy and emotion recognition as primary outcomes (RQ 4) were tested by conducting a six-week multicenter RCT with 82 children on the AS at three study sites in Germany and Austria. In addition, transfer effects (e.g., on emotion regulation, reduction of autism social symptoms) were examined and it was explored whether changes in emotional awareness/emotion regulation over the course of the training would predict changes in emotion recognition/empathy three months after the intervention.

Study 1 on RQ 1 confirmed the hypothesis that hostile attribution bias increases aggression in the case of covert and verbal aggression, but not for more physical forms of aggression. As expected, dysfunctional emotion regulation had an additional and direct impact on bullying, verbal aggression, and covert aggression and – only in the case of the latter subtypes – an indirect impact through enhancing hostile attribution bias. Other than expected, better emotion recognition accuracy was associated with a stronger tendency to attribute hostile intentions to others. Regarding the development of a digital intervention to foster empathy and related prosocial skills more holistically (RQ 2), the manualized, caregiver-assisted serious game "*Zirkus Empathico*" could be realized within an interdisciplinary team of psychologists, autism experts, interaction designers, developers, and film specialists. Persons on the AS contributed to the

application in an advisory manner and initial pilot studies showed good usability and acceptability (Technical Report; Online Supplementary of Study 2). Moreover, the multicenter RCT testing the novel intervention in a naturalistic setting showed very promising results. Beyond high rates of treatment satisfaction and acceptability in children and caregivers, the training seemed to be suited to feasibly be applied within the families' daily routines (RQ 3). Improvements in parent-rated general empathy and behaviorally assessed emotion recognition after the six-week training suggested good effectiveness (RQ 4). Since the training effects were not maintained at the three-month follow-up, the hypothesis on the effectiveness of the digital intervention was only partly confirmed. Secondary analyses revealed moderate and maintained improvements in emotional awareness, which were positively related to later gains in general empathy. In addition, since emotion regulation was strengthened and a reduction in autism social symptomatology was observed, the results point to an actual transfer of the digital training to real-world social behavior, which was furthermore maintained at follow-up.

These findings should be discussed in the following under a common perspective (Chapter 0). As expected, they are in line with established and comprehensive information processing models that integrate various interacting cognitive and emotional processes to explain empathic and social behavior. This strongly underlines the usefulness of grounding social research *and* intervention approaches in autism on established and comprehensive frameworks (e.g., SCIP models, Lemerise & Arsenio, 2000; SOME; Bird & Viding, 2014). Second, emotion dysregulation, which is potentially rooted in the core characteristics of autism (Mazefksy et al., 2013; Mazefksy & White, 2014), seemed to have a significant impact on socio-cognitive processing and social behavior enactment in children on the AS (compare Weiss, 2014). Here, the present work highlights the prominent function of the formerly often neglected disturbed emotion regulation in autism research. Further exploration of the interplay between emotional processes such as emotional awareness, emotion regulation, and socio-cognitive factors that characterize individuals on the AS (e.g., cognitive empathy, emotion recognition) might contribute to providing improved and individualized (digital) interventions (compare Sofronoff et al., 2014). Thinking transdiagnostically and adopting network theory approaches (e.g., Borsboom, 2017) might be beneficial for gaining more profound insights into the mutually intertwined relationships between emotional and cognitive factors underlying social behavior and for developing more effective and transdiagnostically applicable social interventions.

Due to its holistic conceptualization, the Zirkus Empathico digital approach might have great potential to be broadly applied in clinical and non-clinical settings (Chapter 6.2). Young autistic and non-autistic children showing different forms of aberrant social behaviors (e.g., social anxiety, aggressive behaviors) or suffering from mental health problems (e.g., internalizing symptoms) might benefit from the training or its modified versions as a complement to standard therapy. Under more neurodiverse perspectives (J. Singer, 2017), Zirkus Empathico might further be used to enhance empathy in parents, siblings, or peers for children on the AS (see Milton, 2012) by providing a communication context for reciprocally sharing significant experiences and associated emotions.

Both, the development process of Zirkus Empathico and the RCT on its effectiveness, acceptability, and feasibility revealed several interesting aspects and challenges that need to be addressed in the future (Chapter 6.3). To ensure an actual clinical benefit, the long-term effectiveness and transfer of digital solutions should be improved, e.g., by integrating further elements of serious games (Whyte et al., 2015) and strengthening participatory research (Frauenberger et al., 2012). Moreover, feasible, accepted, and convenient ways of integrating digital interventions into family lives should be explored, and the scientific development of digital interventions as well as their transfer from academic contexts into the supply system should be facilitated.

Several methodological limitations resulted from the broad perspective of this work and the practical restrictions within the naturalistic setting of the studies (Chapter 6.4). In this context, primarily the risk of potential biases and the limited mechanistic understanding must be mentioned. Future studies should assess the acceptability and feasibility of digital intervention approaches more systematically and single case studies could allow additional insights into training mechanisms (compare Barton et al., 2017). Using digitalized behavioral paradigms (e.g., Drimalla et al., 2020) might also help to conduct elaborate research on digital interventions within naturalistic settings.

6.1.1 Motivating Comprehensive Approaches for Research and Intervention in Autism And Beyond

The results of the present work are well in line with established and comprehensive frameworks that postulate several interacting socio-cognitive and emotional processes underlying social behaviors. This also underlines the relevance of grounding research and intervention models on comprehensive approaches to studying various predictors of social behaviors in conjunction (Chapter 6.1.2). Within both studies, a prominent impact of emotion (dys)regulation on social behavior is further observed (Chapter 6.1.3) and future studies might thus consider its potential transdiagnostic function and use comprehensive and transdiagnostic approaches (e.g., network theory) to disentangle the complex interplay of different socio-emotional factors and to design effective interventions (Chapter 6.1.4).

6.1.2 The Relevance of Holistic Frameworks Integrating Socio-Cognitive and Emotional Processes

Various socio-cognitive and emotional processes engage in mutual interactions within social information processing in interactive situations, which subsequently results in behavior enactment (Lemerise & Arsenio, 2000). Investigating this complex interplay, and subsequently developing effective social interventions, require a profound theoretical framework of how specific behaviors evolve. Therefore, within this dissertation, the SCIP models (Crick & Dodge, 1994, 1996; Lemerise & Arsenio, 2000) were used to inform the mediation models aiming to investigate maladaptive social behavior (Study 1), and the SOME model (Bird & Viding, 2014) to ground the digital intervention approach in empathy theory (Technical Report, Study 2). Importantly, since it was aimed to provide comprehensive perspectives, both models integrate cognitive (e.g., perspective taking, decision making) and emotional processes (e.g., emotion recognition, emotion regulation, empathic resonance).

In sum, both models are supported by the results of the present studies. Hence, applying holistic approaches might provide informative insights into social phenomena, or respectively, might result in offering effective interventions. This should encourage future investigations to partly shift their attention from studying isolated skills (e.g., differences in emotion recognition between non-autistic and autistic children) to investigating specific patterns of functional or disturbed information processing. For example, such studies could aim to disentangle the many potential interactions between

various problems in emotional processes, biased social information processing and reduced ToM, and other autism-related features (e.g., hyperarousal, perseveration, rigidity, poor problem solving), which are likely to diminish the quality of social interaction (see Mazefksy et al., 2013; Mazefksy & White, 2014). Such studies could help to define multiple profiles of socio-cognitive and emotional processes characterizing individuals on the AS, which, in turn, determine specific and individualized ways of intervening (compare Mazefksy & White, 2014; Sofronoff et al., 2014). Furthermore, our holistic training of emotional awareness, emotion recognition, affective and cognitive aspects of empathy, and basic prosocial skills seem to have resulted in maintained effects and transfer effects on social skills. This is well in line with other studies on comprehensive digital interventions (e.g., SAS, Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017; FaceSay™, Hopkins et al., 2011; Rice et al., 2015; and Emotiplay, Fridenson-Hayo et al., 2017), while, in contrast, an exclusive focus on isolated skills such as emotion recognition tended to *not* show transfer effects on social behavior (see review by Zhang et al., 2021). In sum, these findings should encourage and inspire the future development of (digital) social interventions to target different socio-cognitive and emotional skills in conjunction.

6.1.3 The Profound Impact of Emotion Dysregulation on Social Behavior

In both studies, emotional processes – specifically emotion regulation – seem to have a significant impact on social cognitive information processing and the engagement in adaptive or maladaptive social behaviors (compare Lemerise & Arsenio, 2000). In Study 1, disturbed emotion regulation, behaviorally expressed as lability-negativity (lack of flexibility, anger dysregulation, and mood lability; ERC-N/L[11]; Shields & Cicchetti, 1997) was shown to be directly and indirectly (through hostile attribution bias) associated with different forms of aggressive behavior. This finding is in line with studies reviewed by Smeijers et al. (2020) on aggressive responses in non-autistic children and adults. In contrast, hostile attribution bias was only related to verbal and covert aggression, but not to physical forms of aggression in our study (compare Helmsen et al., 2012). In reference to cross-sectional and longitudinal studies in non-autistic individuals (e.g., Blandon et al., 2010; Fite et al., 2008; Goldweber et al., 2011; Halligan et al., 2013; Musher-Eizenman et al., 2004), it might be suggested that emotion dysregulation plays a prominent role with regard to favoring the presence of

[11] ERC-N/L: Emotion Regulation Checklist – Negativity/Lability

maladaptive social behaviors in children on the AS (compare Weiss, 2014). Further mediation studies that are ideally conducted longitudinally to prevent biases (see Cole & Maxwell, 2003; Maxwell & Cole, 2007) are needed to study the exact nature of the relationships. For example, while our models assumed that the relationship between emotion dysregulation and aggression is mediated by hostile attribution bias (compare Musher-Eizenman et al., 2004), other studies assumed that the relationship between disturbed social cognition and aggression is rather moderated by emotion dysregulation (e.g., Fite et al., 2008). Since emotion dysregulation encompasses several phenomena, future studies should also disentangle the role of different subcomponents such as impulsivity and executive functioning on maladaptive social behavior.

In individuals on the AS, problems in emotion regulation have been associated with impairments in emotional awareness, empathy, emotion recognition, and perspective-taking (e.g., Mazefksy et al., 2013; Jahromi et al., 2012; Konstantareas & Stewart, 2006; Mazefksy & White, 2014; Samson et al., 2012), which are target skills of Zirkus Empathico. Indeed, a maintained improvement in emotion regulation has been demonstrated by our study. Given the strong association between functional emotion regulation and prosocial behaviors (S. Denham et al., 2003), we tentatively suggest that the observed transfer effect on social skills might actually be due to the strengthening of emotion regulation capacities. Clearly, this assumption of emotion regulation functioning as a (training) mediator between socio-cognitive/emotional skills and social behavior as an outcome should be investigated in future longitudinal and more mechanistic intervention studies (see limitations, Chapter 6.4). However, concerning the results of Zirkus Empathico and the comparable SAS intervention (e.g., Beaumont & Sofronoff, 2008; Einfeld et al., 2018; Sofronoff et al., 2017), it could be concluded that targeting social behavior through enhancing, among others, emotion regulation, potentially is a promising approach. Furthermore, especially disturbed emotion regulation and related alexithymia are increasingly considered transdiagnostic risk factors for diminished well-being and the development of mental conditions (e.g., depression, anxiety) in the general population (e.g., Aldao et al., 2016) as well as in individuals on the AS (e.g., Oakley et al., 2022). Therefore, it would be interesting to explore the effects of Zirkus Empathico on the regulation of different emotions such as anxiety or anger and their transfer to mental health problems in autistic and, potentially, in non-autistic children (see further discussion in Chapter 6.2).

6.1.4 The Need for Comprehensive, Transdiagnostic Approaches to Disentangle Complex Interplays and to Design Effective Interventions

Defining multiple profiles of socio-cognitive and emotional processes characterizing individuals on the AS requires disentangling the many potential interactions between the various impairments in socio-cognitive and emotional processes and, in addition, potentially contributing external factors (e.g., parental factors such as parental stressors or parenting styles; Mills et al., 2022). Given the significant complexity of this interplay, future research could strongly benefit from theoretical and methodological approaches that allow for exploring complex relationships. In addition, since some processes (e.g., emotion regulation) seem to have an important transdiagnostic function (see Chapter 6.1.3), adopting a transdiagnostic perspective might result in more comprehensive insights, which facilitate the development and implementation of customized interventions for different target groups. With respect to both aspects, network theory, which received increasing popularity in the last decade (Berta et al., 2022), could be especially useful since it enables the conceptualization and investigation of complex phenomena (e.g., psychopathologies) as mutually interacting elements represented as nodes (e.g., symptoms, biological components, environmental risk factors) within a complex network (see Isvoranu et al., 2022).[12] In the case of mental disorders, the nodes represent symptoms that may be activated by an external triggering event (e.g., loss of a partner). If the nodes within a network are strongly connected (e.g., due to personal dispositions), the activation of a node spreads through the network by engaging in various feedback loops, which results in the development and maintenance of a mental disorder, even after the initial trigger has disappeared (Borsboom, 2017). Since symptom clusters of different mental disorders can structurally overlap (e.g., fatigue and concentration problems playing a role in PTSD[13] and depression; Borsboom, 2017), the activation of these so-called "*bridge symptoms*" (Borsboom, 2017, p. 8) could result in comorbidities between disorders (Borsboom, 2017; Fried & Cramer, 2017).

[12] According to network theory, each person is characterized by a specific network that can be visualized as a network of nodes and edges between nodes of different thicknesses. The magnitude of the relationships between different nodes, for example, personal factors such as emotionality, is determined by interindividual differences in their variability as described by Coughlan et al. (2021).

[13] PTSD: post-traumatic stress disorder

In the context of the present work, using network approaches and their methodologies (e.g., partial correlation networks; Bringmann et al., 2022; Epskamp & Fried, 2018; vector autoregressive models; Epskamp, 2020) might be especially fruitful to explore adaptive and maladaptive social behaviors in conditions that are associated with social symptomatology (e.g., autism, social anxiety disorder, alexithymia, ADHD, and schizophrenia), either within a specific condition (e.g., Hajdúk et al., 2021; Hirota et al., 2020) or across conditions (e.g., see Coughlan et al., 2021 for a network analysis in children with ADHD and autism). For example, concerning the presence and development of aggressive behaviors in autistic children, the conditional associations between inherited personal traits (e.g., impulsivity, callous-unemotional traits, Ibrahim et al., 2019), emotion dysregulation, and problems/biases in other processes (e.g., emotion recognition, ToM, social problem-solving skills, hostile attribution bias, see Chapter 1.2), and environmental factors (e.g., negative experiences such as bullying, Maïano et al., 2016; aggressive models, Bandura, 1973) could be examined (compare the ontogenetic approach to psychopathology applied to externalizing behaviors by Beauchaine & McNulty, 2013). Since we found disturbed emotion regulation, expressed as lability-negativity, to be a prominent predictor of different forms of aggressive behaviors (Study 1), it might be postulated that the node representing emotion dysregulation would be highly connected, and thus central, to this network (compare Beauchaine & McNulty, 2013). Consequently, emotion dysregulation represents an important target for intervention (Rodebaugh et al., 2018; Weiss, 2014). Preliminary network studies further point to irritability (which is conceptualized comparably to lability-negativity) serving as an important bridge symptom between aggression and other problem behaviors (e.g., hyperactivity, lethargy/social withdrawal, and internalizing symptoms) in children on the AS (Hirota et al., 2020) and non-autistic adolescents (Madole et al., 2019). Addressing irritability together with other bridge symptoms such as interpersonal difficulty (frustration and displeasure with others), depressive mood, and oppositional functioning (e.g., rule-breaking, conduct problems) through combining different modalities of treatment could potentially ease the complicated symptom network and thereby reduce maladaptive and aggressive behaviors in individuals on the AS (Hirota et al., 2020).

Information on network architectures (e.g., central nodes, relationships between nodes) could also be used to inform future intervention models. For example, the first network studies in non-autistic individuals by Briganti and colleagues (2020; 2020)

found that difficulties in describing feelings, and, especially poor fantasy and emotional insight, are the most central factors in the construct of alexithymia. Thus, they might be considered the most meaningful targets for alexithymia interventions (Briganti & Linkowski, 2020). In addition, alexithymia was found to serve as the key bridge factor between interoceptive deficits, self-awareness, and empathic impairments in individuals on the AS (Yang et al., 2022). Consequently, and in light of the observed gains in emotional awareness during the Zirkus Empathico intervention predicting empathy improvements three months later (Study 2; compare Cook et al., 2013; Moriguchi et al., 2006; Moriguchi et al., 2007), targeting clinical and subclinical levels of alexithymia might indeed leverage the development of enhanced empathic and prosocial behavior (compare Beaumont & Sofronoff, 2008). Finally, since the first network analysis by Briganti and colleagues (2018) reported empathic concern as being the central (and thus highly connected) factor within the construct of empathy, we might speculate that empathy interventions should focus on empathic concern beyond cognitive empathy, as we have (in outline) already implemented in Zirkus Empathico (module IV).

6.2 Identifying Future Perspectives for Zirkus Empathico

In the light of the generally high acceptance, feasibility, treatment satisfaction, and good ecological transfer of serious game effects to social abilities in daily-life situations (e.g., Beaumont & Sofronoff, 2008; Thomeer et al., 2015), the results of Study 2 are promising regarding the practical implementation of the serious game Zirkus Empathico in current interventions for children with special needs. Based on the previous discussion, in the following section, it should be highlighted how applications such as Zirkus Empathico could be applied transdiagnostically to autistic and non-autistic children (Chapter 6.2.1), with a special focus on aggressive behaviors under consideration of the SCIP models (Chapter 6.2.2). Finally, from a more neurodiverse perspective, Zirkus Empathico might be applied to enhance empathy in the parents or peers of children on the AS by providing a communication context for reciprocally sharing significant experiences and associated emotions (Chapter 6.1.46.2.3).

6.2.1 Potential Transdiagnostic Application Fields

Study 2 showed promising results for the effectiveness and feasibility of the parent-guided digital intervention Zirkus Empathico in children on the AS in the home

setting. Modularizing Zirkus Empathico to be applied in different populations and settings might be promising because in face-to-face therapy, transdiagnostic, and therefore modularly designed approaches were shown to yield good results (compare Fleming, Beurs, et al., 2016). For example, in light of the current serious gap between the need for support and its supply (see Chapter 1.3.1), Zirkus Empathico might be useful to strengthen socio-emotional competencies as a basic preparation for later psychotherapy (e.g., during waiting times) for children with conditions associated with limited social and communicative skills such as social anxiety (see Pickard et al., 2018). Furthermore, given that Zirkus Empathico seems to be most effective in reducing alexithymia and emotion dysregulation, which both represent transdiagnostically-relevant risk factors for developing mental health problems (see Chapter 6.1.3), it could potentially be used as a complement to the treatment, or, respectively, prevention, of mental conditions that are associated with emotional difficulties (e.g., internalizing disorders; see Aldao et al., 2016; Oakley et al., 2022; Weiss, 2014). Given the promising effects of the comparable SAS training (Beaumont & Sofronoff, 2008) on different symptoms of anxiety (see below), this assumption should be tested by investigating the transfer effects of skills targeted by Zirkus Empathico (e.g., emotional awareness) on closely-related competencies such as emotion regulation (Samson et al., 2012) and, distantly, on mental health in different populations.

However, since well-being only trended towards a positive intervention effect in the sample of Study 2, Zirkus Empathico might need to be supplemented by further modules targeting functional emotion regulation more comprehensively (e.g., in teaching adaptive regulation strategies; compare the app "*Emodiscovery*,"[14] Pacella & López-Pérez, 2018), to affect well-being and symptoms of mental illnesses. Various studies on the English-speaking SAS program for children between 8 and 12 years (Beaumont & Sofronoff, 2008), which targets emotion regulation skills (e.g., coping techniques) in conjunction with social skills (e.g., conversational skills and turn-taking), showed that a such an approach is promising for significantly improving children's emotional-regulation skills and anxiety levels as well as social functioning in autistic children (e.g., Beaumont et al., 2021), children with learning difficulties, ADHD, anxiety disorders, and children without formal diagnoses (Beaumont et al., 2019), across different contexts (Beaumont et al., 2021), and also for up to one year after the

[14] http://emodiscovery.com/the-project.html

end of the intervention (Einfeld et al., 2018). A German adaptation of some of the SAS contents and elements for the younger target groups of Zirkus Empathico could potentially result in more pronounced and long-lasting intervention effects and allow for an even more transdiagnostic use of the application. Significantly, given its limited content and scope, it is recommended to only use Zirkus Empathico as a complement to therapist-led intervention in clinical contexts (e.g., treatment of internalizing disorders). For example, within the child-therapist interaction, Zirkus Empathico could be applied as a platform that provides life-like stimuli, which might encourage the child to engage in reciprocal communication about emotional experiences (see also Chapter 6.2.3). Similarly, Zirkus Empathico might be a feasible tool that easily and actively involves parents in their child's therapy, e.g., as transfer facilitators using Zirkus Empathico with their children in home settings.

Finally, Zirkus Empathico could be used as a preventative tool to strengthen social development in non-autistic preschoolers since fostering socio-emotional competencies within the early years of development represents a critical educational task to prevent manifestations of psychiatric disorders (Fryers & Brugha, 2013), and fostering school readiness (Slot et al., 2020) and subsequent academic success (S. A. Denham, 2018). In this context, a first RCT by Naumann and colleagues (in submission, see Naumann et al., 2021 for a preprint) found preschoolers aged 4–6 years showing gains in parent-rated empathy, prosocial behavior, and reduced problem behavior, as well as improved emotion recognition accuracy after six weeks of Zirkus Empathico training. Further, the first evidence of changes in neural plasticity through the Zirkus Empathico training was obtained, as indicated by disparate brain patterns (assessed via EEG[15]) between control and training groups for processing happy facial expressions (Naumann et al., 2021).

6.2.2 A Modified Version Targeting Maladaptive Behaviors under Consideration of the Social Cognitive Information Processing Models

Concerning the finding that emotion dysregulation was found to play a prominent role in enhancing different aggressive behaviors in Study 1, and that the Zirkus Empathico intervention was shown to be effective in enhancing functional

[15] EEG, electroencephalography

emotion regulation and underlying emotional awareness, the question arises if training with Zirkus Empathico might also reduce aggressive behaviors in children on the AS (and potentially in non-autistic children). Although Study 2 did not investigate if the training resulted in a reduction of aggressive behaviors (see limitations, Chapter 6.4), it can be speculated that the training has some potential in this regard. First, the ERC results point to a reduction of lability-negativity (which is more strongly related to aggressive tendencies than functional emotion regulation as measured by the ERC-ER subscale (Henriques Reis et al., 2016) after training. Similarly, short-term intervention effects were observed for callous-unemotional traits (lack of guilt, empathy, or remorse, A. A. Moore et al., 2017), which are associated with aggressive tendencies in autistic children with comorbid externalizing behaviors (Ibrahim et al., 2019). But, given that the reduction in both predictors of aggression was not maintained to follow-up, a more long-term, clinically significant effect on maladaptive behaviors is unlikely.

Since Zirkus Empathico does not have a closed game logic (as given in more story-based games), it could easily be extended to allow a stronger focus on the development of prosocial and the reduction of maladaptive, e.g., externalizing/aggressive behaviors. For example, additional modules teaching functional impulse/anger control through adaptive emotion regulation strategies (e.g., cognitive reappraisal, compare Helmsen et al., 2012) and strengthening the adaptive communication of anger and other stressful emotions (see Fitzpatrick et al., 2016) could help to target aggressive tendencies. Indeed, a first pilot study on the interactive mobile game "*RegnaTales*" for children with a clinical diagnosis of disruptive behavior disorders demonstrated that a digital CBT intervention teaching various anger management strategies might be of use for reducing reactive aggression in clinically aggressive, non-autistic children (Ong et al., 2019).

Nevertheless, since Zirkus Empathico was based on the SOME (Bird & Viding, 2014), apart from motivating a few empathic behaviors (e.g., helping, comforting; module IV), the training currently does not teach further steps towards functional social behavior as defined by the SCIP models (see

Figure 3.1). Zirkus Empathico in its current version thus might only have an impact on the first two SCIP operations whereby training emotion recognition and empathic responsiveness might affect operation 1 (encoding of emotional and social

cues) and the module on cognitive empathy might simplify the interpretation of social information (operation 2). A stronger effect on social behavior (including a reduction of maladaptive responses) might be achieved, for example, by adding CBT-based modules teaching techniques to modify unhelpful thought patterns (see Lochman & Wells, 2002) that bias information processing within operation 2. Regarding the specific socio-emotional profile of children on the AS, such contents should be grounded in an intensified training of cognitive empathy and intent attribution (see van Nieuwenhuijzen & Vriens, 2012; Ziv et al., 2014 for studies on the relationship between ToM and hostile attribution bias). Furthermore, teaching social problem-solving skills (SCIP operations 4–5) could enhance the selection of adaptive social response strategies in social situations (compare Channon et al., 2001 and Ong et al., 2019 and A. B. Craig et al., 2016 for the first digital tools incorporating social problem-solving skills). In sum, extending the SOME-based Zirkus Empathico training with contents relating to the SCIP models might provide a larger toolbox of functional emotional and social skills that ideally also prevent maladaptive responses (e.g., compare Beaumont & Sofronoff, 2008).

6.2.3 A Communication Context to Foster Mutual Empathy

Based on the parent reports in Study 2, it can be proposed that another added benefit of Zirkus Empathico consists in providing a communication context for reciprocally sharing emotional experiences with family members and also – if integrated into the training – peers or siblings. Here, it might be interesting to consider the idea of "*neurodiversity*" (J. Singer, 2017), which, broadly speaking, assumes that differences (e.g., between the autistic minority and the non-autistic majority) in thinking, learning, and behaving should be respected instead of being considered as deficient, abnormal, or impaired. As stated by Milton (2012), non-autistic individuals might generally have just as much difficulty in understanding the autistic mind as vice versa ("*double empathy problem*"; Milton, 2012, p. 884) and, therefore, the condition of autism should rather be understood as a "*bidirectional failure of empathy*" (Mitchell et al., 2021, p. 8). Interestingly, preliminary studies suggest that autistic people might have a unique interaction style that is significantly more readable by other autistic than non-autistic persons (Mitchell et al., 2021), which led to increased social affiliation when autistic adults were partnered with other autistic people (Morrison et al., 2020). It might be thus more accurate to frame social interaction difficulties in autism as a relational rather than an individual impairment (Morrison et al., 2020).

In this context, by incorporating a variety of realistic video examples of emotional experiences, the training environment of Zirkus Empathico might enable the training partners (e.g., autistic child and their parents) to learn about each other's emotional responses. Similarly, the video content might stimulate reciprocal communication about associated real-life experiences which could subsequently support the corresponding understanding of the other's perspectives and, in the future, enable a better interpretation of socio-emotional signals emanating from the autistic, or respectively, non-autistic individual (compare Mitchell et al., 2021). Ideally, a better understanding of the autistic mind and interaction style might result in more welcoming and accepting attitudes and behaviors of parents/peers towards the autistic child (compare Sasson & Morrison, 2019), which potentially strengthen the child's sense of belonging and self-esteem (see Mitchell et al., 2021). Enhanced acceptance of the children's characteristics might have a positive impact on their social behavior (see "*transactional account of development*"; Mitchell, 2017; Mitchell et al., 2021) and prevent social camouflaging of autistic traits, which is associated with poor mental health in adulthood (Cassidy et al., 2018; Cassidy et al., 2020).

Interestingly, the preliminary interventions in this context are grounded on comparable ideas. For example, Jones and colleagues (2021) investigated whether an autism acceptance training program, which was designed to increase autism knowledge and familiarity among non-autistic people, reduces biases toward autism, and van Wingerden and colleagues (2018) aimed to improve caregivers' attachment to children with mild to moderate intellectual impairments by a mobile learning intervention targeting the caregivers' empathy and self-efficacy. Thus, it might be of interest to investigate if, and under which conditions (e.g., setting, amount of tutor supervision and education, tutor/peer characteristics), the training with Zirkus Empathico (or a modified version addressing the caregiver's empathy and knowledge about autism more explicitly; compare D. R. Jones et al., 2021; Mitchell et al., 2021; van Wingerden et al., 2018) indeed enhances empathy *for* autistic children, which, in addition potentially affects the children's well-being and behavior.

6.3 Addressing the Challenging Real-Life Application of Digital Interventions

As discussed in the previous chapters, Zirkus Empathico might be a suitable tool for addressing various target areas (e.g., empathy, prosocial behavior, emotion regulation, internalizing symptoms) within different groups, for example, autistic children or non-autistic children with socio-emotional impairments. Future RCTs on Zirkus Empathico should carefully test these assumptions and also identify group-specific training profiles and mechanisms to adjust the training accordingly. However, since a clinical intervention should be evaluated especially in terms of having a clinically significant impact on the intended population, ways to improve generalized *and* maintained changes in symptom-relevant real-world behavior (Fletcher-Watson, 2014) should further be explored for Zirkus Empathico and comparable digital interventions (Chapter 6.3.1). In this context, it might be very fruitful to develop digital interventions by integrating their future users into informed treatment decisions as it is suggested by participatory research frameworks (Chapter 6.3.2). Since the actual use of digital social interventions in real-life settings further depends on their acceptability and feasibility, ideas to improve these aspects can be derived from the promising results of Zirkus Empathico (Chapter 6.3.3). Finally, due to restrictions and barriers in the current research, funding, and care systems, the challenging transfer of validated digital solutions such as Zirkus Empathico into autism supply must be addressed to create a real benefit for the families in need (Chapter 6.3.4).

6.3.1 Possibilities to Enhance Maintenance and Generalization

As suggested by the findings of Study 2, the current Zirkus Empathico intervention partly resulted in generalized behavioral changes: caregivers and, importantly, teachers rated prosocial skills as measured by the Social Responsiveness Scales (SRS; Constantino & Gruber, 2007) to be improved, which shows a generalization across different contexts that is comparable to the one shown by Beaumont and colleagues (2021) for SAS. Furthermore, caregivers indicated attainment of real-life treatment goals at post-treatment (T2), which was further supported by children's and parents' reports on perceived behavioral changes. However, gains in empathy and emotion recognition were not maintained at the three-months follow-up. In addition, children and parents were only interviewed qualitatively at T2 and no assessments were conducted after more than three months post-training. Hence, it is unknown, if the detected generalized changes (e.g., in prosocial behavior) were

maintained in the long term. These limitations and uncertainties regarding maintenance and generalization are well in line with other studies on digital interventions (compare Gev et al., 2017; and see Zhang et al., 2021 for a recent meta-analysis). Therefore, it is necessary to identify the strengths of the present approach on the one hand and to discuss ideas for further improving generalization and maintenance on the other.

First, integrating caregivers into the training as assisting tutors to organize and provide learning opportunities for children within and outside the game (e.g., by role modeling targeted behaviors, providing corrective feedback, and integrating transfer tasks into the natural environment; compare "*blended computer and traditional in-person instruction model*", Whyte et al., 2015, p. 3828) might have been supportive for training transfer (McConachie & Diggle, 2007; reviews by Hong et al., 2017; Zhang et al., 2021). While the caregivers reported almost no difficulties with their role, unsystematic observations during training supervision suggest that some caregivers were more able than others to fulfill this role, e.g., by adopting the limited training content (see below) flexibly to their child's age, skill level, or individual needs. Future studies should systematically investigate the caregiver-related effects to identify caregivers' characteristics and training conditions that allow a good quality of tutor support and are related to beneficial training outcomes. Such investigations could pave the way for providing tailor-made tutor support and professional supervision that is oriented to their specific needs.

Besides its blended model approach, another strength of the Zirkus Empathico training might consist of the implemented elements of serious games, such as prompts and support (compare Fletcher-Watson, 2014; Hollis et al., 2017), theme-based and partly immersive and naturalistic video content (compare Baron-Cohen et al., 2010), an engaging reward system with non-social rewards oriented to the children's preferences (compare Fletcher-Watson, 2014; Fletcher-Watson et al., 2016), and the provision of choice (e.g., free selection of open modules and tasks; compare Whyte et al., 2015). As Whyte and colleagues (2015) suggested, elements of serious games provide immersive and contextualized learning environments that scaffold learning of difficult behaviors and skills through enhancing the intrinsic motivation in children to learn and maintain them (Whyte et al., 2015) and, interestingly, the greatest evidence of generalized learning was reported for interventions with the greatest number of serious game

elements (e.g., Beaumont & Sofronoff, 2008; Hopkins et al., 2011; see review by Whyte et al., 2015). The Zirkus Empathico program was further implemented on touchscreen technologies, which are very popular and highly motivating media among families with children on the AS (compare Fletcher-Watson et al., 2016).

However, based on other results, several starting points for improving the limitations in maintenance and generalization of the present approach can be identified. Regarding the caregiver-guided approach, treatment transfer might be further enhanced by adding caregiver modules that provide instructions on how to effectively transfer skills to the children's lives (e.g., through engaging in child-initiated teaching, modeling transfer tasks on autistic learning and play, and using natural reinforcement; compare Schuck et al., 2021). In the context of naturalistic intervention approaches that might be applied within neurodiversity frameworks, adding elements that support the development of individualized and subjective significant treatment goals with the children might help to enhance the children's intrinsic motivation during training (compare Fleming, Beurs, et al., 2016; Schuck et al., 2021). Since individuals on the AS often display strong analytic or systemizing skills (Baron-Cohen, 2002), steps needed to reach individualized goals should be defined and made measurable (e.g., by implementing tracking mechanisms and/or using emotion-sensitive technology) with progress being feedbacked frequently (compare Whyte et al., 2015). However, due to the internal game logic of Zirkus Empathico, it might not be possible to implement immersive storylines that relate to these targeted goals (e.g., learning about emotions to successfully navigate a character through an adventure; compare Beaumont & Sofronoff, 2008), which is another suggested element of serious games (see Whyte et al., 2015). Nevertheless, Zirkus Empathico might be extended to allow for more spontaneous user interactions, which is regarded as useful for training transfer (Whyte et al., 2015; see Ke & Moon, 2018 for naturalistic and interactive virtual reality [VR] approaches). In this context, Hassan and Pinkwart (2020) developed a prototype of a multiplayer version of Zirkus Empathico in cooperation with the author of this dissertation, which should be evaluated in future studies.

Another possibility might be to extend the duration of the intervention since it has been shown that more sustainable changes can be reached by a duration of more than 10 weeks (compare Laugeson et al., 2012; Zhang et al., 2021). However, since

caregivers and children already criticized the fact that the provided video content of Zirkus Empathico was too limited and therefore was perceived as repetitive or boring, extending its duration requires adding more learning content which should also contain more difficult tasks (e.g., more complex, less expressive, or mixed emotional stimuli) to prevent ceiling performances, boredom, and demotivation (compare Whyte et al., 2015). It might also be necessary to account for individual performance, e.g., through control over the frequency, intensity, difficulty, and content of exercises (compare Fletcher-Watson, 2014; Hollis et al., 2017; Whyte et al., 2015).

The idea for Zirkus Empathico was already pursued in 2019 in a student seminar of the Department of Informatics of the Humboldt-Universität zu Berlin, which was held by an associated Ph.D. candidate in cooperation with the author. To allow a flexible adaptation of tasks (module II, emotion recognition) to the children's actual performance, the students followed the approach by Moebert et al. (2019), who developed an algorithm (Elo score) for adjusting the difficulty of the online social cognition training "*Emotionen Verstehen und Ausdrücken"* (EVA), formerly the "*Social Cognition Training Tool"* (SCOTT) (Moebert et al., 2019; Rosenblau et al., 2020). The results of the seminar (algorithm and as well user accounts) are planned to be implemented and tested in a future version of Zirkus Empathico.

6.3.2 The Importance of Using Participation Research Approaches

It has been argued that the currently limited generalizability of available digital interventions (Berggren et al., 2017) underscores the importance of already involving children on the AS and, especially in the case of younger/non-expressive children, their stakeholders (e.g., parents, autism professionals, adults on the AS) respecting their individual goals, desires, needs and strengths is furthermore a logical and necessary consequence of the concept of neurodiversity and the potential gap between the perspectives of allistic researchers and autistic children (Spiel et al., 2017; see Chapter 6.2.3). While the development of Zirkus Empathico corresponds to the preliminary stages of participatory research (consultation of adults on the AS; integrating children's feedback after prototype testing; see Technical Report), genuine participation requires the people being researched to have a direct, formal influence on the research project in the form of co-determination, and thus, partial or full decision-making power (see Hartung et al., 2020; and Mummah et al., 2016; Porayska-Pomsta et al., 2012 for framework and approaches for participatory development and evaluation of digital

interventions). Therefore, in light of the promising results of other studies using co-creation methods with autistic children (e.g., Porayska-Pomsta et al., 2012; Spiel et al., 2017; Wilson et al., 2019), the potential of the Zirkus Empathico approach might not yet have been fully exploited. For example, as discussed in Study 2, parents seemed to prefer improving their children's handling of their own emotions instead of targeting the primary outcomes of empathy and emotion recognition. Similarly, in a follow-up project of Zirkus Empathico that aimed to develop a robot-assisted intervention ("*ERIK*"[16]) in a more participatory manner through having different autism stakeholders (e.g., caregivers, professionals, adults on the AS) representing the children's needs ("*participation via proxy*"; Frauenberger et al., 2012, p. 368), it was indicated that the need to improve emotion regulation, especially the regulation of stress and frustration, is more urgent than social cognition (compare A. L. Davis & Neece, 2017; Firth & Dryer, 2013). To conclude, besides enhancing the children's intrinsic motivation, e.g., through the use of more serious game elements (see Chapter 6.3.1), already fostering a more collaborative and equal partnership between different parties (e.g., autistic children, autism researchers, and caregivers) during the intervention development and implementation could be mutually beneficial for furthering the aims of all involved parties (e.g., children, caretakers, autism professionals, compare Schuck et al., 2021), for lowering attrition rates associated with internet interventions (Fleming, Beurs, et al., 2016), and for ensuring good ethical practice (see Montreuil et al., 2021 for ethical considerations in participatory research with children).

6.3.3 Ways to Strengthen Acceptability and Feasibility

Feasibility and the related aspects of acceptability and usability are important outcomes of novel digital interventions, which should be accessed prior to or in parallel to their effectiveness to ensure later use and sustainability in real-life settings (Drotar & Lemanek, 2001). However, these aspects are still rarely addressed in studies on technology-based interventions for individuals on the AS (see Valentine et al., 2020 for a recent meta-analysis). Thus, by testing usability (pilot study) and integrating caregivers' and children's reports on acceptability and feasibility (Study 2), the studies on Zirkus Empathico represent one of the first best-practice examples. Despite existing methodological limitations (see Chapter 6.4), the findings are promising in pointing to good usability and acceptability as shown by good treatment satisfaction, high levels of

[16] https://www.scs.fraunhofer.de/de/publikationen/studien/studie-erik-anforderungsanalyse.html

enjoyment and motivation to play, satisfactory treatment fidelity, and low drop-out rates as reported by children and caregivers (see Technical Report, Study 2 and its supplement). Beyond this, the feasibility of the training, operationalized by compatibility with family life, training-induced stress, quality of supervision, and understanding of training content, was rated as good by caregivers. Overall, Zirkus Empathico might be suitable to be implemented as a parent-guided complement to current autism interventions (e.g., specialized emotional and social skills training, see recommendation by Berggren et al., 2017 and compare Beaumont & Sofronoff, 2008) in German-speaking countries.

The approach for the actual feasible implementation of Zirkus Empathico into daily supply might need further improvement, also to prevent the high attrition rates typically reported for the use of validated tools outside research contexts (Fleming, Beurs, et al., 2016). For example, while the amount of caregiver-supervision by training operators (one hour before the intervention, 30 minutes per training week over six weeks, see Study 2) was rated as sufficient and satisfactory by caregivers, it might not be feasible to be implemented in the autism treatment supply because professionals needed for supervision are lacking (see Chapter 1.3.1). As outlined in a previous BMBF[17] research proposal under the participation of the author, a future project could aim to provide Zirkus Empathico on a digital platform, which also integrates digitalized parent instructions and coaching (e.g., through using video examples, psychoeducative materials, or webinars; compare Beaumont et al., 2021). In light of the initial promising results on parent-mediated interventions delivered via telehealth, such an approach might also improve parent knowledge, increase parent intervention fidelity, and in turn improve social behavior and communication in children on the AS (see review by Parsons et al., 2017). Interestingly, Kuravackel and colleagues (2018) reported preliminary results on treatment gains for children's tantrums and aggression, parenting competency, and parenting stress after providing parents with a manualized 8-week telehealth intervention. In addition, since therapeutic relationships are an important element in therapy (Weisz et al., 2006), it might further be relevant for platform solutions to increase the children's feeling of being socially connected to others within the computer program, e.g., by integrating virtual characters that guide users through the intervention (compare the "fox" character in Zirkus Empathico), and which also actively

[17] Bundesministerium für Bildung und Forschung

build a rapport (Fleming, Beurs, et al., 2016 and see Fleming, Lucassen, et al., 2016 for a first approach). Parents might benefit from integrated elements of computer-mediated communication, e.g., automated messages to provide feedback and built-in explanations of why and how the program might help (Fleming, Beurs, et al., 2016). In sum, carefully designed and user-centered platform solutions, which provide customized digital interventions addressing children on the one hand and parent-training and support on the other, might be suitable to feasibly and cost-effectively address the existing gaps between intervention needs and intervention supply (Parsons et al., 2017).

6.3.4 Challenges in the Academic Development of Digital Solutions

In general, there is a great need to rigorously develop and evaluate digital interventions addressing serious outcomes (e.g., mental health, social skills) before providing them to their respective target group (Mummah et al., 2016). Otherwise, parents and professionals might rely on digital applications developed by the industry that lack evidence concerning their efficacy, costs, or user impact (Valentine et al., 2020), which holds several risks, especially for the children (e.g., false promises of a cure, unexpected adverse effects). In recent years, there has been a steep increase in using evidence-based technology for clinical purposes (Fleming, Beurs, et al., 2016), and, for example, the potential of using it in health care has been recognized by the German Digital Healthcare Act in 2019 ("*Gesetz für eine bessere Versorgung durch Digitalisierung und Innovation*")[18]. However, it remains to be seen whether the implemented certification process aiming at rapid approval, scientific testing, and reimbursement of digital health apps ("*Digitale Gesundheitsapplikation*"; DiGA)[19] paves the way for innovative and evidence-based apps in the regular care and statutory reimbursement system in Germany. Concerning solutions developed in academia, several practical restrictions and barriers within the current research and funding system challenge a quick and easy transfer of validated digital solutions such as Zirkus Empathico into the actual supply (compare the review by Valentine et al., 2020 and see Mummah et al., 2016). Discussing obstacles and difficulties that accompanied the present work might therefore help to identify starting points for simplified development and practical transfer of academic digital solutions.

[18] https://www.bundesgesundheitsministerium.de/digitale-versorgung-gesetz.html
[19] https://diga.bfarm.de/de

For clarity, the application was not developed within the framework of a third-party funded project, and therefore, the financial means covered by the Freie Universität Berlin and the Humboldt Universität zu Berlin, Germany, to compensate the involved specialists and acquire the necessary materials were very limited. The position of the author was financed by two scholarships and the technical concept of the application was developed in the form of a Master's thesis in a collaboration with the Department of Informatics of the Potsdam University, Germany. Given the limited financial scope, the first challenge in the program development was to recruit suitable persons from a variety of different disciplines, concretely, informatics/software engineering, UI/UX[20] design, and film production. Second, due to its high interdisciplinarity, managing the program development and bridging the gaps between different backgrounds, terminologies, and techniques were challenging. However, the fruitfulness of such interdisciplinary work is underlined by the reported high levels of enjoyment, motivation, and satisfaction in children using the application and the low drop-out rates in the study (see Study 2, compare Fleming, Beurs, et al., 2016). Reduced interdisciplinarity, as given, for example, in projects developed within engineering science/industry that lack psychological expertise (e.g., knowledge about behavior change strategies, systematic testing; compare Mummah et al., 2016), or in programs designed by psychologists/researchers that lack expertise in UX/UI or game design, might result in limited generalization of the trained skills (see Chapter 6.3.1), low user adherence, and high remission rates when applied under real-life conditions (compare Fleming, Beurs, et al., 2016; Whyte et al., 2015). For the development of Zirkus Empathico, it might also have been beneficial to integrate end-users more collaboratively and iteratively into the intervention design. As pointed out by Fleming and colleagues (2016), progressive user-testing of prototypes with increasing levels of implemented details, followed by larger RCTs for evaluating the final product might maximize the impact of the end product. However, researcher-driven approaches often do not integrate numerous rapid cycles of fine-tuning based on user feedback (Mummah et al., 2016), which are common in modern models of rapid software development and iterative testing (Fleming, Beurs, et al., 2016). Apart from a lack of expertise in user-centered design, this might also be due to restrictions in personnel resources and time since funding periods (including Ph.D. scholarships) are often limited to three years. To

[20] UI: user interface; UX: user experience

facilitate qualitative research with a real and sustainable impact on the people being researched (e.g., persons with mental health problems), funding institutions such as the German Federal Ministry for Education and Research (BMBF) should acknowledge that developing and testing technology-based interventions needs prolonged project times and personnel from interdisciplinary fields. Moreover, the actual and sustained transfer of digital interventions into supply should be funded as an integral part of the research project. As shown by the present example of Zirkus Empathico, this transfer remains challenging (at least in Germany) since the distribution channels from university to supply are largely absent and researchers (at least in the field of psychology) are primarily required to focus on publications as research outcomes.

Finally, technology-focused calls by funding institutions (e.g., BMBF, BMWE[21]) often require (industrial) partners to define high *technical* risks to justify funding (see for example the BMBF call "Kleine Patienten, großer Bedarf"[22]). This might result, for example, in integrating cutting-edge technologies (e.g., optical sensors plus algorithms to detect and classify emotional signals from voices and faces), which might have a limited potential to be realistically applied under real-life conditions (e.g., due to sensors not being robust towards movement or changes in lighting conditions). In contrast, strongly application-oriented projects such as Zirkus Empathico might not be eligible for funding because of low technical risks although they do come with another significant risk of their own: since technology is generally developing rapidly while research and publishing processes require much time, carefully designed and clinically validated programs are often outdated when evidence for their effectiveness is finally given (Valentine et al., 2020). This might, as in the case of Zirkus Empathico, either result in offering software with technical bugs, which might limit its usability by affecting acceptability and effectiveness, or in low rates of implementation and public availability of evidence-based digital interventions despite their promising evidence (Fleming, Beurs, et al., 2016; Mummah et al., 2016). In sum, it might be concluded that the conditions under which research on digital interventions is conducted should be improved to ensure an actual and maintained societal benefit. For example, funding institutions should recognize interdisciplinary collaboration, user-centered design, and testing, followed by elaborate evaluation (see Berggren et al., 2017) and research-

[21] Bundesministerium für Wirtschaft und Energie

[22] https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2017/05/1357_bekanntmachung.html

practice transfer as (additional) justifications for receiving funding and more long-term support.

6.4 Limitations and Further Directions

As outlined in the previous chapters, this dissertation examines the socio-emotional behavior of autistic children from two sides: Beyond providing insights into the potential causes of different maladaptive social behaviors based on established social information processing models (Study 1), an interdisciplinary and holistic digital approach is presented and discussed, which could be applied transdiagnostically to foster various socio-emotional competencies in children with special needs (Technical Report). To our knowledge (compare Beaumont et al., 2021; Berggren et al., 2017), Study 2 is one of the biggest RCTs on digital interventions in children on the AS, which integrated an *active* control group (as opposed to a waitlist comparison, or "treatment-as-usual" comparison) and a follow-up assessment, and measured generalized changes in social skills by using parent *and* teacher reports to account for the transfer to different environments (compare Beaumont et al., 2021 for a similar design and results). However, despite these strengths, this work also has some limitations, some of which are due to practical restrictions resulting from the naturalistic setting (e.g., reliance on parent questionnaires, lack of non-autistic comparison groups). These methodological limitations might have increased the likelihood of biases (Chapter 6.4.1). In addition, the models used lack a detailed specification of the relationships between constructs, and, as a result, information on (training) mechanisms is largely absent, which limits the explanatory power of the studies (Chapter 6.4.2). Future studies should investigate additional factors contributing to social behavior or its training (Chapter 6.4.3) and assess the acceptability and feasibility of novel intervention approaches more systematically (Chapter 6.4.4). Moreover, since comprehensive and feasible research with good methodologies is needed for conducting future studies in naturalistic settings, complementing elaborate RCTs with single case studies and using digitalized behavioral paradigms might help to overcome some of the identified restrictions (Chapter 6.4.5).

6.4.1 Practical Restrictions Potentially Biasing the Results

Some of the methodological limitations are due to both studies having been conducted in naturalistic contexts to provide the children with familiar testing environments (e.g., in the home environment, autism outpatient clinics) and to prevent

families from having to travel long distances to take part in the four assessments. The assessment of outcome variables relied to a large extent on online parent questionnaires to spare children, especially the younger/more severely affected ones, from having to take part in extensive behavioral testing sessions. In addition, due to the great effort involved in the implementation of Study 2 (including the development of Zirkus Empathico), Study 1 was integrated into the baseline assessment of Study 2. Thus, the measures that were originally selected for the second study were used to address the research question of Study 1, with two parent questionnaires on aggressive attitudes and behaviors being added.

These practical considerations resulted in several methodological limitations, which might have increased the likelihood of biases in interpreting the results. Despite large amounts of lacking data in the online assessments, relying mainly on parental judgements might partly have biased the results because parents are prone to observer bias (especially in the case of unblinded treatment conditions as in Study 2) and can only provide third-person perspectives. Future studies on the research questions of both studies should therefore include more naturalistic, behavioral, or observer-based assessments and rely less on parental judgment. For example, and also to be more comparable to past research in the field, a testing battery could include pictorial interviews using vignettes displaying ambiguous social situations to assess biased social information processing in the context of aggressive behaviors (compare Helmsen et al., 2012; Mazza et al., 2017; Ziv et al., 2014), and performance-based tests/behavioral observations of emotion regulation (e.g., Fogleman et al., 2018), empathy (MET/MET-J/K[23]; Dziobek et al., 2008; Poustka et al., 2010), and ToM/social cognition (MASC[24]; Dziobek et al., 2006; Müller et al., 2016). Since many of these existing tests address older age groups, more ecologically valid tasks for younger children should be developed (see outlook in Chapter 6.4.5).

Beyond this, only a limited number of measures could be included in the studies due to the mentioned practical restrictions. Therefore, information on some aspects of the multifaceted constructs (e.g., empathy, emotion regulation) is lacking. In addition, cognitive aspects of ToM were not assessed even though the ability has frequently been considered as being central to autism social impairments (e.g., Baron-Cohen et al.,

[23] Multifaceted Empathy Test – Jugendliche/Kinder
[24] MASC: Movie for the Assessment of Social Cognition

1985). Regarding Study 1, integrating a measure of ToM abilities might have contributed to a more comprehensive understanding, also in light of other studies showing an impact of ToM on social information processing (e.g., Mazza et al., 2017; Ziv et al., 2014). In Study 2, it was decided to only use the total score of the Griffith Empathy Measure (GEM; Dadds et al., 2008) to estimate changes in the participants' general empathy because the validity of its subscales, especially of the cognitive, has been questioned (Murphy, 2019). In addition, since it was not possible to validly administer the MET-J/K as a behavioral measure of cognitive and affective empathy, Study 2 lacks a valid assessment of changes in cognitive empathy, despite this ability being targeted by Zirkus Empathico (module III). Furthermore, both studies lack information on the use or, respectively, change, in emotion regulation strategies (e.g., anger management), which are not assessed by the Emotion Regulation Checklist that was used (ERC; Shields & Cicchetti, 1997). The lacking information on emotion regulation strategies limits the comparison of our results with the findings of other studies in autistic children (e.g., Samson, Hardan, Lee, et al., 2015 investigating the relationship between low levels of adaptive cognitive reappraisal, negative emotional experiences, and externalizing behaviors).

Another limitation consists in the lack of non-autistic comparison groups (e.g., Study 1: children without any condition; Study 2: non-autistic children with other conditions, e.g., social anxiety, ADHD), which resulted in reduced specificity of the results (especially in Study 1) and only speculative transdiagnostic perspectives for Zirkus Empathico. In this regard, and probably contrary to expectations, the potential effects of Zirkus Empathico on aggressive behaviors have not yet been investigated (even though hostile attribution bias and aggressive behaviors were assessed at post-treatment and follow-up by conducting Study 2). This is primarily due to the initial focus of the dissertation on providing autistic children with a validated digital socio-emotional intervention aimed at fostering *prosocial* behavior. Additionally, since Study 1 is one of the first studies applying the SCIP models to understand the relationship between several predictors and maladaptive behaviors in autistic children, it was decided to use a cross-sectional research design in Study 1 to investigate the proposed relationships in an untrained, and therefore, homogenous sample. Nevertheless, a follow-up study could use the existing datasets (see above) to investigate the developmental trajectories and directionality of the relations between risk factors and aggressive behaviors longitudinally to fully understand their causal relationships

(compare Maxwell & Cole, 2007). In addition, the factor "intervention group" could be integrated into these research models to understand the effect of an intervention such as Zirkus Empathico on the presence of co-occurring aggressive behaviors (see discussion in Chapter 6.2.2). Regarding Study 2, there is a need for additional RCTs with rigorous methodology (e.g., active controls, distant generalization measures) and additional long-term assessments (> 3 months) to further explore the long-term effect and transfer of the training.

6.4.2 Limited Mechanistic Understanding

The designs of both studies were not well suited to provide more mechanistic insights into the investigated phenomena. Apart from the fact that the main aim of the data collection was to evaluate Zirkus Empathico, the theoretical frameworks (SCIP models, SOME) used are underspecified in certain aspects. The SCIP models focus on reciprocally interacting mental operations that are influenced by various processes. While they allow for adopting a developmental perspective (e.g., on the development of the hostile attribution bias; Lemerise & Arsenio, 2000), these models do not provide detailed definitions and elaborations of the assumed relationships (e.g., directionality) and the function of the processes during social information processing (e.g., moderator versus mediator). For example, in Study 1, better emotion recognition skills were found to predict enhanced hostile attribution bias—a finding which was rather unexpected (see discussion in Study 1). From a developmental perspective, the causal relationship between these variables could be reversed in the sense that preexisting tendencies to attribute hostile intentions to others motivate the children to train their emotion recognition skills to detect hostile cues earlier (see discussion within Study 1, and compare Helmsen et al., 2012). However, due to the cross-sectional design of Study 1, this interpretation remains speculative. Furthermore, since the SCIP models do not explicitly define if variables are thought to function as mediators or moderators, there might be alternative models to the one proposed in Study 1, which assumes that the relationship between emotion dysregulation and aggression is mediated by hostile attribution bias (compare Musher-Eizenman et al., 2004). It also seems plausible that dysregulated emotions and related traits such as impulsivity might shape the relationship between disturbed social information processing and maladaptive behavior. For example, Fite and colleagues (2008) reported that non-autistic adolescents' impulsivity moderated the association between endorsement of aggressive responses at

age 13 and later aggressive behaviors in the sense that a positive association was only given for participants with medium to high levels of impulsivity.

In contrast to the rather broad perspective of the SCIP models, the SOME defines interrelations between internal systems on a more specified level to explain how feelings are shared between two persons (Bird & Viding, 2014). While the model was useful to inform the concept of Zirkus Empathico, it does not provide a link from empathy to actual behavior enactment and the framework thus does not provide a theoretical foundation for how the trained competencies might have resulted in an actual improvement of prosocial skills. Moreover, even though improvements in emotional awareness during training were found to predict gains in general empathy three months after the training, the study does not provide an understanding of the developmental pathways and mechanisms that might account for the detected effects. In sum, future studies with more experimental and controlled designs are needed, which aim to detect mechanisms underlying aggressive behaviors or which account for behavioral changes.

6.4.3 Future Directions: Studying Additional Influences

From a broader perspective, future research could also examine the contribution of environmental factors that very likely shape the developmental trajectories of social behaviors and influence social responses within interpersonal situations (see Lemerise & Arsenio, 2000). In the context of the first research question, for example, exposure to aggressive models (Bandura, 1973) or negative social experiences (e.g., being bullied; Maïano et al., 2016) might contribute to the development of hostile attribution biases, and aggressive behaviors could be learned and maintained through automatic reinforcement by the children's social surroundings (e.g., gaining attention or access to perseverative activities, escaping demanding tasks or environments after engaging in aggression; see Matson et al., 2011 for a review). Integrating these factors, ideally in longitudinal studies, might enable a better understanding of aggressive behaviors in autistic children, followed by interventions, which target the children's social environments in addition to individual therapy (e.g., see Sydow et al., 2013 for a systematic review on the efficacy of systemic therapy for childhood and adolescent externalizing disorders).

It might further be suggested that the effectiveness and feasibility of Zirkus Empathico were impacted by personal variables of the assisting caregivers such as

personality traits (e.g., social-emotional or communicative skills, creativity, autism traits, alexithymia), level of engagement and motivation, and others (e.g., gender, age, education, ethnicity, time availability, socio-economic status; compare Beaumont et al., 2021; Sofronoff et al., 2017 for preliminary results). While some of these variables were assessed in Study 2, they were not integrated into the statistical models to ensure enough power for detecting the main effects. Since comprehensive research on parental predictors of behavior change in children is still in its infancy, whereas parental involvement in standard and digital interventions is considered promising (Klinger et al., 2021), future studies should explore their effects on effectiveness and feasibility. Moreover, such studies should identify other influences such as environmental factors (e.g., professional-guided training versus caregiver-assisted training, at home/school/autism care unit) or child characteristics (beyond IQ or verbal age which did not moderate the training outcome in Study 2). The results might help to customize interventions such as Zirkus Empathico to individual needs and to identify good training conditions, which, in sum, also inform future development.

6.4.4 Future Directions: Systematically Assessing Feasibility and Acceptability

Finally, aspects of feasibility and acceptability of digital interventions should be explored systematically by using more rigorous methodologies (e.g., validated questionnaires, user tests) to inform customized and user-friendly developments. For example, designing studies along with established and popular models on user acceptance of information technology (e.g., *UTAUT model*; Venkatesh et al., 2003) might help to identify factors such as perceived usefulness, perceived ease of use, and facilitating conditions associated with the digital intervention, which are thought to predict later acceptability and real-life use with personal user characteristics such as age or gender potentially moderating the relationships (Venkatesh et al., 2003). Additionally, feasibility studies should access the extent, likelihood, and manner in which the intervention can be implemented as planned in uncontrolled settings (e.g., different families, schools, kindergarten, autism care units), the extent of intervention delivery under constrained resources, time, and commitment, and the level of system change needed to integrate the new program into existing infrastructures (e.g., into standard autism therapies; compare Bowen et al., 2009). In such studies, adverse effects should also be considered to a greater extent and more systematically (e.g., by using the "*Negative Effects Questionnaire*" by Rozental et al., 2019) than done in our study and generally in research on non-pharmacological autism interventions (Bottema-Beutel,

Crowley, et al., 2021; Dawson & Fletcher-Watson, 2022) to ensure safe training environments.

6.4.5 Outlook: Suggestions for Innovative and Feasible Study Designs

Given the societal relevance for rigorously evaluating digital interventions and the need for gaining more profound insights into the specific training mechanisms, it might be fruitful to complement the conduction of elaborate RCTs with single-case studies which involve repeated measurement of outcomes as dependent variables and varying levels of intervention as independent variables in one or several subjects (Widdowson, 2011). In contrast to RCTs which focus on large amounts of generalized quantitative data, and therefore, might not account for the complexity of an intervention, single case studies could enable researchers to draw valid causal explanations for behavior change (Widdowson, 2011). Interestingly, the systematic review and meta-analysis by Barton and colleagues (2017) on technology-based interventions in autistic participants showed comparable evidence for single-case research and RCTs.

In addition, primarily concerning the considerations of the practicability of large clinical studies, it is necessary to consider how the study design and administration can both be simplified and improved. For example, it must be ensured that the testing of participants remains feasible since the large testing batteries that are needed to investigate, for example, potential training mechanisms, involves a great expenditure of time, investment, and effort, which can place a significant burden on children and their families. Behavioral observations (e.g., measuring social behavior in the classroom) that might be more convenient for participants, are very time-consuming, and, in addition, they require the involvement of different observers to ensure inter-rater reliability. This might not be feasible in investigations such as Study 2, which required testing of more than 80 children under the given limitations in financial and staff resources (see Chapter 6.3.4). Hence, there is a need for developing more short but comprehensive tasks with good ecological validity, which are suitable to assess young children's behavior effortlessly and feasibly. In this regard, there could be great potential in using digital assessments, which can provide the dynamic, multimodal, context-embedded, interactive, and immersive environments needed for ecologically valid testing (Osborne-Crowley, 2020), while, in contrast to natural behavioral observations, situations can be presented realistically but with better standardization and control (Alcañiz et al., 2022). For example, the Simulated Interaction Task (SIT) by Drimalla and colleagues (2020)

aims to differentiate between autistic and non-autistic adults by automatically quantifying biomarkers (facial expressions, gaze behavior, and voice characteristics) of social interaction deficits within a virtual conversation about food preferences with an avatar. Also recently, Alcañiz and colleagues (2022) published pilot data on an eye-tracking paradigm in a virtual environment which included visual, auditory, and olfactory stimulation, to measure differences in attunement to and extraction of socially relevant information to distinguish between autistic and non-autistic children. In sum, assessing socio-cognitive and emotional skills, ideally in one comprehensive setting (e.g., a VR environment triggering emotion regulation and social cognition, etc.) could be a way to gather parental evaluations in an ecologically valid, feasible, and easy manner. Furthermore, the ability to deliver both tests and intervention remotely is particularly useful in light of the social distancing restrictions imposed by the COVID-19 pandemic containment measures.

7 Summary and Conclusions

The two studies and the technical report integrated into the present dissertation revealed several interesting insights into social behavior in children on the AS and its fostering by digital means. First, it was shown that different forms of maladaptive social behaviors are associated with lability-negativity as a symptom of emotional dysregulation, with the relationship being mediated by hostile attribution bias in the case of more complex aggression subtypes (Study 1). Second, the manualized, caregiver-assisted, and holistic digital intervention Zirkus Empathico for fostering empathy and prosocial behavior in children aged 5–10 years could be realized in an interdisciplinary team (Technical Report). The approach was evaluated in a six-week multicenter randomized controlled trial with 82 children on the AS at three study sites in Germany and Austria. The results revealed high acceptability in children and their caregivers, and the feasibility of the training was rated as satisfactory (Study 2). Improvements in general empathy and emotion recognition were observed at the post-treatment assessment and secondary analyses revealed moderate effects on emotional awareness, emotion regulation, and autism social symptomatology after training and at the three-month follow-up (Study 2).

Overall, the present work contributes to a multifaceted perspective on social behavior in children on the AS. Both studies revealed various interrelations between different socio-emotional constructs with emotion dysregulation and related alexithymia

potentially having a prominent function, which should be further explored from comprehensive and transdiagnostic perspectives. Additionally, (digital) training approaches aiming at improving prosocial skills and/or reducing maladaptive social behaviors in autistic and non-autistic children might benefit from a stronger focus on emotional processes as given in Zirkus Empathico or the comparable intervention SAS (Beaumont & Sofronoff, 2008).

From a clinical perspective, implementing the validated digital intervention Zirkus Empathico as a complement to standard therapy might be promising for improving generalized social behavior in children on the AS, and, potentially, for strengthening reciprocal socio-emotional communication and perspective-sharing within autistic-non-autistic pairs. Given its effectiveness for improving skills associated with emotional awareness and regulation, it might further be suitable for children with other conditions such as social anxiety or internalizing disorders, or as a prevention tool for non-autistic and healthy children. By integrating additional content to address social information processing and anger management more specifically, Zirkus Empathico could easily be adapted to complement interventions on maladaptive, e.g., aggressive behaviors.

Since a clinical benefit of a new intervention is only given if an intervention results in a generalized and maintained change in symptom-relevant behavior, it should be further investigated how both aspects can be improved regarding digital approaches, e.g., by integrating serious game elements or pursuing participatory research. Furthermore, questions of acceptability and feasibility as well as starting points for their improvement should be explored more systematically to facilitate their later use in real-life settings. Finally, the challenges and barriers resulting from the current research and funding system need to be addressed to allow a successful and quick transfer of validated digital solutions such as Zirkus Empathico into the autism treatment supply.

Several limitations – which are mostly related to the studies being conducted in natural contexts that gave rise to practical restrictions – were addressed in this work. Even though the results of the studies indicated various interactions between socio-emotional and cognitive processes, future studies are needed to provide a more mechanistic understanding of these findings. Moreover, such studies could address additional influences on social behavior or its training. Single case studies could complement elaborate RCTs to provide additional and more mechanistic insights.

Finally, digitalized behavioral paradigms might be fruitful tools to facilitate the assessment of natural social behavior.

In conclusion, this dissertation demonstrates that it is possible—even under constrained conditions–to develop and apply a theory-based digital intervention fostering socio-emotional competencies and validate its effectiveness, acceptability, and feasibility by using a thorough clinical study design. Both the promising results of the Zirkus Empathico evaluation and the weaknesses and challenges identified (either within the app itself or in the research system) might inspire and improve future intervention development within academia. In addition, this work provides interesting insights into highly interrelated socio-emotional competencies, which might further inform the development of more mechanistic and customized digital support for children on the AS and their families.

List of Abbreviations

ADI-R	Autism Diagnostic Interview-Revised
ADHD	Attention-Deficit Hyperactivity Disorder
ADOS-G	Autism Diagnostic Observation Scale Generic
ADOS-2	Autism Diagnostic Observation Scale-2
AIC	Akaike Information Criterion
AS	Autism Spectrum
ASC	Autism Spectrum Conditions
AQ	Autism Quotient
CBT	Cognitive-Behavioral Therapy
CBCL 4/18	Child Behavior Checklist 4/18
CFI	Comparative Fit Index
CG	Control Group
CPM	Colored Progressive Matrices
C-SHARP	Children's scale of hostility and aggression: Reactive/Proactive
BIC	Bayesian Information Criterion
BMBF	Bundesministerium für Bildung und Forschung
BMWE	Bundesministerium für Wirtschaft und Energie
DiGa	Digitale Gesundheitsapplikation
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
EEG	Electroencephalography
ERC	Emotion Regulation Checklist
ERC-N/L	Emotion Regulation Checklist – Negativity/Lability (subscale)
ERC-ER	Emotion Regulation Checklist – Emotion Regulation (subscale)
ERIK	Entwicklung einer Roboterplattform zur Unterstützung neuer Interaktionsstrategien bei Kindern mit eingeschränkten sozio-emotionalen Fähigkeiten
EVA	Emotionen Verstehen und Ausdrücken
FAVK	Fragebgen zum aggressiven Verhalten von Kindern

FIML	Full Information Maximum Likelihood
GAS	Goal Attainment Scaling
GEM	Griffith Empathy Measure
HAB	Hostile Attribution Bias
HU	Humboldt–Universität
ICD-10	International Classification of Diseases, Tenth Revision
ICU	Inventory of Callous-Unemotional Traits
ISCED	International Standard Classification of Education
IT	Information Technology
IQ	Intelligence Quotient
KERMIT	Kids Emotion Recognition Multiple Images Task
KJPP AUG	Kinder- und Jugendpsychiatrie und –psychotherapie Augsburg
LEAS-C	Level of Emotional Awareness Scale for Children
M	Mean
MANOVA	Multivariate Analysis of Variance
MASC	Movie for the Assessment of Social Cognition
MedUni	Medizinische Universität [Wien]
MET-J/K	Multifaceted Empathy Test - Jugendliche/Kinder
MLM	Multilevel Modeling
PDD-NOS	Pervasive Developmental Disorder Not Otherwise Specified
PPVT	Peabody Picture Vocabulary Test
PTSD	Post-Traumatic Stress Disorder
PVQ	Pediatric Volitional Questionnaire
RCT	Randomized Controlled Trial
RMSEA	Root-Mean-Square-Error of Approximation
RQ	Research Questions
SAS	Secret Agent Society
SCIP	Social Cognitive Information Processing
SCQ	Social Communication Questionnaire
SD	Standard Deviation

List of Abbreviations

SIP	Social Information Processing
SCOTT	Social Cognition Traininig Tool
SIT	Simulated Interaction Task
SOME	Self to Other Model of Empathy
SRMR	Standardized Root-Mean-Square Residual
SRS	Social Responsiveness Scale
TAS	Toronto Alexithymia Scale
TD	Typically Developed
TG	Training Group
ToM	Theory of Mind
UI	User Interaction [design]
UX	User Experience [design]
VA	Verbal Age
VR	Virtual Reality
ZE	Zirkus Empathico

List of Figures

Figure 1.1 The Self to Other Model of Empathy 12

Figure 3.1 The revised Social Cognitive Information-Processing model. 36

Figure 3.2 Path models testing the emotion model (H1; compare Lemerise & Arsenio, 2000) against the classical model (compare Crick & Dodge, 1994, 1996; Huesmann, 1998) 42

Figure 3.3 Results of the *emotion model.* 46

Figure 4.1 The game concept consists of four training modules, a generalization module and a library with information in emotions. The modules and levels are available depending on the learning success in previous tasks..... 57

Figure 4.2 Software architecture and technologies are aligned to an easy maintenance and extendability of the app..... 60

Figure 4.3 Single steps of a task are realized as finite state automata 60

Figure 4.4 Exemplary tasks in modules 1 to 4 and in the generalization module (a) and selected game elements (b) 62

Figure 5.1 Modules and elements of the serious game *Zirkus Empathico*..... 71

Figure 5.2 Trial time flow. 81

Figure 5.3 Graphs showing group means at baseline (T1) and estimated means (unstandardized intercepts) at post-treatment (T2), and follow-up (T3) for primary and secondary outcomes. The differences in intercepts (DI) and effect sizes (Cohen's d) at T2 and T3 are presented for each outcome 87

List of Tables

Table 3.1 Examples of items of the selected FAVK subscale as a measure of hostile attribution bias, ERC subscale lability-negativity, and C-SHARP subscales measuring subtypes of aggressive behavior..... 40

Table 3.2 Demographics and clinical characteristics of the total sample, N = 60..... 44

Table 3.3 Correlation matrix (Pearson's *r*) between demographic variables (age, verbal and nonverbal IQ, autism social symptomatology), predictors (emotion recognition, lability-negativity, hostile attribution bias), and aggression subtypes. 45

Table 3.4 Model fit indices (*CFI, AIC*/Adj. *BIC*) for the *classical model* and the *emotion model* 45

Table 5.1 Demographic and clinical characteristics of the total sample (n = 82) by training group..... 82

Table 5.2 Primary and secondary outcome measures at post-treatment (week 6) and three-month follow-up. Model choice is marked. Smaller AIC/BIC values suggest a better fit, negative CFI Delta values prefer the equal model over the fixed means model (cut-off = 0.002; Meade et al., 2008). 84

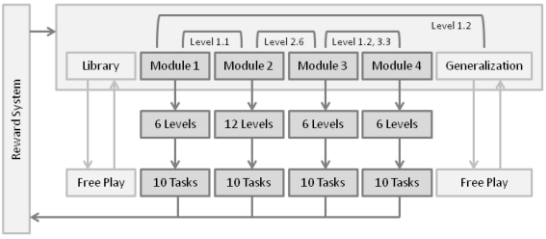
Table 5.3 Standardized regression coefficients..... 85

Supplement of Study 2

S1: CONSORT 2010 Checklist

Table S1 displays the CONSORT 2010 Checklist applied to the randomized controlled trial testing the efficacy of the serious game Zirkus Empathico.

Table S1: CONSORT Checklist Criteria	
TITLE AND ABSTRACT	
1a RCT in title	Reported in the main manuscript.
1b Structured summary	Reported in the main manuscript.
INTRODUCTION: BACKGROUND AND OBJECTIVES	
2a Scientific Background and rationale	Reported in the main manuscript.
2b Specific objectives and hypotheses	Reported in the main manuscript.
METHODS: TRIAL DESIGN	
3a Description of trial design	Reported in the main manuscript. Summary: • Study Type: Interventional • Allocation: Randomized controlled trial • Allocation ratio: 1:1 (ZE training group, control group) • Assignment: Parallel • Study sites: 3 • Blinding: Open • Control: Placebo, active control intervention • Type of data: Quantitative data. Some qualitative data for treatment satisfaction, acceptance, and feasibility.
3b Changes to methods after trial commencement	The duration of the intervention was prolonged to seven weeks for nine participants and to nine weeks for one participant to cover missed treatment time due to illnesses, holidays, and other disturbing events. Three participants trained less than six weeks (4 and 5 weeks). No other significant changes after trial commencement.
METHODS: PARTICIPANTS	
4a Eligibility Criteria	Reported in the main manuscript. Additional information: • Exclusion and inclusion criteria were checked by parental report. • Verbal age (VA) was calculated by multiplying chronological age (CA) with tested verbal IQ divided by 100 (Tanaka et al., 2010).
4b Settings and locations of data collection	Reported in the main manuscript. Additional information: **Recruitment plan and procedure of recruitment** Once the participating centers were recruited and the training supervisors were trained in the administration of the Zirkus Empathico intervention the study was advertised on the study website (****) and several German and Austrian autism interest organizations (e.g., https://elternzentrum-berlin.de, https://www.autismus.de). Information was also circulated by informative meetings in autism care units/social-pediatric centers, and by study brochures sent out Germany and Austria-wide to autism care units, social-pediatric centers, and parent organizations. KJPP AUG and MedUni Wien recruited most of their participants with personal information after a given autism diagnosis. Participants and parents who were recruited via self-referrals were contacted by the research coordinator of the respective study center for a preliminary telephone eligibility screening interview and to provide general

	information about the ZE intervention and study procedure. In case participants were eligible, further study information and written consent forms were sent to the caretakers. When written informed consent was obtained, dates for diagnostic investigations were fixed and links to diagnostic online questionnaires were sent by e-mail to the caretakers. **Incentives** Participants received 7 EUR per testing hour (Diagnostics, T1, T2, T3) in HU und KJP AUG and 15 EUR per testing session (1.5-2 hours) in MedUni Wien.
5 Intervention	Reported in the main manuscript. Additional information: **Training intervention** *Zirkus Empathico* (ZE) is a manualized serious game for tablets and online browser in German. For description and demonstration see Figure 1 in the manuscript and the demo video online: https://youtu.be/ab5jraGe1uc Figure S2 (below) shows the game concept of the serious game.  **Figure S2:** The game concept consists of four training modules, a generalization module, and a library. The modules and levels are activated stepwise depending on the learning success in previous tasks/modules (e.g., Module 2 opens up when level 1 in Module 1 is achieved. Figure by Zoerner et al., 2016). <u>Functions of the training assisting caregiver:</u> (1) Serving as a role model by talking about own emotional experiences (2) Supporting the association between the shown situations and the child`s real-life experiences (3) Providing help, explanations, and motivation when needed (4) Directing the child`s attention to relevant aspects, and encouraging the child to use the generalization module in their family life. During supervision, caregivers and training operators as supervisors agreed on concrete individual training goals targeting the transfer of currently trained skills into real-life settings such as recognition of joy and anger in parents/siblings, or expressing and talking about anger in relation to specific situations (e.g. "*I will tell my mum when I feel sad or angry*."). A paper-based reward system with individually defined physical or social rewards was provided to reward children externally for fulfilling these goals. The design of the reward system was oriented at the level system of the ZE application (see Fig. S3).  **Fig. S3**: Paper-based reward system: Rewards were collected for fulfilling transfer goals. For each new "cake", either the current goal was repeated or a new goal was defined according to the child`s current learning status. **Control intervention**

	Families of the CG received online educational games targeting non-social everyday-life skills/knowledge. Main games: • "Ampelini": www.ampelini.de; Application for three- to eight-year-old children training traffic safety • "Pedalpiraten": www.pedalpiraten.de: Application for six- to twelve-year-old children training safe bike riding • "Mein Körper und ich": www.unserkoerper.de; Platform for eight- to twelve-year-olds transmitting body-related knowledge. • "Lernspass für Kinder": www.lernspass-fuer-kinder.de; General, school- and nature-related knowledge Additional online games for different age groups were provided for the children`s free choice in case the training times could not be fulfilled by the main games: • Music knowledge: www.klingklangland.com • Knowledge of aerospace and physics: www.multiverso.de • Knowledge about Vikings: www.isungur.de To keep the generalization constant in both conditions, caregiver and supervisors agreed on specific generalization goals targeting the current needs of the child, which were inspired by the training content (e.g., "I stop when I see the red traffic light."; "I brush my teeth every day by myself."). A similar paper-format token system was used, and children were rewarded with physical or social rewards. **Training manuals** The manuals for operators and caregiver manuals for ZE training and control intervention were integrated into the intervention to increase the standardization of the intervention, to facilitate the conductance and comparability between centers, and to enhance clinical feasibility and adherence of the study. The two manuals for caregivers contained on 21 pages (Zirkus Empathico)/12 pages (control intervention) instructions on how to conduct the training in the home environment with detailed information on agreements on training times and number of training sessions per week, information on the caregiver`s role and tasks during training and training transfer, and an explanation of the token system for rewarding transfer goals. Additionally, the ***Zirkus Empathico manual*** contained background information on empathy, emotional awareness, and emotion regulation in children with autism. For each module, explanations of the respective aims and functions, as well as examples of possible transfer goals and concrete exercises, are given. The ***manual of the control intervention*** informs about the aim of the intervention (confidence training) and explains the aims and functions of the two main educational games ("Ampelini", "Mein Körper und ich") with examples of possible transfer goals and exercises. Complete manuals are available on request in German. **Setting of the interventions** The training was conducted in a home environment with supervision of the assisting caregivers via telephone once a week for 20-30 min by one of four training operators: One doctoral candidate in psychology (main operator and study coordinator of the HU, ***), two graduated psychologists (KJPP AUG, MedUni Wien) and one undergraduate psychology student (HU). All operators received a supervisory training manual. They were instructed intensively prior to the intervention by the main operator. During the intervention study, operators were supervised face-to-face/per telephone/Email every two weeks to once a month by the main operator. **Training Duration, Frequency, and Intensity** Reported in the main manuscript. The duration and quantity of the single training sessions were individually determined with respect to the individual attention span by the supervisor and the caregiver.

	Control of training intensity and frequency Reported in the main manuscript. **Training Procedure/Assessment of treatment fidelity** After the baseline testing, participants and caregivers were informed about their training condition, and caregivers were introduced to the relevant training content and procedure by the respective training operator. They received the training manual, a timetable with personalized training sessions, and a paper-based reward system. During weekly supervision (20-30min), caregivers of both groups were interviewed targeting the following topics: • Training progress within the last week: Training content, open modules/levels, training times. • Communication/exchange about content/feelings within the game. • Linkage of training content to own emotional experiences/experiences of the child (ZE) • Individual transfer goal: Application of training content to everyday life/usage of the transfer module • Adherent events • Motivation questionnaire (PVQ) • Caregiver´s questions/problems • Change of medication during the intervention Adjustments were made if necessary. After the call, the caretakers received an E-mail with a summary of the relevant information talked about. The conversation was documented in the training protocol for each participant.
6a Primary and secondary outcome measures	Reported in the main manuscript. More detailed descriptions are provided here. **Primary outcome measures** (1) The ***Griffith Empathy Measure*** (GEM, Dadds et al., 2008, German adaptation: Greimel et al., 2010) consists of 23 items assessing empathy in children and teenagers by using a nine-point rating scale (ranging from -4 to +4). It captures an overall dimension of empathy as well as two independent subscales of affective (nine items) and cognitive empathy (six items). Internal consistency was good for the whole scale (Cronbach`s α = .91) and the affective empathy subscale (α = .83), but non-sufficient for the cognitive subscale (α = .62). The test-retest reliability over 6 months was sufficient (r = .69).  (2) The ***Kids Emotion Recognition Multiple Images Task*** (KERMIT) is the children`s version of the Berlin Emotion Recognition Test (BERT) for adults (Drimalla & Dziobek, 2019; Drimalla, Landwehr, Hess, & Dziobek, 2019). BERT/KERMIT is a computer-based task for the sensitive assessment of emotion recognition. The test consists of 48 photos of facial expressions of professional actors displaying one of the six basic emotions (anger, fear, joy, sadness, surprise). There are eight pictures per emotion, four female and four male faces. The correct label of the targeted emotion and a distractor are presented below the picture. For each item, the most difficult distractor out of the five incorrect emotion labels was identified within a pre-study. Children with sufficient reading skills (7-10 years) read and clicked by themselves. For younger/not literally fluent children, labels were read out loud and clicked by the testing operator according to the child`s verbal answer. The accuracy score of the KERMIT is calculated by the sum of all correctly identified emotion labels, each scoring one point. Internal consistency of the BERT assessed in eighty adult participants was satisfactory (Cronbach's α = .74, McDonald's Omega ωT = .75). For the KERMIT, analyses within seventy-three children of the total sample of the present RCT study with valid data at baseline and sixty-four additionally measured typically developed children revealed good reliability (McDonald`s Omega; ωT = .91). The test-retest reliability was not assessed.

	Secondary outcome measures We used a series of 28 pictures of the **pictures of facial affect set by Ekman & Friesen** (1976) to measure emotion recognition (Dziobek et al., 2006). Pictures were presented on a computer screen and participants had to choose the correct emotion label out of a wordlist of six basic emotional states (happiness, sadness, fear, disgust, anger, surprise), intermixed with the word "neutral". Labels were displayed in random order. Each correctly identified emotion label scored one point, the total sum forms the accuracy score of the participant. The testing procedure was the same as described above (KERMIT). The internal consistency in our sample at baseline (N = 73 children on the AS, N = 64 non-autistic children; compare KERMIT) was good (McDonald's Omega = .94). The **Social Responsiveness Scale** (SRS, Constantino & Gruber, 2007) is a 65-item parent/teacher questionnaire measuring the severity of autism spectrum symptoms in children (4-18 years) in five domains: Social awareness, social cognition, social communication, social motivation, and autistic manners. Behavior is rated on a four-point-rating scale (ranging from 0 to 3). Higher scores reflect more severe impairments. It has demonstrated high external validity, excellent internal consistency (Cronbach's α = .97) and a good test-retest reliability of r = .77 (for females) to r = .85 (for males). The **Level of Emotional Awareness Scale for Children** (LEAS-C; Bajar, Ciarrochi, Lane, & Deane, Frank, P., 2005) is a performance-based assessment with 12 evocative interpersonal scenarios to assess the complexity of emotional awareness, defined as the degree of differentiation/specificity of the described emotional states. The complexity of emotional awareness is assessed on five levels (0: no emotional awareness, to 5: high complexity with emotion blends). For each scenario, three scores are allocated: a score for self-awareness, other-awareness, and total-awareness. Inter-rater reliability was shown to be good (self-LEAS-C self: r = .93, other-LEAS-C: r = .86, total-LEAS-C: r = .89). The internal consistency of all subscales was sufficient (self-LEAS-C: Cronbach `s α. = .71, other-LEAS-C: α = .64, total-LEAS-C: α = .66). The **Emotion Regulation Checklist** (ERC; Shields & Cicchetti, 1997) is a parent questionnaire for the evaluation of the level of emotion regulation in children aged six to twelve by means of two scales, Emotion Regulation (ER, 8 items) and Emotional Lability/Negativity (L/N, 15 items). ER assesses the expression of emotions, empathy, and constructive emotional self-awareness, while L/N assesses the lack of flexibility, anger dysregulation, and mood lability. The 24 items of the ERC are assessed on a four-point-rating scale (1: never; 2: sometimes; 3: often; 4: usually). The ERC shows good convergent validity with similar instruments and the internal consistency has shown to be adequate (L/N: α = .96; ER: α = .83). The **Inventory of Callous-Unemotional Traits** (ICU, Essau, Sasagawa, & Frick, 2006) is a 24-item parent questionnaire with items scoring on a four-point rating scale (0: not at all true, to 3: definitely true). A general callous-unemotional factor and three subfactors are identified: Callousness (e.g., "the feelings of others are unimportant to me"), unemotional (e.g., "I hide my feelings from others"), and uncaring (e.g., "I try not to hurt others' feelings") (reversely scored item). The reliability and construct validity of the ICU has been supported in several various samples using different translations. The internal consistency for the whole scale was acceptable (Cronbach`s α = .77 - .81), as well as the test–retest reliability over M = 23 days (r = .84; Moore et al., 2017). The **Kiddy-Kindl** (Ravens-Sieberer & Bullinger, 1998) is a parent questionnaire for assessing health-related quality of life in children and adolescents aged either three to six years (version 1) or seven to thirteen

	years (version 2) in 24 items and six dimensions: Physical well-being, emotional well-being, self-worth, well-being in the family, well-being related to friends/peers, and kindergarten/school-related well-being. The internal consistency for the whole scale was acceptable across different age groups, with Cronbach`s α = .85. Within our study, the sixth dimension of the questionnaire (kindergarten/school-related well-being) was not used for calculating the total score, because it was not comparable between the two versions for different age groups. The **Multifaceted Empathy Test for Adolescents** (MET-J; Poustka et al., 2010) is a photo-based test to measure cognitive empathy and emotional concern in adolescents (≥ 12 years). The 32 pictures show faces with emotional expressions in emotion elicitating situations with 16 pictures targeting negative affect and 16 pictures showing positive affect. Cognitive empathy is assessed by selecting the correct emotion label out of four possible options. After receiving feedback on the correct answer, emotional concern is assessed by using the Self-Assessment Manikin (SAM, Lang, et al., 1999) on a nine-point-rating scale from (0) "I am not feeling with the person" to (9) "I am strongly feeling with the person." Within the current study, the cognitive items were left out and children were asked to evaluate their emotional concern either concerning positive affect ("How much are you happy for the person") or negative affect ("How much are you sorry for the person?") on a nine-point-rating scale. The **Paediatric Volitional Questionnaire** (PVQ, Basu et al., 2008) is an observational assessment tool for children aged 2 to 7 years, that examines a child's motivation to perform occupation/to engage in actions by systematically capturing how a child reacts to and acts within his/her environment. Volition is measured by fourteen behavioral indicators representing the volitional continuum form exploration (e.g., "initiates actions"), competency ("stays engaged"), to achievement (e.g., "seeks challenges"). Each item is rated on a four-point scale ranging from (1) "passive", (2) "hesitant", (3) "involved", to (4) "spontaneous" according to the amount of support, structure, or encouragement the child needs to display the behaviors. In the current study, assisting caregivers were asked to rate their child`s behavior during the training sessions on 9 selected items at 5 time-points within the intervention. Note: The instrument was not validated in a parent sample. The **Goal Attainment Scaling** (GAS; Kiresuk & Sherman, 1968; McDougall & King, 2007) is an instrument for assessing individual goal achievement in psychotherapy. Treatment goals are defined pre-treatment by the patient/caregiver and therapist. The degree of goal achievement is evaluated after treatment by using (-2) for no change in behavior, (-1) for slight change towards goal, (0) for goal achieved, (+1) for goal overachieved, (+2) for change far beyond goal. For the current study, two training goals out of the domains emotion recognition, emotional awareness and communication, and facets of emotional empathy and prosocial actions were chosen and operationalized by parents and training operators. **Generalizability and quality of outcome measures** No blinded observations by clinicians were included. Primary and secondary outcome measures with established good psychometric properties were used. **Treatment Satisfaction Report for treatment evaluation, treatment feasibility, and treatment fidelity** An unstandardized questionnaire ("Treatment Satisfaction Report") was used post-treatment to account for treatment evaluation (satisfaction, acceptance), feasibility, fidelity, and changes in generalized behavior not otherwise assessed within TG and CG. The questionnaire for the TG incorporated 41 quantitative items, answers were given on a five-point-rating scale ranging

	from (1) “No, never.”/”No, not at all.” to (5) “Yes, very often.”/”Yes, always.” In some cases, additional qualitative questions were added to access more precise information. The questionnaire was presented online and filled out by training caregivers. Older children with good verbal and cognitive capacities were interviewed with a modified and shortened version of the questionnaire. **Assessment procedure and time** Primary and secondary outcomes were measured at (i) at baseline, immediately prior to the intervention (T1), (ii) after six weeks, immediately after the intervention (T2), and (iii) at follow-up, three months after the end of the intervention (T3). All parent/teacher questionnaires were presented online using the platform SoSci-Survey (Leiner, 2014) /Limesurvey (Limesurvey GmbH; MedUni Wien). Concerning the behavioral testing (KERMIT, EKMAN, LEAS-C), participants were assessed by the respective study operator in GERMANY: HU sample: Berlin (HU), Bonn (autism center), home environment (Niedersachsen, Hamburg, Hessen, Rheinland-Pfalz). KJP AUG: Augsburg (autism center/child psychiatry). AUSTRIA: MedUni Wien: Vienna (autism center/child psychiatry)
6b Changes to trial outcomes	The data of the Multifaceted Empathy Test for Adolescents (MET-J; Poustka et al., 2010) was excluded from data analyses because even though instructions were simplified due to the younger age of the children in our sample (<11y), the majority did not demonstrate a full understanding of the instructions and the concept of emotional concern (e.g., as shown by systematic or repetitive response tendencies when asked to indicate how much they felt for another person).
7a Sample size estimation	Reported in the manuscript. More detailed information: In conducting a power analysis with the software G*Power (version 3.1.9.2 for Mac; Faul et al., 2009¸), the required sample size was estimated according to the reported effect sizes of previous studies targeting computer-based training of emotion recognition skills in children (Grynszpan et al., 2014). The calculation is based on a t-test at T2: with an assumed power of 0.8, the effect size d = 0.58, and an assumed dropout rate of 7%, 82 subjects were required.
8-9 Randomisation	Minimization; reported in the manuscript. Additional information: According to the Consort guidelines (2010), minimization, as an assignment strategy ensuring balance between intervention groups for specific prognostic factors, is an acceptable alternative to random assignment.
10 Implementation	The training operators within each study center enrolled eligible participants by using the online tool MinimPy.
11a Blinding	Reported in the manuscript.
12 Statistical methods	Reported in the manuscript. Additional information: **Statistical software** Analyses were conducted using IBM SPSS statistics, version 25.0 (2017), and RStudio software version 1.1.463 (RStudio Team, 2015) with the following R packages: lavaan (Rosseel, 2012), SemPlot (Epskamp, 2017), tidyverse (Wickham, 2017), haven (Wickham & Miller, 2018), psych (Revelle, 2018), lawstats (Gastwirth et al., 2017), foreign (R Core Team, 2018a), semTools (Jorgensen et al., 2018) and ggplot2 (Wickham, 2016).
RESULTS	
13a Participant flow	Trial time flow is reported in Figure 5.2 in the manuscript.
13b Losses and Exclusion after randomization	Two children of the TG (5%) and four of the CG (10%) did not complete the respective training (loss between T1 and T2). At follow-up, two children of the TG group and three children of the CG were not accessible (see Fig 2). In all cases, participants dropped out for personal reasons (e.g., death of a grandparent, separation of parents).

14a Recruitment

Recruited and trained between December 2015 and April 2018. No significant overarching event affecting the outcome occurred.

15 Baseline data

Reported in the manuscript, Table 1. Additional information:

Differences in baseline characteristics across sites
Autism symptomatology (SCQ) differed significantly across sites ($F(2,77) = 3.87$, $p = .025$, $\eta^2 = .09$). Post-hoc tests revealed a higher symptomatology within the HU sample ($M = 22.3$, $SD = 6.5$) when compared to the KJPP AUG ($M = 17.2$, $SD = 5.8$), but not MedUni Wien ($M = 21.6$, $SD = 5.8$). All other baseline characteristics were comparable across the three study sites.

Demographics of assisting caregivers
Reported in the manuscript, see Table S4 for the demographics of both caregivers.
Assisting caregivers/raters
The training was conducted mainly by the children`s mothers (n = 66; fathers: n = 9; grandmother: n = 1; neighbor: n = 1, mother`s partner: n = 1, missing data: n = 4). In 79% of the cases, questionnaires were rated by the caregiver, who conducted the training, in 11% a second person did the rating (10% missing data).

Additional information on sample characteristics
Assessed information, which is not included in the manuscript/supplement:

- Child: Problematic behavior (CBCL)
- Child: Temperament/character (JTCI)
- Child: Frequency of aggressive behavior (parental report)
- Child: Psychological treatment (parental report)
- Child: Education/school (parental report)
- Child: Gaming experience (parental report)
- Caregiver: Family size (parental report)
- Caregiver: Profession (parental report)
- Caregiver: Stress level (parental report)

16 Numbers analyzed

Attrition rates of primary outcomes were reported in the main manuscript. Overall three time points, both groups and all primary and secondary measures, 17.1% of data were missing:

	T1		T2		T3	
	N	%	N	%	N	%
GEM	6	7.3	19	23.2	16	19.5
EKMAN	5	6.1	16	19.5	21	25.6
ERC-ER	8	9.8	18	22.0	15	18.3
ERC-LabNeg	8	9.8	17	20.7	15	18.3
ICU	6	7.3	17	20.7	14	17.1
KERMIT	4	4.9	13	15.9	20	24.4
Kiddy Kindl	6	7.3	19	23.2	15	18.3
LEAS-C	9	11.0	9	11.0	16	19.5
SRS parent	6	7.3	17	2.7	13	15.9
SRS teacher	17	20.7	23	28.0	34	41.5
Total	75	9.1	168	20.5	179	21.8

Note: All randomized participants were included in the analysis according to the intention-to-treat principle. Statistical models were estimated by using the full information maximum likelihood (FIML) method, which can handle missing data.

17 Outcomes and estimation

Reported in the main manuscript. See Table S7 for means and intercepts of primary and secondary outcome measures at each time point.

Assumptions: Linearity, univariate and multivariate normality
Assumptions for path analyses were checked for each model within training group: Linearity between outcome variables at each time-point (T1, T2, and T3) and between outcome variables and SCQ was given. All outcome

	variables including the moderator variables SCQ, verbal age, and nonverbal IQ were normally distributed (univariate normality). Multivariate normality (MVN) for most path models was given as tested by the Mardia Skewness and Mardia Kurtosis test. For the "Kiddy Kindl" (well-being) data in the control group, the Mardia Skewness test revealed that the data was not distributed according to the Multinormal Distribution (p = .04).
18 Ancillary analyses	• Training intensity and treatment fidelity: Reported in the main manuscript and Tables S5 and S10a. • Child`s motivation during training: Table S6 • Moderator analyses and regression: Reported in the main manuscript and Table S9 below. • For detailed results of the treatment satisfaction report of caregivers and children see the main manuscript, Tables S10a/b and Tables S11a/b.
19 Harms	No harm was reported by caregivers or participants.
DISCUSSION	
20 Limitations	Reported in the main manuscript.
21 Generalisability	Reported in the main manuscript.
22 Interpretation	Reported in the main manuscript.
OTHER INFORMATION	
23 Registration	Reported in the main manuscript.
24 Protocol	https://www.drks.de/drks_web/navigate.do?navigationId=trial.HTML&TRIAL_ID=DRKS00009337
25 Funding	Funding organizations were reported in the main manuscript. The funding organizations had no role in the design of the serious game and the design and conduct of the study, collection management, analysis, and interpretation of the data, review, or approval of the manuscript, and decision to submit the manuscript for publication.

Table S2. Number and percentage of children (total sample, n=82) receiving autism diagnosis by listed institutions.

Diagnostic Institution	N	%
Specialized outpatient clinic Augsburg (KJPP; study site)	17	20.7
Specialized outpatient clinic in Vienna (MedUni Wien; study site)	11	13.4
Other specialized outpatient clinics	8	9.8
Specialized psychiatrists in residence	19	23.3
Social pediatric center/autism services	24	29.3
Unknown	3	3.7

Table S3. Autism diagnosis by measure, number, and percentage of children not meeting the respective cut-offs are displayed

Diagnostic Instrument and Cut-Off for Autism Spectrum	Children Assessed	Children Not Meeting the Cut-off	
	N	N	% of Assessed Children
ADOS-G; cut-off communication + reciprocal social interaction = 7	60	4	5.5%
ADOS-2; cut-off social affect + repetitive and restrictive behavior = 7	13		
ADI-R short interview; cut-off = 5	80	7	8.8%
SCQ; cut-off = 11[a]	80	4	5.0%

[a] Cut-off recommended by Schwenck & Freitag, 2014 children on the autism spectrum without intellectual diability to increase sensitivity.

Table S4: Caregiver demographics and clinical characteristics: Data refers primarily to the caregiver, who assisted the child`s training (caregiver 1, N = 78). In N = 13 cases, a second person was involved in the training (caregiver 2).

	Zirkus Empathico Caregiver 1: N= 41 Caregiver 2: N= 6			**Control Condition** Caregiver 1: N = 37 Caregiver 2: N = 7			
Variable	***M***	***SD***	***Range***	***M***	***SD***	***Range***	***p***
Age (y), Caregiver 1	40.5	5.8	29 - 52	41.7	7.3	29 - 59	.446
Age (y), Caregiver 2	43.0	3.0	38 - 46	42.7	5.3	37 - 52	.285
AQ, Caregiver 1 total score	14.9	9.3	3 - 42	17.7	19.7	4 - 132	.410
AQ, Caregiver 2 total score	19.0	12.2	2 - 32	10.8	6.3	5 - 18	.219
TAS, Caregiver 1 total score	63.2	10.4	34 - 79	61.6	7.0	43 - 73	.414
TAS, Caregiver 2 total score	63.0	6.3	58 - 70	61.0	8.0	45 - 66	.719
	N	**%**		**N**	**%**		
Gender, Caregiver 1							
Male	5	12.2		5	13.5		1.00
Female	36	87.8		32	86.5		
Gender, Caregiver 2							
Male	6	85.7		5	62.5		.569
Female	1	14.3		3	37.5		
Relationship to participant, Caregiver 1							
Father	5	12.2		4	10.8		
Mother	36	87.8		30	81.1		.484
Grandmother	0	0.0		1	2.7		
Partner of child`s mother	0	0.0		1	2.7		
Neighbor	0	0.0		1	2.7		
Relationship to participant, Caregiver 2							
Father	4	66.7		4	57.1		.380
Mother	6	16.7		3	42.9		
Foster father	1	16.7		0	0.0		
Level of education[a], Caregiver 1							
Lower secondary education	1	2.4		1	2.7		
Upper secondary education	21	51.2		16	43.2		.780
Academic education	19	46.3		20	54.1		
Level of education[a], Caregiver 2							
Lower secondary education	0	0.0		0	28.6		
Upper secondary education	3	60.0		5	71.4		.679
Academic education	2	40.0		2	28.6		
Psychological diagnosis, Caregiver 1[b]							
Yes	2	7.7		3	12.0		.668
No	24	92.3		22	88.0		
Psychological treatment within the last 6 months, Caregiver 1							
Yes	4	10.8		8	21.6		.345
No	33	89.2		29	78.4		
Psychological treatment within the last 6 months, Caregiver 2							
Yes	1	16.7		14.3	16.7		1.00
No	5	83.3		85.7	83.3		
Previous involvement in autism therapy, Caregiver 1							
Yes	24	61.5		19	54.3		.638
No	15	38.5		16	45.7		
Previous involvement in autism therapy, Caregiver 2							
Yes	3	75.0		4	44.4		.190
No	1	25.0		5	55.6		

Note: AQ = Autism Quotient; TAS = Toronto Alexithymia Scale.

[a] The level of education was determined according to the International Standard Classification of Education (ISCED) applied to the German and Austrian school system: *Lower secondary education (ISCED-Level-2):* Hauptschulabschluss/Pflichtschulabschluss; *Upper secondary education*

SUPPLEMENT OF STUDY 2

Table S5: Training intensity: Results of parent and tracking records

	Zirkus Empathico N = 32				Control Condition N = 27				
Variable	***Min***	***Max***	***M***	***SD***	***Min***	***Max***	***M***	***SD***	***p***
Training weeks, parent record	4	9	6.2	.74	6	6	6.0	.0.0	.103
Training sessions, average over 6 weeks	1.8	7.0	4.57	1.46	2.8	7.0	4.71	1.36	.692
Training intensity (h), parent record	5.1	15.2	9.7	2.8	8.8	22.0	13.2	3.6	.000
Training intensity per single session (min), parent record	11.3	46.5	22.7	8.5	15.6	57.2	30.4	11.7	.006
Training intensity (h), tracking record (n = 37)	3.1	12.1	7.3	2.4	---	---	---	---	---
Frequency of transfer module usage (n = 37), tracking record	0	33	5.4	6.4	---	---	---	---	---

Note Minimum (Min), Maximum (Max), Means (M), and Standard Deviations (SD) of training times within intervention group.

Table S6: Children`s motivation to engage in actions (volition): Results of the Pediatric Volitional Questionnaire (PVQ).

Items	Zirkus Empathico N = 33				Control Condition N = 33				
4-point scale: (1) "passive", (2) "hesitant", (3) "involved", (4) "spontaneous"	***Median***	***Mode***	***M***	***SD***	***Median***	***Mode***	***M***	***SD***	***p***
1. Explores novelty	3.5	4.0	3.5	.44	3.7	4.0	3.6	.35	.660
2. Initiates actions	3.8	4.0	3.7	.35	3.8	4.0	3.7	.31	.852
3. Is task directed	3.5	4.0	3.5	.45	3.5	3.5	3.5	.39	.463
4. Shows preference	3.5	3.0	3.6	.41	4.0	4.0	3.8	.34	.017
5. Tries new things	3.6	4.0	3.4	.53	3.3	4.0	3.3	.62	.613
6. Stays engaged	3.3	3.0	3.3	.40	3.3	4.0	3.2	.56	.936
7. Expresses pride/mastery pleasure	3.5	4.0	3.4	.48	3.5	4.0	3.5	.49	.602
8. Tries to solve problems	3.0	3.0	3.1	.55	3.0	3.0	3.3	.49	.347
9. Practices skills	3.0	3.0	3.1	.62	3.3	3.0	3.3	.46	.118
Volition total score	3.4	3.5	3.4	.30	3.5	3.5	3.5	.31	.297

Note: Median, Mode, Means (M) and Standard Deviations (SD) within intervention group. Scores [1-9] represent the average score over 5 times of measurement within the 6-weeks training period. The "volition total score" represents the mean of the single items over 5 measurement points.

Table S7: Raw means (*SD*) and unstandardized intercepts (estimates: *EST; EST SD*) of primary and secondary outcome measures at each time point per group. For estimating intercepts, outcome measures were centered to zero (grand mean centering). For T1, no intercepts, but centered means (*M centr)* are displayed. Estimations are extracted from the model, which fitted the respective data best.

Zirkus Empathico
N = 42

Measure	Baseline (T1)			Post-treatment (T2)			Follow-up (T3)		
	M	***M centr***	***SD***	***M***	***EST***	***SD***	***M***	***EST***	***SD***
GEM	-13.1	-2.2	23.8	4.7	7.9	22.0	-0.7	-3.1	25.8
KERMIT	30.2	0.1	4.4	32.7	0.8	3.2	31.8	-0.1	3.6
EKMAN	14.3	-0.8	4.7	17.3	1.3	3.0	16.6	0.0	3.0
LEAS-C	2.4	0.0	0.6	2.7	0.1	0.5	2.7	0.0	0.5
ERC ER	20.3	-3.3	3.4	23.1	1.1	3.3	22.7	0.6	3.1
ERC N/L	40.5	1.0	6.3	35.5	-1.2	6.8	36.3	0.0	7.5
SRS parent	108.5	2.7	28.5	89.3	-10.8	30.6	87.3	-5.3	28.5
SRS teacher	82.8	-3.8	29.3	71.1	-2.1	26.0	77.2	-1.2	28.6
ICU	38.2	1.7	9.9	30.2	-2.1	9.4	30.6	0.0	9.4
Kiddy Kindl	62.0	0.0	10.0	65.7	0.6	11.7	65.2	1.1	12.2

Control condition
N = 40

Measure	Baseline (T1)			Post-treatment (T2)			Follow-up (T3)		
	M	***M centr***	***SD***	***M***	***EST***	***SD***	***M***	***EST***	***SD***
GEM	8.4	2.24	27.0	-7.3	-9.1	25.8	-2.0	1.7	29.0
KERMIT	30.0	-0.1	3.4	31.0	-1.1	4.6	31.8	0.6	3.9
EKMAN	16.0	0.9	3.4	15.7	-1.5	3.6	17.0	0.1	3.8
LEAS-C	2.5	0.0	0.4	2.5	-0.2	0.5	2.4	-0.1	0.5
ERC ER	21.0	0.4	3.4	21.2	-1.2	3.3	21.3	-0.6	3.8
ERC N/L	38.4	-1.1	1.4	36.8	2.1	7.1	36.7	-0.2	6.5
SRS parent	102.5	-3.1	23.3	99.4	7.4	21.3	93.8	1.8	20.3
SRS teacher	90.5	3.9	28.3	88.4	-2.1	23.3	82.6	-1.2	22.8
ICU	34.6	-1.9	10.1	33.1	3.2	9.4	32.5	0.6	10.2
Kiddy Kindl	61.9	0.0	8.8	62.7	0.6	10.5	63.0	1.1	6.2

Note: Raw means (M), centered means (M centr*)*, standard deviations (*SD*) and unstandardized intercepts (*EST)*. EKMAN = Ekman & Friesen Pictures of Facial Affect Set; ERC ER = Emotion Regulation Checklist - Subscale Emotion Regulation; ERC N/L = ERC Subscale Negativity/Lability; GEM = Griffith Empathy Measure; ICU = Inventory of Callous/Unemotional Traits; KERMIT = Kids Emotion Recognition Multiple Images Tasks; LEAS-C = Level of Emotional Awareness Scale for Children, self-score; SRS = Social Responsiveness Scale.

Table S8: Correlation matrix (Pearson's *r*); increases in emotional awareness, emotion regulation, and cognitive and empathy between T1 and T2 and increases in emotion recognition and empathy between T2 and T3 within the intervention group.

Zirkus Empathico
N = 42

Variable	***M***	***SD***	**1**	**2**	**3**	**4**	**5**
1. LEAS-C change score T2-T1	.33	.58					
2. ERC-ER change score T2-T1	2.87	2.43	.06				
3. GEM change score T2-T1	20.71	22.74	-.09	.46			
4. KERMIT change score T2-T1	2.42	6.69	-.05	.22	.19		
5. GEM change score T3-T2	-3.97	14.46	**.55**	-.30	-.36	.05	
6. KERMIT change score T3-T2	-0.76	3.00	-.09	-.10	-.12	-.32	.00

Note: Means (M), standard deviations (SD), and correlations coefficients (Pearson's *r*) of changes scores. Variables refer to emotional awareness (LEAS-C), emotion regulation (ERC-ER), empathy (GEM), and emotion recognition (KERMIT). They represent changes during training (T1 to T2) and changes from post-treatment to follow-up (T2 to T3), respectively. Significance thresholds were corrected for multiple comparisons by using the Bonferroni-Holm procedure.
*p < .05, **p < .01, *** p < .001.

Table S9: Results of the moderator analyses within TG. Chosen models based on sample-size adjusted BIC /AIC comparisons are marked.

	Moderator: Autism symptomatology (SCQ)				**Moderator: Verbal Age (VA)**			
	Main effects only model		*Interaction model*		*Main effects only model*		*Interaction model*	
Measure	*AIC*	*BIC ad.*	*AIC*	*BIC ad.*	*AIC*	*BIC ad.*	*AIC*	*BIC ad.*
GEM	919.8	902.5	1693.2	1666.3	1379.8	1351.9	1774.9	1738.6
KERMIT	596.5	579.2	1243.9	1217.4	1051.6	1023.7	1359.6	1323.4

Note: Akaike Information Criterion (AIC); Bayesian information criterion (BIC), sample size adjusted; Griffith Empathy Measure (GEM); Kids Emotion Recognition Multiple Images Task (KERMIT); Social Communication Questionnaire (SCQ); Verbal Age (VA): Chronological Age * Verbal IQ/100

S2: Treatment Evaluation: Results of the Treatment Satisfaction Report for Caregivers and Children and Results of the Goal Attainment Scaling

In the TG 34 caregivers (30 mothers, 2 fathers, 2 without gender specification) and the same amount of children could be assessed by the Treatment Satisfaction Report after the intervention. In the CG, the answers of 27 caregivers (24 mothers, one father, and two other caregivers) and 22 children could be recorded (see Tables S10a/b, S11a/b).

Table S10a: Caregiver Report: Treatment satisfaction, feasibility, and fidelity within group.

Item	**Zirkus Empathico** N = 34		**Control Condition** N = 27		
5-point Likert Scale (1) "no, never", to (5) "yes, always"	***M***	***SD***	***M***	***SD***	***p***
Did your child enjoy the training?	4.74	.71	4.46	.65	.960
Did you [caregiver] enjoy the training?	4.47	.75	3.96	.77	.013
Was your child generally motivated to play with the app(s)?	4.70	.64	4.27	.73	.055
Has your child often been frustrated, stressed, bored, demotivated while playing, or did it refuse to train?	1.92	2.82	--	--	--
Did your child want to play longer/more often than planned?	4.13	1.02	--	--	--
Have you been motivated to conduct the training as agreed? [for reasons, see below]	4.32	.77	4.07	.87	.240
Did your child have difficulties in understanding the app/the modules?	1.78	.91	--	--	--
Have the contents/modules of the app been always self-explanatory to you?	4.55	.79	--	--	--
Were the suggestions from the training manual regarding playing with the app helpful?	4.35	.84	--	--	--
Do you need external support to carry out the training?	2.88	1.50	--	--	--
Did you feel adequately and well supervised during the study?	4.88	.41	4.85	.36	.762
Was the training compatible with your daily routine, family life, job, and school/kindergarten?	4.00	.75	4.07	.68	.692
Were you mentally strained or stressed by the training?	1.73	.88	1.74	.81	.951
Have you felt comfortable in assisting your child`s training?	4.47	.72	--	--	--
Has it been easy for you to transfer the training contents to your everyday life?	3.66	.97	--	--	--
On average, how many minutes per week did your child play alone?	24.96	30.96	34.23	27.13	.252
Did your child play alone too?					
Yes	27	79.4	25	92.6	.276
No	7	20.6	2	7.4	
Has your child's medication changed during training?					
No medication	18	52.9	17	63.0	
No	7	20.6	3	11.1	.580
Yes	0	0.0	0	0.0	
No answer	9	26.5	9	25.9	
Has emotional content been addressed within treatment as usual in parallel to the study?					.891
No	16	47.1	15	55.6	
I don`t know	1	2.9	1	3.7	
Yes	1	2.9	1	3.7	
No answer given	16	47.1	10	37.0	
If [you were not motivated to conduct the training as agreed], what stopped you?[a]					.136
No demotivation/no reasons provided	22	67.7	16	59.3	
Time-related reasons	7	20.6	2	7.4	
Caregiver`s energy/stress related reasons	2	5.9	0	0.0	
Child-related reasons	2	5.9	2	7.4	
Problems with assisting role	0	0.0	2	7.4	

Study-related reasons	1	2.9	1	3.7	
Technical problems	0	0.0	2	7.4	
Health-related reasons	0	0.0	2	7.4	
Have you used the transfer module of the ZE in your everyday life?					
Never	4	11.8	--	--	--
1-2 times/week	6	17.6	--	--	--
3-5 times/week	16	47.1	--	--	--
Daily	6	17.6	--	--	--
No answer	2	5.9	--	--	--

[a] Classification of reasons provided descriptively by caregivers; examples:
Time-related reasons: "Difficult to integrate into daily routines."; "Lack of time." *Reasons related to the caregiver´s energy/stress level*: "I'm a single mother and I work a lot. Sometimes I was too tired or simply had no time." *Child-related reasons:* "Stressful situations with [child`s name] were sometimes demotivating. He had many tantrums during this time. " *Problems with assisting role*: "Too boring to sit next to my child all the time. My son often wanted no interference by me." *Reasons related to study participation*: "Daily record of playing times was annoying."; "Placebo group." *Technical problems*: "Some of the games did not work properly. The trying/restarting was time-consuming." *Health-related reasons:* "[Child] was sick and did not want to play."

Table S10b: Children Report: Treatment Satisfaction and Acceptance

Item	**Zirkus Empathico** N = 27		**Control Condition** N = 22		
5-point Likert Scale	***M***	***SD***	***M***	***SD***	***p***
Was it fun to play with Zirkus Empathico (ZE)/the apps? *(1) no fun at all, (5) a lot of fun*	4.46	1.03	3.85	.93	.037
Which smiley do you give to ZE/your favorite app?* *(1) very negative smiley given, (5) very positive smiley given*	4.48	.94	4.15	.86	.204
Did you always want to play when it was scheduled, or have you sometimes not been in the mood to play? *(1) I was never in the mood, (5) I was always in the mood*	4.19	.98	4.18	1.02	.960
Have the games been easy or difficult for you? [modules on average in the ZE group; apps on average in the CG] *(1) very difficult, (5) very easy*	4.15	1.01	3.94	1.26	.559

Note: Within the CG, the first question referred to the total selection of provided apps (see Table S1). The second question targets the app, which was played most of the time by the CG children as indicated by their parents.

Table S11a: Caregiver Report: Changes in Targeted Behaviors and Family Life

Item	**Zirkus Empathico** N = 34		**Control Condition** N = 27		
5-point Likert Scale (1) "no, not at all", to (5) "yes, totally"	***M***	***SD***	***M***	***SD***	***p***
Has your child changed in terms of his or her behavior at school/kindergarten/family?	2.94	1.0	2.12	.97	.003
Has the emotional approach, relationship with your child, and/or interaction/communication with your child improved compared to when you started the training?	3.12	1.24	2.04	1.15	.001
Have the topic "feelings" and emotional communication, in general, become more present within your family - even outside the training?	3.66	1.21	--	--	--
Have you noticed changes in yourself in your emotional perception and your empathic interaction with other people?	2.39	1.38	--	--	--
Item *5-point Likert Scale (1) "no changes", to (5) "strong changes"*	***M***	***SD***			
Rating of perceived changes in the child's behavior after the training in …					
… general interest in emotions	3.22	1.36	--	--	--
… dealing with own (good and bad) feelings	2.97	1.06	--	--	--
… recognition of other´s emotions	3.25	1.11	--	--	--
… Adequate reactions to the feelings of other people	2.81	.931	--	--	--
Has your family atmosphere changed during/after the training?	2.84	1.27	--	--	--
Item *5-point Likert Scale (1) "no, never", to (5) "yes, always"*	***M***	***SD***			
Is your child more open-minded or outgoing towards other children (siblings, peers, etc.)?	2.63	1.16	--	--	--
Has your child expanded its social environment, i.e. does it spend more time with other children?	1.97	.948	--	--	--
Item	**N**	**%**	**N**	**%**	
Would you attribute your child's development to the training or other circumstances?					
Training	12	38.7	6	28.6	.032
Other circumstances	1	3.2	6	28.6	
Training and other circumstances	18	58.1	9	42.9	
Would you attribute the changes in the family atmosphere to the training or other circumstances?					
Training	14	41.2	--	--	--
Other circumstances	1	2.9	--	--	--
Training and other circumstances	13	38.2	--	--	--
No answer	6	17.6	--	--	--

Note: Means (M) and standard deviations (SD).

Table S11b: Children Report: Perceived Changes in Targeted Behaviors

Item: After the ZE training … *5-point Likert Scale ranging from* *(1) "no, not at all", to (5) "yes, much better" /* *(1) "less", (3) "the same as before", (5) "much more"*	**Zirkus Empathico** N = 20*	
	M	***SD***
Do you recognize your own feelings better now?	3.6	1.67
Do you recognize other person´s feelings better now?	3.6	1.64
Do you feel/empathize now more, less, or to the same amount as before with other people?	3.6	.89
Do you now know better, less, or equally well how to react to the feelings of other people?	3.9	.93
Do you play more, less, or as much as before with other children?	3.2	.63
Item: After the ZE training …	**n**	**%**
Have you made any new friends?		
Yes	7	35.0
No	13	65.0

Note: Means (M) and standard deviations (SD) in the intervention group. In seven additionally interviewed children, the understanding of the questions was not sufficient to be evaluated.

Table S12: Results of the Goal Attainment Scaling (GAS). Parent-report within TG.

	Zirkus Empathico N = 40	
Goal definition pre-training	***N***	***%***
Target of first goal named by parents:		
Own emotionality	26	65.0
Emotion recognition	6	15.0
Empathy and empathic action	8	19.0
	Zirkus Empathico N = 30	
Goal attainment rating post-training	***N***	***%***
Goal 1:		
No change [GAS score = -2]	4	13.3
Change below defined goal [GAS score = -1]	8	26.7
Goal achieved [GAS score = 0]	6	20.0
Change above goal [GAS score = 1]	9	30.0
Change high above goal [GAS score = 2]	3	10.0
Goal 2:		
No change [GAS score = -2]	0	0.0
Change below defined goal [GAS score = -1]	9	30.0
Goal achieved [GAS score = 0]	10	33.3
Change above goal [GAS score = 1]	10	33.3
Change high above goal [GAS score = 2]	1	3.2
Goal attainment rating post-training	***M***	***SD***
Goal 1	-.03	1.25
Goal 2	.10	.89

S3: Zirkus Empathico Stimuli Production and SG Design

S3a: Stimuli Production and Validation

Videos of facial expressions: The videos of the facial expressions embedded in the training were produced in the film studio of the Computer and Media Service (CMS) of Humboldt-Universität zu Berlin, Germany. The production of the videos showing adult expressions was part of a previous comprehensive project to produce an ecologically valid stimulus set of 40 different emotions (Kliemann et al. 2013). More than 50 professional actors (18-65 years) were either instructed to imagine typical events associated with a certain emotion (expectant: "*Imagine, your finance comes back from a long trip and you can`t wait to see him again*."), or they were asked to put themselves imaginatively into a personal, emotionally charged situation. All videos were filmed frontally with a neutral on- and off-set.

Of the approximately 45 videos per emotion, a subset of 100 was validated in an expert validation study (10 psychologists, 4 males, age: M = 29.6 years, SD = 4.3). The emotion recognition rates were high on average (92.6%; SD = 10%) and the videos were rated as believable on a six-point-rating scale with (1) being not believable and (6) being very believable (M = 4.4, SD = 0.1). For the Zirkus Empathcio application, 170 videos depicting the targeted basic emotions and the neutral state were selected (62 showing male, 108 showing female faces). Additionally, 78 videos of children`s emotional expressions (20 males, 58 females) were produced, with a slightly modified procedure: Twelve children (4-13 years; naïve actors) were instructed to put themselves in an emotion eliciting context, which was either a personal event the child had experienced or a situation associated with the respective emotion (Joy: "*Imagine you are running a race, you are in the second position, now in first… you win the race!")*. Children were asked to show the targeted emotion several times, with strong as well as weak expressivity. Emotional expressions were demonstrated in case children were not able to express them spontaneously. The validation of the children`s emotional videos was done in two steps: First, invalid/non-believable videos were excluded during production by the first and last author. Second, the remaining video clips were validated by seven psychologists (age: M =29.9, SD = 3.6) working in the field of social cognition. The results showed high average emotion recognition rate (85.4%; SD = 17.3%) and sufficient believability on a six-point-rating scale form (1) not believable to (6) very believable (M = 3.9, SD = 1.0).

Context videos: The decision to integrate context video stimuli to improve emotion recognition was based on a pilot study with 24 non-autistic children and 15 children on the autism spectrum (AS) aged 8-11 years (Kirst et al., 2014), looking at the contribution of context to emotion recognition. The results showed a clear emotion recognition deficit for facial expressions within the AS group. On the contrary, when the facial emotional expression was embedded into the emotion-eliciting context, children on the AS and average IQ improved their recognition skills. Beyond that, in children on the AS, but not in comparison children, general IQ, thus systemizing skills, mediated the ability to recognize emotions from contextual information, pointing to a compensatory mechanism. Consequently, ZE module III aims at fostering a potential compensatory mechanism for deficient facial emotion recognition.

The production of context videos for modules I, III, and IV was based on interviews with 10 non-autistic elementary school children (5 males, 5 females) between seven and eleven years, who were asked to describe emotional experiences associated with each of the five basic emotions (anger, fear, surprise, joy, sadness). Appropriate narratives were selected and transformed into scripts for video production. Scripts either included social situations (e.g. anger: being bullied by children) or non-social situations (sadness: losing a teddy bear). Twelve non-professional actors (5 children, 7 adults) participated in the production of the short video clips (n = 56), each displaying emotion eliciting contexts targeting one of the basic emotions or a neutral state. Examples are given in Table S13. All videos were filmed in first-person perspective to allow the player of ZE to immerse into the respective situation as the agent. Six additional videos with creative commons licenses were also integrated, resulting in 62 video

clips in total (length approx. 30-40sec). Each video is introduced in the respective ZE modules by an illustration and an audio sample (German) describing the background of the context (i.e.: Mod. I: "*Imagine you are at home. You are sick….*" or, respectively, Mod. III/IV: "*Imagine a child is at home…"),* the videos themselves are free of speech. For the emotion recognition/empathy tasks (module III, IV), nonverbal emotional sounds ("*oh*!" etc.) were added to the video content to support the display of the targeted emotion.

An expert rating by three female psychologists working in the field of social cognition (age: $M = 28.7$, $SD = 2.3$) revealed sufficient validity of the stimuli (recognition rate of emotions elicited through situations: $M = 90\%$, $SD = 3\%$; mean confidence on a five-point-rating-scale from (1) not confident to have recognized the targeted emotion to (5) very confident: $M = 4.1$, $SD = 0.3$).

Audio material: The audio material was produced in cooperation with the CMS audio studio of Humboldt-Universität zu Berlin. Nonverbal emotional sounds of children and adults (e.g. surprise: "*Oh*!"; sadness: a groan), which were integrated into modules III and IV (see above), were recorded during the facial expression video production sessions. Audio samples of the fox character used for introduction to the context videos, game introductions, explanations, and appraisal were spoken by a professional male actor.

S3b: Design Principles, Design Approach, and Usability Testing

The conception of the training app was based on principles and techniques (e.g. prompts, rewards) of behavioral therapy for children in the autism spectrum (Bernard-Opitz, 2009b). Following previous recommendations, multi-media content was integrated, specifically, graphics (Hopkins et al., 2011; D. Moore et al., 2005; Williams et al., 2002) were used. Considering the needs and cognitive capacities of the ZE target- and age group, a clear and unambiguous interface design without distracting details was required. Moreover, the audio examples used in the app are characterized by precise wording and simple grammar (rules of "easy language", Netzwerk Leichte Sprache, 2013). Their content is visualized by icons and visual metaphors and animations (Basil & Reyes, 2003), which allows even pre-school children a self-determined gaming experience. The game setting is appropriate for children to maintain their motivation and attention, through the integration of several key elements, which have been found particularly relevant to enhancing motivation to play in serious games: Immersive storylines, goals directed around targeted skills, rewards, and feedback about goal progress, and the provision of choice (Whyte et al., 2015). To guarantee an optimum level of motivation, the design of the objects for the reward system (circus environment) was based on typical preferences of children in the AS for certain toys, e.g. spinners, whirligig, toys with audio-visual effects, or technical objects. Two adults on the autism spectrum (one male) were asked several times for advice and feedback on the design and the content of the different modules during the conceptual and technical development.

A pilot study with eleven non-autistic children aged 7 to 12 was carried out to test the usability of the prototype of the ZE application. The children were monitored during the gameplay and were interviewed afterward. The study confirmed an intuitive and self-determined use of the app and a good understanding of all relevant game elements (like buttons, visual feedback, and visualization of emotions). The results were used for a more precise design of the game elements. Within a second pilot study, the second version of the prototype was given for two weeks to four children on the AS (age: 10-12 years, all males) to analyze their application and understanding of the app. The children and their parents provided feedback on motivation, enjoyment, and attention during training and ideas for improving the app.

Table S13: Examples of training context videos per targeted emotion

Targeted emotion	Audio introduction to context video	Context video in first-person perspective
Anger	(A) "Imagine, you are playing ball in the park. Older children are there as well."	(A) The child`s hands are playing with a ball until a taller child takes the ball and holds it out of reach of the first child. The second child is making fun of the first one.
	(B) „Imagine, you are with a friend at the beach."	(B) 2 pairs of children`s hands are building a castle out of sand. Suddenly, a third person steps into the castle, which is destroyed afterward.
Fear	(A) "Imagine, you are walking in the streets."	(A) A dog runs towards the viewer and starts barking aggressively.
	(B) "Imagine, you are in your bed. You are alone."	(B) It is dark, an open balcony door is squeaking, a curtain blows a little, on the walls are moving shadows.
Sadness	(A) "Imagine you have a favorite teddy bear. You are playing with the bear on a bridge."	(A) Hands of a child are playing with a teddy bear on a bridge railing. Suddenly, the teddy bear falls into the water.
	(B) You have given a drawn picture to your uncle as a gift. Now, you are going into your uncle´s office."	(B) A rumpled picture is shown in a paper basket. It is taken out and smoothed out. A child`s drawing becomes visible.
Joy	(A) "Imagine, you are in a city. It is very hot."	(A) The viewer is entering an ice cream parlor. The friendly-looking ice-cream seller is handing over colorful ice cream.
	(B) "Imagine, you have birthday. Your aunt has a present for you."	(B) The hands of a child are stroking a little rabbit.
Surprise	(A) "Imagine, you are at home. You are going to the letterbox."	(A) A letter is taken out of the letterbox and is opened. The viewer reads "First prize" on it.
	(B) "Imagine, you are at your aunt´s house. You want to go to bed."	(B) The blanket is pulled away, underneath lies a little dog.
Neutral	(A) "Imagine, you are outside. You have a letter."	(A) The viewer approaches a mailbox; a hand drops the letter in.
		(B) A woman is folding clothes on a table.

References

Alcañiz, M., Chicchi-Giglioli, I. A., Carrasco-Ribelles, L. A., Marín-Morales, J., Minissi, M. E., Teruel-García, G., Sirera, M., & Abad, L. (2022). Eye gaze as a biomarker in the recognition of autism spectrum disorder using virtual reality and machine learning: A proof of concept for diagnosis. *Autism Research: Official Journal of the International Society for Autism Research*, *15*(1), 131–145. https://doi.org/10.1002/aur.2636

Aldao, A., Gee, D. G., De Los Reyes, A., & Seager, I. (2016). Emotion regulation as a transdiagnostic factor in the development of internalizing and externalizing psychopathology: Current and future directions. *Development and Psychopathology*, *28*(4pt1), 927–946. https://doi.org/10.1017/S0954579416000638

American Psychiatric Association (2013). Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.

Andersson, G., Cuijpers, P., Carlbring, P., Riper, H., & Hedman, E. (2014). Guided Internet-based vs. Face-to-face cognitive behavior therapy for psychiatric and somatic disorders: A systematic review and meta-analysis. *World Psychiatry: Official Journal of the World Psychiatric Association (WPA)*, *13*(3), 288–295. https://doi.org/10.1002/wps.20151

Astington, J. W., Harris, P. L., & Olson, D. R. (1990). *Developing theories of mind*. Cambridge University Press.

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., Kurzius-Spencer, M., Zahorodny, W., Robinson Rosenberg, C., White, T., Durkin, M. S., Imm, P., Nikolaou, L., Yeargin-Allsopp, M., Lee, L.-C., Harrington, R., Lopez, M., Fitzgerald, R. T., Hewitt, A., . . . Dowling, N. F. (2018). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years - Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2014. *Morbidity and Mortality Weekly Report. Surveillance Summaries*, *67*(6), 1–23. https://doi.org/10.15585/mmwr.ss6706a1

Baker, B. L., Blacher, J., Crnic, K. A., & Edelbrock, C. (2002). Behavior Problems and Parenting Stress in Families of Three-Year-Old Children With and Without Developmental Delays. *American Journal on Mental Retardation*, *107*(6), 433.

Bandura, A. (1973). Aggression: A Social Learning Analysis. *Stanford Law Review*, *26*(1), 239. https://doi.org/10.2307/1227918

Baños, R. M., Botella, C [C.], Quero, S., Garcia-Palacios, A., & Alcañiz, M. (2011). Engaging Media for Mental Health Applications: The EMMA project: Studies in Health Technology and Informatics. In J. D. Westwood (Ed.), *Studies in health technology and informatics: v. 163. Medicine meets virtual reality 18: Nextmed.* IOS Press.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, *6*(6), 248–254. https://doi.org/10.1016/S1364-6613(02)01904-6

Baron-Cohen, S., Golan, O., Wheelwright, S. J., Granader, Y., & Hill, J. J. (2010). Emotion word comprehension from 4 to 16 years old: A developmental survey. *Frontiers in Evolutionary Neuroscience*, *2*, 109. https://doi.org/10.3389/fnevo.2010.00109

Baron-Cohen, S., Golan, O., Wheelwright, S. J., & Hill, J. J. (2004). *Mind reading* [Computer software]. Kingsley. London.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a “theory of mind” ? *Cognition*, *21*(1), 37–46. https://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., & Wheelwright, S. J. (2004). The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, *34*(2), 163–175. https://doi.org/10.1023/b:jadd.0000022607.19833.00

Baron-Cohen, S., Wheelwright, S. J., Hill, J. J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" Test Revised Version: A Study with Normal Adults, and Adults with Asperger Syndrome or High-functioning Autism. *Journal of Child Psychology and Psychiatry*, *42*(2), 241–251. https://doi.org/10.1017/S0021963001006643

Barton, E. E., Pustejovsky, J. E., Maggin, D. M., & Reichow, B. (2017). Technology-Aided Instruction and Intervention for Students With ASD: A Meta-Analysis Using Novel Methods of Estimating Effect Sizes for Single-Case Research. *Remedial and Special Education*, *38*(6), 371–386. https://doi.org/10.1177/0741932517729508

Basil, C., & Reyes, S. (2003). Acquisition of literacy skills by children with severe disability. *Child Language Teaching and Therapy*, *19*(1), 27–48. https://doi.org/10.1191/0265659003ct242oa

Basu, S., Kafkes, A., Schatz, R., Kiraly, A., & Kielhofner, G. (2008). *The Pediatric Volitional Questionnaire (PVQ)* (2.1st ed.). The University of Illinois at Chicago.

Bauminger, N., Edelsztein, H. S., & Morash, J. (2005). Social information processing and emotional understanding in children with LD. *Journal of Learning Disabilities*, *38*(1), 45–61. https://doi.org/10.1177/00222194050380010401

Beauchaine, T. P., & McNulty, T. (2013). Comorbidities and continuities as ontogenic processes: Toward a developmental spectrum model of externalizing psychopathology. *Development and Psychopathology*, *25*(4 Pt 2), 1505–1528. https://doi.org/10.1017/S0954579413000746

Beaumont, R. B., Pearson, R., & Sofronoff, K. (2019). A Novel Intervention for Child Peer Relationship Difficulties: The Secret Agent Society. *Journal of Child and Family Studies*, *28*(11), 3075–3090. https://doi.org/10.1007/s10826-019-01485-7

Beaumont, R. B., & Sofronoff, K. (2008). A multi-component social skills intervention for children with Asperger syndrome: The Junior Detective Training Program. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *49*(7), 743–753. https://doi.org/10.1111/j.1469-7610.2008.01920.x

Beaumont, R. B., Walker, H., Weiss, J. A., & Sofronoff, K. (2021). Randomized Controlled Trial of a Video Gaming-Based Social Skills Program for Children on the Autism Spectrum. *Journal of Autism and Developmental Disorders*, *51*(10), 3637–3650. https://doi.org/10.1007/s10803-020-04801-z

Begeer, S., Koot, H. M., Rieffe, C., Meerum Terwogt, M., & Stegge, H. (2008). Emotional competence in children with autism: Diagnostic criteria and empirical evidence. *Developmental Review*, *28*(3), 342–369. https://doi.org/10.1016/j.dr.2007.09.001

Begeer, S., Rieffe, C., Terwogt, M. M., & Stockmann, L. (2006). Attention to facial emotion expressions in children with autism. *Autism: The International Journal of Research and Practice*, *10*(1), 37–51. https://doi.org/10.1177/1362361306057862

Ben Shalom, D., Mostofsky, S. H., Hazlett, R. L., Goldberg, M. C., Landa, R. J., Faran, Y., McLeod, D. R., & Hoehn-Saric, R. (2006). Normal physiological emotions but differences in expression of conscious feelings in children with high-functioning autism. *Journal of Autism and Developmental Disorders*, *36*(3), 395–400. https://doi.org/10.1007/s10803-006-0077-2

Benesch, C., Görtz-Dorten, A., Breuer, D., & Döpfner, M. (2013). Erfassung aggressionsauslösender und -aufrechterhaltender Faktoren bei Kindern mit oppositionellen und aggressiven Verhaltensstörungen im Eltern-, Lehrer- und Selbsturteil. *Zeitschrift Für Klinische Psychologie Und Psychotherapie*, *42*(4), 269–279. https://doi.org/10.1026/1616-3443/a000226

Berggren, S., Fletcher-Watson, S., Milenkovic, N., Marschik, P. B., Bölte, S., & Jonsson, U. (2017). Emotion recognition training in autism spectrum disorder: A systematic review of challenges related to generalizability. *Developmental Neurorehabilitation*, *21*(3), 141–154. https://doi.org/10.1080/17518423.2017.1305004

Bernard-Opitz, V. (2009a). Applied-Behavior Analyses (ABA) / Autismusspezifische Verhaltenstherapie. In S. Bölte (Ed.), *Autismus. Spektrum, Ursachen, Diagnostik, Intervention, Perspektiven* (1st ed.). Huber.

Bernard-Opitz, V. (2009b). Applied-Behavior Analyses (ABA) / Autismusspezifische Verhaltenstherapie. In S. Bölte (Ed.), *Autismus. Spektrum, Ursachen, Diagnostik, Intervention, Perspektiven* (1st ed.). Huber.

References

Berta, A., Castellanos, M. Á., González-Sanguino, C., & Rubén, H. (2022). A bibliometric analysis of 10 years of research on symptom networks in psychopathology and mental health. *Psychiatry Research*, *308*, 114380. https://doi.org/10.1016/j.psychres.2021.114380

Berthoz, S., & Hill, E. L. (2005). The validity of using self-reports to assess emotion regulation abilities in adults with autism spectrum disorder. *European Psychiatry*, *20*(3), 291–298. https://doi.org/10.1016/j.eurpsy.2004.06.013

Bird, G., & Cook, R. (2013). Mixed emotions: The contribution of alexithymia to the emotional symptoms of autism. *Translational Psychiatry*, *3*, e285. https://doi.org/10.1038/tp.2013.61

Bird, G., Press, C., & Richardson, D. C. (2011). The role of alexithymia in reduced eye-fixation in Autism Spectrum Conditions. *Journal of Autism and Developmental Disorders*, *41*(11), 1556–1564. https://doi.org/10.1007/s10803-011-1183-3

Bird, G., Silani, G., Brindley, R., White, S., Frith, U., & Singer, T. (2010). Empathic brain responses in insula are modulated by levels of alexithymia but not autism. *Brain: A Journal of Neurology*, *133*(Pt 5), 1515–1525. https://doi.org/10.1093/brain/awq060

Bird, G., & Viding, E. (2014). The self to other model of empathy: Providing a new framework for understanding empathy impairments in psychopathy, autism, and alexithymia. *Neuroscience and Biobehavioral Reviews*, *47*, 520–532. https://doi.org/10.1016/j.neubiorev.2014.09.021

Blair, R. J. (2016). The Neurobiology of Impulsive Aggression. *Journal of Child and Adolescent Psychopharmacology*, *26*(1). https://doi.org/10.1089/cap.2015.0088

Blandon, A. Y., Calkins, S. D., & Keane, S. P. (2010). Predicting emotional and social competence during early childhood from toddler risk and maternal behavior. *Development and Psychopathology*, *22*(1), 119–132. https://doi.org/10.1017/S0954579409990307

Boden, M. T., & Thompson, R. J. (2015). Facets of emotional awareness and associations with emotion regulation and depression. *Emotion*, *15*(3), 399–410. https://doi.org/10.1037/emo0000057

Bölte, S. (2009). Computer und Informationstechnik. In S. Bölte (Ed.), *Autismus. Spektrum, Ursachen, Diagnostik, Intervention, Perspektiven* (1st ed., pp. 400–410). Huber.

Bölte, S., Feineis-Matthews, S., Leber, S., Dierks, T., Hubl, D., & Poustka, F. (2002). The development and evaluation of a computer-based program to test and to teach the recognition of facial affect. *International Journal of Circumpolar Health*, *61*(sup 2), 61–68. https://doi.org/10.3402/ijch.v61i0.17503

Bölte, S., Golan, O., Goodwin, M. S., & Zwaigenbaum, L. (2010). What can innovative technologies do for Autism Spectrum Disorders? *Autism: The International Journal of Research and Practice*, *14*(3), 155–159. https://doi.org/10.1177/1362361310365028

Bons, D., van den Broek, E., Scheepers, F., Herpers, P., Rommelse, N., & Buitelaaar, J. K. (2013). Motor, emotional, and cognitive empathy in children and adolescents with autism spectrum disorder and conduct disorder. *Journal of Abnormal Child Psychology*, *41*(3), 425–443. https://doi.org/10.1007/s10802-012-9689-5

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry: Official Journal of the World Psychiatric Association (WPA)*, *16*(1), 5–13. https://doi.org/10.1002/wps.20375

Bos, M. G. N., Diamantopoulou, S., Stockmann, L., Begeer, S., & Rieffe, C. (2018). Emotion Control Predicts Internalizing and Externalizing Behavior Problems in Boys With and Without an Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *48*(8), 2727–2739. https://doi.org/10.1007/s10803-018-3519-8

Bottema-Beutel, K., Crowley, S., Sandbank, M., & Woynaroski, T. G. (2021). Research Review: Conflicts of Interest (COIs) in autism early intervention research - a meta-analysis of COI influences on intervention effects. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *62*(1), 5–15. https://doi.org/10.1111/jcpp.13249

Bottema-Beutel, K., Kapp, S. K., Lester, J. N., Sasson, N. J., & Hand, B. N. (2021). Avoiding Ableist Language: Suggestions for Autism Researchers. *Autism in Adulthood*, *3*(1), 18–29. https://doi.org/10.1089/aut.2020.0014

Boucher, J. (2012). Putting theory of mind in its place: Psychological explanations of the socio-emotional-communicative impairments in autistic spectrum disorder. *Autism: The International Journal of Research and Practice*, *16*(3), 226–246. https://doi.org/10.1177/1362361311430403

Bowen, D. J., Kreuter, M., Spring, B., Cofta-Woerpel, L., Linnan, L., Weiner, D., Bakken, S., Kaplan, C. P., Squiers, L., Fabrizio, C., & Fernandez, M. (2009). How we design feasibility studies. *American Journal of Preventive Medicine*, *36*(5), 452–457. https://doi.org/10.1016/j.amepre.2009.02.002

Brakemeier, E.-L., Wirkner, J., Knaevelsrud, C., Wurm, S., Christiansen, H., Lueken, U., & Schneider, S. (2020). Die COVID-19-Pandemie als Herausforderung für die psychische Gesundheit. *Zeitschrift für Klinische Psychologie und Psychotherapie*, *49*(1), 1–31. https://doi.org/10.1026/1616-3443/a000574

Briganti, G., Kempenaers, C., Braun, S., Fried, E. I., & Linkowski, P. (2018). Network analysis of empathy items from the interpersonal reactivity index in 1973 young adults. *Psychiatry Research*, *265*, 87–92. https://doi.org/10.1016/j.psychres.2018.03.082

Briganti, G., & Linkowski, P. (2020). Network Approach to Items and Domains From the Toronto Alexithymia Scale. *Psychological Reports*, *123*(5), 2038–2052. https://doi.org/10.1177/0033294119889586

Briganti, G., Scutari, M., & Linkowski, P. (2020). A machine learning approach to relationships among alexithymia components. *Psychiatria Danubina*, *32*(1), 180–187. https://hrcak.srce.hr/file/381760

Bringmann, L. F., Albers, C., Bockting, C., Borsboom, D., Ceulemans, E., Cramer, A. O. J., Epskamp, S., Eronen, M. I., Hamaker, E., Kuppens, P., Lutz, W., McNally, R. J., Molenaar, P., Tio, P., Voelkle, M. C., & Wichers, M. (2022). Psychopathological networks: Theory, methods and practice. *Behaviour Research and Therapy*, *149*, 104011. https://doi.org/10.1016/j.brat.2021.104011

Bundesärztekammer. (2020). *Ergebnisse der Ärztestatistik zum 31.12.2020*. https://www.bundesaerztekammer.de/baek/ueber-uns/aerztestatistik/aerztestatistik-2020

Bundesverband zur Förderung von Menschen mit Autismus. https://www.autismus.de/

Bury, S. M., Jellett, R., Spoor, J. R., & Hedley, D. (2020). "It Defines Who I Am" or "It's Something I Have": What Language Do Autistic Australian Adults on the Autism Spectrum Prefer? *Journal of Autism and Developmental Disorders.* Advance online publication. https://doi.org/10.1007/s10803-020-04425-3

Cai, R. Y., Richdale, A. L., Dissanayake, C., & Uljarević, M. (2018). Brief Report: Inter-Relationship between Emotion Regulation, Intolerance of Uncertainty, Anxiety, and Depression in Youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *48*(1), 316–325. https://doi.org/10.1007/s10803-017-3318-7

Capps, L., Kasari, C., Yirmiya, N., & Sigman, M. D. (1993). Parental perception of emotional expressiveness in children with autism. *Journal of Consulting and Clinical Psychology*, *61*(3), 475–484. https://doi.org/10.1037/0022-006X.61.3.475

Capps, L., Yirmiya, N., & Sigman, M. D. (1992). Understanding of simple and complex emotions in non-retarded children with autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *33*(7), 1169–1182. https://doi.org/10.1111/j.1469-7610.1992.tb00936.x

Casale, M. B., Stahmer, A., Mittal, A., Whalen, C., Quiocho, J., & Vejnoska, S. (2015). One Size Does Not Fit All: A Smarter Way to Develop Computer-Assisted Interventions for Children with ASD. *International Journal of Serious Games*, *2*(2). https://doi.org/10.17083/ijsg.v2i2.63

Cassidy, S. A., Bradley, L., Shaw, R., & Baron-Cohen, S. (2018). Risk markers for suicidality in autistic adults. *Molecular Autism*, *9*(1), 42. https://doi.org/10.1186/s13229-018-0226-4

Cassidy, S. A., Gould, K., Townsend, E., Pelton, M., Robertson, A. E., & Rodgers, J. (2020). Is Camouflaging Autistic Traits Associated with Suicidal Thoughts and Behaviours? Expanding the Interpersonal Psychological Theory of Suicide in an Undergraduate Student Sample. *Journal of Autism and Developmental Disorders*, *50*(10), 3638–3648. https://doi.org/10.1007/s10803-019-04323-3

REFERENCES

Chalfant, A. M., Rapee, R., & Carroll, L. (2007). Treating anxiety disorders in children with high functioning autism spectrum disorders: A controlled trial. *Journal of Autism and Developmental Disorders*, *37*(10), 1842–1857. https://doi.org/10.1007/s10803-006-0318-4

Channon, S., Charman, T., Heap, J., Crawford, S., & Rios, P. (2001). Real-life-type problem-solving in Asperger's syndrome. *Journal of Autism and Developmental Disorders*, *31*(5), 461–469. https://doi.org/10.1023/A:1012212824307

Chester, V., & Langdon, P. E. (2016). The clinical utility of social information processing theory in assessing and treating offenders with autism spectrum disorder. *Advances in Autism*, *2*(4), 154–171. https://doi.org/10.1108/AIA-07-2016-0019

Chung, S., Son, J.-W., Lee, S., Ghim, H.-R., Lee, S.-I., Shin, C.-J., Kim, S., Ju, G., Choi, S. C., Kim, Y. Y., & Koo, Y. J. (2016). Neural Correlates of Cognitive and Emotional Empathy in Patients with Autism Spectrum Disorder. *Journal of the Korean Academy of Child and Adolescent Psychiatry*, *27*(3), 196–206. https://doi.org/10.5765/jkacap.2016.27.3.196

Cibralic, S., Kohlhoff, J., Wallace, N., McMahon, C., & Eapen, V. (2019). A systematic review of emotion regulation in children with Autism Spectrum Disorder. *Research in Autism Spectrum Disorders*, *68*, 101422. https://doi.org/10.1016/j.rasd.2019.101422

Cole, D. A., & Maxwell, S. E. (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of Abnormal Psychology*, *112*(4), 558–577. https://doi.org/10.1037/0021-843X.112.4.558

Colizzi, M., Sironi, E., Antonini, F., Ciceri, M. L., Bovo, C., & Zoccante, L. (2020). Psychosocial and Behavioral Impact of COVID-19 in Autism Spectrum Disorder: An Online Parent Survey. *Brain Sciences*, *10*(6). https://doi.org/10.3390/brainsci10060341

Connor, D. F., Melloni, R. H., & Harrison, R. J. (1998). Overt categorical aggression in referred children and adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry*, *37*(1), 66–73. https://doi.org/10.1097/00004583-199801000-00019

Constantino, J. N., & Gruber, C. P. (2007). *Social Responsiveness Scale (SRS)*. German Version by S. Bölte, F. Poustka. Huber.

Cook, R., Bird, G., Catmur, C., Press, C., & Heyes, C. (2014). Mirror neurons: From origin to function. *The Behavioral and Brain Sciences*, *37*(2), 177–192. https://doi.org/10.1017/S0140525X13000903

Cook, R., Brewer, R., Shah, P., & Bird, G. (2013). Alexithymia, not autism, predicts poor recognition of emotional facial expressions. *Psychological Science*, *24*(5), 723–732. https://doi.org/10.1177/0956797612463582

Coughlan, B [Barry], Woolgar, M., van IJzendoorn, M. H., & Duschinsky, R. (2021). Socioemotional profiles of autism spectrum disorders, attention deficit hyperactivity disorder, and disinhibited and reactive attachment disorders: A symptom comparison and network approach. *Development and Psychopathology*, 1–10. https://doi.org/10.1017/S0954579421000882

Coury, D. (2010). Medical treatment of autism spectrum disorders. *Current Opinion in Neurology*, *23*(2), 131–136. https://doi.org/10.1097/WCO.0b013e32833722fa

Coy, K., Speltz, M. L., DeKlyen, M., & Jones, K. (2001). Social–Cognitive Processes in Preschool BoysWith and Without Oppositional Defiant Disorder. *Journal of Abnormal Child Psychology*, *29*(2), 107–119. https://doi.org/10.1023/A:1005279828676

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews. Neuroscience*, *3*(8), 655–666. https://doi.org/10.1038/nrn894

Craig, A. B., Brown, E. R., Upright, J., & DeRosier, M. E. (2016). Enhancing Children's Social Emotional Functioning Through Virtual Game-Based Delivery of Social Skills Training. *Journal of Child and Family Studies*, *25*(3), 959–968. https://doi.org/10.1007/S10826-015-0274-8

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social information-processing mechanisms in children's social adjustment. *Psychological Bulletin*, *115*(1), 74–101. https://doi.org/10.1037/0033-2909.115.1.74

Crick, N. R., & Dodge, K. A. (1996). Social Information-Processing Mechanisms in Reactive and Proactive Aggression. *Child Development*, *67*(3), 993–1002. https://doi.org/10.1111/j.1467-8624.1996.tb01778.x

Crick, N. R., & Dodge, K. A. (1999). 'Superiority' is in the Eye of the Beholder: A Comment on Sutton, Smith, and Swettenham. *Social Development (Oxford, England)*, *8*(1), 128–131. https://doi.org/10.1111/1467-9507.00084

Crick, N. R., & Grotpeter, J. K. (1995). Relational aggression, gender, and social-psychological adjustment. *Child Development*, *66*(3), 710–722. https://doi.org/10.1111/j.1467-8624.1995.tb00900.x

Dadds, M. R., Hunter, K., Hawes, D. J., Frost, A. D. J., Vassallo, S., Bunn, P., Merz, S., & Masry, Y. E. (2008). A measure of cognitive and affective empathy in children using parent ratings. *Child Psychiatry and Human Development*, *39*(2), 111–122. https://doi.org/10.1007/s10578-007-0075-4

Darling, S. J., Goods, M., Ryan, N. P., Chisholm, A. K., Haebich, K., & Payne, J. M. (2021). Behavioral Intervention for Social Challenges in Children and Adolescents: A Systematic Review and Meta-analysis. *JAMA Pediatrics*, *175*(12), e213982. https://doi.org/10.1001/jamapediatrics.2021.3982

Davidov, M., Zahn-Waxler, C., Roth-Hanania, R., & Knafo, A. (2013). Concern for Others in the First Year of Life: Theory, Evidence, and Avenues for Research. *Child Development Perspectives*, *7*(2), 126–131. https://doi.org/10.1111/cdep.12028

Davis, A. L., & Neece, C. L. (2017). An Examination of Specific Child Behavior Problems as Predictors of Parenting Stress Among Families of Children With Pervasive Developmental Disorders. *Journal of Mental Health Research in Intellectual Disabilities*, *10*(3), 163–177. https://doi.org/10.1080/19315864.2016.1276988

Davis, M. (1980). A multidimensional approach to individual differences in empathy. *JSAS Catalog of Selected Documents in Psychology*(10), 85. https://www.uv.es/friasnav/davis_1980.pdf

Davis, M. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113–126. https://doi.org/10.1037/0022-3514.44.1.113

Dawson, M., & Fletcher-Watson, S. (2022). When autism researchers disregard harms: A commentary. *Autism: The International Journal of Research and Practice*, *26*(2), 564–566. https://doi.org/10.1177/13623613211031403

Decety, J. (2010). The neurodevelopment of empathy in humans. *Developmental Neuroscience*, *32*(4), 257–267. https://doi.org/10.1159/000317771

Decety, J. (2011). The neuroevolution of empathy. *Annals of the New York Academy of Sciences*, *1231*, 35–45. https://doi.org/10.1111/j.1749-6632.2011.06027.x

Decety, J., & Lamm, C. (2006). Human empathy through the lens of social neuroscience. *TheScientificWorldJournal*, *6*, 1146–1163. https://doi.org/10.1100/tsw.2006.221

Decety, J., & Lamm, C. (2009). Empathy versus Personal Distress: Recent Evidence from Social Neuroscience. In J. Decety & W. Ickes (Eds.), *The Social Neuroscience of Empathy* (pp. 199–214). The MIT Press. https://doi.org/10.7551/mitpress/9780262012973.003.0016

Decety, J., Meidenbauer, K. L., & Cowell, J. M. (2018). The development of cognitive empathy and concern in preschool children: A behavioral neuroscience investigation. *Developmental Science*, *21*(3), e12570. https://doi.org/10.1111/desc.12570

Decety, J., & Meyer, M. (2008). From emotion resonance to empathic understanding: A social developmental neuroscience account. *Development and Psychopathology*, *20*(4), 1053–1080. https://doi.org/10.1017/S0954579408000503

Denham, S. A. (2018). Implications of Carolyn Saarni's work for preschoolers' emotional competence. *European Journal of Developmental Psychology*, *15*(6), 643–657. https://doi.org/10.1080/17405629.2018.1479250

Denham, S., Blair, K. A., DeMulder, E., Levitas, J., Sawyer, K., Auerbach-Major, S., & Queenan, P. (2003). Preschool emotional competence: Pathway to social competence? *Child Development*, *74*(1), 238–256. https://doi.org/10.1111/1467-8624.00533

REFERENCES

Di Tella, M., Adenzato, M., Catmur, C., Miti, F., Castelli, L., & Ardito, R. B. (2020). The role of alexithymia in social cognition: Evidence from a non-clinical population. *Journal of Affective Disorders*, *273*, 482–492. https://doi.org/10.1016/j.jad.2020.05.012

Döpfner, M., & Arbeitsgruppe Deutsche Child Behavior Checklist. (2003). *Elternfragebogen über das Verhalten von Kindern und Jugendlichen (CBCL/4-18).: Deutsche Bearbeitung der Child Behavior Checklist (CBCL/4-18).*

Drimalla, H., Scheffer, T., Landwehr, N., Baskow, I., Roepke, S., Behnia, B., & Dziobek, I. (2020). Towards the automatic detection of social biomarkers in autism spectrum disorder: Introducing the simulated interaction task (SIT). *NPJ Digital Medicine*, *3*, 25. https://doi.org/10.1038/s41746-020-0227-5

Drotar, D., & Lemanek, K. (2001). Steps toward a clinically relevant science of interventions in pediatric settings: Introduction to the special issue. *Journal of Pediatric Psychology*, *26*(7), 385–394. https://doi.org/10.1093/jpepsy/26.7.385

DuBois, D., Ameis, S. H., Lai, M.-C., Casanova, M. F., & Desarkar, P. (2016). Interoception in Autism Spectrum Disorder: A review. *International Journal of Developmental Neuroscience : The Official Journal of the International Society for Developmental Neuroscience*, *52*, 104–111. https://doi.org/10.1016/j.ijdevneu.2016.05.001

Dunn, L. M., & Dunn, D. M. (2015). *Peabody Picture Vocabulary Test*. Translated by A. Lenhard, W. Lenhard, R. Segerer, S. Suggate (4. Ausgabe). Pearson.

Dziobek, I., Fleck, S., Kalbe, E., Rogers, K., Hassenstab, J., Brand, M., Kessler, J., Woike, J. K., Wolf, O. T., & Convit, A. (2006). Introducing MASC: A movie for the assessment of social cognition. *Journal of Autism and Developmental Disorders*, *36*(5), 623–636. https://doi.org/10.1007/s10803-006-0107-0

Dziobek, I., Rogers, K., Fleck, S., Bahnemann, M., Heekeren, H. R., Wolf, O. T., & Convit, A. (2008). Dissociation of cognitive and emotional empathy in adults with Asperger syndrome using the Multifaceted Empathy Test (MET). *Journal of Autism and Developmental Disorders*, *38*(3), 464–473. https://doi.org/10.1007/s10803-007-0486-x

Einfeld, S. L., Beaumont, R. B., Clark, T., Clarke, K. S., Costley, D., Gray, K. M., Horstead, S. K., Redoblado Hodge, M. A., Roberts, J., Sofronoff, K., Taffe, J. R., & Howlin, P. (2018). School-based social skills training for young people with autism spectrum disorders. *Journal of Intellectual & Developmental Disability*, *43*(1), 29–39. https://doi.org/10.3109/13668250.2017.1326587

Eisenberg, N. (2000). Emotion, regulation, and moral development. *Annual Review of Psychology*, *51*, 665–697. https://doi.org/10.1146/annurev.psych.51.1.665

Eisenberg, N., Eggum, N. D., & Di Giunta, L. (2010). Empathy-related Responding: Associations with Prosocial Behavior, Aggression, and Intergroup Relations. *Social Issues and Policy Review*, *4*(1), 143–180. https://doi.org/10.1111/j.1751-2409.2010.01020.x

Eisenberg, N., & Miller, P. A. (1987). The relation of empathy to prosocial and related behaviors. *Psychological Bulletin*, *101*(1), 91–119. https://doi.org/10.1037/0033-2909.101.1.91

Eisenberg, N., & Morris, A. S. (2002). Children's Emotion-Related Regulation. In *Advances in Child Development* (pp. 189–229). https://doi.org/10.1016/s0065-2407(02)80042-8

Eisenberg, N., & Spinrad, T. L. (2004). Emotion-related regulation: Sharpening the definition. *Child Development*, *75*(2), 334–339. https://doi.org/10.1111/j.1467-8624.2004.00674.x

Ekman, P., & Friesen, W. E. (1976). *Pictures of Facial Affect*. Consulting Psychologists Press.

Elsabbagh, M., Divan, G., Koh, Y.-J., Kim, Y. S., Kauchali, S., Marcín, C., Montiel-Nava, C., Patel, V., Paula, C. S., Wang, C., Yasamy, M. T., & Fombonne, E. (2012). Global prevalence of autism and other pervasive developmental disorders. *Autism Research: Official Journal of the International Society for Autism Research*, *5*(3), 160–179. https://doi.org/10.1002/aur.239

Embregts, P., & van Nieuwenhuijzen, M. (2009). Social information processing in boys with autistic spectrum disorder and mild to borderline intellectual disabilities. *Journal of Intellectual Disability Research: JIDR*, *53*(11), 922–931. https://doi.org/10.1111/j.1365-2788.2009.01204.x

Epskamp, S. (2017). *semPlot: Path Diagrams and Visual Analysis of Various SEM Packages`Output*. R package version 1.1.

Epskamp, S. (2020). Psychometric network models from time-series and panel data. *Psychometrika*, *85*(1), 206–231. https://doi.org/10.1007/s11336-020-09697-3

Epskamp, S., & Fried, E. I. (2018). A tutorial on regularized partial correlation networks. *Psychological Methods*, *23*(4), 617–634. https://doi.org/10.1037/met0000167

Euler, F., Steinlin, C., & Stadler, C. (2017). Distinct profiles of reactive and proactive aggression in adolescents: Associations with cognitive and affective empathy. *Child and Adolescent Psychiatry and Mental Health*, *11*, 1. https://doi.org/10.1186/s13034-016-0141-4

Farmer, C. A., & Aman, M. G. (2009). Development of the Children's Scale of Hostility and Aggression: Reactive/Proactive (C-SHARP). *Research in Developmental Disabilities*, *30*, 1155-1167. https://doi.org/10.1016/j.ridd.2009.03.001

Farmer, C. A., & Aman, M. G. (2010). Psychometric properties of the Children's Scale of Hostility and Aggression: Reactive/proactive (C-SHARP). *Research in Developmental Disabilities*, *31*(1), 270–280. https://doi.org/10.1016/j.ridd.2009.09.014

Farmer, C. A., & Aman, M. G. (2011a). Aggressive behavior in a sample of children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *5*(1), 317–323. https://doi.org/10.1016/j.rasd.2010.04.014

Farmer, C. A., & Aman, M. G. (2011b). Aripiprazole for the treatment of irritability associated with autism. *Expert Opinion on Pharmacotherapy*, *12*(4), 635–640. https://doi.org/10.1517/14656566.2011.557661

Farmer, C. A., Butter, E. M., Mazurek, M. O., Cowan, C., Lainhart, J. E., Cook, E. H., DeWitt, M. B., & Aman, M. G. (2015). Aggression in children with autism spectrum disorders and a clinic-referred comparison group. *Autism: The International Journal of Research and Practice*, *19*(3), 281–291. https://doi.org/10.1177/1362361313518995

Farmer, C. A., Kaat, A. J., Mazurek, M. O., Lainhart, J. E., DeWitt, M. B., Cook, E. H., Butter, E. M., & Aman, M. G. (2016). Confirmation of the Factor Structure and Measurement Invariance of the Children's Scale of Hostility and Aggression: Reactive/proactive in Clinic-Referred Children With and Without Autism Spectrum Disorder. *Journal of Child and Adolescent Psychopharmacology*, *26*(1), 10–18. https://doi.org/10.1089/cap.2015.0098

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Feineis-Matthews, S., & Schlitt, S. (2009). Umschriebene Verhaltenstherapeutische Maßnahmen. In S. Bölte (Ed.), *Autismus. Spektrum, Ursachen, Diagnostik, Intervention, Perspektiven* (1st ed.). Huber.

Firth, I., & Dryer, R. (2013). The predictors of distress in parents of children with autism spectrum disorder. *Journal of Intellectual & Developmental Disability*, *38*(2), 163–171. https://doi.org/10.3109/13668250.2013.773964

Fite, J. E., Goodnight, J. A., Bates, J. E., Dodge, K. A., & Pettit, G. S. (2008). Adolescent aggression and social cognition in the context of personality: Impulsivity as a moderator of predictions from social information processing. *Aggressive Behavior*, *34*(5), 511–520. https://doi.org/10.1002/ab.20263

Fitzpatrick, S. E., Srivorakiat, L., Wink, L. K., Pedapati, E. V., & Erickson, C. A. (2016). Aggression in autism spectrum disorder: Presentation and treatment options. *Neuropsychiatric Disease and Treatment*, *12*, 1525–1538. https://doi.org/10.2147/NDT.S84585

Fleming, T., Beurs, D. de, Khazaal, Y., Gaggioli, A., Riva, G., Botella, C [Cristina], Baños, R. M., Aschieri, F., Bavin, L. M., Kleiboer, A., Merry, S., Lau, H. M., & Riper, H. (2016). Maximizing the Impact of e-Therapy and Serious Gaming: Time for a Paradigm Shift. *Frontiers in Psychiatry*, *7*, 65. https://doi.org/10.3389/fpsyt.2016.00065

Fleming, T., Lucassen, M., Stasiak, K., Shepherd, M., & Merry, S. (2016). The impact and utility of computerised therapy for educationally alienated teenagers: The views of adolescents who

participated in an alternative education-based trial. *Clinical Psychologist*, *20*(2), 94–102. https://doi.org/10.1111/cp.12052

Fletcher-Watson, S. (2014). A Targeted Review of Computer-Assisted Learning for People with Autism Spectrum Disorder: Towards a Consistent Methodology. *Review Journal of Autism and Developmental Disorders*, *1*(2), 87–100. https://doi.org/10.1007/s40489-013-0003-4

Fletcher-Watson, S., & Bird, G. (2020). Autism and empathy: What are the real links? *Autism: The International Journal of Research and Practice*, *24*(1), 3–6. https://doi.org/10.1177/1362361319883506

Fletcher-Watson, S., Petrou, A., Scott-Barrett, J., Dicks, P., Graham, C., O'Hare, A., Pain, H., & McConachie, H. (2016). A trial of an iPad™ intervention targeting social communication skills in children with autism. *Autism: The International Journal of Research and Practice*, *20*(7), 771–782. https://doi.org/10.1177/1362361315605624

Flood, A. M., Julian Hare, D., & Wallis, P. (2011). An investigation into social information processing in young people with Asperger syndrome. *Autism: The International Journal of Research and Practice*, *15*(5), 601–624. https://doi.org/10.1177/1362361310387803

Fogleman, N. D., Leaberry, K. D., Rosen, P. J., Walerius, D. M., & Slaughter, K. (2018). How do children with and without ADHD talk about frustration? Use of a novel emotion narrative recall task. *Attention Deficit and Hyperactivity Disorders*, *10*(4), 297–307. https://doi.org/10.1007/s12402-018-0255-z

Fontaine, R. G. (2008). On-line social decision making and antisocial behavior: Some essential but neglected issues. *Clinical Psychology Review*, *28*(1), 17–35. https://doi.org/10.1016/j.cpr.2007.09.004

Frauenberger, C., Good, J., & Alcorn, A. M. (2012). Challenges, opportunities and future perspectives in including children with disabilities in the design of interactive technology. In H. Schelhowe (Ed.), *Proceedings of the 11th International Conference on Interaction Design and Children - IDC '12* (p. 367). ACM Press. https://doi.org/10.1145/2307096.2307171

Fridenson-Hayo, S., Berggren, S., Lassalle, A., Tal, S., Pigat, D., Meir-Goren, N., O'Reilly, H., Ben-Zur, S., Bölte, S., & Baron-Cohen, S. (2017). 'emotiplay': A serious game for learning about emotions in children with autism: Results of a cross-cultural evaluation. *European Child & Adolescent Psychiatry*, *26*(8), 979–992. https://doi.org/10.1007/s00787-017-0968-0

Fried, E. I., & Cramer, A. O. J. (2017). Moving Forward: Challenges and Directions for Psychopathological Network Theory and Methodology. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *12*(6), 999–1020. https://doi.org/10.1177/1745691617705892

Frith, C. D. (2009). Role of facial expressions in social interactions. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1535), 3453–3458. https://doi.org/10.1098/rstb.2009.0142

Frith, C. D., & Singer, T. (2008). The role of social cognition in decision making. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *363*(1511), 3875–3886. https://doi.org/10.1098/rstb.2008.0156

Fryers, T., & Brugha, T. (2013). Childhood determinants of adult psychiatric disorder. *Clinical Practice and Epidemiology in Mental Health : CP & EMH*, *9*, 1–50. https://doi.org/10.2174/1745017901309010001

Gaigg, S. B. (2012). The Interplay between Emotion and Cognition in Autism Spectrum Disorder: Implications for Developmental Theory. *Frontiers in Integrative Neuroscience*, *6*, 113. https://doi.org/10.3389/fnint.2012.00113

Gastwirth, J. L., Gel, Y. R., Wallace Hui, W. L., Lyubchich, V., Miao, W., & Noguchi, K. (2017). *lawstat: Tools for Biostatistics, Public Policy, and Law*. https://CRAN.R-project.org/package=lawstat

Gev, T., Rosenan, R., & Golan, O. (2017). Unique effects of the transporters animated series and of parental support on emotion recognition skills of children with ASD: Results of a randomized controlled trial. *Autism Research: Official Journal of the International Society for Autism Research*, *10*(5), 993–1003. https://doi.org/10.1002/aur.1717

Giannotti, M., Falco, S. de, & Venuti, P. (2020). Alexithymia, Not Autism Spectrum Disorder, Predicts Perceived Attachment to Parents in School-Age Children. *Frontiers in Psychology*, *11*, 332. https://doi.org/10.3389/fpsyg.2020.00332

Giuliani, N. R., McRae, K., & Gross, J. J. (2008). The up- and down-regulation of amusement: Experiential, behavioral, and autonomic consequences. *Emotion*, *8*(5), 714–719. https://doi.org/10.1037/a0013236

Golan, O., Ashwin, E., Granader, Y., McClintock, S., Day, K., Leggett, V., & Baron-Cohen, S. (2010). Enhancing emotion recognition in children with autism spectrum conditions: An intervention using animated vehicles with real emotional faces. *Journal of Autism and Developmental Disorders*, *40*(3), 269–279. https://doi.org/10.1007/s10803-009-0862-9

Golan, O., & Baron-Cohen, S. (2006). Systemizing empathy: Teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. *Development and Psychopathology*, *18*(2), 591–617. https://doi.org/10.1017/S0954579406060305

Goldweber, A., Bradshaw, C. P., Goodman, K., Monahan, K., & Cooley-Strickland, M. (2011). Examining factors associated with (in)stability in social information processing among urban school children: A latent transition analytic approach. *Journal of Clinical Child and Adolescent Psychology*, *40*(5), 715–729. https://doi.org/10.1080/15374416.2011.597088

Gormley, E., Ryan, C., & McCusker, C. (2022). Alexithymia is Associated with Emotion Dysregulation in Young People with Autism Spectrum Disorder. *Journal of Developmental and Physical Disabilities*, *34*(1), 171–186. https://doi.org/10.1007/s10882-021-09795-9

Görtz-Dorten, A., & Döpfner, M. (2010). *Fragebogen zum aggressiven Verhalten von Kindern (FAVK) [German questionnaire for aggressive behaviour]*. Hogrefe.

Gotham, K., Brunwasser, S. M., & Lord, C. (2015). Depressive and anxiety symptom trajectories from school age through young adulthood in samples with autism spectrum disorder and developmental delay. *Journal of the American Academy of Child and Adolescent Psychiatry*, *54*(5), 369-76.e3. https://doi.org/10.1016/j.jaac.2015.02.005

Greimel, E., Schulte-Rüther, M., Kircher, T., Kamp-Becker, I., Remschmidt, H., Fink, G. R., Herpertz-Dahlmann, B., & Konrad, K. (2010). Neural mechanisms of empathy in adolescents with autism spectrum disorder and their fathers. *NeuroImage*, *49*(1), 1055–1065. https://doi.org/10.1016/j.neuroimage.2009.07.057

Griffin, C., Lombardo, M. V., & Auyeung, B. (2016). Alexithymia in children with and without autism spectrum disorders. *Autism Research: Official Journal of the International Society for Autism Research*, *9*(7), 773–780. https://doi.org/10.1002/aur.1569

Grist, R., Croker, A., Denne, M., & Stallard, P. (2019). Technology Delivered Interventions for Depression and Anxiety in Children and Adolescents: A Systematic Review and Meta-analysis. *Clinical Child and Family Psychology Review*, *22*(2), 147–171. https://doi.org/10.1007/s10567-018-0271-8

Gross, J. J. (1998). The Emerging Field of Emotion Regulation: An Integrative Review. *Review of General Psychology*, *2*(3), 271–299. https://doi.org/10.1037/1089-2680.2.3.271

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*(3), 281–291. https://doi.org/10.1017/S0048577201393198

Gross, J. J. (2015). Emotion Regulation: Current Status and Future Prospects. *Psychological Inquiry*, *26*(1), 1–26. https://doi.org/10.1080/1047840X.2014.940781

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*(2), 348–362. https://doi.org/10.1037/0022-3514.85.2.348

Grynberg, D., Luminet, O., Corneille, O., Grèzes, J., & Berthoz, S. (2010). Alexithymia in the interpersonal domain: A general deficit of empathy? *Personality and Individual Differences*, *49*(8), 845–850. https://doi.org/10.1016/j.paid.2010.07.013

Grynszpan, O., Weiss, P. L., Perez-Diaz, F., & Gal, E. (2014). Innovative technology-based interventions for autism spectrum disorders: A meta-analysis. *Autism: The International Journal of Research and Practice*, *18*(4), 346–361. https://doi.org/10.1177/1362361313476767

REFERENCES

Gutschmidt, R., Jürgensen, H., & Lucke, U. (2013). Ein Framework für die Erstellung von Simulationen zur Verhaltenstherapie. *1617-5468*. https://dl.gi.de/handle/20.500.12116/4812

Guy, A., Lee, K., & Wolke, D. (2017). Differences in the early stages of social information processing for adolescents involved in bullying. *Aggressive Behavior*, *43*(6), 578–587. https://doi.org/10.1002/ab.21716

Hadjikhani, N., Zürcher, N. R., Rogier, O., Hippolyte, L., Lemonnier, E., Ruest, T., Ward, N., Lassalle, A., Gillberg, N., Billstedt, E., Helles, A., Gillberg, C., Solomon, P., & Prkachin, K. M. (2014). Emotional contagion for pain is intact in autism spectrum disorders. *Translational Psychiatry*, *4*, e343. https://doi.org/10.1038/tp.2013.113

Hajdúk, M., Penn, D. L., Harvey, P. D., & Pinkham, A. E. (2021). Social cognition, neurocognition, symptomatology, functional competences and outcomes in people with schizophrenia - A network analysis perspective. *Journal of Psychiatric Research*, *144*, 8–13. https://doi.org/10.1016/j.jpsychires.2021.09.041

Halldorsson, B., Hill, C., Waite, P., Partridge, K., Freeman, D., & Creswell, C. (2021). Annual Research Review: Immersive virtual reality and digital applied gaming interventions for the treatment of mental health problems in children and young people: The need for rigorous treatment development and clinical evaluation. *Journal of Child Psychology and Psychiatry*, *62*(5), 584–605. https://doi.org/10.1111/jcpp.13400

Halligan, S. L., Cooper, P. J., Fearon, P., Wheeler, S. L., Crosby, M., & Murray, L. (2013). The longitudinal development of emotion regulation capacities in children at risk for externalizing disorders. *Development and Psychopathology*, *25*(2), 391–406. https://doi.org/10.1017/S0954579412001137

Happé, F. G. E., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *36*(1), 5–25. https://doi.org/10.1007/s10803-005-0039-0

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, *20*(3), 290–322. https://doi.org/10.1007/s11065-010-9138-6

Harmsen, I. E. (2019). Empathy in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *49*(10), 3939–3955. https://doi.org/10.1007/s10803-019-04087-w

Hartley, S. L., Sikora, D. M., & McCoy, R. (2008). Prevalence and risk factors of maladaptive behaviour in young children with Autistic Disorder. *Journal of Intellectual Disability Research: JIDR*, *52*(10), 819–829. https://doi.org/10.1111/j.1365-2788.2008.01065.x

Hartung, S., Wihofszky, P., & Wright, M. T. (2020). *Partizipative Forschung*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-30361-7

Hassan, A., & Pinkwart, N. (2020). Zirkus Empathico 2.0' A serious mobile game for empathy enhancement in children with Autism. *1617-5468*. https://dl.gi.de/handle/20.500.12116/34196

Healey, M. L., & Grossman, M. (2018). Cognitive and Affective Perspective-Taking: Evidence for Shared and Dissociable Anatomical Substrates. *Frontiers in Neurology*, *9*, 491. https://doi.org/10.3389/fneur.2018.00491

Helmsen, J., Koglin, U., & Petermann, F. (2012). Emotion regulation and aggressive behavior in preschoolers: The mediating role of social information processing. *Child Psychiatry and Human Development*, *43*(1), 87–101. https://doi.org/10.1007/s10578-011-0252-3

Henriques Reis, A., Silva de Oliveira, Sergio Eduardo, Ruschel Bandeira, D., Cortes Andrade, N., Abreu, N., & Mara Sperb, T. (2016). Emotion Regulation Checklist (ERC): Preliminary studies of cross-cultural adaptation and validation for use in Brazil. *Trends in Psychology / Temas Em Psicologia*, *24*(1), 97–116. DOI: 10.9788/TP2016.1-07

Herbrecht, E., & Bölte, S. (2009). Training sozialer Fertigkeiten. In S. Bölte (Ed.), *Autismus. Spektrum, Ursachen, Diagnostik, Intervention, Perspektiven* (1st ed.). Huber.

Hill, A. P., Zuckerman, K. E., Hagen, A. D., Kriz, D. J., Duvall, S. W., van Santen, J., Nigg, J., Fair, D., & Fombonne, E. (2014). Aggressive Behavior Problems in Children with Autism Spectrum Disorders: Prevalence and Correlates in a Large Clinical Sample. *Research in Autism Spectrum Disorders*, *8*(9), 1121–1133. https://doi.org/10.1016/j.rasd.2014.05.006

Hill, E. L., Berthoz, S., & Frith, U. (2004). Brief report: Cognitive processing of own emotions in individuals with autistic spectrum disorder and in their relatives. *Journal of Autism and Developmental Disorders*, *34*(2), 229–235. https://doi.org/10.1023/b:jadd.0000022613.41399.14

Hill, E. L., & Frith, U. (2003). Understanding autism: Insights from mind and brain. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *358*(1430), 281–289. https://doi.org/10.1098/rstb.2002.1209

Hirota, T., Deserno, M. K., & McElroy, E. (2020). The Network Structure of Irritability and Aggression in Individuals with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *50*(4), 1210–1220. https://doi.org/10.1007/s10803-019-04354-w

Hobson, R. P. (1986). The autistic child's appraisal of expressions of emotion. *Journal of Child Psychology and Psychiatry*, *27*(3), 321–342. https://doi.org/10.1111/j.1469-7610.1986.tb01836.x

Hodges, S. D., & Myers, M. W. (2007). Empathy. In R. F. Baumeister & K. D. Vohs (Eds.), *Encyclopedia of social psychology* (pp. 296–298). Sage Publications.

Hodgetts, S., Nicholas, D., & Zwaigenbaum, L. (2013). Home Sweet Home? Families' Experiences With Aggression in Children With Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, *28*(3), 166–174. https://doi.org/10.1177/1088357612472932

Hoffmann, W., Heinzel-Gutenbrunner, M., Becker, K., & Kamp-Becker, I. (2015). Screening von Kindern und Jugendlichen mit hochfunktionaler Autismus-Spektrum-Störung anhand ausgewählter Items des ADI-R. *Zeitschrift fur Kinder- und Jugendpsychiatrie und Psychotherapie*, *43*(3), 207-18. https://doi.org/10.1024/1422-4917/a000354

Hollis, C., Falconer, C. J., Martin, J. L., Whittington, C., Stockton, S., Glazebrook, C., & Davies, B. E. (2017). Annual Research Review: Digital health interventions for children and young people with mental health problems - a systematic and meta-review. *Journal of Child Psychology and Psychiatry*, *58*(4), 474–503. https://doi.org/10.1111/jcpp.12663

Hong, E. R., Gong, L.-Y., Ninci, J., Morin, K., Davis, J. L., Kawaminami, S., Shi, Y.-Q., & Noro, F. (2017). A meta-analysis of single-case research on the use of tablet-mediated interventions for persons with ASD. *Research in Developmental Disabilities*, *70*, 198–214. https://doi.org/10.1016/j.ridd.2017.09.013

Hopkins, I. M., Gower, M. W., Perez, T. A., Smith, D. S., Amthor, F. R., Wimsatt, F. C., & Biasini, F. J. (2011). Avatar assistant: Improving social skills in students with an ASD through a computer-based intervention. *Journal of Autism and Developmental Disorders*, *41*(11), 1543–1555. https://doi.org/10.1007/s10803-011-1179-z

Hudley, C., & Graham, S. (1993). An Attributional Intervention to Reduce Peer-directed Aggression among African-American Boys. *Child Development*, *64*(1), 124–138. https://doi.org/10.1111/j.1467-8624.1993.tb02899.x

Huesmann, L. R. (1998). The Role of Social Information Processing and Cognitive Schema in the Acquisition and Maintenance of Habitual Aggressive Behavior. In R. G. Geen & E. I. Donnerstein (Eds.), *Human aggression: Theories, research, and implications for social policy* (pp. 73–109). Academic Press. https://doi.org/10.1016/B978-012278805-5/50005-5

IBM Corp. (2017). *IBM SPSS Statistics for Windows* (Version Version 25.0) [Computer software]. IBM Corp. Armonk, NY.

Ibrahim, K., Eilbott, J. A., Ventola, P., He, G., Pelphrey, K. A., McCarthy, G., & Sukhodolsky, D. G. (2019). Reduced Amygdala-Prefrontal Functional Connectivity in Children With Autism Spectrum Disorder and Co-occurring Disruptive Behavior. *Biological Psychiatry. Cognitive Neuroscience and Neuroimaging*, *4*(12), 1031–1041. https://doi.org/10.1016/j.bpsc.2019.01.009

Imuta, K., Henry, J. D., Slaughter, V., Selcuk, B., & Ruffman, T. (2016). Theory of mind and prosocial behavior in childhood: A meta-analytic review. *Developmental Psychology*, *52*(8), 1192–1205. https://doi.org/10.1037/dev0000140

Israelashvili, J., Oosterwijk, S., Sauter, D., & Fischer, A. (2019). Knowing me, knowing you: Emotion differentiation in oneself is associated with recognition of others' emotions. *Cognition & Emotion*, *33*(7), 1461–1471. https://doi.org/10.1080/02699931.2019.1577221

REFERENCES

Israelashvili, J., Sauter, D., & Fischer, A. (2019). How Well Can We Assess Our Ability to Understand Others' Feelings? Beliefs About Taking Others' Perspectives and Actual Understanding of Others' Emotions. *Frontiers in Psychology*, *10*, 2475. https://doi.org/10.3389/fpsyg.2019.02475

Israelashvili, J., Sauter, D., & Fischer, A. (2020). Two facets of affective empathy: Concern and distress have opposite relationships to emotion recognition. *Cognition & Emotion*, *34*(6), 1112–1122. https://doi.org/10.1080/02699931.2020.1724893

Isvoranu, A.-M., Ziermans, T., Schirmbeck, F., Borsboom, D., Geurts, H. M., & Haan, L. de (2022). Autistic Symptoms and Social Functioning in Psychosis: A Network Approach. *Schizophrenia Bulletin*, *48*(1), 273–282. https://doi.org/10.1093/schbul/sbab084

Jahromi, L. B., Bryce, C. I., & Swanson, J. (2013). The importance of self-regulation for the school and peer engagement of children with high-functioning autism. *Research in Autism Spectrum Disorders*, *7*(2), 235–246. https://doi.org/10.1016/j.rasd.2012.08.012

Jahromi, L. B., Meek, S. E., & Ober-Reynolds, S. (2012). Emotion regulation in the context of frustration in children with high functioning autism and their typical peers. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *53*(12), 1250–1258. https://doi.org/10.1111/j.1469-7610.2012.02560.x

Johnson, S. A., Filliter, J. H., & Murphy, R. R. (2009). Discrepancies between self- and parent-perceptions of autistic traits and empathy in high functioning children and adolescents on the autism spectrum. *Journal of Autism and Developmental Disorders*, *39*(12), 1706–1714. https://doi.org/10.1007/s10803-009-0809-1

Jones, A. P., Happé, F. G. E., Gilbert, F., Burnett, S., & Viding, E. (2010). Feeling, caring, knowing: Different types of empathy deficit in boys with psychopathic tendencies and autism spectrum disorder. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *51*(11), 1188–1197. https://doi.org/10.1111/j.1469-7610.2010.02280.x

Jones, D. R., DeBrabander, K. M., & Sasson, N. J. (2021). Effects of autism acceptance training on explicit and implicit biases toward autism. *Autism: The International Journal of Research and Practice*, *25*(5), 1246–1261. https://doi.org/10.1177/1362361320984896

Jorgensen, T. D., Pornprasertmanit, S., Schoemann, A. M., & Rosseel, Y. (2018). *semTools: Useful tools for structural equation modeling*. https://CRAN.R-project.org/package=semTools

Juen, F., Bänninger Huber, E., & Peham, D. (2012). Geschlechts- und Altersunterschiede in der Emotionserkennung von Kindern und Jugendlichen. *Zeitschrift Für Entwicklungspsychologie Und Pädagogische Psychologie*, *44*(4), 178–191. https://doi.org/10.1026/0049-8637/a000072

Kaartinen, M., Puura, K., Helminen, M., Salmelin, R., Pelkonen, E., & Juujärvi, P. (2014). Reactive aggression among children with and without autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(10), 2383–2391. https://doi.org/10.1007/s10803-012-1743-1

Kanne, S. M., & Mazurek, M. O. (2011). Aggression in children and adolescents with ASD: Prevalence and risk factors. *Journal of Autism and Developmental Disorders*, *41*(7), 926–937. https://doi.org/10.1007/s10803-010-1118-4

Kasari, C., & Patterson, S. Y. (2012). Interventions addressing social impairment in autism. *Current Psychiatry Reports*, *14*(6), 713–725. https://doi.org/10.1007/s11920-012-0317-4

Kazdin, A. E. (2003). Psychotherapy for children and adolescents. *Annual Review of Psychology*, *54*(1), 253–276. https://doi.org/10.1146/annurev.psych.54.101601.145105

Ke, F., & Moon, J. (2018). Virtual collaborative gaming as social skills training for high-functioning autistic children. *British Journal of Educational Technology*, *49*(4), 728–741. https://doi.org/10.1111/bjet.12626

Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism: The International Journal of Research and Practice*, *20*(4), 442–462. https://doi.org/10.1177/1362361315588200

Keysers, C., & Gazzola, V. (2009). Expanding the mirror: Vicarious activity for actions, emotions, and sensations. *Current Opinion in Neurobiology*, *19*(6), 666–671. https://doi.org/10.1016/j.conb.2009.10.006

Kirst, S., Diehm, R., Bögl, K., Wilde-Etzold, S., Bach, C., Noterdaeme, M., Poustka, L., Ziegler, M., & Dziobek, I. (2020). Fostering Socio-Emotional Competencies in Children with Autism using a Parent-Assisted Serious Game: A Multicenter Randomized Controlled Trial (Preprint). Advance online publication. https://doi.org/10.31219/osf.io/pgc7m

Kirst, S., Maldonado, N., Esser, G., & Dziobek, I. (2014). Facial and contextual emotion recognition in children with autism spectrum disorder: Implications for the development of a new intervention tool. In Wissenschaftliche Gesellschaft Autismus-Spektrum (Chair), *Wissenschaftliche Tagung Autismus-Spektrum,* Frankfurt/Main.

Kliemann, D., Rosenblau, G., Bölte, S., Heekeren, H. R., & Dziobek, I. (2013). Face puzzle-two new video-based tasks for measuring explicit and implicit aspects of facial emotion recognition. *Frontiers in Psychology*, *4*, 376. https://doi.org/10.3389/fpsyg.2013.00376

Kliemann, D., Rosenblau, G., Heekeren, H. R., & Dziobek, I. (2011). Introducing "Face Puzzle" and "Who Speaks": Two New Naturalistic Tasks for Measuring Explicit and Implicit Emotion Recognition Performances from Faces and Voices. In Wissenschaftliche Gesellschaft Autismus-Spektrum (Chair), *Proc. 4 Wissenschaftliche Tagung Autismus-Spektrum,* Berlin.

Klimecki, O. M., & Singer, T. (2013). Empathy from the Perspective of Social Neuroscience. In *The Cambridge Handbook of Human Affective Neuroscience* (1st ed., pp. 533–550). Cambridge University Press. https://doi.org/10.1017/cbo9780511843716.029

Klinger, L. G., Cook, M. L., & Dudley, K. M. (2021). Predictors and Moderators of Treatment Efficacy in Children and Adolescents with Autism Spectrum Disorder. *Journal of Clinical Child and Adolescent Psychology*, *50*(4), 517–524. https://doi.org/10.1080/15374416.2020.1833735

Konstantareas, M. M., & Stewart, K. (2006). Affect regulation and temperament in children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *36*(2), 143–154. https://doi.org/10.1007/s10803-005-0051-4

Kopp, C. B. (1989). Regulation of distress and negative emotions: A developmental view. *Developmental Psychology*, *25*(3), 343–354. https://doi.org/10.1037/0012-1649.25.3.343

Köppen, M., Lucke, U., Neugebauer, S., & Warschburger, P. (2013). Eine App zum Ecological Momentary Assessment für die posttherapeutische Begleitung von Adipositas-Patienten. In *DeLFI,* Berlin.

Kouo, J. L., & Egel, A. L. (2016). The Effectiveness of Interventions in Teaching Emotion Recognition to Children with Autism Spectrum Disorder. *Review Journal of Autism and Developmental Disorders*, *3*(3), 254–265. https://doi.org/10.1007/s40489-016-0081-1

Krasny, L., Williams, B. J., Provencal, S., & Ozonoff, S. (2003). Social skills interventions for the autism spectrum: Essential ingredients and a model curriculum. *Child and Adolescent Psychiatric Clinics of North America*, *12*(1), 107–122. https://doi.org/10.1016/S1056-4993(02)00051-2

Kuravackel, G. M., Ruble, L. A., Reese, R. J., Ables, A. P., Rodgers, A. D., & Toland, M. D. (2018). Compass for Hope: Evaluating the Effectiveness of a Parent Training and Support Program for Children with ASD. *Journal of Autism and Developmental Disorders*, *48*(2), 404–416. https://doi.org/10.1007/s10803-017-3333-8

LaCava, P. G., Golan, O., Baron-Cohen, S., & Smith Myles, B. (2007). Using Assistive Technology to Teach Emotion Recognition to Students With Asperger Syndrome. *Remedial and Special Education*, *28*(3), 174–181. https://doi.org/10.1177/07419325070280030601

LaCava, P. G., Rankin, A., Mahlios, E., Cook, K., & Simpson, R. L. (2010). A single case design evaluation of a software and tutor intervention addressing emotion recognition and social interaction in four boys with ASD. *Autism: The International Journal of Research and Practice*, *14*(3), 161–178. https://doi.org/10.1177/1362361310362085

Lamm, C., Decety, J., & Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. *NeuroImage*, *54*(3), 2492–2502. https://doi.org/10.1016/j.neuroimage.2010.10.014

Lane, R. D. (2000). *Levels of emotional awareness: Neurological, psychological, and social perspectives*. https://psycnet.apa.org/record/2001-00355-008

REFERENCES

Lane, R. D., & Schwartz, G. E. (1987). Levels of emotional awareness: A cognitive-developmental theory and its application to psychopathology. *The American Journal of Psychiatry*, *144*(2), 133–143. https://doi.org/10.1176/ajp.144.2.133

Larkin, P., Jahoda, A., & MacMahon, K. (2013). The Social Information Processing model as a framework for explaining frequent aggression in adults with mild to moderate intellectual disabilities: A systematic review of the evidence. *Journal of Applied Research in Intellectual Disabilities : JARID*, *26*(5), 447–465. https://doi.org/10.1111/jar.12031

Laugeson, E. A., Frankel, F., Gantman, A., Dillon, A. R., & Mogil, C. (2012). Evidence-based social skills training for adolescents with autism spectrum disorders: The UCLA PEERS program. *Journal of Autism and Developmental Disorders*, *42*(6), 1025–1036. https://doi.org/10.1007/s10803-011-1339-1

Laurent, A., & Rubin, E. (2004). Challenges in Emotional Regulation in Asperger Syndrome and High-Functioning Autism. *Topics in Language Disorders*, *24*(4), 286–297. https://doi.org/10.1097/00011363-200410000-00006

Leiner, D. J. (2014). *SoSci Survey (Version 2.5 00-i)* [Computer software]. https://www.soscisurvey.de

Lemerise, E. A., & Arsenio, W. F. (2000). An Integrated Model of Emotion Processes and Cognition in Social Information Processing. *Child Development*, *71*(1), 107–118. https://doi.org/10.1111/1467-8624.00124

Leopoldina. (2021). *Kinder und Jugendliche in der Coronavirus-Pandemie: psychosoziale und edukative Herausforderungen und Chancen.* Leopoldina, Nationale Akademie der Wissenschaften. https://www.leopoldina.org/uploads/tx_leopublication/2021_Corona_Kinder_und_Jugendliche.pdf

Limesurvey GmbH. *LimeSurvey: An Open Source survey tool* [Computer software]. LimeSurvey GmbH. Hamburg, Germany. http://www.limesurvey.org

Lochman, J. E., & Wells, K. C. (2002). Contextual social-cognitive mediators and child outcome: A test of the theoretical model in the Coping Power program. *Development and Psychopathology*, *14*(4), 945–967. https://doi.org/10.1017/S0954579402004157

Lockwood, P. L., Bird, G., Bridge, M., & Viding, E. (2013). Dissecting empathy: High levels of psychopathic and autistic traits are characterized by difficulties in different social information processing domains. *Frontiers in Human Neuroscience*, *7*, 760. https://doi.org/10.3389/fnhum.2013.00760

Lombardo, M. V., Barnes, J. L., Wheelwright, S. J., & Baron-Cohen, S. (2007). Self-referential cognition and empathy in autism. *PloS One*, *2*(9), e883. https://doi.org/10.1371/journal.pone.0000883

Loomes, R., Hull, L., & Mandy, W. (2017). What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. *Journal of the American Academy of Child and Adolescent Psychiatry*, *56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

Lord, C., & Risi, S. (1998). Frameworks and methods in diagnosing autism spectrum disorders. *Mental Retardation and Developmental Disabilities Research Reviews*, *4*(2), 90–96. https://doi.org/10.1002/(SICI)1098-2779(1998)4:2<90::AID-MRDD5>3.0.CO;2-0

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., Pickles, A., & Rutter, M. (2000). The autism diagnostic observation schedule-generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, *30*(3), 205–223.

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, L. S. (2015). *Autism Diagnostic Observation Schedule - 2*. German Version by L. Poustka, D. Rühl, S. Feineis-Matthews, F. Poustka, M. Hartung, S. Bölte. Huber.

Lozier, L. M., Vanmeter, J. W., & Marsh, A. A. (2014). Impairments in facial affect recognition associated with autism spectrum disorders: A meta-analysis. *Development and Psychopathology*, *26*(4 Pt 1), 933–945. https://doi.org/10.1017/S0954579414000479

Lucke, U., & Castro, T. (2016). The Process of Inclusive Design. In *2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT)* (pp. 446–447). IEEE. https://doi.org/10.1109/ICALT.2016.132

Madole, J. W., Rhemtulla, M., Grotzinger, A. D., Tucker-Drob, E. M., & Harden, P. K. (2019). Testing Cold and Hot Cognitive Control as Moderators of a Network of Comorbid Psychopathology Symptoms in Adolescence. *Clinical Psychological Science : A Journal of the Association for Psychological Science*, *7*(4), 701–718. https://doi.org/10.1177/2167702619842466

Maenner, M. J., Rice, C. E., Arneson, C. L., Cunniff, C., Schieve, L. A., Carpenter, L. A., van Naarden Braun, K., Kirby, R. S., Bakian, A. V., & Durkin, M. S. (2014). Potential impact of DSM-5 criteria on autism spectrum disorder prevalence estimates. *JAMA Psychiatry*, *71*(3), 292–300. https://doi.org/10.1001/jamapsychiatry.2013.3893

Maïano, C., Normand, C. L., Salvas, M.-C., Moullec, G., & Aimé, A. (2016). Prevalence of School Bullying Among Youth with Autism Spectrum Disorders: A Systematic Review and Meta-Analysis. *Autism Research: Official Journal of the International Society for Autism Research*, *9*(6), 601–615. https://doi.org/10.1002/aur.1568

Martinelli, A., Ackermann, K., Bernhard, A., Freitag, C. M., & Schwenck, C. (2018). Hostile attribution bias and aggression in children and adolescents: A systematic literature review on the influence of aggression subtype and gender. *Aggression and Violent Behavior*, *39*, 25–32. https://doi.org/10.1016/j.avb.2018.01.005

Matson, J. L., Kozlowski, A. M., Worley, J. A., Shoemaker, M. E., Sipes, M., & Horovitz, M. (2011). What is the evidence for environmental causes of challenging behaviors in persons with intellectual disabilities and autism spectrum disorders? *Research in Developmental Disabilities*, *32*(2), 693–698. https://doi.org/10.1016/j.ridd.2010.11.012

Maxwell, S. E., & Cole, D. A. (2007). Bias in cross-sectional analyses of longitudinal mediation. *Psychological Methods*, *12*(1), 23–44. https://doi.org/10.1037/1082-989X.12.1.23

Mayberry, M. L., & Espelage, D. L. (2007). Associations Among Empathy, Social Competence, & Reactive/Proactive Aggression Subtypes. *Journal of Youth and Adolescence*, *36*(6), 787–798. https://doi.org/10.1007/s10964-006-9113-y

Mayeux, L., & Cillessen, A. H. N. (2003). Development of social problem solving in early childhood: Stability, change, and associations with social competence. *The Journal of Genetic Psychology*, *164*(2), 153–173. https://doi.org/10.1080/00221320309597975

Mazefksy, C. A., Herrington, J., Siegel, M., Scarpa, A., Maddox, B. B., Scahill, L., & White, S. W. (2013). The role of emotion regulation in autism spectrum disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(7), 679–688. https://doi.org/10.1016/j.jaac.2013.05.006

Mazefksy, C. A., Pelphrey, K. A., & Dahl, R. E. (2012). The Need for a Broader Approach to Emotion Regulation Research in Autism. *Child Development Perspectives*, *6*(1), 92–97. https://doi.org/10.1111/j.1750-8606.2011.00229.x

Mazefksy, C. A., & White, S. W. (2014). Emotion regulation: Concepts & practice in autism spectrum disorder. *Child and Adolescent Psychiatric Clinics of North America*, *23*(1), 15–24. https://doi.org/10.1016/j.chc.2013.07.002

Mazon, C., Fage, C., & Sauzéon, H. (2019). Effectiveness and usability of technology-based interventions for children and adolescents with ASD: A systematic review of reliability, consistency, generalization and durability related to the effects of intervention. *Computers in Human Behavior*, *93*, 235–251. https://doi.org/10.1016/j.chb.2018.12.001

Mazurek, M. O., Kanne, S. M., & Wodka, E. L. (2013). Physical aggression in children and adolescents with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *7*(3), 455–465. https://doi.org/10.1016/j.rasd.2012.11.004

Mazza, M., Mariano, M., Peretti, S., Masedu, F., Pino, M. C., & Valenti, M. (2017). The Role of Theory of Mind on Social Information Processing in Children With Autism Spectrum Disorders: A Mediation Analysis. *Journal of Autism and Developmental Disorders*, *47*(5), 1369–1379. https://doi.org/10.1007/s10803-017-3069-5

McConachie, H., & Diggle, T. (2007). Parent implemented early intervention for young children with autism spectrum disorder: A systematic review. *Journal of Evaluation in Clinical Practice*, *13*(1), 120–129. https://doi.org/10.1111/j.1365-2753.2006.00674.x

REFERENCES

McHugh, L., Bobarnac, A., & Reed, P. (2011). Brief report: Teaching situation-based emotions to children with autistic spectrum disorder. *Journal of Autism and Developmental Disorders*, *41*(10), 1423–1428. https://doi.org/10.1007/s10803-010-1152-2

McRae, K., Misra, S., Prasad, A. K., Pereira, S. C., & Gross, J. J. (2012). Bottom-up and top-down emotion generation: Implications for emotion regulation. *Social Cognitive and Affective Neuroscience*, *7*(3), 253–262. https://doi.org/10.1093/scan/nsq103

Meade, A. W., Johnson, E. C., & Braddy, P. W. (2008). Power and sensitivity of alternative fit indices in tests of measurement invariance. *The Journal of Applied Psychology*, *93*(3). https://doi.org/10.1037/0021-9010.93.3.568

Merkle, E. C., You, D., & Preacher, K. J. (2016). Testing nonnested structural equation models. *Psychological Methods*, *21*(2), 151–163. https://doi.org/10.1037/met0000038

Meyer, J. A., Mundy, P. C., van Hecke, A. V., & Durocher, J. S. (2006). Social attribution processes and comorbid psychiatric symptoms in children with Asperger syndrome. *Autism: The International Journal of Research and Practice*, *10*(4), 383–402. https://doi.org/10.1177/1362361306064435

Miclea, M., Ciuca, A., & Miclea, S. (2009). How to produce e-content for e-mental health solutions. Basic guidelines. *Cognition, Brain, Behavior. An Interdisciplinary Journal*, *XIII*(1), 1–9.

Mills, A. S., Tablon-Modica, P., Mazefksy, C. A., & Weiss, J. A. (2022). Emotion dysregulation in children with autism: A multimethod investigation of the role of child and parent factors. *Research in Autism Spectrum Disorders*, *91*, 101911. https://doi.org/10.1016/j.rasd.2021.101911

Milosavljevic, B., Carter Leno, V., Simonoff, E., Baird, G., Pickles, A., Jones, C. R. G., Erskine, C., Charman, T., & Happé, F. G. E. (2016). Alexithymia in Adolescents with Autism Spectrum Disorder: Its Relationship to Internalising Difficulties, Sensory Modulation and Social Cognition. *Journal of Autism and Developmental Disorders*, *46*(4), 1354–1367. https://doi.org/10.1007/s10803-015-2670-8

Milton, D. E. (2012). On the ontological status of autism: the 'double empathy problem'. *Disability & Society*, *27*(6), 883–887. https://doi.org/10.1080/09687599.2012.710008

Minio-Paluello, I., Baron-Cohen, S., Avenanti, A., Walsh, V., & Aglioti, S. M. (2009). Absence of embodied empathy during pain observation in Asperger syndrome. *Biological Psychiatry*, *65*(1), 55–62. https://doi.org/10.1016/j.biopsych.2008.08.006

Mitchell, P. (2017). Mindreading as a transactional process: insights from autism. In V. Slaughter & M. de Rosnay (Eds.), *Theory of mind development in context* (p. 16). Routledge, Taylor & Francis Group.

Mitchell, P., Sheppard, E., & Cassidy, S. A. (2021). Autism and the double empathy problem: Implications for development and mental health. *The British Journal of Developmental Psychology*, *39*(1), 1–18. https://doi.org/10.1111/bjdp.12350

Moebert, T., Schneider, J. N., Zoerner, D., Tscherejkina, A., & Lucke, U. (2019). 4. How to use socio-emotional signals for adaptive training. In *Personalized Human-Computer Interaction* (pp. 103–132). De Gruyter. https://doi.org/10.1515/9783110552485-004

Montreuil, M., Bogossian, A., Laberge-Perrault, E., & Racine, E. (2021). A Review of Approaches, Strategies and Ethical Considerations in Participatory Research With Children. *International Journal of Qualitative Methods*, *20*, 160940692098796. https://doi.org/10.1177/1609406920987962

Moore, A. A., Carney, D., Moroney, E., Machlin, L., Towbin, K. E., Brotman, M. A., Pine, D. S., Leibenluft, E., Roberson-Nay, R., & Hettema, J. M. (2017). The Inventory of Callous-Unemotional Traits (ICU) in Children: Reliability and Heritability. *Behavior Genetics*, *47*(2), 141–151. https://doi.org/10.1007/s10519-016-9831-1

Moore, D., Cheng, Y., McGrath, P., & Powell, N. J. (2005). Collaborative Virtual Environment Technology for People with Autism. *Focus on Autism and Other Developmental Disabilities*, *20*(4), 231–243. https://doi.org/10.1177/10883576050200040501

Moriguchi, Y., Decety, J., Ohnishi, T., Maeda, M., Mori, T., Nemoto, K., Matsuda, H., & Komaki, G. (2007). Empathy and judging other's pain: An fMRI study of alexithymia. *Cerebral Cortex (New York, N.Y. : 1991)*, *17*(9), 2223–2234. https://doi.org/10.1093/cercor/bhl130

Moriguchi, Y., Ohnishi, T., Lane, R. D., Maeda, M., Mori, T., Nemoto, K., Matsuda, H., & Komaki, G. (2006). Impaired self-awareness and theory of mind: An fMRI study of mentalizing in alexithymia. *NeuroImage*, *32*(3), 1472–1482. https://doi.org/10.1016/j.neuroimage.2006.04.186

Morris, A. S., Silk, J. S., Morris, M. D. S., Steinberg, L., Aucoin, K. J., & Keyes, A. W. (2011). The influence of mother-child emotion regulation strategies on children's expression of anger and sadness. *Developmental Psychology*, *47*(1), 213–225. https://doi.org/10.1037/a0021021

Morrison, K. E., DeBrabander, K. M., Jones, D. R., Faso, D. J., Ackerman, R. A., & Sasson, N. J. (2020). Outcomes of real-world social interaction for autistic adults paired with autistic compared to typically developing partners. *Autism: The International Journal of Research and Practice*, *24*(5), 1067–1080. https://doi.org/10.1177/1362361319892701

Mul, C.-L., Stagg, S. D., Herbelin, B., & Aspell, J. E. (2018). The Feeling of Me Feeling for You: Interoception, Alexithymia and Empathy in Autism. *Journal of Autism and Developmental Disorders*, *48*(9), 2953–2967. https://doi.org/10.1007/s10803-018-3564-3

Müller, N., Baumeister, S., Dziobek, I., Banaschewski, T., & Poustka, L. (2016). Validation of the Movie for the Assessment of Social Cognition in Adolescents with ASD: Fixation Duration and Pupil Dilation as Predictors of Performance. *Journal of Autism and Developmental Disorders*, *46*(9), 2831–2844. https://doi.org/10.1007/s10803-016-2828-z

Mummah, S. A., Robinson, T. N., King, A. C., Gardner, C. D., & Sutton, S. (2016). Ideas (Integrate, Design, Assess, and Share): A Framework and Toolkit of Strategies for the Development of More Effective Digital Interventions to Change Health Behavior. *Journal of Medical Internet Research*, *18*(12), e317. https://doi.org/10.2196/jmir.5927

Muralidharan, A., Yoo, D., Ritschel, L. A., Simeonova, D. I., & Craighead, W. E. (2010). Development of emotion regulation in children of bipolar parents: Putative contributions of socioemotional and familial risk factors. *Clinical Psychology: Science and Practice*, *17*(3), 169–186. https://doi.org/10.1111/j.1468-2850.2010.01209.x

Murphy, B. A. (2019). The Griffith Empathy Measure Does Not Validly Distinguish between Cognitive and Affective Empathy in Children. *Australian Psychologist*, *54*(3), 159–164. https://doi.org/10.1111/ap.12336

Musher-Eizenman, D. R., Boxer, P., Danner, S., Dubow, E. F., Goldstein, S. E., & Heretick, D. M. (2004). Social-cognitive mediators of the relation of environmental and emotion regulation factors to children's aggression. *Aggressive Behavior*, *30*(5), 389–408. https://doi.org/10.1002/ab.20078

Naumann, S., Bayer, M., Kirst, S., van der Meer, E., & Dziobek, I. (2021). *Effectiveness of the digital socio-emotional competence training Zirkus Empathico in preschoolers: A randomized controlled trial.* https://doi.org/10.31234/osf.io/dkxp9

Nelson, D. A., & Crick, N. R. (1999). Rose-Colored Glasses. *The Journal of Early Adolescence*, *19*(1), 17–38. https://doi.org/10.1177/0272431699019001002

Nemiah, J. C., & Sifneos, P. E. (1970). Alexithymia: a view of the psychosomatic process. *Modern Trends in Psychosomatic Medicine*, *3*, 430–439.

Netzwerk Leichte Sprache. (2013). *Regeln fuer Leichte Sprache.* Lebenshilfe Bremen. https://www.leichte-sprache.org/

Oakley, B. F. M., Jones, E. J. H., Crawley, D., Charman, T., Buitelaaar, J. K., Tillmann, J., Murphy, D. G., & Loth, E. (2022). Alexithymia in autism: Cross-sectional and longitudinal associations with social-communication difficulties, anxiety and depression symptoms. *Psychological Medicine*, *52*(8), 1458–1470. https://doi.org/10.1017/S0033291720003244

Olesen, J., Gustavsson, A., Svensson, M., Wittchen, H.-U., & Jönsson, B. (2012). The economic cost of brain disorders in Europe. *European Journal of Neurology*, *19*(1), 155–162. https://doi.org/10.1111/j.1468-1331.2011.03590.x

Ong, J. G., Lim-Ashworth, N. S., Ooi, Y. P., Boon, J. S., Ang, R. P., Goh, D. H., Ong, S. H., & Fung, D. S. (2019). An Interactive Mobile App Game to Address Aggression (RegnaTales): Pilot Quantitative Study. *JMIR Serious Games*, *7*(2), e13242. https://doi.org/10.2196/13242

REFERENCES

Ōno, T. (1988). *Toyota production system: Beyond large-scale production*. Productivity Press. https://www.taylorfrancis.com/books/mono/10.4324/9780429273018/toyota-production-system-taiichi-ohno-norman-bodek https://doi.org/10.4324/9780429273018

Orsmond, G. I., Krauss, M. W., & Seltzer, M. M. (2004). Peer relationships and social and recreational activities among adolescents and adults with autism. *Journal of Autism and Developmental Disorders*, *34*(3), 245–256. https://doi.org/10.1023/B:JADD.0000029547.96610.df

Osborne-Crowley, K. (2020). Social Cognition in the Real World: Reconnecting the Study of Social Cognition With Social Reality. *Review of General Psychology*, *24*(2), 144–158. https://doi.org/10.1177/1089268020906483

Otero-López, José M., Castro, C., Cristina, Villardefrancos, Estíbaliz, Santiago, & María J. (2009). Job dissatisfaction and burnout in secondary school teachers: student's disruptive behaviour and conflict management examined. *European Journal of Education and Psychology*, *2*(2), 99–111.

Pacella, D., & López-Pérez, B. (2018). Assessing children's interpersonal emotion regulation with virtual agents: The serious game Emodiscovery. *Computers & Education*, *123*, 1–12. https://doi.org/10.1016/j.compedu.2018.04.005

Park, H. R., Lee, J. M., Moon, H. E., Lee, D. S., Kim, B.-N., Kim, J., Kim, D. G., & Paek, S. H. (2016). A Short Review on the Current Understanding of Autism Spectrum Disorders. *Experimental Neurobiology*, *25*(1), 1–13. https://doi.org/10.5607/en.2016.25.1.1

Parsons, D., Cordier, R., Vaz, S., & Lee, H. C. (2017). Parent-Mediated Intervention Training Delivered Remotely for Children With Autism Spectrum Disorder Living Outside of Urban Areas: Systematic Review. *Journal of Medical Internet Research*, *19*(8), e198. https://doi.org/10.2196/jmir.6651

Petermann, F., & Koglin, U. (2015). *Aggressive Kinder und Jugendliche: Prävention und Therapie -- ein Überblick*. *Essentials*. Springer.

Pickard, H., Happé, F. G. E., & Mandy, W. (2018). Navigating the social world: The role of social competence, peer victimisation and friendship quality in the development of social anxiety in childhood. *Journal of Anxiety Disorders*, *60*, 1–10. https://doi.org/10.1016/j.janxdis.2018.09.002

Politte, L. C., Fitzpatrick, S. E., & Erickson, C. A. (2019). Aggression in autism spectrum disorder and other neurodevelopmental disorders. In E. F. Coccaro (Ed.), *Aggression: Clinical Features and Treatment Across the Diagnostic Spectrum* (pp. 53–80). American Psychiatric Association Publishing.

Porayska-Pomsta, K., Frauenberger, C., Pain, H., Rajendran, G., Smith, T., Menzies, R., Foster, M. E., Alcorn, A. M., Wass, S., Bernadini, S., Avramides, K., Keay-Bright, W., Chen, J., Waller, A., Guldberg, K., Good, J., & Lemon, O. (2012). Developing technology for autism: an interdisciplinary approach. *Personal and Ubiquitous Computing*, *16*(2), 117–127. https://doi.org/10.1007/s00779-011-0384-2

Poustka, L., Rehm, A., Holtmann, M., Bock, M., Böhmert, C., & Dziobek, I. (2010). Dissoziation von kognitiver und affektiver Empathie bei Jugendlichen mit Autismus-Spektrum-Störungen. *Kindheit Und Entwicklung*, *19*(3), 177–183. https://doi.org/10.1026/0942-5403/a000022

Pouw, L. B. C., Rieffe, C., Oosterveld, P., Huskens, B., & Stockmann, L. (2013). Reactive/proactive aggression and affective/cognitive empathy in children with ASD. *Research in Developmental Disabilities*, *34*(4), 1256–1266. https://doi.org/10.1016/j.ridd.2012.12.022

Proctor, E., Silmere, H., Raghavan, R., Hovmand, P., Aarons, G., Bunger, A., Griffey, R., & Hensley, M. (2011). Outcomes for implementation research: Conceptual distinctions, measurement challenges, and research agenda. *Administration and Policy in Mental Health*, *38*(2), 65–76. https://doi.org/10.1007/s10488-010-0319-7

Quan, F., Yang, R., Zhu, W., Wang, Y [Yueyue], Gong, X., Chen, Y [Yunli], Dong, Y., & Xia, L.-X. (2019). The relationship between hostile attribution bias and aggression and the mediating effect of anger rumination. *Personality and Individual Differences*, *139*, 228–234. https://doi.org/10.1016/j.paid.2018.11.029

R Core Team. (2018a). *foreign: Read Data Stored by 'Minitab', 'S', 'SAS', 'SPSS', 'Stata',*. https://CRAN.R-project.org/package=foreign

R Core Team. (2018b). *foreign: Read Data Stored by 'Minitab', 'S', 'SAS', 'SPSS', 'Stata',*. https://CRAN.R-project.org/package=foreign

Raven, J. C. (2002). *Coloured Progressive Matrices (CPM)*. German translation and norms. Pearson Assessment.

Ravens-Sieberer, U., & Bullinger, M. (1998). Assessing health-related quality of life in chronically ill children with the German KINDL: First psychometric and content analytical results. *Quality of Life Research*, *7*(5), 399–407. https://doi.org/10.1023/A:1008853819715

Ravens-Sieberer, U., Kaman, A., Erhart, M., Devine, J., Schlack, R., & Otto, C. (2022). Impact of the COVID-19 pandemic on quality of life and mental health in children and adolescents in Germany. *European Child & Adolescent Psychiatry*, *31*(6), 879–889. https://doi.org/10.1007/s00787-021-01726-5

Ravens-Sieberer, U., Kaman, A., Erhart, M., Otto, C., Devine, J., Löffler, C., Hurrelmann, K., Bullinger, M., Barkmann, C., Siegel, N. A., Simon, A. M., Wieler, L. H., Schlack, R., & Hölling, H. (2021). Quality of life and mental health in children and adolescents during the first year of the COVID-19 pandemic: Results of a two-wave nationwide population-based study. *European Child & Adolescent Psychiatry*, 1–14. https://doi.org/10.1007/s00787-021-01889-1

Ravens-Sieberer, U., Kaman, A., Otto, C., Adedeji, A., Napp, A.-K., Becker, M., Blanck-Stellmacher, U., Löffler, C., Schlack, R., Hölling, H., Devine, J., Erhart, M., & Hurrelmann, K. (2021). Seelische Gesundheit und psychische Belastungen von Kindern und Jugendlichen in der ersten Welle der COVID-19-Pandemie – Ergebnisse der COPSY-Studie [Mental health and psychological burden of children and adolescents during the first wave of the COVID-19 pandemic-results of the COPSY study]. *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz*, *64*(12), 1512–1521. https://doi.org/10.1007/s00103-021-03291-3

Reniers, R. L. E. P., Corcoran, R., Drake, R., Shryane, N. M., & Völlm, B. A. (2011). The QCAE: A Questionnaire of Cognitive and Affective Empathy. *Journal of Personality Assessment*, *93*(1), 84–95. https://doi.org/10.1080/00223891.2010.528484

Revelle, W. (2018). *psych: Procedures for Psychological, Psychometric, and Personality Research*. https://CRAN.R-project.org/package=psych

Reyes, N. M., Pickard, K., & Reaven, J. (2019). Emotion regulation: A treatment target for autism spectrum disorder. *Bulletin of the Menninger Clinic*, *83*(3), 205–234. https://doi.org/10.1521/bumc.2019.83.3.205

Rice, L. M., Wall, C. A., Fogel, A., & Shic, F. (2015). Computer-Assisted Face Processing Instruction Improves Emotion Recognition, Mentalizing, and Social Skills in Students with ASD. *Journal of Autism and Developmental Disorders*, *45*(7), 2176–2186. https://doi.org/10.1007/s10803-015-2380-2

Rieber, L. P. (2012). Multimedia Learning in Games, Simulations, and Microworlds. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 549–568). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.034

Rive, M. M., van Rooijen, G., Veltman, D. J., Phillips, M. L., Schene, A. H., & Ruhé, H. G. (2013). Neural correlates of dysfunctional emotion regulation in major depressive disorder. A systematic review of neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *37*(10 Pt 2), 2529–2553. https://doi.org/10.1016/j.neubiorev.2013.07.018

Robb, A. S. (2010). Managing irritability and aggression in autism spectrum disorders in children and adolescents. *Developmental Disabilities Research Reviews*, *16*(3), 258–264. https://doi.org/10.1002/ddrr.118

Rodebaugh, T. L., Tonge, N. A., Piccirillo, M. L., Fried, E. I., Horenstein, A., Morrison, A. S., Goldin, P., Gross, J. J., Lim, M. H., Fernandez, K. C., Blanco, C., Schneier, F. R., Bogdan, R., Thompson, R. J., & Heimberg, R. G. (2018). Does centrality in a cross-sectional network suggest intervention targets for social anxiety disorder? *Journal of Consulting and Clinical Psychology*, *86*(10), 831–844. https://doi.org/10.1037/ccp0000336

Rogers, K., Dziobek, I., Hassenstab, J., Wolf, O. T., & Convit, A. (2007). Who cares? Revisiting empathy in Asperger syndrome. *Journal of Autism and Developmental Disorders*, *37*(4), 709–715. https://doi.org/10.1007/s10803-006-0197-8

REFERENCES

Röll, J., Koglin, U., & Petermann, F. (2012). Emotion Regulation and Childhood Aggression: Longitudinal Associations. *Child Psychiatry & Human Development*, *43*(6), 909–923. https://doi.org/10.1007/s10578-012-0303-4

Rosenblau, G., O'Connell, G., Heekeren, H. R., & Dziobek, I. (2020). Neurobiological mechanisms of social cognition treatment in high-functioning adults with autism spectrum disorder. *Psychological Medicine*, *50*(14), 2374–2384. https://doi.org/10.1017/S0033291719002472

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*(2). https://doi.org/10.18637/jss.v048.i02

Rozental, A., Kottorp, A., Forsström, D., Månsson, K., Boettcher, J., Andersson, G., Furmark, T., & Carlbring, P. (2019). The Negative Effects Questionnaire: Psychometric properties of an instrument for assessing negative effects in psychological treatments. *Behavioural and Cognitive Psychotherapy*, *47*(5), 559–572. https://doi.org/10.1017/S1352465819000018

RStudio Team. (2015). *RStudio: Integrated Development for R [*Computer software]. RStudio. Boston, MA. http://www.rstudio.com/

Rump, K. M., Giovannelli, J. L., Minshew, N. J., & Strauss, M. S. (2009). The development of emotion recognition in individuals with autism. *Child Development*, *80*(5), 1434–1447. https://doi.org/10.1111/j.1467-8624.2009.01343.x

Russo-Ponsaran, N. M., McKown, C., Johnson, J. K., Allen, A. W., Evans-Smith, B., & Fogg, L. (2015). Social-Emotional Correlates of Early Stage Social Information Processing Skills in Children With and Without Autism Spectrum Disorder. *Autism Research: Official Journal of the International Society for Autism Research*, *8*(5), 486–496. https://doi.org/10.1002/aur.1463

Rutter, M., Bailey, A., & Lord, C. (2006). *Social Communication Questionnaire (SCQ)*. German Version by S.Bölte, F. Poustka. Huber.

Samson, A. C., Hardan, A. Y., Lee, I. A., Phillips, J. M., & Gross, J. J. (2015). Maladaptive Behavior in Autism Spectrum Disorder: The Role of Emotion Experience and Emotion Regulation. *Journal of Autism and Developmental Disorders*, *45*(11), 3424–3432. https://doi.org/10.1007/s10803-015-2388-7

Samson, A. C., Hardan, A. Y., Podell, R. W., Phillips, J. M., & Gross, J. J. (2015). Emotion regulation in children and adolescents with autism spectrum disorder. *Autism Research: Official Journal of the International Society for Autism Research*, *8*(1), 9–18. https://doi.org/10.1002/aur.1387

Samson, A. C., Huber, O., & Gross, J. J. (2012). Emotion regulation in Asperger's syndrome and high-functioning autism. *Emotion*, *12*(4), 659–665. https://psycnet.apa.org/doi/10.1037/a0027975

Samson, A. C., Phillips, J. M., Parker, K. J., Shah, S., Gross, J. J., & Hardan, A. Y. (2014). Emotion dysregulation and the core features of autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(7), 1766–1772. https://doi.org/10.1007/s10803-013-2022-5

Sandgreen, H., Frederiksen, L. H., & Bilenberg, N. (2021). Digital Interventions for Autism Spectrum Disorder: A Meta-analysis. *Journal of Autism and Developmental Disorders*, *51*(9), 3138–3152. https://doi.org/10.1007/s10803-020-04778-9

Sasson, N. J., & Morrison, K. E. (2019). First impressions of adults with autism improve with diagnostic disclosure and increased autism knowledge of peers. *Autism: The International Journal of Research and Practice*, *23*(1), 50–59. https://doi.org/10.1177/1362361317729526

Sato, W., Toichi, M., Uono, S., & Kochiyama, T. (2012). Impaired social brain network for processing dynamic facial expressions in autism spectrum disorders. *BMC Neuroscience*, *13*, 99. https://doi.org/10.1186/1471-2202-13-99

Schuck, R. K., Tagavi, D. M., Baiden, K. M. P., Dwyer, P., Williams, Z. J., Osuna, A., Ferguson, E. F., Jimenez Muñoz, M., Poyser, S. K., Johnson, J. F., & Vernon, T. W. (2021). Neurodiversity and Autism Intervention: Reconciling Perspectives Through a Naturalistic Developmental Behavioral Intervention Framework. *Journal of Autism and Developmental Disorders*, 1–21. https://doi.org/10.1007/s10803-021-05316-x

Schulte-Rüther, M., Greimel, E., Markowitsch, H. J., Kamp-Becker, I., Remschmidt, H., Fink, G. R., & Piefke, M. (2011). Dysfunctions in brain networks supporting empathy: An fMRI study in adults with autism spectrum disorders. *Social Neuroscience*, *6*(1), 1–21. https://doi.org/10.1080/17470911003708032

Schultz, D., Izard, C. E., & Bear, G. (2004). Children's emotion processing: Relations to emotionality and aggression. *Development and Psychopathology*, *16*(2), 371–387. https://doi.org/10.1017/S0954579404044566

Schulz, K. F., Altman, D. G., & Moher, D. (2010). Consort 2010 statement: Updated guidelines for reporting parallel group randomised trials. *PLoS Medicine*, *7*(3), e1000251. https://doi.org/10.1371/journal.pmed.1000251

Shamay-Tsoory, S. G., Aharon-Peretz, J., & Perry, D. (2009). Two systems for empathy: A double dissociation between emotional and cognitive empathy in inferior frontal gyrus versus ventromedial prefrontal lesions. *Brain: A Journal of Neurology*, *132*(Pt 3), 617–627. https://doi.org/10.1093/brain/awn279

Shamay-Tsoory, S. G., Harari, H., Aharon-Peretz, J., & Levkovitz, Y. (2010). The role of the orbitofrontal cortex in affective theory of mind deficits in criminal offenders with psychopathic tendencies. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *46*(5), 668–677. https://doi.org/10.1016/j.cortex.2009.04.008

Shields, A., & Cicchetti, D. (1997). Emotion Regulation Among School-Age Children: The Development and Validation of a New Criterion Q-Sort Scale. *Developmental Psychology*, *33*(6), 906–916.

Silver, M., & Oakes, P. (2001). Evaluation of a new computer intervention to teach people with autism or Asperger syndrome to recognize and predict emotions in others. *Autism: The International Journal of Research and Practice*, *5*(3), 299–316. https://doi.org/10.1177/1362361301005003007

Simantov, T., Lombardo, M. V., Baron-Cohen, S., & Uzefovsky, F. Self-Other Distinction. In *The Neural Basis of Mentalizing* (pp. 85–106). https://doi.org/10.1007/978-3-030-51890-5_5 (Original work published 2021)

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity, and associated factors in a population-derived sample. *Journal of the American Academy of Child and Adolescent Psychiatry*, *47*(8), 921–929. https://doi.org/10.1097/CHI.0b013e318179964f

Singer, J. (2017). *Neurodiversity: The birth of an idea* [publisher not identified].

Singer, T. (2012). The past, present and future of social neuroscience: A European perspective. *NeuroImage*, *61*(2), 437–449. https://doi.org/10.1016/j.neuroimage.2012.01.109

Singer, T., & Lamm, C. (2009). The social neuroscience of empathy. *Annals of the New York Academy of Sciences*, *1156*, 81–96. https://doi.org/10.1111/j.1749-6632.2009.04418.x

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science (New York, N.Y.)*, *303*(5661), 1157–1162. https://doi.org/10.1126/science.1093535

Slot, P. L., Bleses, D., & Jensen, P. (2020). Infants' and Toddlers' Language, Math and Socio-Emotional Development: Evidence for Reciprocal Relations and Differential Gender and Age Effects. *Frontiers in Psychology*, *11*, 580297. https://doi.org/10.3389/fpsyg.2020.580297

Smeijers, D., Benbouriche, M., & Garofalo, C. (2020). The Association Between Emotion, Social Information Processing, and Aggressive Behavior: A Systematic Review. *European Psychologist*, *25*(2), 81–91. https://doi.org/10.1027/1016-9040/a000395

Smith, A. (2009a). Emotional empathy in autism spectrum conditions: Weak, intact, or heightened? *Journal of Autism and Developmental Disorders*, *39*(12), 1747-8; author reply 1749-54. https://doi.org/10.1007/s10803-009-0799-z

Smith, A. (2009b). The Empathy Imbalance Hypothesis of Autism: A Theoretical Approach to Cognitive and Emotional Empathy in Autistic Development. *The Psychological Record*, *59*(2), 273–294. https://doi.org/10.1007/BF03395663

Smith, A. (2009c). The Empathy Imbalance Hypothesis of Autism: A Theoretical Approach to Cognitive and Emotional Empathy in Autistic Development. *The Psychological Record*, *59*(2), 273–294. https://doi.org/10.1007/BF03395663

Sofronoff, K., Beaumont, R. B., & Weiss, J. A. (2014). Treating Transdiagnostic Processes in ASD: Going Beyond Anxiety. In *Handbook of Autism and Anxiety* (pp. 171–183). Springer, Cham. https://doi.org/10.1007/978-3-319-06796-4_12

REFERENCES

Sofronoff, K., Silva, J., & Beaumont, R. B. (2017). The Secret Agent Society Social-Emotional Skills Program for Children With a High-Functioning Autism Spectrum Disorder. *Focus on Autism and Other Developmental Disabilities*, *32*(1), 55–70. https://doi.org/10.1177/1088357615583467

Song, Y., Nie, T., Shi, W., Zhao, X., & Yang, Y. (2019). Empathy Impairment in Individuals With Autism Spectrum Conditions From a Multidimensional Perspective: A Meta-Analysis. *Frontiers in Psychology*, *10*, 1902. https://doi.org/10.3389/fpsyg.2019.01902

Speyer, L. G., Brown, R. H., Camus, L., Murray, A. L., & Auyeung, B. (2022). Alexithymia and Autistic Traits as Contributing Factors to Empathy Difficulties in Preadolescent Children. *Journal of Autism and Developmental Disorders*, *52*(2), 823–834. https://doi.org/10.1007/s10803-021-04986-x

Spiel, K., Frauenberger, C., & Fitzpatrick, G. (2017). Experiences of autistic children with technologies. *International Journal of Child-Computer Interaction*, *11*, 50–61. https://doi.org/10.1016/j.ijcci.2016.10.007

Statistisches Bundesamt. (2020). https://de.statista.com/

Sucksmith, E., Allison, C., Baron-Cohen, S., Chakrabarti, B., & Hoekstra, R. H. A. (2013). Empathy and emotion recognition in people with autism, first-degree relatives, and controls. *Neuropsychologia*, *51*(1), 98–105. https://doi.org/10.1016/j.neuropsychologia.2012.11.013

Sullivan, M. O., Gallagher, L., & Heron, E. A. (2019). Gaining Insights into Aggressive Behaviour in Autism Spectrum Disorder Using Latent Profile Analysis. *Journal of Autism and Developmental Disorders*, *49*(10), 4209–4218. https://doi.org/10.1007/s10803-019-04129-3

Sydow, K. von, Retzlaff, R., Beher, S., Haun, M. W., & Schweitzer, J. (2013). The efficacy of systemic therapy for childhood and adolescent externalizing disorders: A systematic review of 47 RCT. *Family Process*, *52*(4), 576–618. https://doi.org/10.1111/famp.12047

Tager-Flusberg, H., & Kasari, C. (2013). Minimally verbal school-aged children with autism spectrum disorder: The neglected end of the spectrum. *Autism Research: Official Journal of the International Society for Autism Research*, *6*(6), 468–478. https://doi.org/10.1002/aur.1329

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., Brown, C., Stahl, S. S., Kaiser, M. D., & Schultz, R. T. (2010). Using computerized games to teach face recognition skills to children with autism spectrum disorder: The Let's Face It! Program. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *51*(8), 944–952. https://doi.org/10.1111/j.1469-7610.2010.02258.x

Tardif, C., Lainé, F., Rodriguez, M., & Gepner, B. (2007). Slowing down presentation of facial movements and vocal sounds enhances facial expression recognition and induces facial-vocal imitation in children with autism. *Journal of Autism and Developmental Disorders*, *37*(8), 1469–1484. https://doi.org/10.1007/s10803-006-0223-x

Thomeer, M. L., Smith, R. A., Lopata, C., Volker, M. A., Lipinski, A. M., Rodgers, J. D., McDonald, C. A., & Lee, G. K. (2015). Randomized Controlled Trial of Mind Reading and In Vivo Rehearsal for High-Functioning Children with ASD. *Journal of Autism and Developmental Disorders*, *45*(7), 2115–2127. https://doi.org/10.1007/s10803-015-2374-0

Thompson, R. A. (1991). Emotional regulation and emotional development. *Educational Psychology Review*, *3*(4), 269–307. https://doi.org/10.1007/BF01319934

Titchener, E. B. (1909). *Lectures on the experimental psychology of the thought-processes*. MacMillan Co. https://doi.org/10.1037/10877-000

Trentacosta, C. J., & Fine, S. E. (2010). Emotion Knowledge, Social Competence, and Behavior Problems in Childhood and Adolescence: A Meta-Analytic Review. *Social Development (Oxford, England)*, *19*(1), 1–29. https://doi.org/10.1111/j.1467-9507.2009.00543.x

Uljarević, M., & Hamilton, A. (2013). Recognition of emotions in autism: A formal meta-analysis. *Journal of Autism and Developmental Disorders*, *43*(7), 1517–1526. https://doi.org/10.1007/s10803-012-1695-5

Valentine, A. Z., Brown, B. J., Groom, M. J., Young, E., Hollis, C., & Hall, C. L. (2020). A systematic review evaluating the implementation of technologies to assess, monitor and treat neurodevelopmental disorders: A map of the current evidence. *Clinical Psychology Review*, *80*, 101870. https://doi.org/10.1016/j.cpr.2020.101870

van Nieuwenhuijzen, M., Orobio de Castro, B., Wijnroks, L., Vermeer, A., & Matthys, W. (2004). The relations between intellectual disabilities, social information processing, and behaviour problems. *European Journal of Developmental Psychology*, *1*(3), 215–229. https://doi.org/10.1080/17405620444000111

van Nieuwenhuijzen, M., & Vriens, A. (2012). (Social) Cognitive skills and social information processing in children with mild to borderline intellectual disabilities. *Research in Developmental Disabilities*, *33*(2), 426–434. https://doi.org/10.1016/j.ridd.2011.09.025

van Wingerden, E., Sterkenburg, P. S., & Wouda, M. (2018). Improving empathy and self-efficacy in caregivers of persons with intellectual disabilities, using m-learning (HiSense APP-ID): Study protocol for a randomized controlled trial. *Trials*, *19*(1), 400. https://doi.org/10.1186/s13063-018-2772-7

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425. https://doi.org/10.2307/30036540

Verhoef, R. E. J., Alsem, S. C., Verhulp, E. E., & De Castro, B. O. de (2019). Hostile Intent Attribution and Aggressive Behavior in Children Revisited: A Meta-Analysis. *Child Development*, *90*(5), e525-e547. https://doi.org/10.1111/cdev.13255

Volk, A. A., Veenstra, R., & Espelage, D. L. (2017). So you want to study bullying? Recommendations to enhance the validity, transparency, and compatibility of bullying research. *Aggression and Violent Behavior*, *36*, 34–43. https://doi.org/10.1016/j.avb.2017.07.003

Waal, F. B. M. de (2008). Putting the altruism back into altruism: The evolution of empathy. *Annual Review of Psychology*, *59*, 279–300. https://doi.org/10.1146/annurev.psych.59.103006.093625

Wang, X., Zhao, J., Huang, S., Chen, S., Zhou, T., Li, Q., Luo, X., & Hao, Y. (2021). Cognitive Behavioral Therapy for Autism Spectrum Disorders: A Systematic Review. *Pediatrics*, *147*(5). https://doi.org/10.1542/peds.2020-049880

Weiss, J. A. (2014). Transdiagnostic Case Conceptualization of Emotional Problems in Youth with ASD: An Emotion Regulation Approach. *Clinical Psychology : A Publication of the Division of Clinical Psychology of the American Psychological Association*, *21*(4), 331–350. https://doi.org/10.1111/cpsp.12084

Weisz, J. R., McCarty, C. A., & Valeri, S. M. (2006). Effects of psychotherapy for depression in children and adolescents: A meta-analysis. *Psychological Bulletin*, *132*(1), 132–149. https://doi.org/10.1037/0033-2909.132.1.132

WHO. (1994a). *The International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10)* (10th ed.).

WHO. (1994b). *The International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).*

Whyte, E. M., Smyth, J. M., & Scherf, K. S. (2015). Designing Serious Game Interventions for Individuals with Autism. *Journal of Autism and Developmental Disorders*, *45*(12). https://doi.org/10.1007/s10803-014-2333-1

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag. http://ggplot2.org

Wickham, H. (2017). *tidyverse: Easily Install and Load the 'Tidyverse'*.

Wickham, H., & Miller, E. (2018). *haven: Import and Export 'SPSS', 'Stata' and 'SAS' Files*. https://CRAN.R-project.org/package=haven

Widdowson, M. (2011). Case Study Research Methodology. *International Journal of Transactional Analysis Research & Practice*, *2*(1). https://doi.org/10.29044/v2i1p25

Williams, C., Wright, B., Callaghan, G., & Coughlan, B [Brian] (2002). Do children with autism learn to read more readily by computer assisted instruction or traditional book methods? A pilot study. *Autism: The International Journal of Research and Practice*, *6*(1), 71–91. https://doi.org/10.1177/1362361302006001006

Wilson, C., Brereton, M., Ploderer, B., & Sitbon, L. (2019). Co-Design Beyond Words. In S. Brewster, G. Fitzpatrick, A. Cox, & V. Kostakos (Eds.), *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–15). ACM. https://doi.org/10.1145/3290605.3300251

REFERENCES

Xu, P., Chen, A., Li, Y., Xing, X., & Lu, H. (2019). Medial prefrontal cortex in neurological diseases. *Physiological Genomics*, *51*(9), 432–442. https://doi.org/10.1152/physiolgenomics.00006.2019

Yang, H.-X., Hu, H.-X., Zhang, Y.-J., Wang, Y [Yi], Lui, S. S. Y., & Chan, R. C. K. (2022). A network analysis of interoception, self-awareness, empathy, alexithymia, and autistic traits. *European Archives of Psychiatry and Clinical Neuroscience*, *272*(2), 199–209. https://doi.org/10.1007/s00406-021-01274-8

Yen, P.-Y., & Bakken, S. (2012). Review of health information technology usability study methodologies. *Journal of the American Medical Informatics Association : JAMIA*, *19*(3), 413–422. https://doi.org/10.1136/amiajnl-2010-000020

Yirmiya, N., Kasari, C., Sigman, M. D., & Mundy, P. C. (1989). Facial expressions of affect in autistic, mentally retarded and normal children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *30*(5), 725–735. https://doi.org/10.1111/j.1469-7610.1989.tb00785.x

Young, R. L., & Posselt, M. (2012). Using the transporters DVD as a learning tool for children with Autism Spectrum Disorders (ASD). *Journal of Autism and Developmental Disorders*, *42*(6), 984–991. https://doi.org/10.1007/s10803-011-1328-4

Zablotsky, B., Black, L. I., Maenner, M. J., Schieve, L. A., & Blumberg, S. J. (2015). Estimated Prevalence of Autism and Other Developmental Disabilities Following Questionnaire Changes in the 2014 National Health Interview Survey. *National Health Statistics Reports*(87), 1–20. https://stacks.cdc.gov/view/cdc/38790

Zahn-Waxler, C., Radke-Yarrow, M., Wagner, E., & Chapman, M. (1992). Development of concern for others. *Developmental Psychology*, *28*(1), 126–136. https://doi.org/10.1037/0012-1649.28.1.126

Zhang, Q., Wu, R., Zhu, S., Le, J., Chen, Y [Yuanshu], Lan, C., Yao, S., Zhao, W., & Kendrick, K. M. (2021). Facial emotion training as an intervention in autism spectrum disorder: A meta-analysis of randomized controlled trials. *Autism Research: Official Journal of the International Society for Autism Research*, *14*(10), 2169–2182. https://doi.org/10.1002/aur.2565

Ziv, Y., Hadad, B. S., Khateeb, Y., & Terkel-Dawer, R. (2014). Social information processing in preschool children diagnosed with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(4), 846–859. https://doi.org/10.1007/s10803-013-1935-3

Zoerner, D., Schütze, J., Kirst, S., & Dziobek, I. (2016). Zirkus Empathico - Mobile Training of Socio-Emotional Competences for Children with Autism. In:. In *Proc. IEEE Int. Conf. on Advanced Learning Technologies (ICALT).* Symposium conducted at the meeting of IEEE CS Press.

Licenses and permissions