Adult Attention-Deficit/Hyperactivity Disorder (ADHD), Emotion Processing, and Emotion Regulation in Virtual Reality

Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS) im Erwachsenenalter, Emotionsverarbeitung und Emotionsregulation in virtueller Realität

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“Den stärksten Anlass zum Handeln bekommt der Mensch immer durch Gefühle.”

Carl von Clausewitz

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ABSTRACT

Attention-Deficit/Hyperactivity Disorder (ADHD) is characterized by symptoms of inattentiveness and hyperactivity/impulsivity. Besides, increasing evidence points to ADHD patients showing emotional dysfunctions and concomitant problems in social life. However, systematic research on emotional dysfunctions in ADHD is still rare, and to date most studies lack conceptual differentiation between emotion processing and emotion regulation. The aim of this thesis was to systematically investigate emotion processing and emotion regulation in adult ADHD in a virtual reality paradigm implementing social interaction. Emotional reactions were assessed on experiential, physiological, and behavioral levels.

Experiment 1 was conducted to develop a virtual penalty kicking paradigm implying social feedback and to test it in a healthy sample. This paradigm should then be applied in ADHD patients later on. Pleasant and unpleasant trials in this paradigm consisted of hits respectively misses and subsequent feedback from a virtual coach. In neutral trials, participants were teleported to different spots of the virtual stadium. Results indicated increased positive affectivity (higher valence and arousal ratings, higher zygomaticus activations, and higher expression rates of positive emotional behavior) in response to pleasant compared to neutral trials. Reactions to unpleasant trials were contradictory, indicating increased levels of both positive and negative affectivity, compared to neutral trials. Unpleasant vs. neutral trials revealed lower valence ratings, higher arousal ratings, higher zygomaticus activations, slightly lower corrugator activations, and higher expression rates of both positive and negative emotional behavior. The intensity of emotional reactions correlated with experienced presence in the virtual reality.

To better understand the impact of hits or misses per se vs. hits or misses with coach feedback healthy participants' emotional reactions, only 50% of all shots were followed by coach feedback in experiment 2. Neutral trials consisted of shots over the free soccer field which were followed by coach feedback in 50 % of all trials. Shots and feedback evoked more extreme valence and arousal ratings, higher zygomaticus activations, lower corrugator activations, and higher skin conductance responses than shots alone across emotional conditions. Again, results speak for the induction of positive emotions in pleasant trials whereas the induction of negative emotions in unpleasant trials seems ambiguous. Technical improvements of the virtual reality were reflected in higher presence ratings than in experiment 1.

Experiment 3 investigated emotional reactions of adult ADHD patients and healthy controls after emotion processing and response-focused emotion regulation. Participants successively went through an ostensible online ball-tossing game (cyber ball) inducing negative emotions, and an adapted version of the virtual penalty kicking game. Throughout cyber ball, participants were included or ostracized by two other players in different experimental blocks. Participants were instructed to explicitly show, not regulate, or hide their emotions in different experimental blocks. Results provided some evidence for deficient processing of positive emotions in ADHD. Patients reported slightly lower positive affect than controls during cyber ball, gave lower valence ratings than controls in response to pleasant penalty kicking trials, and showed lower zygomaticus activations than controls especially during penalty kicking. Patients in comparison with controls showed slightly increased processing of unpleasant events during cyber ball (higher ratings of negative affect, especially in response to ostracism), but not during penalty kicking. Patients showed lower baseline skin conductance levels than controls, and impaired skin conductance modulations. Compared to controls, patients showed slight over-expression of positive as well as negative emotional behavior. Emotion regulation analyses revealed no major difficulties of ADHD vs. controls in altering their emotional reactions through deliberate response modulation. Moreover, patients reported to habitually apply adaptive emotion regulation strategies even more frequently than controls. The analyses of genetic high-risk vs. low-risk groups for ADHD across the whole sample revealed similar results as analyses for patients vs. controls for zygomaticus modulations during emotion processing, and for modulations of emotional reactions due to emotion regulation.

To sum up, the virtual penalty kicking paradigm proved to be successful for the induction of positive, but not negative emotions. The importance of presence in virtual reality for the intensity of induced emotions could be replicated. ADHD patients showed impaired processing of primarily positive emotions. Aberrations in negative emotional responding were less clear and need further investigation. Results point to adult ADHD in comparison to healthy controls suffering from baseline deficits in autonomic arousal and deficits in arousal modulation. Deficits of ADHD in the deliberate application of response-focused emotion regulation could not be found.

ZUSAMMENFASSUNG

Die Aufmerksamkeitsdefizit-/hyperaktivitätsstörung (ADHS) ist gekennzeichnet durch Symptome der Unaufmerksamkeit und Hyperaktivität/Impulsivität. Zudem sprechen zunehmende Befunde für emotionale Defizite und damit einhergehende soziale Probleme bei ADHS. Bisher gibt es jedoch kaum systematische Untersuchungen zu emotionalen Defiziten bei ADHS, und die meisten bisherigen Studien trennen nicht klar zwischen den Konzepten der Emotionsverarbeitung und Emotionsregulation. Das Ziel dieser Arbeit war es, Emotionsverarbeitung und Emotionsregulation bei erwachsenen ADHS Patienten in einem Paradigma in virtueller Realität mit sozialer Interaktion zu untersuchen. Emotionale Reaktionen wurden auf Erlebnisebene, physiologischer Ebene und Verhaltensebene erfasst.

In Experiment 1 wurde ein virtuelles Elfmeterparadigma mit sozialem Feedback entwickelt und an einer gesunden Stichprobe getestet. Dieses Paradigma sollte später mit ADHS Patienten verwendet werden. Angenehme und unangenehme Versuchsdurchgänge bestanden aus Treffern bzw. gehaltenen Torschüssen und einer darauffolgenden Rückmeldung von einem virtuellen Trainer. In neutralen Durchgängen wurden die Teilnehmer zu verschiedenen Punkten im virtuellen Stadion teleportiert. Die Ergebnisse sprechen für erhöhte positive Affektivität (höhere Valenz- und Arousalratings, höhere Zygomaticusaktivität, mehr positiver emotionaler Ausdruck) durch angenehme im Vergleich zu neutralen Durchgängen. Reaktionen auf unangenehme im Vergleich zu neutralen Durchgängen waren widersprüchlich und sprechen für erhöhte positive und negative Affektivität. Unangenehme vs. neutrale Durchgänge führten zu niedrigeren Valenzratings, höheren Arousalratings, höherer Zygomaticusaktivität, etwas niedrigerer Corrugatoraktivität und mehr positivem und negativem emotionalen Ausdruck. Die Intensität emotionaler Reaktionen korrelierte mit dem Präsenzerleben in der virtuellen Realität.

Um den Einfluss von Torschüssen allein vs. Torschüssen mit Trainerrückmeldung auf emotionale Reaktionen bei Gesunden besser zu verstehen, folgte in Experiment 2 nur auf 50 % aller Schüsse eine Trainerrückmeldung. Neutrale Durchgänge bestanden aus freien Schüssen über das Fußballfeld, auf die zu 50 % eine Trainerrückmeldung folgte. Schüsse mit Rückmeldung führten durchgängig zu stärkeren Valenz- und Arousalratings, höherer Zygomaticusaktivität, niedrigerer Corrugatoraktivität, und höheren Hautleitfähigkeitsreaktionen als Schüsse allein. Auch diese Ergebnisse sprechen für die Induktion positiver Emotionen durch angenehme Durchgänge, während die Induktion negativer Emotionen durch unangenehme Durchgänge uneindeutig scheint. Technische Verbesserungen der virtuellen Realität schlugen sich in höherem Präsenzerleben als in Experiment 1 nieder.

Experiment 3 untersuchte emotionale Reaktionen von erwachsenen ADHS Patienten und gesunden Kontrollen nach Emotionsverarbeitung und reaktionsfokussierter Emotions-regulation. Versuchsteilnehmer absolvierten nacheinander ein vorgebliches Online-Ballspiel (Cyber Ball) welches negative Emotionen induzierte, und eine weiterentwickelte Version des virtuellen Elfmeterspiels. Während Cyber Ball wurden die Teilnehmer von zwei anderen Mitspielern in verschiedenen Versuchsblöcken entweder eingeschlossen oder ausgeschossen. Die Teilnehmer wurden in verschiedenen Versuchsblöcken instruiert, ihre Emotionen entweder deutlich zu zeigen, nicht zu regulieren, oder zu verbergen. Einige Ergebnisse sprechen für eine defizitäre Verarbeitung positiver Emotionen bei ADHS. Patienten berichteten niedrigeren positiven Affekt als Kontrollen während Cyber Ball, niedrigere Valenzratings als Kontrollen nach angenehmen Elfmeterdurchgängen, und zeigten niedrigere Zygomaticusaktivität als Kontrollen insbesondere während des Elfmeterschießens. Im Vergleich zu Kontrollen zeigten Patienten eine leicht verstärkte Verarbeitung von unangenehmen Ereignissen beim Cyber Ball (höhere Ratings von negativem Affekt v.a. nach Ausschluss), aber nicht beim Elfmeterschießen. Patienten zeigten eine niedrigere Baseline-Hautleitfähigkeit als Kontrollen, sowie beeinträchtigte Hautleitfähigkeitsmodulationen. Im Vergleich zu Kontrollen zeigten Patienten leicht erhöhten Ausdruck von positiven und negativen Emotionen. Emotionsregulationsanalysen zeigten keine bedeutenden Einschränkungen von ADHS vs. Kontrollen im Verändern ihrer emotionalen Reaktionen durch absichtliche reaktionsfokussierte Emotionsregulation. Außerdem gaben Patienten an, gewohnheitsmäßig sogar häufiger als Kontrollen adaptive Emotionsregulationsstrategien anzuwenden. Der Vergleich einer genetischen Hochrisikogruppe mit einer Niedrigrisikogruppe für ADHS über die gesamte Stichprobe zeigte ähnliche Ergebnisse wie die Analysen für Patienten vs. Kontrollen in der Modulation von Zygomaticusaktivität während der Emotionsverarbeitung, sowie in der Modulation emotionaler Reaktionen durch Emotionsregulation.

Zusammenfassend lässt sich sagen, dass das virtuelle Elfmeterparadigma geeignet scheint, um positive, aber nicht negative Emotionen zu induzieren. Die Bedeutsamkeit von Präsenzerleben in einer virtuellen Realität für die Intensität von induzierten Emotionen konnte repliziert werden. ADHS Patienten zeigten Beeinträchtigungen v.a. in der Verarbeitung von positiven Emotionen. Abweichungen in der negativen emotionalen Reagibilität waren weniger eindeutig und sollten weiter untersucht werden. Die Ergebnisse deuten darauf hin, dass erwachsene ADHS Patienten im Vergleich zu gesunden Kontrollen eine niedrigere autonome Erregbarkeit bei Baseline und Defizite in der Erregbarkeitsmodulation zeigen. Es zeigten sich keine Defizite von ADHS in der absichtlichen Anwendung von ausdrucksfokussierter Emotionsregulation.

ABBREVIATIONS

ADD	Attention Deficit Disorder
ADHD	Attention-Deficit/Hyperactivity Disorder
ANOVA	Analysis of variance
BDI	Beck's Depression Inventory
BSI	Brief Symptom Inventory
CD	Conduct Disorder
DNA	Deoxyribonucleic acid
DSM	Diagnostic and Statistical Manual of Mental Disorders
EEG	Electroencephalogram
EMG	Electromyography
ERI	Emotionsregulationsinventar
ERP	Event related potential
FACS	Facial Action Coding System
fMRI	functional Magnetic Resonance Imaging
HASE	Homburger ADHS Skalen für Erwachsene
HC	Healthy controls
IAT	Implicit Association Test
ICD	International Classification of Diseases
IPQ	Igroup Presence Questionnaire
ITI	Intertrial Interval
LPP	Late positive potential
ODD	Oppositional Defiant Disorder
PANAS	Positive and Negative Affect Schedule
PCR	Polymerase chain reaction
RSES	Rosenberg Self-Esteem Scale
SCID	Structured Clinical Interview for the DSM
SCL	Skin conductance level
SCR	Skin conductance response
SLC6A4	Solute carrier family 6, member 4
SNP	Single nucleotide polymorphism
STAI	State-Trait Anxiety Inventory

TPH2	Tryptophan hydroxylase-2 gene
VR	Virtual Reality
WHO	World Health Organization
5-HT	Serotonin
5-HTT	Serotonin transporter

THEORETICAL BACKGROUND

1.1. ATTENTION-DEFICIT/HYPERACTIVITY DISORDER (ADHD)

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most common psychiatric disorders in childhood and adolescence and often persists into adulthood. Whereas research on both genesis and therapeutic interventions in children and adolescents suffering from ADHD has been flourishing over the past decades, quite little is still known about specific diagnostic and therapeutic interventions for adults. Furthermore, research in both children and adults suffering from ADHD has long just concentrated on the core symptoms of inattentiveness and hyperactivity/impulsivity, but neglected other difficulties, especially problems of emotion processing and emotion regulation.

Therefore, this thesis focuses on differences in emotion processing and emotion regulation between adult ADHD patients and healthy control subjects. First, I give a theoretical introduction to ADHD and theoretical concepts of emotion processing and emotion regulation. I explain diagnostic criteria of ADHD in the current version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V, American Psychiatric Association, 2013), and point out differences to the DSM-IV as well as to the current version of the International Classification of Diseases (ICD-10, World Health Organization, 1992). I will briefly explain different etiological models for ADHD, especially the endophenotype concept. Moreover, I will briefly discuss genetic influences on the development and persistence of ADHD and shortly introduce two polymorphisms that have been discussed in the context of emotion dysregulation and ADHD. I will introduce different endophenotypes that have been discussed for ADHD and give a short overview of corresponding research results. I want to introduce the emotional-motivational endophenotype and stress the importance of social interactions as elicitors of strong emotions in healthy controls as well as in ADHD patients. I will introduce the concepts of emotion processing and emotion regulation as they have been described in a comprehensive model by Gross (1998b, 1999, 2002). Thereon, I will differentiate between emotional reactions on experiential, physiological, and behavioral levels, and introduce corresponding experimental measures. I will outline emotion induction in virtual reality paradigms and then come back to difficulties in emotion processing and emotion regulation in ADHD. After this theoretical introduction, I will present three empirical studies. The first and second studies concentrated on the development of a virtual penalty kicking paradigm with feedback from a virtual soccer coach for emotion induction. The third study investigated emotional reactions and emotion regulation capabilities in adult ADHD patients and healthy controls in the aforementioned virtual penalty kicking paradigm and a virtual ball-tossing game. I present a short introduction, a detailed description of experimental methods, of results, and a discussion for each of the three studies. Finally, I discuss the findings of all studies in the light of current literature.

1.1.1. Diagnostic Criteria and Epidemiology of ADHD

According to the DSM-V (American Psychiatric Association, 2013), patients should be diagnosed with one of three presentations of ADHD (predominantly inattentive presentation, predominantly hyperactive presentation, combined presentation) when they present at least five (respectively at least six when diagnosed before the age of 17) out of nine symptoms of inattentiveness (e.g. failure to pay close attention to details, difficulty organizing tasks and activities) or hyperactivity/impulsivity (e.g. excessive talking, fidgeting, or difficulties remaining seated). The combined presentation has to show both at least five (respectively at least six when diagnosed before the age of 17) symptoms of inattentiveness and at least five symptoms of hyperactivity/impulsivity. Those symptoms have to be present before the age of 12, show in multiple settings of everyday life (e.g., school or work, and home), result in impairments in social, educational, or work settings, and may not better be explained by any other psychiatric disorder. Adaptations of symptoms for adults have mostly applied to symptoms of hyperactivity. For example "often leaving the seat in situations when remaining seated is expected" (a diagnostic criterion for hyperactivity) has been re-formulated to "difficulties remaining seated". Equally, children diagnosed with ADHD (predominantly hyperactive type or combined type) have to "often run about or climb in situations where it is not appropriate", whereas adults just have to present a "feeling of restlessness". See DSM-V (American Psychiatric Association, 2013) for the exact description of diagnostic criteria for children/adolescents and adults. See A 1 for a short overview of diagnostic criteria for adults according to the DSM-V.

The current version of the International Classification of Diseases (ICD-10, World Health Organization, 1992) allows for the diagnosis of three subtypes of ADHD, which are slightly different than the DSM-IV subtypes or DSM-V presentations. F90.0 accordingly codes for "disturbance of activity and attention" (which is comparable to the combined presentation in the DSM). F90.1 codes for "hyperkinetic conduct disorder" (which is comparable to ADHD combined presentation, and comorbid oppositional defiant disorder in the DSM). The ICD-10 does not provide a specific diagnostic category for the predominantly inattentive presentation. It subsumes "attention disorder without hyperactivity" under F98.8 which codes for "other specified behavioral and emotional disorders with onset usually occurring in childhood and adolescence". Moreover, the ICD-10 does not allow for diagnosis of the predominantly hyperactive/impulsive presentation, with symptoms of hyperactivity and impulsivity, but no or only a small number of inattentive symptoms.

Prevalence rates of ADHD seem to be stable over time and relatively stable across different cultures. In a big metaregression analysis study, Polanczyk, Lima, Horda, Biederman, & Rohde (2007) estimated the worldwide prevalence of ADHD in children and adolescents to be 5.29 %. Boys seem to be affected more frequently than girls (sex ratio approximately 3:1). This holds true especially for the predominantly hyperactive/impulsive presentation and the combined presentation, whereas prevalence rates of the predominantly inattentive presentation hardly differ between boys and girls (Willcutt, 2012). Prevalence rates in children, adolescents, and adults vary a lot depending on the diagnostic systems applied and are expected to increase due to the changes made in the DSM-V vs. the DSM-IV. It has been particularly difficult to find exact prevalence rates in adults. This seems mostly due to a lack of clear diagnostic criteria. Simon, Czobor, Bálint, Mészáros, & Bitter (2009) estimated the prevalence of ADHD in adults to be 2.5 %, whereas Haavik, Halmøy, Lundervold, & Fasmer (2010) stated it to be even 4-5 %. In adults, men and women seem to be affected by ADHD almost equally frequent (Faraone et al., 2015). Inattentive symptoms seem to be more stable across the lifespan, thus resulting in higher prevalence of inattentiveness than of hyperactivity and impulsivity in adults. Wender (1995) and Wender, Wolf, & Wasserstein (2001) first introduced diagnostic guidelines for ADHD in adults, taking into account not only the core symptoms of inattentiveness and hyperactivity/impulsivity, but also symptoms like "affective lability", "hot temper, explosive short-lived outbursts", "emotional over reactivity", and "associated features". Particularly symptoms of emotion dysregulation, though still not part of the diagnostic criteria of the DSM and the ICD, are currently discussed as a crucial impairment in children and adults suffering from ADHD.

ADHD is a highly comorbid disorder, with most patients suffering at least from one other psychiatric disorder alongside ADHD. Among those are mood and anxiety disorders, personality disorders, and drug/alcohol abuse (Haavik et al., 2010). It is extremely important to consider individual impairments resulting from both ADHD symptoms and symptoms of different co-morbidities for successful treatment of those patients (Faraone et al., 2015). A huge number of ADHD patients suffer from difficulties in social interactions, including peer rejection (Paulson, Buermeyer, & Nelson-Gray, 2005) and social immaturity (Carpenter Rich, Loo, Yang, Dang, & Smalley, 2009). Moreover, they seem to be less securely attached than healthy controls (Scharf, Oshri, Eshkol, & Pilowsky, 2014), and more sensitive to experienced injustice and social rejection (Bondü & Esser, 2015).

ADHD is widely treated with stimulant medication, most commonly methylphenidate compounds. The effectiveness of both stimulant and non-stimulant medications for reducing ADHD symptoms in both children and adults is well studied. Stimulants (methylphenidate and amphetamine) are more efficacious than non-stimulants (atomoxetine, guanfacine, and clonidine), so that stimulant treatment is the first choice if patients respond to it and do not show severe side effects. Stimulant treatment is well tolerated in the majority of patients. Stimulants modulate the action of dopamine in the brain by blocking the dopamine transporter, thus resulting in normalization of activations in fronto-striatal pathways (Faraone et al., 2015). Apart from pharmacological treatments, researchers as well as clinicians suggest behavioral interventions based on the principles of positive and negative reinforcement and social learning. Cognitive-behavioral psychotherapy is especially helpful in addressing parent-child interaction problems, problems in peer interaction, increasing self-management in keeping a structured learning environment, and problems resulting from co-morbid disorders. However, cognitive-behavioral treatments are recommended to complement, not replace, pharmacological treatment (Faraone et al., 2015). Neurofeedback training seems to positively affect symptoms of inattentiveness. However, these effects seem to be rather small (Faraone et al., 2015). There is also some evidence for positive, though small, effects of dietary interventions, especially supplementation with free fatty acids, on ADHD symptoms (Faraone et al., 2015).

1.1.2. Different Etiological Models for ADHD and the Endophenotype Concept

ADHD is a highly heritable disorder, with parents and siblings of ADHD patients showing a fivefold to tenfold increased risk to develop the disorder themselves, compared to the general population. Heritability estimates reach between 70-80%, thus suggesting a genetic influence on pathogenesis that is much higher than for most other psychiatric diseases. Symptoms of inattentiveness and hyperactivity/impulsivity show genetic correlations of about 0.6 (Faraone et al., 2015). However, the pathogenesis of ADHD is not dependent on the expression of one single genetic factor. Complex interactions of various different gene expressions seem to have a cumulative effect which accounts for the genetic risk to develop the disorder (Hawi et al., 2015). There are also genetic overlaps with symptoms of emotion dysregulation and with other psychopathologies, such as conduct disorder, cognitive impairment, autism spectrum disorders, and mood disorders (Faraone et al., 2015). Moreover, gene x environment interactions seem to play a key role when an individual presents a genetic vulnerability for ADHD (Geissler & Lesch, 2011). Environmental risk factors for the development of ADHD include severe early deprivation, family psychosocial adversity, and, importantly, maternal smoking during pregnancy (Castellanos & Tannock, 2002).

Concerning the association of certain candidate genes with the pathogenesis of ADHD, Hawi et al. (2015) in a recent review discuss a number of genes involved mostly in dopaminergic and serotonergic systems, and some glutamate receptor genes. Hawi et al. (2015) as well as others (Geissler & Lesch, 2011; Kiser, Rivero, & Lesch, 2015; Lesch et al., 2008) emphasize the importance of genome wide association studies in large samples that offer the possibility to identify the expression of multiple genetic factors. Those studies might help to incrementally get a better understanding of which genes might be involved in the pathogenesis of ADHD, to which extent, at which exact expressions, and in interaction with which other genes. However, as this is beyond the scope of this thesis, I want to concentrate on two candidate genes involved in the serotonergic system, which in some studies have been associated with ADHD symptoms on the one hand and affective abnormalities on the other hand (Franke et al., 2011), and are therefore of particular interest for my research question. The first gene which was of particular interest for me is the tryptophan hydroxylase-2 gene (TPH2), the rate-limiting enzyme that is important in serotonin synthesis and thereby modulates responsiveness of limbic brain circuits (Gutknecht et al., 2007). Walitza et al. (2005) reported an overexpression of the G-allele of SNP 25 of the TPH2 gene in children and adolescents diagnosed with ADHD. Baehne et al. (2009) found risk alleles of SNP 25 to be associated with altered prefrontal brain functioning during a response control task both in adult ADHD patients and healthy controls. Still, other studies found no differences in TPH2 expression in ADHD vs. healthy controls and no associations between ADHD symptoms and TPH2 expression (Franke et al., 2011). Another gene which was of particular interest for me is solute carrier family 6, member 4 (SLC6A4). SLC6A4 is a serotonin transporter gene. SNP 5-HTT of this gene can express a long allele (l) or a short allele (s). Müller et al. (2008) found the l-allele to be associated with increased severity of ADHD symptoms, particularly of affective dysregulation, when taking into account stressors, in an adult sample. Retz, Thombe, Blocher, Baader, & Rösler (2002) reported the l/l genotype (in comparison with s/l or s/s genotypes) to be associated with persistence of ADHD symptoms.

Over the course of time, a number of etiological models arose, trying to explain the pathogenesis of ADHD and development of symptoms across lifetime. Barkley (1997) first introduced a comprehensive theoretical model describing ADHD symptoms as the result of deficits in different executive functions. Though this model did not hold true after thorough empirical testing (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), it is interesting to note that Barkley (1997) considered not only cognitive deficits, but also deficits in self-regulation of affect, as important for the pathogenesis of ADHD.

Castellanos & Tannock (2002) first introduced the concept of endophenotypes modulating the pathogenesis of ADHD. Endophenotypes are heritable outlasting features of an individual which predict the individual's vulnerability to develop a certain disorder and which are closer related to underlying genetic characteristic than the phenotype of the disorder (Gottesman & Gould, 2003). Castellanos & Tannock (2002) stated in their very influential article that such endophenotypic psychological constructs, mediating the relationship between gene expressions and manifest phenotypes, should help to better understand the development of the disorder. Castellanos & Tannock (2002) suggested focusing on the description of endophenotypes that are based on neuroscientific findings. They introduced three endophenotypes which they considered relevant for ADHD and which were based on neuroscientific findings (delay aversion, deficits in temporal processing, and deficits in working memory). The two "pathways" underlying the phenotype of ADHD introduced by Sonuga-Barke (2002; poor inhibitory control, and delay aversion as a motivational style), which I explain in more detail below, might also be regarded as endophenotypes reflecting in neurological abnormalities, and seem to show at least partly also in unaffected relatives of ADHD patients (Pauli-Pott et al., 2014).

1.1.3.1. Different Endophenotypes for ADHD

Castellanos & Tannock (2002) suggested three endophenotypes that they considered relevant for the pathogenesis of ADHD: a *shortened delay gradient*, resulting in delay aversion, *deficits in temporal processing*, and *deficits in working memory.* The authors suggested putative underlying brain abnormalities for all three endophenotypes. In accordance with Sonuga-Barke (2002), Castellanos & Tannock (2002) defined delay aversion as "the intolerance for waiting that can manifest as a tendency to select an immediate reward over a larger reward for which the subject has to wait". Castellanos & Tannock (2002) suggested three putative brain abnormalities underlying delay aversion: excessive striatal dopamine transporter density, cerebellar vermis hypoplasia, or striatal lesions. Deficits in temporal processing reflect in poorer performance of ADHD patients compared to healthy controls in tasks that require sustained attention (Hall et al., 2015), and in abnormalities in reproducing temporal durations (Barkley, Koplowith, Anderson, & McMurray, 1997; Barkley, Murphy, & Bush, 2001). Deficits in working memory (especially in visual-spatial working memory) are mostly linked to abnormalities in dopaminergic prefrontal activations in Castellanos & Tannock's (2002) model. The authors conclude by emphasizing the necessity to detect and empirically test further endophenotypes possibly underlying the manifestation of ADHD symptoms.

Sonuga-Barke (2002) introduced a dual pathway model for ADHD, suggesting that the phenotype of ADHD might result from a dysregulation of action and thought due to *poor inhibitory control* associated with the meso-cortical branch of the dopamine system, or a motivational style, *delay aversion*, which in turn is associated with the meso-limbic branch of the dopamine system. He reviews in his original article Sonuga-Barke (2002) evidence for both pathways and concludes that poor inhibitory control and delay aversion might be "core, but unrelated, characteristics of AD/HD", resulting in two phenotypically identical or at least similar, but endophenotypically different subgroups of ADHD patients. In a later article, Sonuga-Barke (2005) confirms and extends this hypothesis, suggesting that the heterogeneity of the phenotype of ADHD might be due to multiple neurodevelopmental pathways, which might be crucial to disentangle for exact diagnosis and treatment of patients suffering from what we nowadays call ADHD. Empirical evidence for ADHD patients having problems in inhibitory control comes from studies using the stop signal paradigm. In this paradigm, participants need to inhibit an already initiated response to a certain signal (a "go signal") when presented with another signal (a "stop signal") shortly afterwards. ADHD patients in comparison with healthy controls show poorer performance in this paradigm, reflecting in a higher error rate and longer reaction times (Nigg, 1999; Oosterlaan & Sergeant, 1998). Studies using transcranial magnetic stimulation could show diminished cortical inhibition in ADHD patients (Hasan et al., 2013; Richter, Ehlis, Jacob, & Fallgatter, 2007), which emphasizes poor inhibitory control underlying the phenotype of ADHD on a neurological basis. The second pathogenic pathway suggested by Sonuga-Barke (2002), delay aversion, has been supported empirically in ADHD patients preferring immediate over larger, delayed rewards (Kuntsi, Oosterlaan, & Stevenson, 2001; Marco et al., 2009). Pauli-Pott et al. (2014) found increased delay aversion compared to healthy controls even in unaffected preschoolers with a family history of ADHD. Plichta et al. (2009) found neuro-functional evidence in line with the theory of diminished reward processing and increased delay aversion in an fMRI study with adult ADHD patients and healthy controls. The authors found hyporesponsiveness in ventral-striatal pathways of ADHD patients in both immediate and delayed reward processing, which are correlated with diminished positive emotionality in anticipation of a reward. Furthermore, they reported hyperactivation in dorsal caudate nucleus, correlated with subjective experiences of craving, wanting, or desire, and amygdala, correlated with an appetitive emotional state, in delayed reward processing of ADHD patients. Sjöwall, Roth, Lindqvist, & Thorell (2013), however, found no difficulties in delay aversion between children suffering from ADHD and healthy control children. However, they found difficulties between ADHD and healthy controls not only in executive functioning, including response inhibition and reaction time, but also in emotion recognition and emotion regulation capacities due to parent ratings. This leads me to the discussion of *emotional-motivational deficits* as an endophenotype for ADHD.

1.1.3.2. Emotional-motivational Difficulties as an Endophenotype for ADHD

Nigg & Casey (2005) introduced and integrative theory of ADHD, considering not only cognitive deficits, but also affective deficits and their neurodevelopmental correlates, as important in the pathogenesis and progression of ADHD symptoms. The authors state that ADHD patients suffer from deficits of *cognitive control* (which they define as "the ability to suppress inappropriate behaviors in response to contextual and temporal cues and adjust behavior accordingly"), and that those deficits are related to *affective responses*. They relate cognitive deficits to abnormalities in frontostriatal and frontocerebellar circuitries, and affective deficits to deviations in the frontoamygdala circuitry. This theory captures earlier ideas emphasizing the importance of affective dysregulation in ADHD (Barkley, 1997; Kramer & Pollnow, 1932; Wender, 1995), and integrates those difficulties into the endophenotype concept of the pathogenesis of ADHD. There is increasing evidence that emotional deficits seem to play a key role in ADHD. Both children and adults suffering from ADHD seem to have deficits in emotion processing (Conzelmann et al., 2009; Conzelmann et al., 2011) and emotion regulation (Bunford, Evans, & Wymbs, 2015). I will briefly review respective empirical findings later on.

Castellanos, Sonuga-Barke, Milham, & Tannock (2006) differentiated between "hot" and "cool" dysfunctions in ADHD patients. They referred to predominantly cognitive deficits as "cool" dysfunctions which are associated primarily with symptoms of inattentiveness, and to deficits in solving of problems with high affective involvement as "hot" dysfunctions which in turn are associated rather with symptoms of hyperactivity and impulsivity. This differentiation suggests that emotional dysfunctions might be an endophenotype for ADHD patients with predominantly hyperactive-impulsive and combined presentations, but not for ADD patients, with predominantly inattentive presentations. In fact, Maedgen & Carlson (2000) found emotional dysregulation in children suffering from combined-type ADHD, but not in the predominantly inattentive subtype, according to the DSM-IV. Conzelmann et al. (2009) found abnormal emotional responding in hyperactive/impulsive, and combined-type, but not in inattentive adult ADHD patients. However, findings on emotional dysfunctions being associated exclusively with symptoms of hyperactivity/impulsivity are ambiguous. Bunford, Evans, & Langberg (2014) found emotion dysregulation to be associated with social impairment in young adolescents with ADHD, irrespective of subtypes. Both inattentive and hyperactive/impulsive symptoms seem to be associated with psychophysiological hypoarousal (Clarke, Barry, McCarthy, Selikowitz, & Mark, 2001; Conzelmann et al., 2014).

Doyle et al. (2005) introduced *arousal deficits* as an endophenotype for ADHD, resulting in different motivational patterns. Sergeant (2005) postulated that ADHD patients in comparison to healthy controls show lower arousal levels both at baseline and in response to stimuli. He assumed that those differences in arousal might be responsible, at least in part, for ADHD symptoms like inhibition deficits, and that arousal deficits might be increased by motivational factors (Sergeant, 2005). In fact, Lazzaro et al. (1999) found reduced cortical arousal and reduced autonomic arousal (lower skin conductance level and less non-specific skin conductance responses) in male adolescent ADHD patients. Also Conzelmann et al. (2014) reported autonomic hypoactivity in boys suffering from ADHD. However, it seems to be unclear whether autonomic hypoarousal can be found also in females and in adults suffering from ADHD.

ADHD symptoms and emotional dysregulation are known to be associated with a number of social difficulties, including conflicts between parents and children, romantic difficulties, substance abuse, and risky sexual behavior (Bunford et al., 2015). Though highly important for the pathogenesis of ADHD and co-morbid disorders, emotional and social difficulties are under-investigated and further research on this topic is highly important. Therefore, this thesis aimed at further investigating emotion processing and emotion regulation in adult ADHD patients implementing social interaction. I will give a short introduction to emotion theory, defining emotion and emotion regulation, and the importance of social interactions for the induction and regulation of emotions.

1.2. Emotion Processing and Emotion Regulation

It is nowadays widely accepted that emotions and/or their regulation play a crucial role in the pathogenesis and persistence of a huge number of psychiatric diseases, and to some degree even in the occurrence or severity of bodily diseases. Therefore, emotional perception, acceptance of emotional states, and emotion regulation are a crucial part of many psychotherapeutic programs (Hayes, Luoma, Bond, Masuda, & Lillis; Hayes, Strosahl, & Wilson, 1999; Kabat-Zinn, 1982; Linehan, 1987; McCullough, 2000; Young, Klosko, & Weishaar, 2003). Moreover, the most efficacious emotion regulation strategies like cognitive reappraisal and acceptance are widely used as psychotherapeutic techniques (Beck, Rush, & Shaw, 1979; Ellis, 1989).

1.2.1. Definitions and Relevance for Everyday Life

Though intensely investigated and highly debated, *emotions* are not easily defined. (Cole, Martin, & Dennis, 2004) define emotions as "*appraisal-action readiness stances*", suggesting them to be "poised, oriented, ready, or inclined to a course of action". Gross (1998a, 1998b) pointed out in his process model of emotion generation that external or internal emotional cues elicit emotional response tendencies on three different levels: a behavioral level, an experiential level, and a physiological level.

Emotions importantly influence our everyday activities and vice versa. We feel different dependent on the situation we are in (i.e., sad when at a funeral vs. happy when at a birthday party), the way we perceive this situation, or the way we think about it. On the other hand, the way we feel influences the probability to which we may engage in certain activities. Thus we are much less likely to go out with a friend when in a sad, "depressed" mood than when we are happy and excited after a successfully passed exam. According to theories on the interplay between emotion and motivation (Bradley & Lang, 2000; Lang, 1995), this may be because sadness goes along with low psychological arousal and the activation of an aversive motivational system, whereas happiness, an emotional state associated with high psychological arousal, activates an appetitive motivational system. This fits with Russell's (1980) circumplex model of affect, later revised as the theory of core affects (Russell, 2003). This theory postulates that all emotions can be pinned down on two dimensions: pleasure-displeasure, and activation-deactivation.

Emotion regulation can be defined as "the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals" (Thompson, 1994). Most research has focused on deliberate emotion regulation. However, as Mauss, Bunge, & Gross (2007) pointed out, this might be too short-sighted, as individuals permanently engage in *automatic emotion regulation* which is pervasive in everyday life. In contrast to deliberate emotion regulation, automatic regulation might not require so many attentional resources, might not be volitional, and might not always be driven by explicit goals.

A very influential model on emotion regulation was established by James J. Gross (Gross, 1998a, 1999, 2002; see Figure 1). As mentioned above, Gross stated that emotional response tendencies on three different levels are triggered after the evaluation of emotional cues (which can be external or internal in nature). Those response tendencies, in a subsequent step, can be modulated and then result in emotional responses. Gross (1998a) distinguished between *antecedent-focused emotion regulation* (e.g. reappraisal) and *response-focused emotion* *regulation* (e.g. suppression). Antecedent-focused emotion regulation strategies can also be referred to as “input processes” of emotion regulation. They take place before a certain response tendency is formed by manipulating the input to the system. Response-focused emotion regulation, by contrast, refers to “output processes” of emotion regulation, as it affects already shaped response tendencies. Gross (1998a, 2002) differentiated various emotion regulation strategies which can step in at different points in the emotion generative process. Those are situation selection, situation modification, attentional deployment, cognitive change (which all are antecedent-focused regulation strategies), and response modulation (which is the only response-focused regulation strategy). *Situation selection* refers to the choice or avoidance of certain situations on the basis of their likely emotional impact. *Situation modification* refers to the modification of an environment as to alter its emotional impact. *Attentional deployment* refers to the focus of attention towards or away from something in order to influence one’s emotions. *Cognitive change*, also referred to as *reappraisal*, implies the reevaluation of either the situation or one’s capacity to manage the situation in order to alter one’s emotion. *Response modulation*, most commonly *suppression*, can imply any strategy suitable to “intensify, diminish, prolong, or curtail ongoing emotional experience, expression, or physiological responding” (Gross, 1998a). In general, antecedent-focused regulation strategies seem to be more effective at down-regulating negative emotional responses, especially on a physiological level (Gross, 1998a).

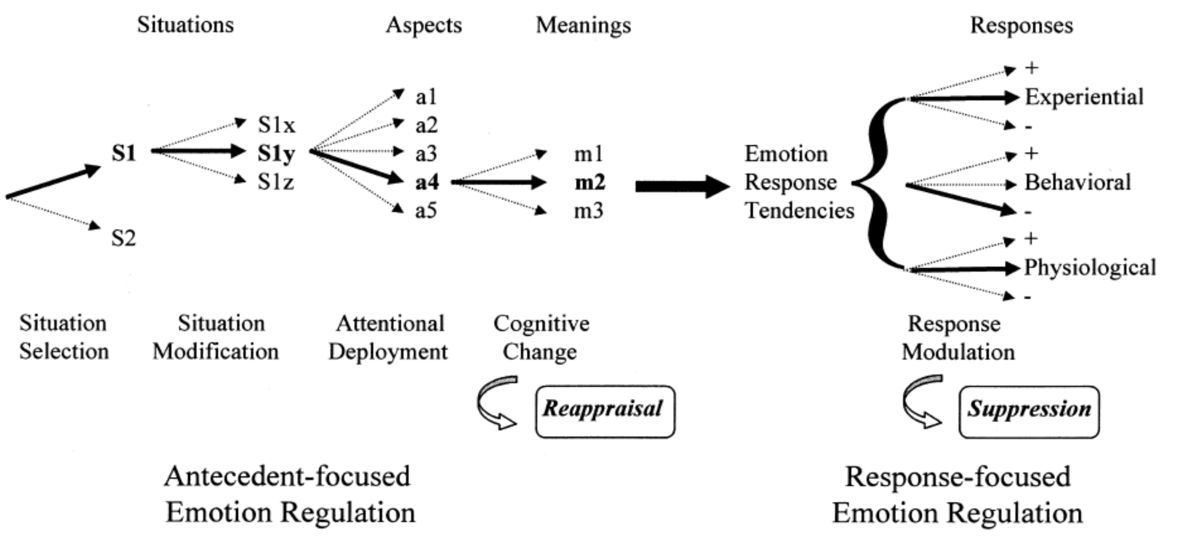

Figure 1. Process model of emotion regulation by James J. Gross.

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This model was adapted for automatic emotion regulation (Mauss, Bunge et al., 2007), stating that just like deliberate emotion regulation, automatic emotion regulation can involve changes at all levels of the emotion process. It can thus comply the exact same steps as deliberate emotion regulation (situation selection, situation modification, attentional deployment, cognitive change, and response modulation). Similarly to deliberate emotion regulation, automatic emotion regulation seems to be more adaptive when using antecedent-focused vs. response-focused strategies (Mauss, Bunge et al., 2007). Problems with emotion regulation, or “emotion dysregulation”, as it is sometimes called, result in multiple impairments and suboptimal functioning. Those problems can concern any or all aspects of the modulatory process of emotion regulation (Bunford et al., 2015). Individuals suffering from emotion dysregulation vary in the number and intensity of affected aspects.

König (2011) developed the so-called “Emotion Regulation Inventory” (“Emotions-regulationsinventar”, ERI) to assess habitually applied emotion regulation strategies in accordance with Gross’ (1998a, 2002) model when experiencing positive and negative emotions. The final version of that questionnaire, which was applied in one of the studies explained below, consists of eight sub scales. Those are “controlled expression of negative emotions”, “uncontrolled expression of negative emotions”, “empathic suppression of negative emotions”, “distraction from negative emotions”, “reappraisal of negative emotions”, “controlled expression of positive emotions”, “uncontrolled expression of positive emotions”, “empathic suppression of positive emotions”, “distraction from positive emotions”, and “expression of positive emotions”. The latter refers to the overall expression of positive emotions, including both controlled and uncontrolled expression.

1.2.2. The Relevance of Social Interactions for Emotion Processing and Emotion Regulation

Social interactions seem to play a key role when talking about emotions in two different ways: social interactions elicit emotions and emotions importantly influence our social interactions van Kleef & Fischer (2016). On the one hand, social interactions are important elicitors of emotional states (Godbold, 2015; van Kleef & Fischer, 2016). An experimental paradigm that has widely been used to study the influence of social ostracism on emotional experiences is the cyber ball paradigm (Williams & Jarvis, 2006). This paradigm consists of an ostensible online ball-tossing game where study participants are systematically ostracized by their ostensible co-players in some experimental conditions. Ostracism in this paradigm has been shown to induce negative affect in children, adolescents, and adults (Abrams, Weick, Thomas, Colbe, & Franklin, 2011; Barkley, Salvy, & Roemmich, 2012). This seems to reflect on a psychophysiological level. Ostracism goes along with increased skin conductance levels (Kelly, McDonald, & Rushby, 2012), increased electro cortical responses and corrugator activations (Kawamoto, Nittono, & Ura, 2013), and increased activity in the ventral anterior cingulate cortex (Bolling, Pelphrey, & Vander Wyk, 2012). Interestingly, Beeney, Franklin, Levy, & Adams (2011) found that the neural response in participants witnessing a friend being ostracized in the cyber ball paradigm was similar to the neural response when being ostracized themselves.

On the other hand, an individual's ability to deal with emotions adaptively seems to be crucially associated with the quality of social relationships (Coté, 2005; Godbold, 2015). Lopes et al. (2004) found a higher ability to manage emotions to be associated with the quality of interactions with friends and the perceived quality of interactions with opposite sex individuals. Gross & John (2003) reported an association between the habitual use of adaptive emotion regulation strategies and good interpersonal functioning.

The pathogenesis of some psychiatric disorders is strongly associated with outlasting painful, sometimes even traumatic social experiences. Consequentially, many patients suffering from divergent psychiatric disorders report major difficulties in their social relationships and have problems with social interactions. For example, borderline patients seem to emotionally react to ostracism in the cyber ball game stronger than healthy controls (Dixon-Gordon, Gratz, Breetz, & Tull, 2013; Lawrence, Chanen, & Allen, 2011b). Moreover, borderline patients showed a bias to feelings of rejection even in cyber ball inclusion blocks (Staebler et al., 2011). Masten et al. (2011) found that responsivity in the subgenual region of the anterior cingulate cortex (which was associated with depression in previous studies) was higher during cyber ball ostracism in youth with higher parent-reported depressive symptoms. Levinson, Langer, & Rodebaugh (2013) found that the reactivity to peer exclusion in the cyber ball game assessed with different questionnaires predicted social anxiety symptoms at a two month follow-up in a young adult sample. Bondü & Esser (2015) reported that children and adolescents suffering from ADHD are more sensitive to social rejection than control children. ADHD patients in their study stated to respond to peer rejection with higher levels of anxiety and anger than controls. Braaten & Rosen (2000) reported that boys diagnosed with ADHD have impairments in empathetic responding to interaction partners. Bunford et al. (2014) reported that various aspects of emotion dysregulation (emotional excitability/impatience, behavioral dyscontrol in the face of strong emotions, and inflexibility/slow return to baseline) are associated with social impairment in young adolescents with ADHD. They found those associations irrespective of ADHD subtype or co-morbid oppositional defiant disorder. Engel, Fritzsche, & Lincoln (2015) found that subclinical negative symptoms of schizophrenia (that comprise among others social withdrawal) are associated with more negative anticipated and recalled emotions in conjunction with social interactions. Individuals with higher negative symptom load anticipated more intense fear when experiencing social inclusion- or exclusion-interactions in a cyber ball game. Interestingly, participants with higher negative symptom load experienced and recalled more sadness related to being socially included and recalled more positive emotions after being excluded.

All in all, social interactions importantly influence our emotions in everyday life, and our emotions heavily influence the way we interact with others and the quality of our relationships (Godbold, 2015). It is therefore important to consider social aspects when investigating emotional reactions and an individual's capability to deal with those.

1.2.3. Emotional Reactions on Different Levels

As mentioned above, emotions are complex in nature and have components on different levels (Gross, 1998a, 2002; Schachter & Singer, 1962). I want to give a short overview over emotional reactions on experiential, physiological, and behavioral levels, in accordance with Gross' (1998a, 2002) model, and experimental methods to assess those reactions. I will start with the experiential level of emotional responses.

1.2.3.1. Experiential Responses

Widely used measures of emotional reactions on an experiential level in psychological studies are ratings of valence and arousal, typically given on likert scales. The underlying theoretical construct is the circumplex model (Russell, 1980) respectively the model of core affects (Russell, 2003) explained above. Participants are asked to rate on two dimensional scales how pleasant or unpleasant (valence scale) and how aroused (arousal scale) they feel. Another possibility to assess emotional responses on an experiential level are different types of questionnaires on emotional experiences. Most questionnaires typically applied in psychological research and for clinical purposes consist of different scales assessing different aspects of an individual's experiences with the help of several likert-scale items. A questionnaire applied for the assessment of emotional states in one of the experiments explained below is the Positive and Negative Affect Schedule (PANAS, Watson, Clark, & Tellegen, 1988; German version by Krohne, Egloff, Kohlmann, & Tausch, 1996). This schedule consists of two different scales, one measuring positive affect, and the other one negative affect, with the help of ten likert-scale items each. The theoretical and factor analytic concept underlying the PANAS is slightly different from Russell's (1980, 2003) deliberations. Watson et al. (1988) argued that, counterintuitively, positive and negative affect are not opposite factors, but rather represent orthogonal, thus independent, dimensions in factor analytic studies of affect. Thus, an individual can experience both positive and negative affect at the same time, to various degrees. Both high positive and high negative affect are marked by high psychological arousal, whereas low positive or negative affect goes along with low arousal.

1.2.3.2. Physiological Responses

Another level of emotional reactions, which was considered important already very early in emotion research (Bard, 1934; Cannon, 1928; James, 1884; Lange, 1887), contains bodily, or physiological responses. There are numerous ways to measure physiological responses, including heart rate, breath rate, and different parameters gained from those, muscle activity modulations, skin conductance modulations, electro cortical activity, or blood oxygenation levels in different parts of the brain. I want to shortly introduce the physiological measures applied in the studies below, facial muscle activity, and skin conductance alterations.

Facial Muscle Activity

Fridlund & Cacioppo (1986) introduced detailed guidelines for electromyographic research, covering the assessment of activations of a number of facial muscles. Activations of (facial) muscles are assessed with surface electrodes which are placed on the skin according to detailed anatomical knowledge. Two neighboring electrodes are attached on the skin to assess the activity of one muscle. Moreover, a ground (and dependent on the system sometimes also reference) electrode is positioned on the forehead (respectively behind the left and the right ear when applying ground and reference electrodes). This way, electric current flowing between the two electrodes placed above the relevant muscle can be assessed and recorded. Probably the most commonly assessed facial muscles in emotion studies are M. zygomaticus major (the muscle which pulls the lip corner up and back) as an indicator of positive affect, and M. corrugator supercilii (the muscle which knits the eyebrow) as an indicator of negative affect (Fridlund & Cacioppo, 1986). Facial EMG is typically recorded from the left side of the face as spontaneous emotional reactivity seems to be dominated by the right brain hemisphere and thus reflects stronger in the activation of left facial muscles (Dimberg & Petterson, 2000; Fridlund, 1988; Silberman & Weingartner, 1986). Participants seem to react to pleasant stimuli with zygomaticus activation and corrugator deactivation, and to unpleasant stimuli with corrugator activation (Baur, Conzelmann, Wieser, & Pauli, 2015; Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, 1990; Wu, Winkler, Andreatta, Hajcak, & Pauli, 2012). Thus, modulations of M. zygomaticus major and M. corrugator supercilii activations might, at least under some conditions, be interpreted as an implicit measure of emotional valence.

Skin Conductance Alterations

Skin conductance modulations reflect changes in electrodermal activity and can be interpreted as an implicit measure of emotional arousal (Boucsein, 2012; Lang, Greendwald, Bradley, &

Hamm, 1993). They are typically derived from different points of the palm of the non-dominant hand with the help of surface electrodes, but can also be derived from other parts of the body, for example the feet. There are various ways to record and preprocess skin conductance measures. Probably the most important distinction is the one between tonic skin conductance level and phasic skin conductance responses. Both measure the activity of sweat glands in the skin. Those in turn are innervated by sympathetic fibers of the autonomic nervous system. Sympathetic pathways are reversed in the hypothalamus in the brain, which in turn gets input from various brain structures, among those limbic regions involving the amygdala and the hippocampus. Consequently, intraindividual skin conductance modulations are known to occur not only as a means of thermoregulation, but also of emotional excitability (Boucsein, 2012). Tonic skin conductance modulations (assessed with changes in *skin conductance level*) are slow changes in electrodermal activity and reflect emotional reactions to a certain context or situation, rather than to an isolated stimulus. Phasic skin conductance modulations (assessed with *skin conductance responses*), by contrast, are rapid changes in electrodermal activity and reflect an acute emotional response to a stimulus. Both skin conductance levels and skin conductance responses have been shown to be elevated in response to emotional, compared to neutral situations or stimuli (Boucsein, 2012; Lang et al., 1993).

1.2.3.3. Behavioral Responses

Behavioral responses as an important part of emotional reactions are emphasized in the definitions and conceptualizations by Cole et al. (2004) and Bradley & Lang (2000) which I explained above. Again, there are numerous ways to assess behavioral responses, ranging from bodily movements to reaction times, approach or avoidance behavior, or the willingness to engage in prosocial behavior, as measured in amounts of money shared with others etc. I want to focus on behavioral responses assessed with systematic behavioral observation systems here, as I considered those especially suitable for my research question. Observation systems are usually applied with the help of videos that are watched by two independent observers who rate the appearance of certain behaviors defined in the system during pre-defined time intervals.

Probably the most known and most elaborated observation system when investigating emotional behavior is the Facial Action Coding System (FACS; Ekman, Friesen, & Hager, 2002). The FACS comprises detailed descriptions for the rating of activations in different “action units” of the face of an observed individual. Those action units are based on anatomical insights, rather than on subjective evaluations of certain muscle activations as emotional displays. Thus, a huge advantage of the FACS is its relative objectivity. However, as the application of this system requires time and money expensive training, I considered it too elaborate for my studies, aiming to investigate emotional reactions not only on a behavioral, but also on an experiential and a physiological level. Moreover, certain behaviors like vocal utterances or bodily movements cannot be coded in the FACS. A behavioral observation system introduced by Saarni (1984, 1992) seemed to be more suitable for my purposes. Saarni's (1992) system consists of four behavioral "aggregates": a positive aggregate, a negative aggregate, a tension/anxiety aggregate, and a social monitoring aggregate (Saarni, 1992). It has successfully been used in various behavioral observation studies, and even in studies investigating emotion regulation in children with ADHD (Maedgen & Carlson, 2000; Walcott & Landau, 2004).

The present thesis aimed at investigating emotion processing and emotion regulation in a comprehensive way, assessing emotional reactions on experiential, physiological, and behavioral levels.

1.2.4. Emotion Processing in Virtual Reality

For a long time, emotions in experimental studies have been induced primarily by emotional pictures (Lang, Bradley, & Cuthbert, 1997), sounds (Bradley & Lang, 2007), music (Khalfa, Isabelle, Jean-Pierre, & Manon, 2002), or films (Hewig et al., 2005). All those stimuli bring with them various advantages and disadvantages. One major advantage of using relatively simple stimuli for emotion induction in experimental settings is their high controllability. However, a major disadvantage of all those methods is their lack of ecological validity. The oversimplification of emotion elicitors to simple pictures or sounds might not always allow for a generalization of experimental findings into everyday life. Emotions elicited in laboratory settings might thus differ widely from those in natural settings, where far more complex situations, very often including social interactions, need to be processed. The introduction of virtual reality applications into psychological research might involve solutions to at least some of the shortcomings of classical methods. In the present thesis, a virtual reality paradigm involving social interaction for emotion induction was developed and tested.

To date, there is little systematic research on processing of different emotions in virtual reality. However, virtual environments have quite widely been applied for the induction of fear and anxiety, and in exposure therapy of related psychiatric disorders (Glotzbach-Schoon, Andreatta, Mühlberger, & Pauli, 2013; Opriş et al., 2012, Rothbaum, 2009, 2009; Shiban, Pauli, & Mühlberger, 2013; Shiban, Reichenberger, Neumann, & Mühlberger, 2015). Herrero, García-Palacios, Castilla, Molinari, & Botella (2014) and Baños et al. (2012) provided evidence that virtual environments seem to be suitable to induce positive emotions. Felnhofer et al. (2015) found emotional arousal (measured with electrodermal activity) to be induced in virtual park scenarios which were designed to evoke different affective states (joy, sadness, boredom, anger, and anxiety). Diemer, Alpers, Peperkorn, Shiban, & Mühlberger (2015) published a review on the impact of perception and presence on emotional reactions in virtual reality.

Presence in a virtual environment is "a subjective experience similar to a feeling" (Schubert, 2003). It is often assessed with the "Igroup Presence Questionnaire" (IPQ; Schubert, 2003) which consists of three subscales: spatial presence, involvement, and realness. *Spatial presence* refers to the degree to which an individual feels surrounded by a virtual environment, directly interacting in it. *Involvement* refers to the degree to which an individual puts his focus of attention on the virtual world, at an expense of attention for the real world. *Realness* (or "experienced realism") refers to how real the virtual environment is judged to be by an individual. Presence is not to be confounded with *immersion*, which covers rather objective, technological aspects of a virtual environment (Slater & Wilbur, 1997). Regenbrecht & Schubert (2002) could show that the possibility to interact in a virtual environment enhances presence experiences, especially spatial presence.

The degree to which an individual feels present in a virtual environment seems to importantly influence the intensity of experienced emotions in this environment (Diemer et al., 2015; Peperkorn, Diemer, & Mühlberger, 2015). Diemer et al. (2015) mark the associations found between presence and the intensity of induced emotions in virtual environments and underline the impossibility to derive causal relationships from previous research findings. Peperkorn et al. (2015) first provided evidence that increased presence in fact seems to cause an amplification of emotional reactions. In their study, presence in a first exposure trial correlated with fear in the second exposure trial, but fear in the first exposure trial did not correlate with presence in the second exposure trial.

1.3. Emotion Processing in ADHD

Abnormalities in emotion processing and emotion regulation in ADHD patients have long been neglected in research, with studies concentrating mostly on cognitive deficits. However, even if emotional deficits might not be specific for ADHD, they seem to be crucial and go along with serious impairment (Bunford et al., 2015). Therefore, it is important to address those difficulties in current and future studies to better understand specific strains of patients suffering from ADHD. Hopefully, a better understanding of associations between emotional difficulties and various symptoms of inattentiveness and hyperactivity/impulsivity will be helpful to develop deliberate and effective interventions, addressing not only cognitive and behavioral, but also emotional impairments of this patient group.

A number of studies point to ADHD patients having difficulties in emotion recognition in faces, voice, and bodily expressions (Cadesky, Mota, & Schachar, 2000; Ludlow, Garrood, Lawrence, & Gutierrez, 2014; Sjöwall et al., 2013), and in empathetic responding to interaction partners displaying emotions (Braaten & Rosen, 2000). Conzelmann et al. (2009) found abnormalities in emotional processing on a physiological level especially in adult ADHD patients of the predominantly hyperactive/impulsive, and combined subtypes, but not so much in predominantly inattentive patients. In their study, predominantly hyperactive/impulsive patients did not show attenuation of the startle response to pleasant pictures and startle potentiation to unpleasant pictures, compared to neutral pictures (which was the response pattern of healthy controls). ADHD patients of the combined type showed no startle attenuation to pleasant pictures, but responded with startle potentiation to unpleasant pictures, similar to healthy controls. Predominantly inattentive patients responded similarly as healthy controls. Herrmann et al. (2009) found diminished early posterior negativities (an event-related potential which is characterized by more negative values in response to emotional as compared to neutral stimuli) in adult ADHD patients vs. healthy controls after the presentation of pleasant, but not unpleasant pictures. Raz & Dan (2015) reported slower reaction times of adult ADHD patients vs. healthy controls in response to happy, but not to angry faces. Those findings point to ADHD patients responding differently than controls especially to pleasant, and not so much to unpleasant stimuli. This is in line with the theory of Sonuga-Barke (2002) suggesting delay aversion as an endophenotype for ADHD to result from differences in reward processing. Another study pointing in that direction is the one by Plichta et al. (2009) already mentioned above, who found diminished striatal activation in ADHD patients during immediate and delayed reward processing. This ventral-striatal hyporesponsiveness of ADHD patients was confirmed in a meta-analytic review on fMRI findings dealing with reward anticipation in ADHD (Plichta & Scheres, 2014).

However, there are a few studies suggesting that in some situations ADHD patients react differently than healthy controls also to unpleasant events. Braaten & Rosen (1997) investigated emotional reactions to reward and punishment on an experiential level, and their relationship to ADHD symptoms. They reported that adults showing high symptoms of ADHD responded lower to negative consequences than controls with low ADHD symptoms. Interestingly, this is in contrast with studies by Conzelmann et al. (2009, 2011, 2014) who never found differences in valence and arousal ratings in response to emotional pictures between combined-type ADHD patients and healthy controls. Moreover, Raz & Dan (2015) found differences in the manifestation of several event-related potentials (ERPs) in a facial oddball-paradigm, in response to happy, neutral, and angry faces in adult ADHD vs. healthy controls. They found P1 (associated with the processing of visual stimuli) to be increased in ADHD vs. healthy controls in response to emotional (both happy and angry), but not to neutral faces. N170 (associated with the neural processing of faces) in their study was more pronounced in response to angry than to happy faces in ADHD, and vice versa in healthy controls. P3 (an ERP mostly elicited in the oddball paradigm, associated with selective attention on rare or task relevant stimuli) was lower in ADHD vs. healthy controls in response to both emotional and neutral faces. Those findings suggest altered emotional responding in ADHD vs. healthy controls not only in response to pleasant but also to unpleasant stimuli, especially faces. Bondü & Esser (2015) reported children and adolescents suffering from ADHD to be more sensitive to social rejection than controls, reflecting in higher rumination and higher experience of negative emotions such as anger or anxiety, and going along with conduct problems. Bunford et al. (2015) reported that youth with ADHD seem to display both positive and negative emotions excessively.

While all those findings reflect abnormal valence modulations of emotional responses in ADHD patients, there are a number of studies indicating that in line with the assumptions of Doyle et al. (2005) and Sergeant (2005) introduced above, those patients also show differences compared to healthy controls in arousal modulations. Conzelmann et al. (2014) found diminished baseline skin conductance levels and lower skin conductance responses to pleasant, neutral, and unpleasant pictures in boys with ADHD compared to healthy controls. Those differences in physiological arousal reflect also in cortical measures. EEG studies found higher activations in low frequency bands (reflecting cortical dearousal) and lower activations in high frequency bands (reflecting cortical arousal) in frontal regions in children with ADHD than in controls (Barry, Clarke, Johnstone, McCarthy, & Selikowitz, 2009; Clarke, Barry, McCarthy, & Selikowitz, 1998; Snyder & Hall, 2006). EEG activations in adults with ADHD seem to be different from those in children, but are not quite understood yet (Clarke et al., 2008, Koehler et al., 2009, 2009; Snyder & Hall, 2006). Moreover, adult ADHD patients seem to be able to compensate for possible deficiencies in cortical arousal when presented with a cognitive task (Loo et al., 2009).

Edel et al. (2015) found emotion processing and alexithymia (difficulties in experiencing emotions) in adult ADHD patients of both predominantly inattentive and combined subtypes to be best predicted by attachment-related variables, and to a lesser extent by childhood and current ADHD symptoms. Especially “acceptance of own emotions” was predicted best by features of anxious and dependent attachment in current relationships, and recalled parental rejection and punishment, but not by ADHD symptoms, in predominantly inattentive and combined-type ADHD patients. “Experiencing being flooded with emotions” was also predicted by a number of attachment variables, as well as by childhood ADHD symptoms and current symptoms of inattentiveness. Those findings underline once more the importance of social interactions, in this case especially interactions with close loved ones, for the induction of emotions. Experiences of social interactions seem to not only influence how ADHD patients feel in the respective interaction situation, but also influence the quality and intensity of induced emotions in future (social) experiences.

1.4. EMOTION REGULATION IN ADHD

Although recently highly debated and widely discussed (Barkley, 2015), emotion regulation deficits in ADHD patients have hardly been investigated systematically. Bunford et al. (2015) pointed out that social impairment in ADHD patients (including risky behaviors like substance abuse, risky sex, and others) is associated with emotion dysregulation, and that emotion dysregulation characteristics might differentiate ADHD patients who respond well to state-of-the-art treatments from those who do not. Emotion dysregulation seems to occur at least in a subgroup of ADHD patients without co-morbidities, or independent of co-morbidities that are known to be associated with emotion dysregulation (like oppositional defiant disorder, depression, or bipolar disorder). There are to date not many well-conducted, controlled studies investigating emotion regulation capacities in ADHD patients. One reason for this is the unclear definition of emotion regulation. This leads to a confounding of theoretical concepts, especially of emotion processing and emotion regulation (Bunford et al., 2015). I will give a short overview over a few relevant studies when talking about emotion regulation in ADHD patients. Most of those studies focus on emotional reactions on the behavioral level, some additionally assessed rating data, very often including retrospective parent ratings rather than self-ratings of patients. Very few studies to date have included psychophysiological correlates of emotion regulation in ADHD patients.

Melnick & Hinshaw (2000) investigated emotion regulation and parenting in high- and low-aggressive ADHD and comparison boys and linked emotion regulation capacities to peer preference in a naturalistic summer camp. They found higher behavioral expressions of negative emotionality during a frustrating puzzle and less effective emotion regulation in highly aggressive ADHD patients than in low aggressive ADHD and healthy comparison boys. Moreover, they found negative emotional expressions to marginally predict social rejection by peers in the summer camp. Maedgen & Carlson (2000) found that combined-type, but not predominantly inattentive ADHD children show problems in emotion regulation when receiving an undesirable prize, reflecting in excessive positive and negative emotional behavioral expressions. In accordance with Melnick & Hinshaw (2000), they found emotion regulation to predict social status. Walcott & Landau (2004) found increased behavioral disinhibition and emotion regulation difficulties when instructed to hide their emotions during a frustrating peer competition in boys with ADHD compared to comparison boys. Again, those difficulties in emotion regulation reflected in increased emotional behavioral expressions.

Sjöwall et al. (2013) reported that children with ADHD have difficulties in regulating especially emotions of anger and sadness, according to parents' ratings. Sjöwall, Backman, & Thorell (2015) found ADHD symptoms to be correlated with deficits in cognitive, affective, and motivation-based regulation already in preschool children. Oliver, Han, Bos, & Backs (2015) found negative emotions and the ability to control emotions to be significant mediators for the relationship between hyperactive/impulsive symptoms and driving anger (anger experienced during driving), but not for the relationship between inattentive symptoms and driving anger in American college students. In the study by Edel et al. (2015) already mentioned above, "experiencing emotion regulation" was predicted by attachment style in both ADHD patients and healthy controls. Especially participants who recalled secure attachment histories with their mothers stated that they were more effective at regulating their emotions than participants who recalled insecure attachment histories with their mothers. Steinberg & Drabick (2015) also emphasized the importance of parenting behaviors as well as ADHD symptoms for the development and maintenance of emotion regulation difficulties in children suffering from ADHD. Van Eck et al. (2015) found emotion regulation deficits of accepting negative emotions, emotional awareness, and goal-oriented behavior, to moderate the effect of ADHD on suicidal ideation, in a non-clinical sample.

Musser et al. (2011) found that children suffering from ADHD did not show the same modulations of autonomic nervous system activation (measured with respiratory sinus arrhythmia and cardiac pre-ejection period) as healthy control children when not regulating or suppressing their positive and negative emotions induced with film clips. While respiratory sinus arrhythmia was elevated when experiencing negative emotions vs. positive emotions and higher when suppressing than when not regulating their emotions in healthy controls, ADHD children showed comparably high parasympathetic activity across all conditions. Matthies, Philipsen, Lackner, Sadohara, & Svaldi (2014) investigated regulation of film-induced sadness through two different emotion regulation strategies (expressive suppression or acceptance) in adult ADHD patients on an experiential level (ratings of sadness, feelings of being overwhelmed by emotions according to self-report) and a physiological level (heart rate, respiratory frequency, pulse transit time). They found that sadness ratings did not differ dependent on the applied emotion regulation strategy over the course of time, but ADHD patients who applied acceptance reported to feel less overwhelmed by their emotions than patients who applied suppression of emotional expressions. Sympathetic activity decreased over the course of time in both the expressive suppression and the acceptance group. Although this study made an important step, systematically comparing the effects of two different emotion regulation strategies on emotional responses on an experiential and a physiological level, I want to critically point out the lack of a healthy control group. Moreover, considering the reflections of Bunford et al. (2015) mentioned above, that not only negative but also positive emotions might be over-expressed in ADHD patients, it would be interesting to investigate the regulation of further negative, as well as positive emotions, in ADHD patients.

Apart from experiential and behavioral correlates of deficits in emotion processing and emotion regulation, it is important to address those deficits on a physiological level in the sense of Gross' (1998b, 2002) model. However, there is hardly any research addressing emotion processing and emotion regulation in ADHD patients with psychophysiological or even neuropsychological dependent variables. This leads me to the aim of my studies and my research questions.

1.5. Aim of the Studies and Main Hypotheses

I aimed to study emotion processing and emotion regulation in adult ADHD patients and matched healthy controls, thereby considering emotional reactions on different levels according to Gross' (1998b, 2002) model of emotion generation and emotion regulation: an experiential level, a physiological level, and a behavioral level. I was interested in the regulation of both positive and negative emotional states. Due to their relevance for everyday life, I concentrated on output processes of emotion regulation. For reasons outlined above, I considered social interactions to be especially important for emotion induction in healthy controls as well as in ADHD patients. I therefore developed a virtual penalty kicking paradigm implying hits and misses and subsequent feedback from a virtual soccer coach for emotion induction.

I hypothesized the following:

(I) Pleasant trials (hits and positive feedback from a virtual coach) induce positive emotions, unpleasant trials (misses and negative feedback from a virtual coach) induce negative emotions, compared to neutral trials. Respective emotional reactions show on experiential, physiological, and behavioral levels.

(II) ADHD patients, in comparison to healthy controls, differ in emotional responding to both pleasant and unpleasant trials. Patients respond weaker to pleasant trials and stronger to unpleasant trials than controls. Those differences reflect variously on experiential, physiological, and behavioral levels.

(III) ADHD patients are less effective than healthy controls at regulating their emotional reactions on experiential, physiological, and behavioral levels. Alterations in emotional reactions through response modulation are weaker in patients than in controls.

2. EXPERIMENTAL STUDIES

2.1. EMOTION PROCESSING IN VIRTUAL REALITY (EXPERIMENT 1)

2.1.1. Introduction

The aim of this study was to establish and validate a paradigm in virtual reality which is suitable to induce positive and negative emotional states with the help of social feedback. I considered this relevant for multiple reasons. First, paradigms in virtual reality show higher ecological validity compared to emotion induction with the help of simple images or sounds. Consequently, results from virtual reality studies should be better transferable into everyday life than results from classical paradigms (Campbell et al., 2009; Grewe et al., 2014; Jansari et al., 2014; Neguţ, Matu, Sava, & David, 2016). Moreover, I considered especially the induction of emotions through social feedback as crucial. We are social beings who are permanently exposed to human interactions and our moods and emotional states depend heavily on the way we perceive those interactions (Godbold, 2015). To keep the participants' motivation during participation high, a game-like structure to the experiment was realized. Throughout the experiment, participants played a virtual penalty kicking game and received feedback from a virtual soccer coach after each shot.

I expected hits and misses with subsequent emotionally congruent feedback from the virtual coach to induce positive and negative emotional states compared to a neutral control condition (teleportations to different spots of the virtual stadium). Positive and negative emotional reactions should be reflected on all levels according to (Gross, 1998b; Gross, 1999)' model of emotion generation. Those comprise an experiential level, a physiological level, and a behavioral level. In line with classical studies using images (Baur et al., 2015), sounds (Plichta et al., 2011), or film clips (Hewig et al., 2005) for emotion induction, I expected valence ratings to be more pleasant in response to hits and feedback than to neutral trials and less pleasant in response to misses and feedback than to neutral trials. For arousal ratings, I expected higher ratings after hits and misses and subsequent feedback than after neutral trials. Arousal ratings after hits and misses and subsequent feedback should be equally high. For M. zygomaticus major, I expected highest activations in response to hits and feedback and lowest activations in response to neutral trials. For M. corrugator supercilii, I expected highest activations in response to misses and feedback and lowest activations in response to hits and feedback. Those expectations were again based on findings of classical EMG studies using images for emotion induction (Baur et al., 2015; Lang et al., 1993; Larsen, Norris, & Cacioppo, John, T., 2003). For the modulation of skin conductance responses, I expected higher amplitudes in response to hits and misses and subsequent feedback than in response to neutral trials. Skin conductance responses should be comparably high in response to hits and feedback vs. misses and feedback. Again, those expectations were based on studies using emotional pictures for emotion induction (Amrhein, Mühlberger, Pauli, & Wiedemann, 2004; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Lang et al., 1993). For behavioral observations reflecting positive affectivity according to a categorical observation scheme (Saarni, 1984, 1992), I expected highest observation rates in response to hits and feedback and lowest observation rates in response to neutral trials. For behavioral observations reflecting negative affectivity, I expected highest observation rates in response to misses and feedback and lowest observation rates in response to neutral trials. I expected that experienced presence in the virtual soccer stadium would correlate positively with the intensity of emotional reactions.

2.1.2. Methods

2.1.2.1. Participants

In the first study there were 27 healthy participants, mostly students from the University of Würzburg. Each participant received either course credit or a small payment for participation. Data of one participant had to be excluded from the analyses due to technical problems, resulting in a total sample of 26 data sets (16 female). The age of the participants ranged from 19 to 54 years (M = 25.19, SD = 6.88) and all reported normal or corrected to normal vision and no hearing disabilities. All participants gave their written informed consent. The study was approved by the ethics committee of the University of Würzburg.

2.1.2.2. Virtual Environment, Stimulus Material and Apparatus

To induce pleasant and unpleasant emotional states, participants played soccer in a virtual stadium that was designed at the Department of Psychology I at the University of Würzburg especially for the purpose of the studies presented here. The stadium was modeled with Blender 2 (https://www.blender.org/) and Hammer software (Tasmania, Australia) and the Source Engine from the Valve Corporation (Bellevue, Washington, USA). The task of the participants was to take penalty kicks at the virtual goal with a joystick (Mad Catz IV; Mad Catz Inc., San Diego, California). Participants could control the direction of their shot on two axes.

The virtual environment was stereoscopically projected onto a 0.325 x 0.2 m power wall (3Dims GmbH, Frankfurt, Germany) using two projectors (projection design F32, resolution: WUXGA, 1920x1200; projection design as, Gamle Fredrikstad, Norway). To see the screen stereoscopically, participants wore passively circular polarized glasses. The 3D presentation was enabled with the help of VrSessionMod 0.5, a modification of the Source Engine (Source SDK, Valve Corporation, Bellevue, Washington, USA). This modification was developed at the Department of Psychology I of the University of Würzburg. The experiment was operated with the software CyberSession CS-Research 5.6.23 beta (VTplus GmbH, Würzburg, Germany).

Pleasant and unpleasant trials consisted of penalty kicks at the virtual goal and subsequent feedback from a virtual soccer coach. In pleasant trials, the virtual goal keeper failed to catch or deflect the ball and the participant scored a goal (hits). In unpleasant trials, the goal keeper saved the shot and the participant did not score a goal (misses). The virtual goal keeper was controlled by a computer algorithm, so that 50 % of all emotional trials were hits and 50 % were misses. As neutral comparison trials, participants were presented with ten different spots of the soccer stadium for 4 s, each.

Pleasant feedback phrases followed hits, unpleasant feedback phrases followed misses. 36 pleasant (e.g., "Great goal!") and 36 unpleasant (e.g., "You loser!") phrases were recorded beforehand with Audacity 2.0.3 (http://sourceforge.net/projects/audacity/). Pleasant and unpleasant phrases did not differ in the number of syllables ($t[70] = 1.39$, $p = .170$) or absolute length in seconds ($t[70] = 0.99$, $p = .326$); see A 2 for a list of the original feedback phrases used in experiment 1). Verbal instructions were also recorded with Audacity 2.0.3 (http://sourceforge.net/projects/audacity/). The feedback phrases as well as the verbal instructions were presented with an audio amplifier (Natural Sound AV Receiver AX-V565, Yamaha Corporation, Hamamatsu, Japan).

Ratings of emotional valence and arousal were assessed with 9-point likert scales. On the valence scale, 1 indicated "very unpleasant" and 9 indicated "very pleasant". On the arousal scale, 1 indicated "not arousing at all" and 9 indicated "very arousing". Rating scales were the same for pleasant, neutral, and unpleasant trials. The original rating scales are implemented in the instructions (see A 6).

An embodied agent provided by the Valve Corporation (Bellevue, Washington, USA) and modified at the Department of Psychology I of the University of Würzburg served as a model for the virtual coach. The goal keeper model an adapted version of a simple model from Blend Swap LLC (http://www.blendswap.com/). Facial expressions (lip synchronizations and emotional expressions) of the coach model were animated with Source SDK Face Poser (Valve Corporation, Bellevue, Washington, USA). Bodily movements of the goal keeper model and the ball animations were provided by VTplus GmbH (Würzburg, Germany). Eight different animations directed the goal keeper to jump to different locations of the goal (center_high, right_high, right_center, right_low, center_low, left_low, left_center, left_high). The different goal keeper animations were triggered by a special computer algorithm which was developed by VTplus GmbH (Würzburg, Germany) in cooperation with the Department of Experimental Psychology, Clinical Psychology and Psychotherapy (University of Regensburg). The algorithm recognized the direction of the shot elicited by the participant with the help of the joystick. In unpleasant trials, the animation with the goal keeper jumping in exactly the same direction as the participant had scored was triggered. The goal keeper consequently saved the penalty kick in these trials. In pleasant trials, one out of the seven remaining animations was triggered by chance. The goal keeper consequently did not save the penalty kick in these trials.

2.1.2.3. Procedure and Design

When they arrived in the laboratory, participants were welcomed by the experimenter. Participants were seated in a chair approximately 2.5 m from the power wall. They read the information form (see A 3) and gave their written informed consent on participation (see A 4). Then they filled in a short sociodemographic questionnaire (see A 5) and after that washed their hands with pure, soapless water. The experimenter attached the electrodes for psychophysiological measurements and explained to the participant how to control the experiment with the joystick (Mad Catz IV; Mad Catz Inc., San Diego, California) and the keyboard[1]. Afterwards, she dimmed the light in the room and started the experiment.

Participants were instructed visually on the power wall and verbally via loudspeakers to imagine themselves to be participating in the final match of an important tournament and having to take the deciding penalty kicks. If they scored enough goals, the whole team would win the match. If not, the whole team would lose (see A 6 for the original instructions).

The trial structure of neutral trials is depicted in Figure 2. Before the penalty kicks, participants were teleported to ten different spots in the stadium for 4 s each. Participants could freely look around from those spots, but could not move in the virtual environment during those 4 s. The emotional reactions to those ten trials served as a neutral baseline in comparison to pleasant and unpleasant trials during the penalty kicking part. After each teleportation, participants were asked to rate the subjective valence and arousal of the spot they had just seen. Facial muscle activity and skin conductance were recorded during the teleportation. There then followed about 5s for rating and an intertrial interval (ITI) of 7s.

[1] The keyboard with which participants could rate their emotions during the experiment1 was a simple computer keyboard with all buttons covered by cardboard except the numbers 1 to 9.

Afterwards, participants went through three blocks of penalty kicking with 12 pleasant and unpleasant trials each. The trial structure of pleasant and unpleasant trials is depicted in Figure 2. Pleasant and unpleasant trials were presented in a pseudorandomized order to prevent order effects. Feedback phrases in the different blocks of the experiment did not differ in number of syllables (ts < 0.44, ps > .663) or absolute length (ts < 0.47, ps > .641).

After the end of each feedback phrase there was a 4 s period during which the coach was still visible with a facial expression appropriate to the feedback phrase just given. The participants then rated the subjective valence and arousal of the feedback they had just got.

After the main experiment, the experimenter took off the electrodes. Participants then filled in questionnaires on their general experiences throughout the experiment (A 7) and their experience of soccer and computer games (A 8) as well as the German version of the Igroup Presence Questionnaire (Schubert, 2003). Before leaving, participants were debriefed and received either course credit or 10 € for their participation. The whole experiment lasted approximately 100 min. An overview of the procedure applied in experiment 1 is given in Figure 2.

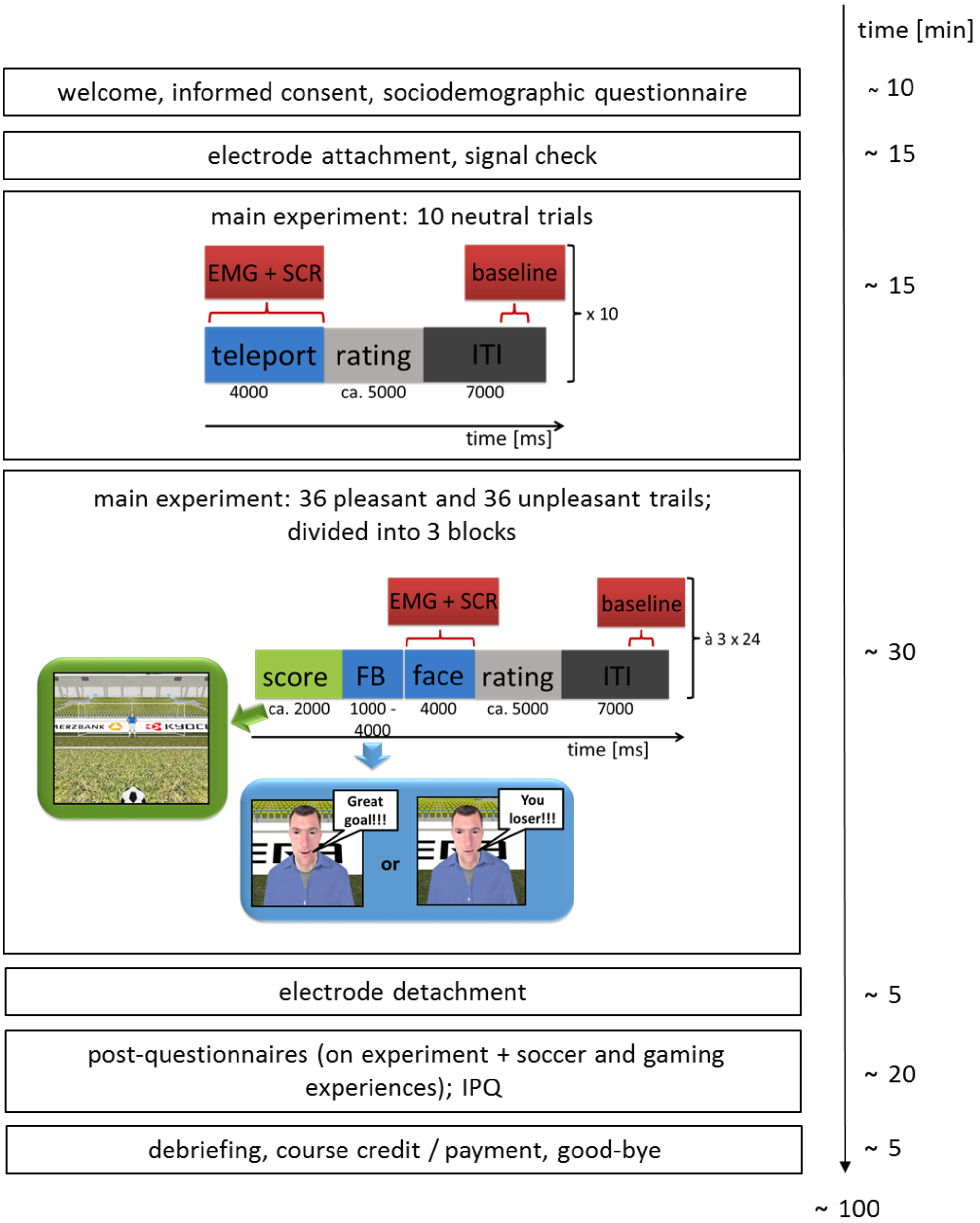


Figure 2. Procedure of experiment 1.

"teleport" = teleport to one out of 10 spots in the soccer stadium; "Score" = kicking at the goal with the joystick; "FB" = feedback from the virtual coach; "face" = period after the feedback during which coach was still showing an emotional facial expression; "rating" = rating of emotional valence and arousal, "ITI" = intertrial interval (black screen); "EMG" = measurement of facial muscle activity in response to teleport picture; "SCR" = measurement of skin conductance responses, "baseline" = baseline measurement of facial muscle activity and skin conductance.

2.1.2.4. Data Recordings and Data Reduction

Physiological data

Physiological data was recorded continuously with 5 mm Ag/AgCl electrodes with a 1000 Hz sampling rate. Ground and reference electrodes were attached behind the right and left ear. For measurement of M. corrugator supercilii activations, the experimenter attached two electrodes over the left eyebrow. For M. zygomaticus major activations, she attached two electrodes over the left corner of the mouth. EMG electrodes were attached according to the guidelines reported by Fridlund & Cacioppo (1986). Skin conductance electrodes were attached on the thenar and hypothenar eminence of the non-dominant hand according to a standard procedure described in Boucsein (2012). Data was recorded with BrainVision Recorder software (Brain Products GmbH, Gilching, Germany) and a V-Amp 16 amplifier (Brain Products GmbH, Gilching, Germany). We used the skin purification gel “Skin Pure” (Nihon Kohden Corporation, Tokyo, Japan) and Softasept® N ethanol-propanol compound (Braun Melsungen AG, Melsungen, Germany) to purify the skin positions where EMG electrodes should be attached. To attach EMG electrodes, we used Sigma Creme Electrode Cream (Parker Laboratories Inc., Fairfield, USA). We kept impedances of EMG electrodes below 10 kΩ. To attach skin conductance electrodes, we used EDA-Paste TD-246 (PAR Medizintechnik GmbH, Berlin, Germany).

Physiological data was preprocessed with BrainVision Analyzer 2.1 (Brain Products GmbH, Gilching, Germany) according to a standard procedure described among others in (Wu et al., 2012). I applied a 30 Hz highpass filter, a 500 Hz lowpass filter, and a 50 Hz notch filter to the raw EMG data. Afterwards, I applied a 125 ms moving average filter to rectify and smooth the data. To the raw skin conductance data, I only applied a 50 Hz notch filter. After filtering, the EMG and skin conductance data were segmented. For neutral trials, the continuous data was cut into 10000 ms segments lasting until the end of the teleport pictures. For pleasant and unpleasant trials, the continuous data was cut into 16000 ms segments lasting until the disappearance of the virtual coach (after the “face” period in Figure 2). Those segmentations were chosen to have long enough segments for baseline correction. A 1000 ms interval extracted from the end of the ITI served as a baseline for EMG activity and SCRs. I subtracted the mean activity during this baseline period from mean EMG activations and mean SCRs during the segments described above. This baseline correction is similar to studies using pictures for emotion induction (Conzelmann et al., 2014; Wiemer, Gerdes, & Pauli, 2013; Wu et al., 2012). To exclude from further analyses trials with strong artifacts during baseline (+/- 8 µV), I applied an artifact correction to the EMG data. To exclude from further analyses trails with strong artifacts during measurement segments (+/- 30 µV), I applied an artifact rejection to EMG data. For neutral trials, I exported for statistical analyses the average activity of M. zygomaticus major and M. corrugator supercilii as well as the highest skin conductance peaks during the 4000 ms at the “teleport” spot. For pleasant and unpleasant trials, I exported average muscle activities and highest skin conductance peaks for the 4000 ms after the end of the feedback phrase during which the virtual coach was still present ("face" period in Figure 2). The export segments were comparable to studies using images for emotion induction (Baur et al., 2015; Gavazzeni, Wiens, & Fischer, 2008; Wu et al., 2012). Skin conductance responses smaller than 0.01 µS were classified as null responses and equated with 0 as described in Gavazzeni et al. (2008). For statistical analyses, I computed averages of mean muscle activations and skin conductance responses over all trials of one experimental condition. To get normally distributed data, I applied a logarithmic transformation onto mean skin conductance responses (log[1+SCR]), as described in previous studies (Conzelmann et al., 2014; Gavazzeni et al., 2008).

Behavioral observations

Facial expressions of the study participants were videotaped with a camcorder (Sony DCR-SR72E; Sony Corporation, Tokyo, Japan). One video was excluded from analyses due to bad picture quality, so that only data of 25 participants remained for the analyses of behavioral observations.

Video data was analyzed by two independent raters according to a coding scheme adapted from (Saarni, 1984, 1992). I adapted the original scheme after carefully watching the videos and extensive literature research on observational coding of emotional facial expressions. Thereby, I deliberately decided not to use the "Facial Action Coding System" (Ekman et al., 2002) as it seemed too elaborate for my purpose and would have overstrained my resources. However, (Saarni, 1992)'s scheme was particularly feasible and applicable even in a series of studies combining ratings of subjective experience, observational coding and psychophysiological measurements on a trial-by-trial basis. To make the coding scheme as fitting and economical as possible, I reduced it to those categories that were relevant for my studies. Moreover, I concentrated only on those categories included in the positive and negative aggregate by (Saarni, 1992), as I was primarily interested in the valence of the emotional expressions. Moreover, I implemented two categories ("nodding" and "shaking of head") that did not occur in Saarni's original system but that I considered relevant after watching the videos. The different observational categories of the coding scheme are depicted in Table 1.

Two trained undergraduate students watched the videos and rated the occurrence of emotional behavior according to the coding scheme. The two raters watched the videos independently and rated whether or not a certain behavior was shown by the study participants in every single trial (1 = "specific behavior was shown by the participant", 0 = "specific behavior was not shown by the participant"). I calculated Cohen's Kappa coefficients for the different observational categories as a measure of interrater reliability according to the standard formula (Grouven, Bender, Ziegler, & Lange, 2007; Landis & Koch, 1977). Coefficients were interpreted according to the standards described in Landis & Koch (1977). Coefficients < .00 accordingly represent "poor" agreement between the two observers. Coefficients .00-.20 represent "slight" agreement, .21-.40 represents "fair" agreement, .41-.60 represents "moderate" agreement", .61-.80 represents "substantial" agreement, and .81-1.00 represents "almost perfect" agreement between the two observers. All but one category ("nodding") revealed satisfying interrater reliabilities. Furthermore, I calculated Cronbach's Alpha coefficients (Cronbach, 1951) of the same categories and of the system in total as a measure of internal consistency. All but one category ("shaking of head") revealed satisfying internal consistencies according to the standards mentioned in George & Mallery (2003). They define coefficients < .5 as "unacceptable", coefficients > .5 as "poor", coefficients > .6 as "questionable", coefficients > .7 as "acceptable", coefficients > .8 as "good", and coefficients > .9 as "excellent". See Table 1 for an overview over all Cohen's Kappa and Cronbach's Alpha coefficients. I conducted further analyses only for those categories that revealed at least "moderate" interrater reliability and "acceptable" internal consistency according to the standards described above.

Table 1. Interrater reliabilities and internal consistencies of the behavioral observation system used in experiment 1.

	Behavioral Category	**Cohen's Kappa**	**Cronbach's Alpha**
Positive Aggregate	Relaxed, broad smile (teeth show or lips parted)	.860	.973
	Raised eyebrows	.876	.862
	Giggling or laughing	.677	.724
	Nodding	.202	.930
Negative Aggregate	Down-turned mouth (as in a frown or grimace)	.520	.773
	Pressing, pursing, biting or sucking of lips	.869	.947
	Sharp breath exhalation, snoring, grumping, or groaning, sighing	.982	.953
	Shaking of head	.443	.639

For further analyses, I averaged the absolute number of each behavioral category over pleasant, neutral, and unpleasant trials.

2.1.2.5. Statistical Data Analysis

Statistical data analyses were conducted with the software SPSS Statistics 23 (IBM Deutschland GmbH, Ehningen, Germany). To test the effect of hits or losses and respective feedback vs. teleports to different spots on emotional reactions, I conducted repeated measures ANOVAs with the within-subjects factor emotion (pleasant vs. neutral vs. unpleasant). I reported Greenhouse-Geisser corrected degrees of freedom and *p*-values whenever the assumption of sphericity was violated. I further analyzed significant main effects with post-hoc two-tailed *t*-tests and Bonferroni-corrected *p*-values. I conducted these analyses for dependent variables on different levels according to Gross' (1998b, 1999) model of emotion generation. In this case, those were valence and arousal ratings, facial muscle activity of M. zygomaticus major and M. corrugator supercilii, skin conductance responses, and the different categories of the behavioral observation system described above. For valence ratings, I additionally conducted one-tailed *t*-tests to test if the mean rating values after pleasant, neutral, and unpleasant trials differed significantly from 5, which was the mean of the valence scale and which I therefore considered as a "neutral" valence.

To compare IPQ scores in my experiment with the scores of a representative sample (http://www.igroup.org/pq/ipq/data.php), I conducted independent sample *t*-tests. To test if there was a relationship between age or presence in the virtual environment and emotional reactions, I conducted bivariate correlations between age and the different dependent variables as well as between the different IPQ scores (Schubert, 2003) and the dependent variables. To test for gender influences on emotional reactions, I conducted split plot ANOVAs with the within-subjects factor emotion and the between-subjects factor gender. To test for the influence of soccer and gaming experiences on emotional reactions, I conducted the same split plot analyses, with the between-subjects factors "soccer fan", "sports club member", "frequency of console playing", and "fondness of console playing". The data of soccer and gaming experiences were collected with the questionnaire in A 8. I conducted all split plot ANOVAs subsequently for the data collected on the different dependent variables explained above. For significant between-factor main effects and interactions, I then calculated post-hoc two-tailed *t*-tests with Bonferroni-adjusted significance levels.

2.1.3. Results

2.1.3.1. Ratings

Means and standard errors of valence and arousal ratings after pleasant, neutral, and unpleasant trials are depicted in Figure 3. The analyses of the valence ratings revealed a significant main effect for emotion ($F[2,50] = 92.25$, $p < .001$, $\eta_p^2 = .79$) due to highest ratings after pleasant trials and lowest ratings after unpleasant trials (*t*s > 3.30, *p*s < .003). The analyses of the arousal ratings also revealed a significant main effect for emotion (F[1,38] = 21.75, $p < .001$, $\eta_p^2 = .47$, $GG\text{-}\varepsilon = .77$). This effect was due to higher ratings after pleasant and unpleasant, compared to neutral trials (ts > 4.58, ps < .001) and comparably high ratings after pleasant and unpleasant trials (t[25] = 1.08, $p = .292$).

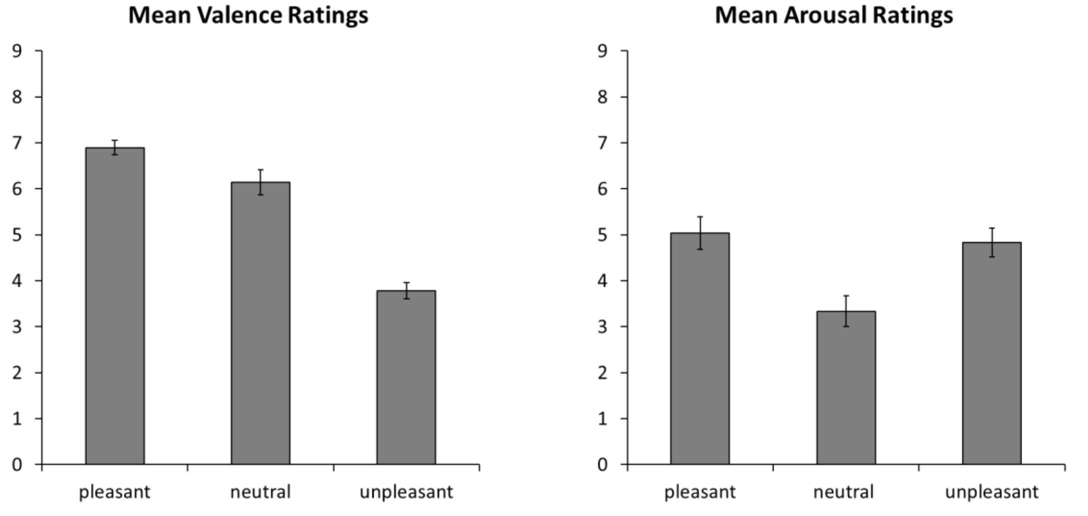


Figure 3. Means and standard errors of valence (left) and arousal (right) ratings after pleasant, neutral, and unpleasant trials in experiment 1.

One-tailed t-tests revealed that the valence ratings after pleasant, neutral, and unpleasant trials all differed significantly from 5 (ts > 4.21, ps < .001). Valence ratings after pleasant and neutral trials were higher than 5. Valence ratings after unpleasant trials were lower than 5.

2.1.3.2. Psychophysiological Recordings

Facial Muscle Activity

Mean zygomaticus and corrugator activations during pleasant, neutral, and unpleasant trials are depicted in Figure 4. The analyses of zygomaticus activations revealed a marginally significant main effect for emotion (F[1,44] = 3.24, $p = .055$, $\eta_p^2 = .12$, $GG\text{-}\varepsilon = .88$). Exploratory post-hoc t-tests revealed that mean zygomaticus activations during pleasant and unpleasant trials were higher than during neutral trials (ts > 2.11, ps < .045). Zygomaticus activations during pleasant and unpleasant trials were comparably high (t[25] = 0.61, p = .547). The analyses of corrugator activations also revealed a marginally significant main effect for emotion (F[1,42] = 2.65, $p = .091$, $\eta_p^2 = .10$, $GG\text{-}\varepsilon = .84$) with lower activations in response to pleasant and unpleasant, compared to neutral trials.

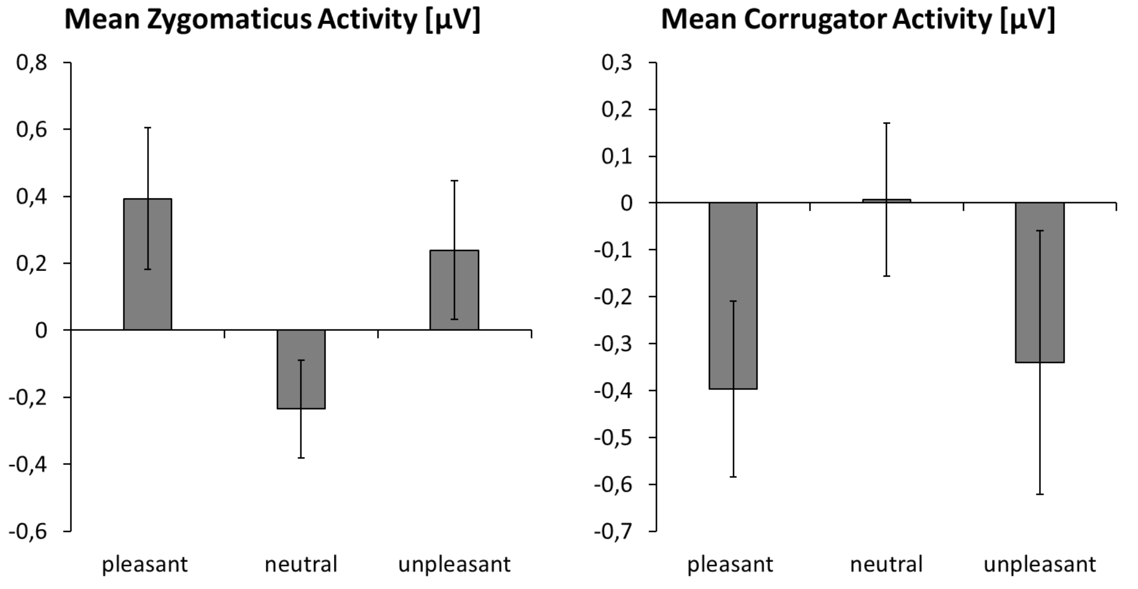


Figure 4. Mean activations and standard errors of M. zygomaticus major (left) and M. corrugator supercilii (right) in pleasant, neutral, and unpleasant trials in experiment 1.

Skin Conductance Responses

Means and standard errors of logarithmic skin conductance responses (SCRs) are depicted in Figure 5. The analysis of SCRs revealed no significant main effect for emotion ($F[1,40] = 0.80$, $p = .431$, $\eta_p^2 = .03$, $GG\text{-}\varepsilon = .80$).

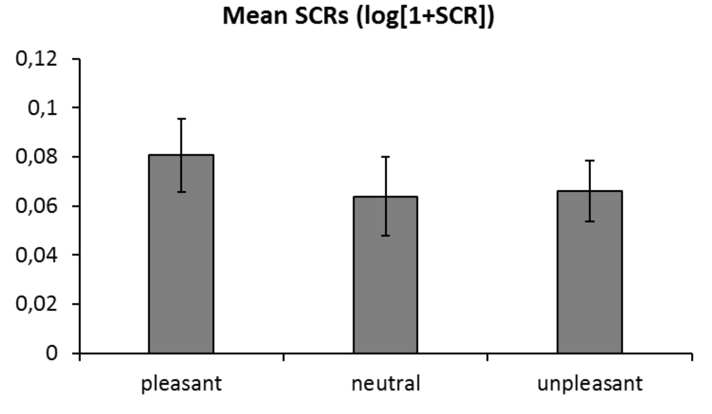
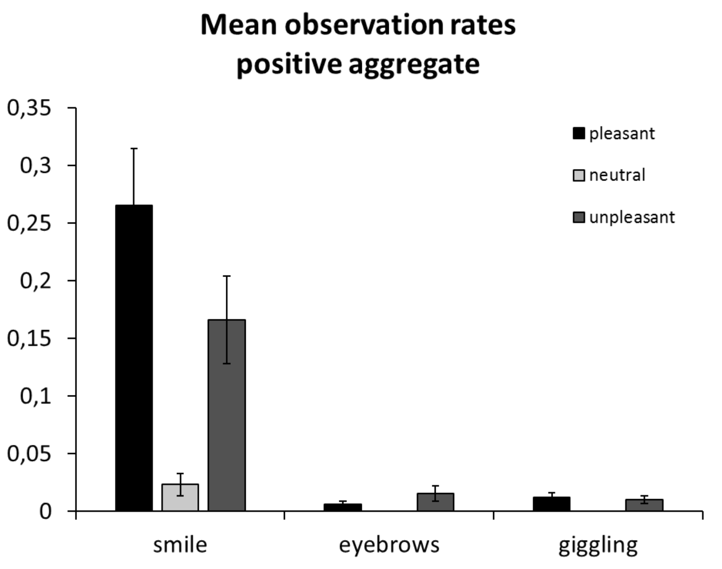


Figure 5. Means and standard errors of logarithmic skin conductance responses during pleasant, neutral, and unpleasant trials in experiment 1.

2.1.3.3. Behavioral Observations

Figure 6 depicts mean observation rates and standard errors of the six behavioral categories with satisfactory interrater reliabilities and internal consistencies. For “relaxed, broad smile”, the analyses revealed a significant main effect for emotion ($F[2,48] = 13.15$, $p < .001$, $\eta_p^2 = .35$) due to highest observation rates during pleasant trials and lowest observation rates during neutral trials (*t*s > 2.12, *p*s < .044). For “raised eyebrows”, I found a significant main effect for emotion ($F[1,29] = 4.29$, $p = .040$, $\eta_p^2 = .15$, $GG\text{-}\varepsilon = .61$) due to higher activations during pleasant and unpleasant, compared to neutral trials (ts > 2.11, ps < .046). Observation rates during unpleasant trials were marginally higher than during pleasant trials ($t[24] = 1.72$, $p = .098$). For "giggling or laughing", there was also a significant main effect for emotion ($F[2,48] = 5.40$, $p = .008$, $\eta_p^2 = .18$). This effect was due to higher observation rates during pleasant and unpleasant, compared to neutral trials (ts > 2.92, ps < .008) and comparably high rates during pleasant and unpleasant trials ($t[24] = 0.39$, $p = .700$).

For "mouth turned down", I found a significant main effect for emotion ($F[1,24] = 12.61$, $p = .002$, $\eta_p^2 = .34$, $GG\text{-}\varepsilon = .51$) due to highest observation rates during unpleasant trials and lowest observation rates during neutral trials (ts > 2.14, ps < .043). For "pressing, pursing, biting or sucking of lips", the main effect for emotion was significant ($F[1,41] = 4.30$, $p = .025$, $\eta_p^2 = .15$, $GG\text{-}\varepsilon = .86$) due to higher observation rates during unpleasant compared to pleasant trials ($t[24] = 3.68$, $p = .001$). Observation rates during unpleasant trials were slightly higher than during neutral trials ($t[24] = 1,71$, $p = .101$). Observations rates during pleasant and neutral trials were comparably low ($t[24] = 1.02$, $p = .319$). For "grumping", I found a marginally significant main effect for emotion ($F[1,24] = 3.11$, $p = .090$, $\eta_p^2 = .12$, $GG\text{-}\varepsilon = .50$) with highest observation rates during unpleasant trials and lowest observation rates during neutral trials.



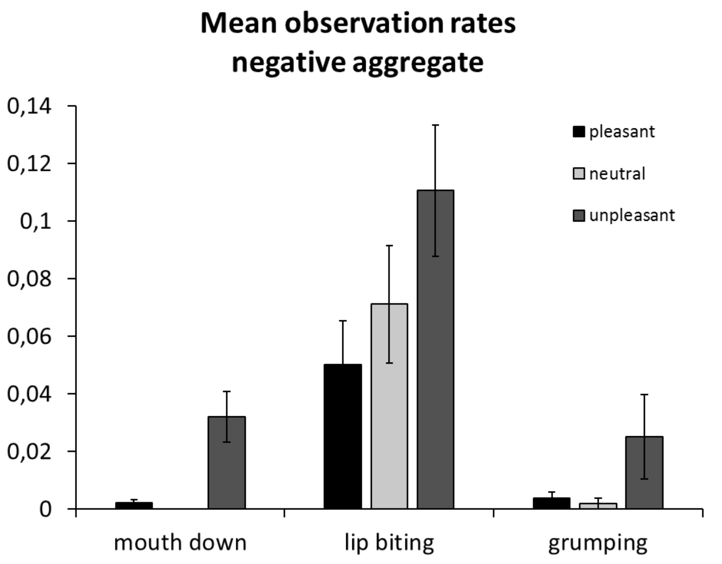


Figure 6. Mean observation rates and standard errors of behavioral categories belonging to the positive (left) and negative (right) aggregates of the observation system in experiment 1.

2.1.3.4. Presence in Virtual Reality and Emotion Processing

The analyses of the different subscores of the Igroup Presence Questionnaire (IPQ, Schubert, 2003) revealed that compared to a representative German sample investigated with the same questionnaire (http://www.igroup.org/pq/ipq/data.php), the virtual environment applied in the current experiment was not well suitable to induce feelings of spatial presence and involvement[2]. "Spatial presence" (t[566] = 2.45, p = .015) and "involvement" (t[566] = 4.66, p < .001) were significantly lower in the current sample than in the representative sample. Results for "experienced realism" did not differ significantly between the two samples (t[566]

[2] See Table 3, page 80 for means and standard deviations of the IPQ sub scores and the total IPQ score of the current sample and the representative sample.

= 1.02, p = .317). The total IPQ-score, however, was significantly lower in the current sample than in the representative sample (t[566] = 2.99, p = .006). Relations between presence experience and emotional reactions were tested with bivariate correlations between the different IPQ scores (Schubert, 2003) and valence and arousal ratings, psychophysiological, and behavioral reactions. For easier readability, I only report exact values of significant correlations.

Correlations with Valence and Arousal Ratings

See Table 2 for correlation coefficients and p-values between IPQ scores and valence and arousal ratings. There were significant correlations between “spatial presence” and arousal ratings after pleasant, neutral, and unpleasant trials. “Experienced realism” was correlated with valence ratings after unpleasant trials and arousal ratings after pleasant and unpleasant trials. The more participants experienced the virtual environment as “real”, the less pleasant the felt in response to unpleasant trials. The more participants felt spatially present in the virtual environment and the more they experienced the virtual environment as if it were “real”, the more aroused they felt in response to pleasant, neutral, and unpleasant trials. The total IPQ score correlated negatively with valence ratings in response to unpleasant trials. Correlations between the total IPQ score and arousal ratings revealed significant correlations for pleasant, neutral, and unpleasant trials. Those effects were “medium” to “large” according to the standard interpretations described by Cohen (1992; rs > .10 = “small”, rs > .30 = “medium, rs > .50 = “large” effects).

Table 2. Correlations between IPQ-scores and valence and arousal ratings of the sample in experiment 1.

	Val_pl	Val_neu	Val_unpl	Ar_pl	Ar_neu	Ar_unpl
Spatial Presence	r = .064	r = -.074	r = -.356	r = .450*	r = .454*	r = .398*
	p = .756	p = .718	p = .074	p = .021	p = .020	p = .044
Involvement	r = -.303	r = -.159	r = -.235	r = .306	r = .338	r = .218
	p = .132	p = .437	p = .248	p = .128	p = .091	p = .284
Experienced Realism	r = -.201	r = -.137	r = -.404*	r = .565**	r = .380	r = .509**
	p = .325	p = .506	p = .041	p = .003	p = .055	p = .008
Total	r = -.180	r = -.147	r = -.390*	r = .519**	r = .457*	r = .442*
	p = .380	p = .475	p = .049	p = .007	p = .019	p = .024

Comments: ** p < .01, * p < .05.

Correlations with Psychophysiological Reactions

There was a significant correlation between "spatial presence" and corrugator activations in response to neutral (r = .48, p = .014) and unpleasant (r = .42, p = .033) trials. The more participants felt spatially present in the virtual environment, the higher corrugator activations they showed in response to neutral and unpleasant trials. The correlation between the total IPQ scores and corrugator activity in response to negative trials also revealed a significant relationship (r = .41, p = .037). There were no significant correlations between IPQ scores and SCRs.

Correlations with Behavioral Reactions

Correlations between IPQ scores and behavioral expression rates revealed a significant relationship between "experienced realism" and "raised eyebrows" in response to pleasant trials (r = .52, p = .007), and "experienced realism" and "grumping" in response to neutral (r = .46, p = .020) and unpleasant (r = .44, p = .029) trials. The more participants had the feeling to experience the virtual environment as "real" the more frequently they showed the respective behaviors. The correlations with total IPQ scores revealed a significant correlation with "raised eyebrows" in response to pleasant trials (r = .438, p = .029). The more participants felt present in the virtual soccer stadium, the more they raised their eyebrows in response to pleasant trials.

2.1.3.5. Additional Analyses

See A 9 for additional analyses concerning influences on sociodemographic variables, soccer and gaming experiences on emotion processing and concerning participants' motivation and experiences throughout the experiment. Taken together, age and gender as well as soccer and gaming experiences of the participants seemed to have no major impact on emotional reactions.

2.1.4. Discussion

The aim of this study was to establish a virtual reality paradigm including social feedback that is suitable to induce pleasant and unpleasant emotional states. A virtual penalty kicking paradigm with feedback from a virtual coach after each shot was realized. Before penalty kicking, participants were teleported to different spots in the virtual stadium. Those teleportations served as neutral control trials. Emotional reactions were assessed on different levels according to the model of emotion generation by Gross (1998b, 1999). Those include an experiential level (valence and arousal ratings), a physiological level (activations of M. zygomaticus major and M. corrugator supercilii; skin conductance responses), and a behavioral level (behavioral expressions coded with a categorical observation scheme).

Additionally, the sense of presence that the virtual environment induced in the participants was assessed with the “Igroup Presence Questionnaire” (Schubert, 2003).

Results on the experiential level are mostly in line with my hypotheses. Valence ratings were higher in response to pleasant trials and lower in response to unpleasant trials, compared to neutral trials. Arousal ratings were modulated as expected with higher ratings in response to pleasant and unpleasant than in response to neutral trials and comparably high ratings in response to pleasant and unpleasant trials. Those results are in line with previous studies using images (Baur et al., 2015), sounds (Plichta et al., 2011), or film clips (Hewig et al., 2005) for emotion induction. Modulations of experiential emotional reactions (Gross, 1998b; Gross, 1999) indicate that hits and misses in a virtual penalty kicking game with subsequent feedback from a virtual soccer coach seem to be equally suitable to induce positive and negative emotional states as conventional stimuli. However, valence ratings in response to neutral trials were higher than 5. This is against my expectations and indicates that participants perceived the “neutral” control condition as slightly pleasant. This is contrary to studies using classical paradigms with emotional pictures as stimuli (Baur et al., 2015; Gerdes et al., 2010). One reason for this finding might be that participants perceived the virtual stadium as pleasant. Most participants reported to be soccer fans. They might thus have had rather positive associations with a soccer stadium due to repeated positive experiences they made in this environment. Numerous studies from our laboratory (e.g., Glotzbach, Ewald, Andreatta, Pauli, & Mühlberger, 2012; Kastner, Flohr, Pauli, & Wieser, 2015; Kastner, Pauli, & Wieser, 2015) have shown that contexts paired with threatening cues repeatedly are perceived as threatening themselves after a certain amount of time. In those studies, participants responded similarly to the conditioned context as to the unconditioned fear stimulus after a learning period. The same learning process might hold true for pleasant stimuli presented in a context or pleasant experiences made in a certain context. After repeated pleasant experiences in soccer stadiums, this previously neutral context might have become a pleasant context for the majority of participants in the current study. Moreover, a virtual environment in general might have become a pleasant context after a similar learning process. The majority of participants in the current study reported to play console games frequently and willingly. Consequently, a virtual environment per se might also be a rather pleasant context for them. Holmes & Westbrook (2014) observed that appetitive context conditioning interferes with the expression of counter conditioned context fear in rats. Moreover, one has to consider that the neutral trials were all presented in the beginning of the experiment. Therefore, participants might have been excited and looking forward to the new experience in virtual reality. Several authors applying experimental paradigms in virtual reality report presenting a habituation phase in the beginning of their experiments to prevent entanglement of the experimental manipulation with general exposure effects in the virtual world (Aymerich-Franch, 2010; Peperkorn et al., 2015). This was not realized in the study described above, presenting the teleportations that served as a “neutral” control condition without any preceding habituation phase. To be able to distinguish between emotional reactions in response to the presented stimuli and reactions in response to the virtual environment per se, it would be important to realize a habituation phase in future studies.

Zygomaticus and corrugator activations were not modulated as expected. Zygomaticus activations in response to pleasant and unpleasant trials were comparably high and higher than in response to neutral trials. The modulation of the corrugator muscle points in the same direction with a deactivation of the muscle in response to pleasant and unpleasant, but not to neutral trials. As the zygomaticus muscle has been shown to be an indicator of positive affectivity and the corrugator muscle has been shown to be an indicator of negative affectivity in numerous studies (Baur et al., 2015; Cacioppo et al., 1986; Dimberg, 1990; Wu et al., 2012), one might conclude that in the current paradigm hits as well as misses followed by feedback from the virtual coach induced pleasant emotional states, compared to the neutral control condition. This is contrary to my expectation that misses and respective coach feedback would induce unpleasant emotional states. It is hard to disentangle which modes of action are responsible for this effect. Probably the most obvious explanation for this is that “unpleasant” feedback phrases and corresponding facial expressions were not perceived as unpleasant by the majority of the participants. At least on average, the phrases might have been perceived as not unpleasant enough to induce respective facial reactions of negative affectivity. Ku et al. (2005) found a linear relation between the intensity of emotional facial expressions of virtual agents and the intensity of valence and arousal ratings of participants. Accordingly, one might conclude that negative facial expressions might not have been intense enough to induce strong negative emotions. Some phrases originally designed to induce negative affectivity might even have induced amusement in the participants, going along with increased zygomaticus activations and decreased corrugator activations. Another explanation for the EMG findings concerns context conditioning. As already pointed out, the virtual environment per se as well as the soccer stadium in specific might have been perceived as a pleasant context by the participants. Kastner, Flohr et al. (2015) found that faces presented in an olfactory conditioned threat context were perceived as less pleasant than the same faces presented in a control context. In the current pleasant context (the virtual soccer stadium), a similar learning process might be responsible for the positively biased perception of facial stimuli. This means that even if participants might have perceived the same phrases and facial expressions as unpleasant when presented without any context, the association of the phrases with the pleasant context might have led to rather pleasant emotional reactions. Interestingly, the current findings are mostly in line with a study by Weyers, Mühlberger, Hefele, & Pauli (2006) measuring zygomaticus and corrugator modulations in response to static and dynamic happy and angry facial expressions of virtual agents. Weyers et al. (2006) found zygomaticus activations and corrugator deactivations in response to happy faces, similarly to the modulation of facial EMG by pleasant picture stimuli. However, in response to angry facial expressions, no matter if presented statically or dynamically, they found no modulations of the zygomaticus or corrugator muscle, compared to neutral facial expressions. They discussed that this might be due to the fact that mimicking the facial expression of an interaction partner might be evolutionary advantageous for happy, but not for angry facial expressions. As the authors state, overtly showing angry affect to an already angry interaction partner "could induce even more anger in the interaction partner" (Weyers et al., 2006). Therefore, even if unpleasant trials did induce negative affect in the current study (as suggested by valence ratings), participants might automatically have suppressed their congruent facial expressions, resulting in corrugator deactivations and slight zygomaticus activations.

The modulation of skin conductance responses failed to reach significance. Amplitudes in response to pleasant, neutral, and unpleasant trials were comparably high. This finding is not in line with my expectations and with the literature. Skin conductance responses have been shown to be an indicator of emotional arousal (Boucsein, 2012; Lang et al., 1993) and should therefore have been enhanced in pleasant and unpleasant, compared to neutral trials. One could conclude that participants were not more aroused by pleasant and unpleasant than by neutral trials in the current paradigm. However, as already pointed out, neutral trials were always presented in the beginning of the experiment, before pleasant and unpleasant trials. Therefore, the psychophysiological arousal that participants showed in the expectance of the experiment per se or in response the virtual environment is very probable to confound those effects. As outlined in Boucsein (2012), skin conductance responses are also increased as part of the "orienting response" to novel stimuli. The orienting response, in turn, decreases after repeated presentation of the same or similar stimuli (Boucsein, 2012). Skin conductance responses in the current experiment thus might have been higher in the first trials compared to later trials partly because of this effect of an orienting response that decreased over time. It would be crucial for future studies to present neutral trials within the same experimental blocks as pleasant and unpleasant trials. Moreover, it would be important to include a habituation phase before the beginning of the main experiment for reasons outlined above.

Behavioral reactions were modulated partly in line with my hypotheses. Smiling behavior was shown most often in pleasant trials and least in neutral trials, as hypothesized. However, the raising of eyebrows which was described as an expression of positive surprise by Saarni (1984) did not differentiate well between pleasant and unpleasant trials in the current study. Participants even showed slightly higher raising activation in response to unpleasant, compared to pleasant trials. This might be due to the fact that “unpleasant” trials in the current study in fact induced at least mixed, if not positive affectivity in participants, as outlined above. This explanation seems to be a plausible one as it is in line with EMG results (corrugator deactivations in response to pleasant and unpleasant trials). Another explanation might be that as participants wore 3D glasses covering huge parts of the eye region during the experiment which, it was hard for the observers to distinguish reliably between raised eyebrows and knit eyebrows. Saarni (1984, 1992) coded raised eyebrows as an expression of positive affectivity and knit eyebrows as an indicator of negative affectivity. Giggling and laughing behavior was observed comparably often in pleasant and unpleasant trials. Again, this might indicate that “unpleasant” trials induced positive, rather than negative emotional states in the participants. Behaviors belonging to the negative aggregate (“mouth turned down”, “pressing, pursing, biting or sucking of lips”, and “grumping”) were all modulated as expected with highest observation rates during unpleasant trials, respectively. Lowest observation rates for “mouth turned down” and “grumping” were found during neutral trials, whereas observation rates for “pressing, pursing, biting or sucking of lips” did not differ in pleasant and neutral trials. Considering results of observational categories belonging to both positive and negative aggregates, one could argue that pleasant and unpleasant trials induced positive and negative affective states, reflecting in respective behavior. However, unpleasant trials seemed to evoke not only expressions of negative affect, but also of positive affect. Behavioral suppression of negative affective states has been discussed as an automatic strategy of emotion regulation (Mauss, Bunge et al., 2007). Strack, Martin, & Stepper (1988) published very influential studies showing that emotional facial expressions influence emotional states even if participants are not aware of the emotional meaning of the expression. Participants in those studies rated film clips as more funny when unconsciously mimicking a smile while holding a pen with their lips than when they watched the same film clips while holding the pen slightly different, not engaging in a smile. Mauss, Cook, & Gross (2007) provided evidence that automatic emotion regulation seems to be effective in regulating unpleasant emotions, especially anger. One might conclude that participants in the current study experienced unpleasant emotions in response to misses and social feedback, reflected by valence ratings. However, they might automatically have suppressed expressions of negative affect, resulting in the behavioral expression of primarily positive affect.

All in all, it seems that age and gender of the participants did not remarkably influence their emotional responses. The comparison of IPQ scores (Schubert, 2003) of the sample in the current experiment with the IPQ scores of a representative sample (http://www.igroup.org/pq/ipq/data.php) revealed that especially for “spatial presence” and “involvement”, scores in response to the current virtual environment were weaker than in response to other virtual environments. Scores of “experienced realism” were also lower for the current virtual environment as for others, but did not differ significantly from the representative sample. Correlational analyses revealed that there were relationships between different presence scores and the strength of emotional reactions especially on the experiential level. Interestingly, strongest correlations were found between presence ratings and arousal ratings. Arousal has been discussed as a mediator between immersion in a virtual environment and induced emotions (Diemer et al., 2015). Those results are correlational and do not allow for causal interpretation. Still, it might be worth to improve the virtual environment for further experiments so that it induces stronger feelings of presence. Hopefully, improvements in presence experience would result in stronger emotional reactions. I have reason to expect this considering a study by Peperkorn et al. (2015) who found higher fear responses in spider-fearful women on subjective and behavioral, but not on a physiological level in a virtual environment inducing high vs. low sense of presence. Importantly, in their study, presence ratings in the first exposure trial correlated significantly with fear ratings in the second exposure trial, but fear ratings in the first exposure trial did not correlate significantly with presence ratings in the second exposure trial. This suggests a causal relationship between presence and the intensity of experienced emotions in virtual reality.

Possible improvements of the applied paradigm involve first of all the neutral control condition. As stated above, the presentation of neutral trials blocked in the beginning of the experiment is highly problematic for several reasons. In future studies, neutral trials should be implemented in the same experimental blocks as emotional trials and presented in a pseudorandomized order to prevent order effects. Before the start of the main experiment, a habituation phase should be implemented to be able to disentangle reactions to experimental manipulations from reactions to the virtual environment per se. Moreover, it is crucial to create a neutral condition that is better comparable to the pleasant and unpleasant conditions in terms of length, social interactivity and complexity. The movements participants have to perform to operate the joystick might influence the activation of facial muscles or skin conductance which are hard to control for in the current paradigm. The same holds true for the social interaction influences on physiological parameters. Participants might be more emotionally aroused, more positively or negatively affected by the pure effect that a virtual agent is addressing them. Pleasant and unpleasant trials were much more complex than a relatively simple picture presented in neutral trials. Consequently, the processing of pleasant and unpleasant trials probably required more cognitive resources than the processing of neutral trials. This might have influenced physiological parameters. As it is impossible to disentangle effects of the movements required to operate the joystick, of social feedback, or of cognitive processing from effects of the “mere” emotional content of the trials, those conditions should be kept constant across experimental conditions. Many participants criticized that the virtual agent that served as a coach model seemed unnatural and somehow odd. Probably this influenced the participants’ reactions to the feedback given by this agent, maybe resulting in weaker emotional reactions (Baylor, 2011). Consequently, for further studies, it might make sense to use a more elaborated embodied agent. Furthermore, the present paradigm allows for no distinction of emotional states induced in pleasant and unpleasant trials by hits or misses vs. by social feedback. The confounding of two events (hit/miss and subsequent feedback) in one single trial makes it impossible to disentangle the impact of every single event on emotional reactions. It would be helpful to investigate those more thoroughly in a future study. As some participants suspected that their influence on the scoring performance was rather low, it might be important to improve goal keeper animations. Moreover, it would be helpful to assess the estimated influence on the scoring performance in future studies to be able to look at the relationship between estimated influence on the performance and intensity of emotional reactions. A more elaborated observation system would allow for coding of more behavioral reactions. For example, the distinction only between a “positive” and a “negative” aggregate is quite limiting and does not allow for coding of behavioral reactions that are not clearly reflecting positive or negative affectivity. For future studies, it would therefore be interesting to use a more elaborated coding scheme with more categories, rather comparable to the one used in Saarni (1992). The latter allows for coding of behaviors that express psychological tension per se and social monitoring, apart from positive and negative emotionality.

Taken together, the results of this study indicate that it seems possible to induce similarly strong emotional reactions in an interactive virtual reality paradigm as in conventional paradigms. The advantages of a virtual reality paradigm (higher ecological validity, higher adaptability of the experimental paradigm, higher motivation of study participants, etc.) speak for further application of this method especially with clinical samples who are known to suffer from motivational deficits, like ADHD patients (Faraone et al., 2015; Sonuga-Barke, 2002; Sonuga-Barke, Dalen, & Remington, 2003). Still, the current paradigm comprises numerous shortcomings which need to be addressed before further application.

2.2. THE ROLE OF SOCIAL FEEDBACK IN EMOTION PROCESSING IN VIRTUAL REALITY (EXPERIMENT 2)

2.2.1. Introduction

The aim of experiment 2 was to further improve the virtual penalty kicking paradigm established in experiment 1, mainly in the sense of increased presence in the virtual reality (Schubert, 2003) and to especially test the role of social feedback (feedback phrases from a virtual soccer coach) on induced emotions. I considered it important to improve the sense of presence in virtual reality as experiment 1 revealed significant correlations between IPQ scores and emotional reactions. Moreover, a number of previous studies indicate that stronger emotions are elicited in virtual environments when participants feel highly present in those environments (Aymerich-Franch, 2010; Banos et al., 2004; Peperkorn et al., 2015). In everyday life, emotions are often elicited by interactions with others. As already pointed out in experiment 1, I therefore considered it important to investigate emotion processing in an interactive virtual environment including social feedback. An interactive virtual reality paradigm should be marked by higher ecological validity than picture processing paradigms previously used to investigate emotion processing in ADHD (Conzelmann et al., 2009; Conzelmann et al., 2011; Conzelmann et al., 2016; Conzelmann, McGregor, & Pauli, 2015). A major goal of this study was to disentangle emotional reactions to shots in a virtual penalty kicking game (hits or misses) from emotional reactions to shots and subsequent feedback from a virtual coach. Furthermore, influences of participants' experiences throughout the experiment on emotional reactions were investigated. Especially, I wondered if the participants' perceived influence on their scoring performance in the penalty kicking game was correlated with the intensity of emotional reactions. Therefore, I realized a version of the penalty kicking paradigm applied to participants in experiment 1 with a number of methodological improvements, implementing feedback from a virtual soccer coach only in 50% of all trials. Emotional reactions were assessed on an experiential level (valence and arousal ratings) and a physiological level (activations of M. zygomaticus major and M. corrugator supercilii, skin conductance responses).

I expected hits and misses in the penalty kicking paradigm to induce pleasant and unpleasant emotional states, compared to a neutral control condition (which consisted of shots over the free soccer field in this experiment). This should show in higher valence ratings, higher zygomaticus activations and lower corrugator activations in response to hits and lower valence ratings and higher corrugator activations in response to misses, compared to shots over the free field. Moreover, I hypothesized that arousal ratings and skin conductance responses would be higher in response to hits and misses, compared to shots over the free field. Those expectations are in line with the hypotheses in experiment 1 and with studies on emotion processing and emotion regulation using classical stimuli like images (Baur et al., 2015), sounds (Plichta et al., 2011) or film clips (Hewig et al., 2005) for emotion induction. I expected feedback from the virtual coach to intensify emotional reactions both on an experiential and a physiological level. Accordingly, I expected valence and arousal ratings, facial muscle activations and skin conductance responses to be more intense after hits and misses followed by feedback from the coach than in response to hits and misses alone. For shots over the free field, I expected comparable reactions to shots alone and to shots followed by feedback from the coach.

2.2.2. Methods

2.2.2.1. Participants

After the exclusion of 2 data sets due to psychiatric disorders (self-report), data of 22 healthy participants (12 female) remained for data preprocessing and statistical data analysis. Participants for experiment 2 were mostly recruited from a local online platform (www.wuewowas.de) and received 10 € for participation. Additionally, three undergraduate psychology students from the University of Würzburg participated in the study who received course credit for participation. Participants' age ranged from 19 to 46 years (*M* = 27.23, *SD* = 7.64) and all reported normal or corrected to normal vision. All but one participant reported to have no hearing disabilities. All participants gave their written informed consent. The study was approved by the ethics committee of the University of Würzburg.

2.2.2.2. Virtual Environment, Stimulus Material and Apparatus

For induction of pleasant and unpleasant emotional states, participants played a penalty kicking game in the same virtual soccer stadium as in experiment 1. The virtual environment was projected onto the same power wall (3Dims GmbH, Frankfurt, Germany) with the same software (VrSessionMod 0.5, Department of Psychology I, University of Würzburg) and the same projectors (projection design F32, resolution: WUXGA, 1920x1200; projection design as, Gamle Fredrikstad, Norway) as used before.

Pleasant and unpleasant trials consisted of hits and misses in a virtual penalty kicking game. Again, the virtual goal keeper was controlled by a computer algorithm, so that 50 % of all penalty kicks were hits and 50 % were misses. This time, neutral trials consisted of shots over the free soccer field. To be able to disentangle effects of a shot only from effects of a shot followed by social feedback, shots were followed by feedback from a virtual coach only in 50 % of all trials. Pleasant and unpleasant feedback phrases were the 15 most pleasant and the 15 most unpleasant phrases of those used in experiment 1 according to the valence ratings given by the sample in experiment 1. Three of the original pleasant phrases (No. 5, 21, and 32 in A 2) and one of the original unpleasant feedback phrases (No. 9 in A 2) were shortened, as they originally were very long. I considered it important to keep the variability of the length of the phrases smaller and to avoid very long phrases as they might be harder to process and therefore impair emotion induction. Pleasant and unpleasant phrases did not differ in arousal according to the ratings given by the sample of experiment 1 ($t[28] = 0.78$, $p = .445$). However, relative valence ratings given in experiment 1 in response to the selected pleasant phrases ($M = 2.04$, $SD = 0.25$) were higher than relative valence ratings in response to the selected unpleasant phrases ($M = 1.57$, $SD = 0.37$; $t[28] = 4.09$, $p < .001$). I considered it more important to induce intense emotions than to be able to directly compare positive and negative emotions. Therefore, the 15 most intense pleasant feedback phrases were chosen, though differing from unpleasant feedback phrases in relative valence. With the objective to induce more intense emotional reactions, animations of the virtual coach were re-edited with Source SDK Face Poser (Valve Corporation, Bellevue, Washington, USA). Thereby, especially negative emotional expressions were intensified. To make the neutral control condition more comparable to pleasant and unpleasant conditions, I implemented 30 shots over the free soccer field in the experiment. Thereof, 50% were followed by "neutral" feedback phrases (i.e. "You just kicked."). Those phrases were again recorded with the software Audacity 2.0.3 (https://sourceforge.net/projects/audacity/). Lip synchronizations of the virtual agent to the spoken words were applied with Source SDK Face Poser (Valve Corporation, Bellevue, Washington, USA). In neutral phrases, no emotional expressions were added. Pleasant, neutral, and unpleasant feedback phrases did not differ in absolute length (ts < 1.10, ps > .286) or number of syllables (ts < 0.55, ps > .591). Feedback phrases in different experimental blocks did not differ in length (ts < 1.23, ps > .229). Pleasant and unpleasant feedback phrases in different experimental blocks did not differ in valence and arousal ratings given by the sample in experiment 1 (ts < 1.42, ps > .194). Additionally, I implemented 2 pleasant, 1 neutral, and 2 unpleasant feedback phrases in practice trials before the main experiment. See A 10 for a list of all feedback phrases used in experiment 2.

Ratings of emotional valence and arousal were assessed with 9-point likert scales similar to the ones used in experiment 1. On the valence scale, 1 indicated "very unpleasant" and 9 indicated "very pleasant". On the arousal scale, 1 indicated "not arousing at all" and 9 indicated "very arousing". However, this time participants were not asked for their evaluation of the feedback phrase they had just heard, as in experiment 1. The original questions were slightly rephrased, now focusing on how pleasant/unpleasant or emotionally aroused the participants had felt during the preceding experimental trial. The original rating scales are implemented in A 12. For easier application of the rating scales throughout the experiment, a keyboard resembling a 9-point likert scale was designed at Department of Psychology I (University of Würzburg) especially for the purpose of the following studies. Moreover, a new virtual agent that was designed by VTplus GmbH (Würzburg, Germany) served as a coach model in experiment 2 (see Figure 7). It was much more elaborated than the standard virtual agent provided by the Valve Corporation utilized in experiment 1.

To increase participants' felt influence on their scoring performance, the computer algorithm triggering the goal keeper animations was refined with help from the Department of Experimental Psychology, Clinical Psychology and Psychotherapy (University of Regensburg). In experiment 1, especially trials in which participants had scored in one direction and the goal keeper had jumped into the exact opposite direction had made them suspicious to not have much influence on their scoring performance. Consequently, in pleasant trials in experiment 2, the goal keeper did not jump in any of the remaining seven positions apart from the scoring direction by chance. Instead, now one out of the two animations with the goal keeper jumping to the positions neighboring the scoring direction was triggered in pleasant trials. In unpleasant trials, the goal keeper still jumped into the same direction as the participant had scored to, as in experiment 1.

2.2.2.3. Procedure and Design

After arriving at the laboratory, participants were seated in a chair app. 2.5 m from the power wall. The experimenter handed them an information form (see A 11) and asked participants to give their written informed consent on participation (see A 4). Participants filled in the same sociodemographic questionnaire as in experiment 1 (see A 5) and the German version of the Rosenberg Self Esteem Scale (Collani & Herzberg, 2003). Afterwards, they washed their hands with pure, soapless water. The experimenter attached electrodes for physiological measurements, provided the participants with 3D-glasses, and then explained them how to operate the joystick (Mad Catz IV; Mad Catz Inc., San Diego, California) and the keyboard throughout the experiment. The experiment was operated with the software CyberSession CS-Research 5.6.23 beta (VTplus GmbH, Würzburg, Germany).

At the beginning of the experiment, participants were instructed visually on the power wall and verbally via loudspeakers to imagine themselves to participate in a test training of a representative soccer team. They should imagine absolutely wanting to play in this very high-class team. Their probability to be chosen from the coach of that team would depend on the number of goals they scored in the test training while being watched by the coach. See A 12 for the original instructions. Before the start of the main experiment, participants went through 10 practice trials (4 pleasant trials, 2 neutral trials, 4 unpleasant trials), of which 50 % comprised a feedback phrase of the virtual coach after the shot. Those practice trials were implemented to make sure the participants understood the experimental task and to give them enough time to habituate to the virtual environment. Afterwards, participants went through three blocks of penalty kicking with 10 pleasant, 10 neutral, and 10 unpleasant trials each. Thereof, 50% comprised a feedback phrase of the virtual coach after the shot.

The trial structure of trials with and without feedback is depicted in Figure 7. Pleasant, neutral, and unpleasant trials with and without feedback were presented in a pseudorandomized order to prevent order effects. In trials with feedback, the face of the virtual agent remained visible for 4 s after the offset of the feedback phrase. In pleasant and unpleasant trials, the coach was still showing a congruent emotional facial expression during this period. In neutral trials, the coach was showing a neutral facial expression during this period. In trials without feedback, the picture of the goal with the goal keeper or the picture of the soccer field was still visible for 4s after the shot. After the offset of the coach face (respectively after the offset of the goal or the soccer field in trials without feedback), participants rated their emotional experiences on 9-point likert scales for valence and arousal. Then, there followed an interstimulus interval (a blank black screen) randomly varying from 6-8 s before the beginning of the next trial. I decided to implement varying interstimulus intervals this time to prevent learning effects influencing skin conductance and facial muscle activity.

After the main experiment, the experimenter took off the electrodes. Participants filled in a revised version of the questionnaire on their experiences throughout the experiment (see A 13), the same questionnaire on soccer and gaming experience as in experiment 1 (A 8) and the German version of the Igroup Presence Questionnaire (Schubert, 2003). They were debriefed and received either 10 € or course credit for their participation. The experiment lasted around 100 min. The procedure is depicted in Figure 7.

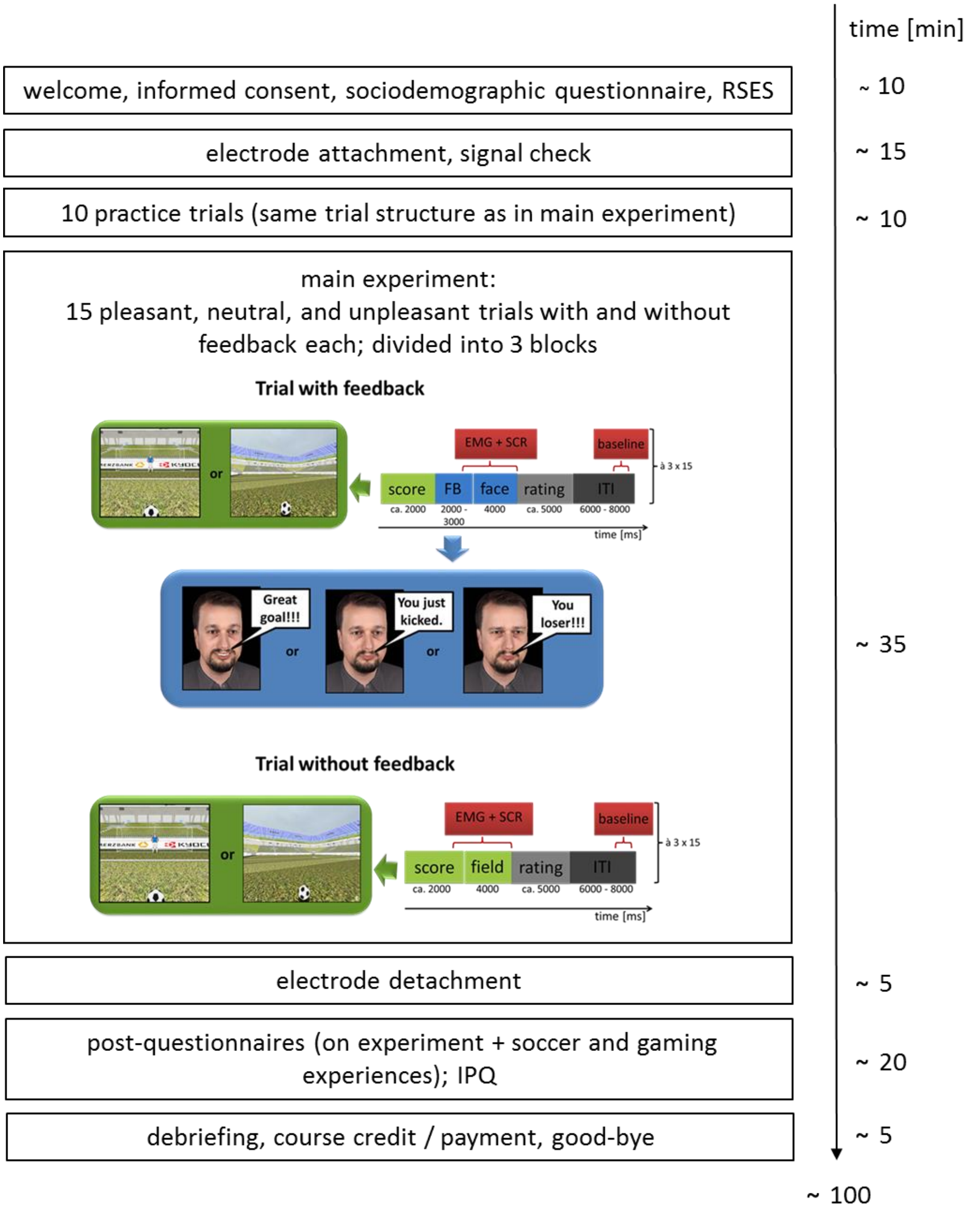


Figure 7. Procedure of experiment 2.

“Score” = kicking at the goal or over the free field with the joystick; “FB” = feedback from the virtual coach; “face” = period after the feedback during which the coach was still visible; “field” = period after the score during which the soccer field was still visible; “rating” = rating of emotional valence and arousal; “ITI” = inter trial interval (black screen); “EMG” = measurement of facial muscle activity; “SCR” = measurement of skin conductance responses, “baseline” = baseline measurement of facial muscle activity and skin conductance.

2.2.2.4. Data Recordings and Data Reduction

Physiological data was recorded with BrainVision Recorder software (Brain Products GmbH, Gilching, Germany) and a V-Amp 16 amplifier (Brain Products GmbH, Gilching, Germany) in the same way as described in experiment 1.

Physiological data was preprocessed with BrainVision Analyzer 2.1 (Brain Products GmbH, Gilching, Germany). To the raw EMG data, a 30 Hz highpass filter, a 500 Hz lowpass filter, a 50 Hz notch filter, and a 125 ms moving average filter were applied. To the raw skin conductance data, a 50 Hz notch filter was applied. EMG and skin conductance data was baseline corrected (1000 ms during the end of the inter stimulus interval). For EMG data, an artifact correction was applied to exclude from further analyses trials with strong artifacts during baseline. Trials with an activity +/- 8 µV during baseline were excluded from further analyses. For correction of strong artifacts during measurement segments, an artifact rejection to EMG data excluded trials with an activity +/- 30 µV during measurement segments from further analyses. Both EMG and skin conductance data were then segmented. For trials with feedback, the continuous data was cut into 6000 ms segments lasting from the last 2000 ms segments of the feedback phrase until the offset of the coach face (see Figure 7). For trials without feedback, the continuous data was cut into 6000 ms lasting from the shot until the offset of the goal picture respectively the picture of the soccer field (see Figure 7). For further analyses, mean EMG activity over the 6000 ms segments described above was exported. For skin conductance analyses, activation peaks during the same 6000 ms segments were exported. As described in Gavazzeni et al. (2008), skin conductance responses smaller than 0.01 µS were considered as null responses and equated with 0. For statistical analyses, I computed averages of mean EMG activations and skin conductance responses of all trials belonging to the same experimental condition. As described in previous studies (Conzelmann et al., 2014; Gavazzeni et al., 2008), for correction of skewness, I applied a logarithmic transformation to mean skin conductance responses (log[1+SCR]).

2.2.2.5. Statistical Data Analyses

Statistical data analyses were conducted with the software SPSS Statistics 23 (IBM Deutschland GmbH, Ehningen, Germany). Effects of different emotional conditions and of social feedback on emotional reactions, were tested with repeated measures ANOVAs with the within-subjects factors emotion (pleasant vs. neutral vs. unpleasant) and feedback (feedback vs. no feedback). Whenever the assumption of sphericity was violated, I reported Greenhouse-Geisser corrected degrees of freedom and *p*-values. Significant main effects and interactions were further analyzed with post-hoc *t*-tests with Bonferroni-corrected significance levels. The same analyses were conducted for valence and arousal ratings, facial muscle activations, and logarithmic skin conductance responses. To test if valence ratings in response to pleasant, neutral, and unpleasant trials differed significantly from the "neutral" mean of the valence scale (5), I additionally conducted one-tailed *t*-tests. To test if EMG activations in response to pleasant, neutral, and unpleasant trials differed significantly from baseline activations, I conducted one-tailed *t*-tests with an activation of 0 serving as reference.

Relationships between the age of the participants and emotional reactions on different levels were analyzed with bivariate Pearson's correlations. Gender influences on emotional reactions were tested with split plot ANOVAs with the within-subjects factors emotion (pleasant vs. neutral vs. unpleasant) and feedback (feedback vs. no feedback) and the between-subjects factor gender (men vs. women). Again, I reported Greenhouse-Geisser corrected values whenever the assumption of sphericity was violated. Significant main effects and interactions were further analyzed with post-hoc *t*-tests with Bonferroni-corrected significance levels. IPQ scores in experiment 2 were compared with the scores obtained in experiment 1 and the scores of a representative sample (http://www.igroup.org/pq/ipq/data.php) with independent samples *t*-tests. Relationships between the participants' experiences throughout the experiment (assessed with a post-experimental questionnaire, see A 13) and emotional reactions were analyzed with bivariate Pearson's correlations.

2.2.3. Results

2.2.3.1. Ratings

Means and standard errors of valence and arousal ratings are depicted in Figure 8. For valence ratings, there was a significant main effect for emotion ($F[1,35] = 48.76$, $p < .001$, $\eta_p^2 = .67$, $GG\text{-}\varepsilon = .85$), a significant main effect for feedback ($F[1,21] = 9.26$, $p = .006$, $\eta_p^2 = .31$) as well as a significant interaction emotion x feedback ($F[2,42] = 11.64$, $p < .001$, $\eta_p^2 = .36$). Valence ratings were higher after pleasant trials and lower after unpleasant trials, compared to neutral trials, in trials with feedback ($F[1,33] = 51.95$, $p < .001$, $\eta_p^2 = .71$, $GG\text{-}\varepsilon = .79$, *t*s > 5.13, *p*s < .001) and without feedback ($F[2,42] = 38.23$, $p < .001$, $\eta_p^2 = .65$, *t*s > 2.63, *p*s < .016). However, this effect was stronger in trials with feedback than in trials without feedback. Ratings were more pleasant in response to pleasant trials with feedback than pleasant trials without feedback ($t[21] = 2.25$, $p = .036$) and more unpleasant in response to neutral and unpleasant trials with feedback than neutral and unpleasant trials without feedback (*t*s > 2,91, *p*s < .008). One-tailed *t*-tests revealed that valence ratings in response to pleasant and neutral trials with and without feedback were significantly higher than 5 (*t*s > 5.86, *p*s <

.001). Valence ratings in response to unpleasant trials with and without feedback did not differ significantly from 5 (*t*s < 1.28, *p*s > .214).

The analyses of arousal ratings revealed significant main effects for emotion ($F[2,42] = 25.06$, $p < .001$, $\eta_p^2 = .54$) and feedback ($F[1,21] = 7.44$, $p < .001$, $\eta_p^2 = .39$), but no significant interaction ($F[1,36] = .54$, $p = .565$, $\eta_p^2 = .03$, $GG\text{-}\varepsilon = .86$). Participants reported higher emotional arousal after pleasant and unpleasant trials, compared to neutral trials (*t*s > 4.39, *p*s < .001), marginally lower emotional arousal after pleasant trials than after unpleasant trials ($t[21] = 2.04$, $p = .054$), and higher emotional arousal after trials with feedback than after trials without feedback ($t[21] = 3.12$, $p = .005$).

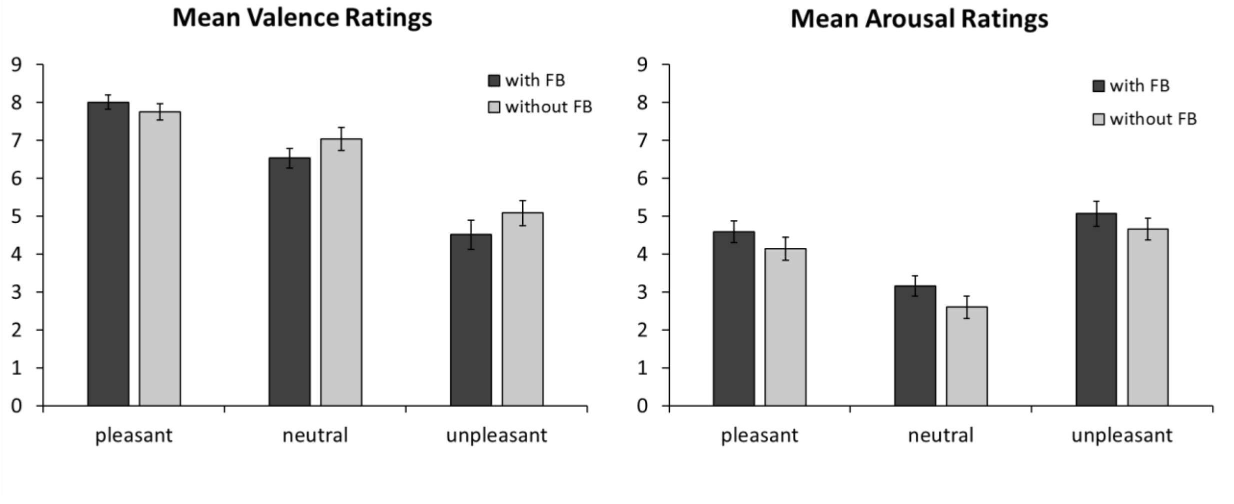


Figure 8. Means and standard errors of valence (left) and arousal (right) ratings in experiment 2.

2.2.3.2. Psychophysiological Recordings

Facial Muscle Activity

Mean activations and standard errors of M. zygomaticus major and M. corrugator supercilii are shown in Figure 9. Zygomaticus modulations showed significant main effects for emotion ($F[1,33] = 7.64$, $p = .003$, $\eta_p^2 = .27$, $GG\text{-}\varepsilon = .80$) with higher activations in pleasant and unpleasant compared to neutral trials, a significant main effect for feedback ($F[1,21] = 27.39$, $p < .001$, $\eta_p^2 = .57$) with higher activations in trials with feedback than in trials without feedback, and a significant interaction for emotion x feedback ($F[2,42] = 3.38$, $p = .043$, $\eta_p^2 = .14$). This interaction was further explored. Post-hoc *t*-tests revealed that activations were higher in trials with feedback vs. trials without feedback for all emotional conditions (*t*s > 3.76, *p*s < .001). In trials with feedback, activations were significantly lower in neutral, compared to pleasant and unpleasant trials ($F[1,32] = 8.41$, $p = .002$, $\eta_p^2 = .29$, $GG\text{-}\varepsilon = .77$; *t*s > 2.74, *p*s < .012), which in turn were comparably high ($t[21] = 1.27$, $p = .217$). In trials without feedback, zygomaticus activations did not differ significantly across emotional conditions ($F[1,36] = 2.44$, $p = .109$, $\eta_p^2 = .10$, $GG\text{-}\varepsilon = .86$). Descriptively, activations were higher in pleasant and unpleasant trials without feedback than in neutral trials without feedback. Trials with feedback evoked zygomaticus activations compared to baseline in pleasant and unpleasant (*t*s > 2.97, *p*s < .007), but not in neutral trials ($t[21] = 1.21$, $p = .241$). Trials without feedback evoked zygomaticus deactivations. Zygomaticus activations were significantly lower than at baseline in pleasant and neutral trials without feedback (*t*s > 3.07, *p*s < .006), but not in unpleasant trials without feedback ($t[21] = 1.36$, $p = .188$).

For corrugator modulations, there was a marginally significant main effect for emotion ($F[1,33] = 2.95$, $p = .078$, $\eta_p^2 = .12$, $GG\text{-}\varepsilon = .79$), a significant main effect for feedback ($F[1,21] = 6.36$, $p = .020$, $\eta_p^2 = .23$), and a significant interaction for emotion x feedback ($F[1,33] = 8.96$, $p = .002$, $\eta_p^2 = .30$, $GG\text{-}\varepsilon = .80$). This interaction was further explored. Post-hoc *t*-tests revealed that corrugator activations were lower for trials with feedback than for trials without feedback in pleasant and unpleasant trials (*t*s > 2.24, *p*s < .036), but not for neutral trials ($t[21] = 0.53$. $p = .603$). For trials with feedback, corrugator activity was significantly lower in pleasant and unpleasant, compared to neutral trials ($F[1,29] = 5.59$, $p = .016$, $\eta_p^2 = .21$, $GG\text{-}\varepsilon = .70$; *t*s > 3.37, *p*s < .003) and did not differ in pleasant vs. unpleasant trials ($t[21] = 0.42$, $p = .680$). For trials without feedback, corrugator activity did not differ dependent on the emotional condition ($F[2,42] = 1{,}58$, $p = .218$, $\eta_p^2 = .07$). In trials with feedback, corrugator activations were lower than at baseline in the pleasant and unpleasant condition (*t*s > 3.11, *p*s < .005), but not in the neutral condition ($t[21] = 0.61$, $p = .547$). In trials without feedback, corrugator activations did not differ from baseline across emotional conditions (*t*s < 1.10, *p*s > .286).

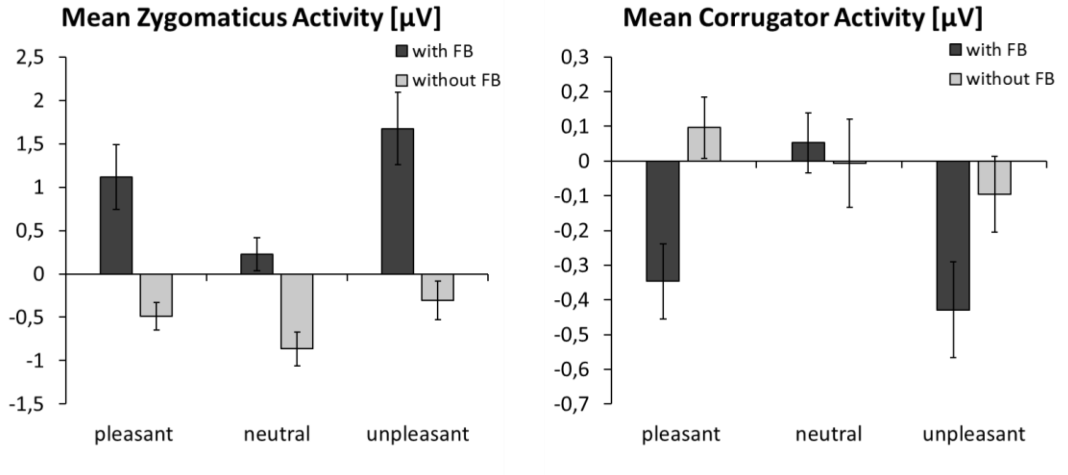


Figure 9. Mean activations and standard errors of M. zygomaticus major and M. corrugator supercilii in experiment 2.

Skin Conductance Responses

See Figure 10 for an overview of the modulation of SCRs in trials with and without feedback. The analyses of the logarithmic skin conductance responses (SCRs) revealed a significant main effect for emotion ($F[1,31] = 11.53$, $p < .001$, $\eta_p^2 = .35$, $GG\text{-}\varepsilon = .74$), a significant main effect for feedback ($F[1,21] = 7.47$, $p = .012$, $\eta_p^2 = .26$), and a significant interaction for emotion x feedback ($F[1,30] = 13.21$, $p < .001$, $\eta_p^2 = .39$). This interaction was further explored. SCRs were higher in pleasant and unpleasant trials with feedback vs. without feedback (ts < 2.98, ps $< .007$) and lower in neutral trials with feedback vs. without feedback ($t[21] = 2.58$, $p = .017$). In trials with feedback, SCRs were higher in pleasant and unpleasant, compared to neutral trials ($F[1,31] = 17.58$, $p < .001$, $\eta_p^2 = .46$, $GG\text{-}\varepsilon = .76$; ts > 4.17, ps $<$ .001), and comparably high in pleasant and unpleasant trials ($t[21] = 0.39$, $p = .702$). In trials without feedback, SCRs did not differ dependent on the emotional condition ($F[1,34] = 0.74$, $p = .458$, $\eta_p^2 = .03$, $GG\text{-}\varepsilon = .82$).

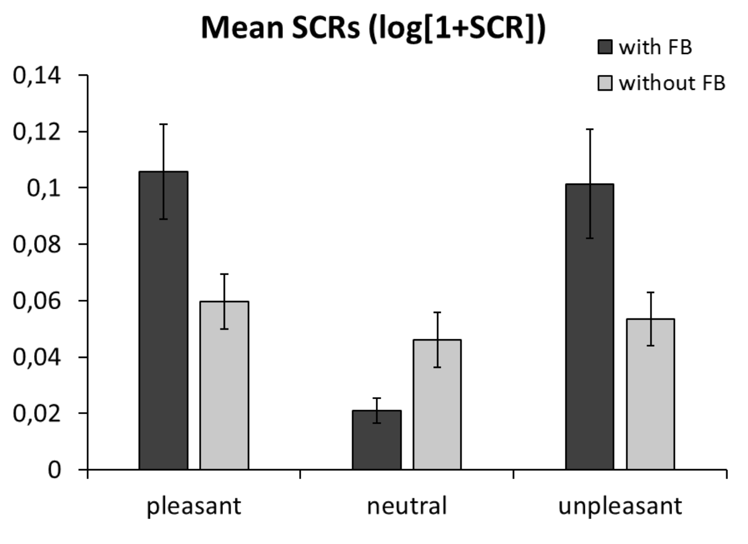


Figure 10. Means and standard errors of logarithmic skin conductance responses of the sample investigated in experiment 2 (*N* = 22).

2.2.3.3. Presence in Virtual Reality

The analyses of the different sub scores of the IPQ (Schubert, 2003) revealed that in comparison with the paradigm applied to the participants in experiment 1, the present experiment was marginally better suitable to induce feelings of "involvement" ($t[40] = 1.99$, $p = .053$) and "experienced realism" ($t[46] = 1.94$, $p = .059$; see Table 3). The sub score for "spatial presence", however, did not increase significantly in experiment 2, compared to experiment 1 ($t[46] = 0.12$, $p = .124$). The total IPQ score was significantly higher in experiment 2 than in experiment 1 ($t[46] = 2.25$, $p = .029$). Compared with the representative sample reported by Schubert (http://www.igroup.org/pq/ipq/data.php), the paradigm applied in experiment 2 revealed satisfactory IPQ scores. Participants investigated in experiment 2 did not differ from the representative sample in "spatial presence" ($t[562] = 0.32$, $p = .753$), "involvement" ($t[21] = 0.52$, $p = .607$), or "experienced realism" ($t[21] = 1.71$, $p = .101$). The total IPQ score of my sample in experiment 2 was also comparable to the representative sample ($t[21] = 0.26$, $p = .795$).

Table 3. Means (*M*) and standard deviations (*SD*) of the subscales of the Igroup Presence Questionnaire applied to the samples in experiment 1 and 2, and to a representative sample reported by Schubert.

	sample experiment 1 (*N* = 26)		sample experiment 2 (*N* = 22)		representative sample (*N* = 542)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Spatial Presence	2.75	0.98	3.20	1.01	3.27	1.07
Involvement	2.22	1.07	2.92	1.32	3.07	0.90
Experienced Realism	1.78	1.10	2.38	1.01	2.00	0.77
Total	2.25	0.89	2.83	0.89	2.78	0.66

Comments: IPQ scores range from 0 to 6; 0 = low presence ratings, 6 = high presence ratings.

2.2.3.4. Influence on Scoring Performance and Emotional Reactions

See Table 10 (A 14) for an overview of means and standard deviations of the ratings on the post-experimental questionnaire. In this questionnaire (see A 13), participants reported that they found the experiment not very tiring, that they did not have difficulties to concentrate throughout the experiment, that they were highly motivated to participate and that it was important for them to perform well in the experimental task. Importantly, participants rated their experienced influence on the performance in the penalty kicking game not very high on average. Participants who were more convinced of their influence on their scoring performance responded stronger to unpleasant trials on the experiential level. The higher participants rated their influence on their performance the lower their valence ratings in response to unpleasant trials with feedback ($r = -.471$, $p = .027$), and the higher their arousal ratings in response to unpleasant trials with ($r = .652$, $p < .001$) and without feedback ($r = .487$, $p = .021$). Moreover, participants who rated their experienced influence on their performance higher (item 11) showed higher zygomaticus activations in pleasant trials with feedback ($r = .526$, $p = .012$).

2.2.3.5. Additional Analyses

Analyses concerning sociodemographic influences on emotional reactions are subsumed in A 14. The age of participants was hardly related to the intensity of emotional reactions. The participants' gender hardly influenced emotional reactions. Only corrugator activations were higher in women than in men especially in trials without feedback.

2.2.4. Discussion

The main purpose of the present study was to test the influence of social feedback on induced emotions in an elaborated version of the virtual penalty kicking paradigm established in experiment 1. I therefore realized a version of the virtual penalty kicking paradigm explained before, in which participants received feedback from a virtual coach only in 50 % of all trials and a number of methodological improvements. Most importantly, the neutral control condition in the current experiment was better comparable with pleasant and unpleasant experimental conditions in terms of cognitive and motor demands. Moreover, neutral trials were presented within the same experimental blocks as pleasant and unpleasant trials. Emotional reactions were assessed on an experiential level (valence and arousal ratings) as well as on a physiological level (activity of M. zygomaticus major and M. corrugator supercilii, skin conductance responses). Furthermore, I was interested in whether the methodological improvements of the virtual environment would go along with improved presence experiences, assessed with the "Igroup Presence Questionnaire" (Schubert, 2003).

In accordance with my expectations, valence and arousal ratings were modulated dependent on the emotional condition. Participants rated pleasant trials (hits with and without subsequent feedback from a virtual coach) as more pleasant than neutral trials (shots over the free soccer field with and without subsequent feedback), and unpleasant trials (losses with and without subsequent feedback) as less pleasant than neutral trials. Moreover, they rated both pleasant and unpleasant trials as more emotionally arousing than neutral trials. Those modulations are in line with the results of experiment 1 and with studies using classical stimuli like pictures, sounds, or films, for emotion induction (Baur et al., 2015; Hewig et al., 2005; Plichta et al., 2011). However, against my expectations, valence ratings in response to neutral trials with and without feedback were higher than 5, and valence ratings in response to unpleasant trials with and without feedback did not differ from 5. Those findings are not in line with the findings in experiment 1 where valence ratings after unpleasant trials (with feedback) were significantly lower than 5. One reason for this might be that the revised facial expressions which were meant to intensify especially negative emotional responses did not work as expected, resulting in more pleasant instead of more unpleasant emotional experiences in response to unpleasant trials. However, as valence ratings in response to unpleasant trials without feedback were even higher than in unpleasant trials with feedback, one might also conclude that the experimental task per se was not suitable to induce negative emotional states. As already outlined in the discussion of experiment 1, a soccer stadium might be perceived as rather pleasant by most participants. Therefore, executing any experimental task in this pleasant environment might bias emotional experiences throughout the experiment in a positive way (Holmes & Westbrook, 2014). This might explain both the slightly positive valence ratings in response to neutral trials and the neutral valence ratings in response to unpleasant trials. To disentangle emotional reactions to the shots and feedback phrases from reactions to the virtual soccer stadium (which might be regarded as a pleasant context), one would have to present both separately while measuring emotional reactions.

Activations of M. zygomaticus major were not modulated in line with my expectations. Activations in pleasant and unpleasant trials were comparably high and both higher than in neutral trials. Modulations of M. corrugator supercilii showed a similar pattern with significant deactivations in pleasant and unpleasant, compared to neutrals trials with feedback. Those results are in line with the results of experiment 1, but contrary to the hypothesis that unpleasant trials would go along with lower zygomaticus activations than pleasant trials and higher corrugator activations than pleasant and neutral trials (Baur et al., 2015; Dimberg, 1990; Lang et al., 1993). One explanation for this might be that both pleasant and unpleasant trials induced positive affective states, resulting in zygomaticus activations and corrugator deactivations (Dimberg, 1990). However, especially activations of M. corrugator supercilii were significantly modulated only in trials with feedback, where facial mimicry effects become important (Seibt, Mühlberger, Likowski, & Weyers, 2015). I will discuss possible impacts of facial mimicry on EMG modulations in trials with feedback later on. Skin conductance responses were modulated in line with my hypothesis only in trials with feedback from the virtual coach. Responses in pleasant and unpleasant trials with feedback were both higher than in neutral trials with feedback, and did not differ from each other. This is in line with studies using images (Haney & Euse, 1976) or music (Khalfa et al., 2002) for emotion induction. Skin conductance responses are known as an implicit measure of emotional arousal irrespective of emotional valence (Boucsein, 2012). Thus, it is impossible to tell from those results alone whether reactions in unpleasant trials should be ascribed to positive or negative affectivity. However, modulations of valence ratings, M. zygomaticus major and M. corrugator supercilii activations rather speak for the induction of positive affectivity in unpleasant trials. Possibly, at least some participants might have been amused by “negative” feedback phrases, resulting in higher positive emotional reactions. Taken together, one might conclude that data are in line with my first hypothesis only concerning the induction of positive, but not of negative affective states. Especially hits with feedback from the virtual coach seem to be suitable to induce positive affect, reflecting in positive emotional reactions on an experiential and a physiological level. However, unpleasant trials with and without feedback seemed to induce positive, rather than negative affective states.

My second hypothesis was that emotional reactions would be more intense in response to shots and subsequent feedback from a virtual coach than in response to shots alone. Results are in line with this hypothesis for the modulation of valence and arousal ratings. Valence ratings in trials with feedback were more intense than in trials without feedback, for both pleasant and unpleasant trials. For neutral trials, valence ratings were lower in trials with feedback than in trials without feedback. Arousal ratings were higher after shots followed by feedback than after shots alone irrespective of the emotional condition. The activity of M. zygomaticus major was higher after trials with feedback compared to trials without feedback across all emotional conditions, which is also in line with my hypothesis. Activations of M. corrugator supercilii, however, were lower in pleasant and unpleasant trials with feedback than in pleasant and unpleasant trials without feedback. This finding speaks against my hypothesis of higher emotional reactions in trials with feedback compared to trials without feedback. One might conclude from these findings that feedback from the virtual coach in general went along with slightly more positive emotional reactions on the physiological level. However, one has to consider that effects of facial mimicry certainly play a role in trials with feedback, but not in trials without feedback. Seibt et al. (2015) recently published a review on differential influences on facial mimicry in social settings. In this article, the authors argue that against earlier hypotheses, facial mimicry is not simply an automatic tendency of the perceiver to show the same facial expression as the sender, but is rather dependent on a number of situational variables, among those social motives like affiliation. Hess & Bourgeois (2010) could show in two very sophisticated studies that both in same sex and in mixed sex interaction partners, smiles, but not frowns were mimicked even when interaction partners were talking about anger episodes. Even in anger episodes, interaction partners engaged mostly in Duchenne smiles, with activations not only of M. zygomaticus major, but also of M. ocularis oculi, and very rarely showed activations of M. corrugator supercilii. Those results are in line with a study by Weyers et al. (2006) who argued that mimicking happy emotional expressions of an interaction partner (going along with activations of M. zygomaticus major) is evolutionary advantageous, whereas mimicking angry facial expressions (going along with activations of M. corrugator supercilii) is not. Hess & Bourgeois (2010) argue in a similar way, stating that “mimicking anger … would not fulfill the affiliation goal that is normally served by emotional mimicry”. Similar effects could explain my results of lower activations of M. corrugator supercilii in both pleasant and unpleasant trials with feedback than in trials without feedback. Kunz, Prkachin, & Lautenbacher (2009, 2013) found increased smiling behavior in response to painful stimuli especially when an intimate of the participant was present. The "smile of pain" (Kunz et al., 2009, 2013) points into the same direction as the results of social mimicry studies (Hess & Bourgeois, 2010; Seibt et al., 2015; Weyers et al., 2006) and the results of the present study, and question the interpretation of smiling behavior solely as an indicator of positive affectivity.

Modulations of skin conductance responses are again in line with my hypothesis with higher responses after hits and misses followed by feedback than after hits and misses alone. Interestingly, skin conductance responses after shots over the free field were diminished by feedback in comparison to skin conductance responses after free shots alone. This parallels the modulation of valence ratings (lower valence ratings in response to free shots and subsequent feedback than in response to free shots alone). Taken together, one could argue that feedback from the virtual coach in general was suitable to increase positive emotionality, whereas the induction of negative emotional responses by feedback remains unclear.

The comparison of IPQ-scores of the sample investigated in the current experiment with the sample investigated in experiment 1 and with the scores of a representative sample (http://www.igroup.org/pq/ipq/data.php) indicate that the current paradigm was more suitable than the one in experiment 1 to induce feelings of presence. This was mostly due to higher feelings of involvement (focusing one's attention on the virtual world and paying less attention to the real world) and higher experienced realism (experiencing the virtual world as comparably "real" as the real world). Those improvements might partly be due to the new, more sophisticated coach model which might have looked much more like a human being than the virtual agent used in experiment 1. Moreover, the more sophisticated computer algorithm triggering the goal keeper animations might have resulted in higher involvement in the experimental task, which in turn is known to influence presence in a virtual environment (Schuemie, van der Straaten, Krijn, & van der Mast, 2001) and is defined as a component of presence in Schubert's (2003) three-component model of presence underlying the IPQ. The reason why the scores for spatial presence (the feeling of directly interacting in the virtual world) did not improve in experiment 2 vs. experiment 1 might be that the participants' interaction possibilities, which are known to influence especially spatial presence (Regenbrecht & Schubert, 2002), did not change.

Participants rated their perceived influence on their scoring performance rather low. Participants' experienced influence on their performance was correlated with their emotional reactions on the experiential level (valence and arousal ratings) to unpleasant trials and their reactions on the physiological level (zygomaticus activations) to pleasant trials. Participants who were convinced that their influence on their performance was rather high thus rated unpleasant trials with feedback as less pleasant, unpleasant trials with and without feedback as more arousing, and showed higher zygomaticus activations in pleasant trials with feedback. A lack of induction of stronger emotional states, especially negative emotional states, might thus be modulated by a lack of self-efficacy (Bandura, 1977) in the penalty kicking task. This explanation would partly be in line with Tritter, Fitzgeorge, Cramp, Valiulis, & Prapavessis (2013) who found correlations between changes in self-efficacy and change in positive well-being and psychological distress in participants engaging in a sprint interval training. Boardley, Jackson, & Simmons (2015) found that increased self-efficacy predicts increased positive affect and reduced negative affect in golfers.

Some shortcomings have to be discussed in the present study. Those include first of all the exact timing of trials with and without feedback. In trials without feedback, time frames for the analyses of facial muscle activity and skin conductance responses include part of the scoring process, whereas this is not the case in trials with feedback (see Figure 7). The cognitive demands while preparing and releasing a shot might go along with increased corrugator activations and concomitant decreased zygomaticus activations, confounding the emotional reactions on the physiological level in trials without feedback. This might explain part of the corrugator deactivations in pleasant and neutral trials without feedback. As the current paradigm allows for no control of the time it took participants to release their shot, it is unclear what exact cognitive and motor processes participants performed during the first 2000 ms of the 6000 ms segments serving for physiological analyses. However, those processes, whatsoever they are, very probably entangled physiological responses. To disentangle effects of emotional reactivity from effects of cognitive and motor processes on physiological reactions, a much more thorough timing would be necessary especially in trials without feedback. Another shortcoming implies participants' low belief in their influence on the performance in the penalty kicking task which may have weakened emotional reactions, as outlined above. However, I can think of no easy solution for this problem while at the same time maintaining a controlled trial order with equal numbers of trials belonging to different experimental conditions. Finally, as EMG activations may not unambiguously be interpreted as emotional reactions (Hess, Philippot, & Blairy, 1998), the study lacks a distinct implicit measure of emotional valence. Explicit measures like valence and arousal ratings are prone to demand characteristics (Orne, 1962) and should therefore not be trusted uncritically. For future studies, it would be helpful to imply measures of emotional valence on a behavioral level in the sense of Gross' (1998b) model of emotion generation. Furthermore, it would be interesting to imply an emotion regulation task and to investigate emotion processing and emotion regulation in patient groups vs. healthy controls.

To sum up, the results of experiment 2 indicate that the paradigm is well suitable to induce positive affective states, which go along with emotional responses on an experiential and a physiological level. Moreover, emotional responses on both an experiential and a physiological level were intensified by social feedback. The methodological improvements of the virtual environment resulted in higher scores of presence (Schubert, 2003). However, the induction of negative affective states remains unclear. Emotional responses to unpleasant states indicated ambiguous, rather than merely negative affectivity. Still, one has to keep in mind that especially explicit ratings assessed in psychological experiments underlie demand characteristics (Orne, 1962), possibly resulting in positively biased responses on the experiential level. As outlined above, modulations of facial muscles in trials with feedback are confounded by mimicry effects. Therefore, in future studies, it would be important to implement measures of emotional responses on another, more implicit level (for example, behavioral responses), to gain further information on the affective states induced in the current paradigm.

2.3. Emotion Processing and Emotion Regulation in Adult ADHD (Experiment 3)

2.3.1. Introduction

The aim of the current experiment was to test whether adult ADHD patients differ from healthy control subjects in the way they process pleasant and unpleasant experiences, and whether they differ from healthy controls in their abilities to deliberately regulate their emotional reactions via response modulation in the sense of Gross'(1998b, 2002) model of emotion regulation.

Previous studies have found both children and adults presenting with combined ADHD to show aberrances in processing of emotional stimuli (Conzelmann et al., 2009; Conzelmann et al., 2014) and suggested that ADHD patients show major impairments in the regulation of positive and negative emotions (Bunford et al., 2014; Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Sjöwall et al., 2013; Walcott & Landau, 2004). Most studies to date investigated emotion processing in ADHD with the help of emotional pictures. Those might lack ecological validity, which limits the transferability of study results into everyday life. On the other hand, studies on emotion regulation in ADHD have mostly been conducted in rather naturalistic interactions (Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Walcott & Landau, 2004). This accounts for higher ecological validity. However, a shortcoming of those studies is the lack of controllability of experimental conditions, bringing along numerous confounding variables which could bias study results. Therefore, the realization of a virtual reality paradigm, combining high controllability with relatively high ecological validity, seemed ideal to investigate emotion processing and emotion regulation in ADHD patients and healthy controls.

As pointed out in the theoretical background section, social interactions have been shown to be elicitors of strong emotions, both in healthy study participants and in ADHD patients (Abrams et al., 2011; Barkley et al., 2012; Bondü & Esser, 2015; Godbold, 2015; van Kleef & Fischer, 2016). Therefore, it seemed suitable to realize a virtual penalty kicking paradigm with feedback from a virtual soccer coach for the induction of strong positive and negative emotions. Pleasant and unpleasant trials in this paradigm consisted of hits respectively misses in penalty kicks and subsequent feedback of a pleased respectively irritated virtual coach. Neutral trials consisted of kicks over the free soccer field with subsequent neutral feedback from the coach. However, the virtual penalty kicking paradigm (developed and tested in experiments 1 and 2) proved to be suitable for the induction of strong positive emotions, while the induction of strong negative emotions was less successful. Therefore, I additionally realized an adapted version of the cyber ball paradigm (Williams & Jarvis, 2006) which has proven to be successful in inducing negative emotions in previous studies (Abrams et al., 2011; Barkley et al., 2012; Bolling et al., 2012; Kawamoto et al., 2013; Kelly et al., 2012). Cyber ball is an ostensible online ball-tossing game in which participants are made to believe they are tossing a ball back and forth with two other players who are logged in to the system at the same time. Participants receive the ball either equally often as their co-players (inclusion condition) or less frequently than the other two players (ostracism condition). Social ostracism in the cyber ball game has been shown to go along with negative emotions. Cyber ball seemed especially suitable to implement in the pleasant study because it realized emotion induction through social interaction, and because of its repeated successful application in previous studies.

Participants in the present study went through different blocks of an adapted version of the cyber ball game (Williams & Jarvis, 2006) and different blocks of the penalty kicking game, subsequently. They were instructed to explicitly show their emotions, not regulate their emotions, and hide their emotions, in different experimental blocks. Emotional reactions were assessed on experiential (valence and arousal ratings, ratings of positive and negative affect), physiological (zygomaticus and corrugator activations, skin conductance modulations), and behavioral levels (emotional expressive behavior assessed with an observational coding scheme). In addition, I assessed baseline skin conductance levels for patients and controls and investigated habitually applied emotion regulation strategies in the sense of Gross' (1998b, 2002) model in patients and controls when facing positive and negative emotions. Finally, I investigated the influence of genotype variations associated with ADHD on emotion processing and emotion regulation.

I expected differences in ADHD patients vs. healthy controls in emotion processing as well as in emotion regulation.

For *emotion processing conditions*, I expected lower valence ratings, higher scores of negative affect and lower scores of positive affect for patients than for controls, especially in ostracism blocks in the cyber ball game, and in response to pleasant as well as unpleasant trials in the virtual penalty kicking game. Moreover, I expected overall lower arousal ratings for patients vs. controls irrespective of the experimental condition. I expected zygomaticus activations to be lower and corrugator activations to be higher in ADHD vs. controls, especially in ostracism blocks in the cyber ball game, and in response to pleasant as well as unpleasant trials in the virtual penalty kicking game. I expected skin conductance levels in the cyber ball game to be lower in patients vs. controls, during both inclusion and ostracism blocks. I expected skin conductance responses in the penalty kicking game to be lower in patients vs. controls for all experimental conditions, and especially so in pleasant and unpleasant trials. On the behavioral level, I expected less expressions of the social monitoring aggregate and more expressions of the positive, negative, and tension aggregates for patients vs. controls, especially during ostracism in the cyber ball game and during pleasant and unpleasant trials in the penalty kicking game.

For *emotion regulation conditions,* I expected ADHD patients to be less successful at suppressing their emotions, especially in ostracism during the cyber ball game and during pleasant and unpleasant trials in the virtual penalty kicking game. This should reflect in weaker modulations of valence and arousal ratings, zygomaticus and corrugator activations, and behavioral expressions in patients vs. controls. Furthermore, I wondered whether patients would also be worse than healthy controls at explicitly expressing their emotions in the penalty kicking game. If so, this should show in weaker modulations of emotional responses (valence and arousal ratings, zygomaticus and corrugator activations, and behavioral observations) in patients vs. controls. Moreover, I was interested in whether explicitly expressing vs. not regulating vs. suppressing positive and negative emotions during the cyber ball and penalty kicking games would go along with weaker skin conductance modulations in patients vs. controls.

I expected patients to show lower baseline skin conductance levels than healthy controls. I expected ADHD patients vs. controls to habitually apply less adaptive emotion regulation strategies like attention allocation and reappraisal. This should reflect in lower scores on respective scales of an emotion regulation questionnaire (ERI, König, 2011).

Finally, I expected participants who show a genotype expression that has previously been associated with increased risk for ADHD and with affective dysregulation (l/l expression of SNP 5-HTT) to show lower levels of positive affectivity, higher levels of negative affectivity, and impaired skin conductance modulations in comparison with participants with the s/l or s/s genotype. Moreover, participants with the l/l genotype were expected to show deficits in emotion regulation in comparison with participants with the s/l or s/s genotype.

2.3.2. Methods

2.3.2.1. Participants

After exclusion of 4 data sets of healthy controls (due to present or past psychiatric disorder reported in clinical interviews) and two data sets of ADHD patients (1 due to addiction of cannabinoids reported in clinical interviews, 1 due to technical problems), data of 30 healthy controls (14 female; age: 18 – 61 years, $M = 36.23$, $SD = 13.22$) and 30 ADHD patients (14 female; age: 18 – 59 years, M = 33.67, SD = 14.67) remained for statistical analyses. Healthy controls were recruited from a local online platform (www.wuewowas.de) and through flyers at local trade schools. ADHD patients were recruited through data bases of the psychiatric clinic and the clinic for child and adolescent psychiatry of the University of Würzburg. Healthy controls were free of any lifetime psychiatric disorders. All patients had been diagnosed with combined ADHD (F90.0 according to the ICD-10, World Health Organization, 1992) by professionals in the psychiatric clinic or the clinic for child and adolescent psychiatry of the University of Würzburg. Healthy controls and ADHD patients did not differ in age (t[57] = 0.71, p = .479), gender distribution (χ^2 = 0.00, p = 1.00), or educational level (χ^2 = 3.54, p = .316).

One control participant reported that her vision was not corrected to normal during the experiment. All other healthy controls and all patients reported that their vision was normal or corrected to normal. Two control participants reported to suffer from slight tinnitus from time to time. Both reported to not suffer acutely during the experiment. All other healthy controls reported no hearing disabilities. One patient reported to have slight hearing problems at very high pitches and another patient reported to hear slightly less on the left ear compared to the right ear. All other patients reported no hearing disabilities. 6 healthy controls and 11 patients reported to be smokers. 4 healthy controls and 16 patients reported to take any kind of medication regularly. Thereof, 6 patients reported to take methylphenidate compounds. Patients were free of methylphenidate medication for at least four days before the experiment according to the guidelines proposed in Benkert (2015). Patients as well as controls did not take any other psychoactive drugs. 6 patients reported to have undergone any kind of psychotherapy.

See Table 4 for an overview over self-reported co-morbidities of patients. According to clinical interviews (German version of the structured clinical interview for the DSM-I, SCID-I Wittchen, Zaudig, & Fydrich, 1997), 11 patients fulfilled the criteria for at least one lifetime episode of major depression. 1 patient fulfilled the criteria for a current episode of major depression, 1 for cannabis abuse, 1 for panic disorder, 2 for social phobia, 3 for specific phobia, 1 for obsessive-compulsive disorder, 1 for unspecific somatoform disorder, 1 for hypochondria, 1 for anorexia nervosa, and 1 for binge eating disorder. Moreover, a number of patients fulfilled the criteria for personality disorders according to the structured clinical interview for the DSM-IV (SCID-II; First, 2014): 1 for dependent personality disorder, 4 for obsessive-compulsive personality disorder, 1 for paranoid personality disorder, 2 for narcissistic personality disorder, 8 for borderline personality disorder, 6 for oppositional-defiant disorder, and 4 for antisocial personality disorder. Please note that the SCID-II has been criticized for being over-sensitive and that it is especially difficult to interpret SCID-II results for patients currently suffering from any axis I disorder (including ADHD; Wittchen et al., 1997). For clinical purposes, a far more thorough and critical diagnostic process should be undertaken. However, this was not the aim of the present study and I only report here the results of the interview without claiming that those results would hold true after a more critical differential diagnostic process.

Table 4. Overview over self-reported comorbidities of ADHD patients according to the structured clinical interview for the DSM, axes I and II.

	Absolute number of patients fulfilling diagnostic criteria (*n*)	Percentage of patients fulfilling diagnostic criteria (%)
Major depression_lifetime	11	36.67
Major depression_current	1	3.33
Cannabis abuse	1	3.33
Panic disorder	1	3.33
Social phobia	2	6.67
Specific phobia	3	10.00
Obsessive-compulsive disorder	1	3.33
Unspecific somatoform disorder	1	3.33
Hypochondria	1	3.33
Anorexia nervosa	1	3.33
Binge eating disorder	1	3.33
Dependent PD	1	3.33
Obsessive-compulsive PD	4	13.33
Paranoid PD	1	3.33
Narcissistic PD	2	6.67
Borderline PD	8	26.67
CD	6	20.00
Antisocial PD	4	13.33

Comments: PD = personality disorder; CD = conduct disorder (criteria fulfilled before the age of 15 according to a retrospective interview, the SCID-II).

On average, patients reported significantly higher scores of various forms of psychopathology than healthy controls in a number of questionnaires (see Table 5).

Table 5. Sociodemographic and psychopathological characteristics of HC and ADHD in experiment 3.

	HC (*n* = 30)	ADHD (*n* = 30)		
	M (*SD*)	*M* (*SD*)	*t*	*p*
Age[a]	36.23 (13.22)	33.67 (14.67)	0.71	.479
No. of cigarettes per day[a]	2.05 (5.08)	5.90 (9.64)	1.94	.060 #
HASE_inattentive	2.70 (2.94)	11.90 (5.83)	7.72	<.001 **
HASE_hyp	1.03 (1.65)	7.03 (3.77)	7.98	<.001 **
HASE_imp	1.20 (1.92)	4.93 (3.35)	5.29	<.001 **
HASE_sum	4.93 (5.38)	23.87 (10.97)	8.48	<.001 **
DSM-int_inattentive_child	0.53 (1.33)	6.93 (1.44)	17.89	<.001 **
DSM-int_inattentive_adult	0.13 (0.35)	5.87 (2.18)	14.25	<.001 **
DSM-int_hyp/imp_child	0.70 (1.39)	6.00 (2.65)	9.69	< .001 **
DSM-int_hyp/imp_adult	0.37 (0.72)	6.17 (1.80)	16.38	< .001 **
RSES	29.07 (6.29)	38.30 (6.58)	2.38	.021 *
BDI-II	2.10 (4.41)	8.87 (8.93)	3.72	< .001 **
STAI_trait	29.07 (6.29)	40.10 (10.25)	4.96	< .001 **
BSI_somatization	44.07 (5.72)	50.27 (10.16)	2.91	.006 **
BSI_obsessive-compulsive	41.40 (8.28)	58.60 (11.79)	6.54	< .001 **
BSI_social insecurity	42.43 (7.04)	49.77 (12.78)	2.75	.008 **
BSI_depression	43.20 (5.28)	49.63 (10.80)	2.93	.005 **
BSI_anxiety	42.67 (8.87)	54.83 (11.68)	4.54	< .001 **
BSI_aggression	42.83 (11.02)	52.10 (12.25)	3.08	< .001 **
BSI_phobic anxiety	46.80 (5.18)	50.73 (8.96)	2.08	.043 *
BSI_paranoia	44.03 (6.97)	52.83 (11.19)	3.66	< .001 **
BSI_psychotizism	46.33 (4.30)	51.77 (9.58)	2.83	.007 **
BSI_total	36.00 (11.97)	52.41 (13.68)	4.91	< .001 **
SCID_II_self-insecure	0.20 (0.61)	1.53 (1.87)	3.71	< .001 **
SCID_ II_dependent	0.30 (0.47)	1.13 (1.43)	3.03	.005 **
SCID_ II_obsessive-compulsive	0.67 (0.84)	2.87 (1.59)	6.69	< .001 **
SCID_ II_negativistic	0.20 (0.48)	1.47 (1.36)	4.81	< .001 **
SCID_ II_depressive	0.27 (0.78)	1.57 (1.65)	3.89	< .001 **
SCID_ II_paranoid	0.30 (0.65)	1.27 (1.57)	3.11	.004 **
SCID_ II_schizotypic	0.13 (0.35)	0.53 (1.17)	1.80	.081 #
SCID_ II_schizoid	0.20 (0.61)	0.37 (0.72)	0.97	.337
SCID_ II_histrionic	0.10 (0.31)	0.73 (1.11)	3.01	.005 **
SCID_ II_narcissistic	0.13 (0.35)	1.30 (1.74)	3.59	< .001 **
SCID_ II_borderline	0.27 (0.64)	2.63 (2.92)	4.34	< .001 **
SCID_ II_oppositional defiant	0.30 (0.65)	1.23 (1.61)	2.94	.006 **
SCID_ II_antisocial	0.77 (0.73)	1.50 (1.39)	2.57	.014 *

Comments: [a] reported in the sociodemographic questionnaire; HASE = Homburger ADHS Skalen für Erwachsene (Rösler et al., 2004), higher scores represent higher symptom load on different subscales; HASE_inattentive = subscale of the HASE measuring inattentive symptoms; HASE_hyp = subscale of the HASE measuring hyperactive symptoms; HASE_imp = subscale of the HASE measuring impulsive symptoms; HASE_sum = total HASE score for inattentive, hyperactive, and impulsive symptoms; DSM-int = diagnostic interview of ADHD symptoms according to the DSM-IV (Krause & Krause, 2005); DSM-int_inattentive_child= no. of inattentive symptoms reported in the interview referring to age 0-7; DSM-int_inattentive_adult = no. of inattentive symptoms reported in the interview referring to adult life; DSM-int_hyp/imp_child = no. of hyperactive and impulsive symptoms reported in the interview referring to age 0-7; DSM-int_hyp/imp_adult; no. of symptoms reported in the interview referring to adult life; RSES = Rosenberg Self Esteem Scale (Collani & Herzberg, 2003), high numbers represent higher self-esteem; BDI-II = Beck's Depression Inventory-II (Hautzinger, Keller, Kühner, & Beck, 2006), high numbers represent higher depressive symptom load; STAI = State-Trait Anxiety Inventory (Laux & Spielberger, 2001), I assessed only scores for trait anxiety, higher numbers represent higher levels of trait anxiety, BSI = Brief Symptom Inventory (Franke & Derogatis, 2000), reported are T-values, higher values represent higher symptom load on the different scales; SCID = structured clinical interview for the DSM – axis II (Wittchen et al., 1997), reported here are the mean number of symptoms reported for every subscale; ** $p < .01$, * $p < .05$, # $p < .10$.

Genotype characteristics of patients and controls are depicted in Table 6. Genotype expressions of SNP 25 of the TPH2 gene were equally distributed across patients and controls. For SNP 5-HTT, there was a slight over-expression of the l-allele in patients vs. controls. As the genotype distribution for SNP 25 TPH2 expressions did not differ in patients vs. controls, further analyses were conducted only for different expressions of SNP 5-HTT. Participants with at least one s-allele (s/l and s/s genotypes) were subsumed as "s carriers". Participants with the l/l genotype were referred to as "non s carriers". Due to the small sample size, patients and controls were subsumed in one group for genotype analyses.

Table 6. Genotype characteristics of HC and ADHD in experiment 3.

		HC (n = 30)	ADHD (n = 29[e])	X^2	p
SNP 25 TPH2[a]	GG	22 (73.33 %)	19 (65.52 %)	1.26	.532
	GT	8 (26.67 %)	9 (31.03 %)		
	TT	0 (0.00 %)	1 (3.45 %)		
	T carrier[c]	8 (26.67 %)	10 (34.48 %)	0.43	.514
SNP 5-HTT[b]	l/l	5 (16.67 %)	11 (37.93 %)	5.09	.078 #
	s/l	23 (76.67 %)	14 (48.28 %)		
	s/s	2 (6.67 %)	4 (13.79 %)		
	s carrier[d]	25 (83.33 %)	18 (62.07 %)	3.37	.066 #

Comments: depicted here are absolute numbers and percentages (in brackets) of different genotype expressions of healthy controls and ADHD patients; [a] single nucleotide polymorphism 25 of the tryptophan hydroxylase-2 gene; [b] single nucleotide polymorphism 5 of the serotonin transporter gene SLC6A4; [c] GT and TT expressions are summarized here in one group; [d] s/l and s/s expressions are summarized here in one group; [e] no DNA could be extracted from the saliva sample of one patient, resulting in a patient sample of only 29; ** $p < .01$, * $p < .05$, # $p < .10$.

All participants gave their written informed consent for participation. The study was approved by the ethics committee of the University of Würzburg.

2.3.2.2. Cyber Ball Paradigm

As induction of negative emotional states had not worked reliably with the virtual penalty kicking paradigm (see experiments 1 and 2), a modification of the Cyber Ball paradigm (Williams & Jarvis, 2006) was additionally applied to participants in the current experiment. Participants went through four blocks of this game which was developed to experimentally test the effects of social ostracism on different psychological variables. In the game, participants were instructed to play an online ball-tossing game with two other players. Participants were led to believe that the research question was about mental visualization skills. They were instructed to visualize the game scene as vividly as possible while tossing a ball back and forth with the other two players. The computer animation was very simple with two simplistic icons representing the other two players (see Williams & Jarvis, 2006). Participants could toss the ball by clicking on those icons or by clicking on the other players' names, which stood below the icons. In fact, the two other players were controlled by a computer algorithm, so that the participant either received the ball as often as the other two players (inclusion condition) or only received the ball twice in the beginning of the game and then did not receive it any more for the rest of the game (ostracism condition).

The original paradigm described in Williams & Jarvis (2006) and different variants of it have repeatedly been used for successful induction of negative affect, in adults (Beeney et al., 2011; Bolling et al., 2012; Chen, DeWall, Poon, & Chen, 2012) and children (Abrams et al., 2011; Barkley et al., 2012), in healthy participants and different patient groups (Dixon-Gordon et al., 2013; Hulme, Hirsch, & Stopa, 2012; Lawrence, Chanen, & Allen, 2011a; Levinson et al., 2013; Masten et al., 2011; Rehman, Ebel-Lam, Mortimer, & Mark, 2009; Staebler et al., 2011).

The structure of cyber ball blocks in the current experiment is depicted in Figure 12. The order of the different cyber ball blocks was pseudorandomized across healthy controls and ADHD patients, separately. After each block, participants filled in the German version of the "Positive and Negative Affect Schedule" (PANAS; Krohne et al., 1996) and a short questionnaire on their emotional experiences throughout the preceding block (see A 19). Before the beginning of each block, the experimenter told the participants that they had to wait for a few more minutes until the other players were ready to start. After the experimenter told the participants that they were allowed to start the game, a loading symbol with the comment "connecting to other players" appeared on the screen for 30s. Then, the game started with three simple icons that represented the three players appearing on the screen. Under each icon stood the name of the respective player. On the top of the screen was an instruction phrase ("You can throw the ball by clicking on the name or picture of another player") which remained for the whole duration of each block. The participants' avatar and name appeared in the middle of the screen, under the other two players' icons and names (which were placed in the upper left and right corners of the screen). The names of the other players differed in each block, making the participants believe they were playing with different co-players in each block. Gender distribution of the co-players was balanced across experimental conditions. The game started with one of the co-players either tossing the ball to the participant or to the third player.

In the current experiment, participants played 4 different blocks of the cyber ball game. One block involved 30 tosses of the ball. In inclusion blocks, all tosses were evenly spread across the three players, so that each of them received the ball ten times. In ostracism blocks, participants received the ball twice in the beginning (once from each co-player), and then did not receive it any more for the rest of the game, with the other two players only tossing the ball between the two of them. On average, one block lasted approximately 2 min. The social inclusion condition (inclusion vs. ostracism) as well as emotion regulation instructions (not regulate emotions vs. hide emotions) were manipulated across different blocks, resulting in four experimental conditions: inclusion_non-regulate (1), ostracism_non-regulate (2), inclusion_hide (3), and ostracism_hide (4). See A 15 for the original instructions of the different cyber ball blocks. Cyber ball blocks of different experimental conditions were presented in separately pseudorandomized orders to both control subjects and ADHD patients.

2.3.2.3. Virtual Environment, Stimulus Material and Apparatus

Furthermore, participants went through a modification of the penalty kicking paradigm described in experiment 2. The same virtual soccer stadium as used in experiments 1 and 2 was projected onto the power wall (3Dims GmbH, Frankfurt, Germany) with VrSessionMod 0.5 (Department of Psychology I, University of Würzburg) and two projectors (projection design F32, resolution: WUXGA, 1920x1200; projection design as, Gamle Fredrikstad, Norway).

The main experiment consisted of 15 pleasant, 5 neutral, and 15 unpleasant trials, divided into 3 experimental blocks. Pleasant, neutral, and unpleasant trials consisted of hits, shots over the free soccer field, and misses, and subsequent feedback from a virtual soccer coach. Feedback phrases for pleasant and unpleasant trials were the same as used in experiment 2. For neutral feedback phrases, I selected the 5 out of 15 phrases applied in experiment 2 that induced average emotional valence (close to 5 on a 9-point likert scale) and low arousal due to the ratings given of the sample in experiment 2. Pleasant, neutral, and unpleasant feedback phrases did not differ in number of syllables or absolute length (*t*s < 1.04, *p*s > .316).

Unpleasant phrases (*M* = 2.15, *SD* = 0.44) did not differ from pleasant (*M* = 2.22, *SD* = 0.46) or neutral phrases (*M* = 1.99, *SD* = 0.11) in absolute length (*t*s < 1.29, *p*s > .215). On average, pleasant phrases were marginally longer than neutral phrases (*t*[17] = 1.85, *p* = .081). Additionally, 4 pleasant, 1 neutral, and 4 unpleasant phrases were presented in practice trials. See A 16 for a list of all feedback phrases used in experiment 3.

Facial animations of the virtual coach were the same as used in experiment 2. Ratings of emotional valence and arousal were given on the same 9-point likert scales as in experiment 2. 1 indicated “very unpleasant” or “not arousing at all”, 9 indicated “very pleasant” or “very arousing”. Additionally, a 9-point rating scale assessing how much participants felt they had hidden or shown their emotions was implemented. On this scale, 1 indicated “strongly hidden”, and 9 indicated “clearly shown”. See A 20 for the original rating scales used in experiment 3. Ratings were given on the same keyboard as in experiment 2.

Three different coach models were used in the current experiment. Those were the same virtual agent as used in experiment 2 and two other virtual agents (see). All agents were provided by VTplus GmbH, (Würzburg, Germany).

Figure 11. Screenshots of the virtual agents used as soccer coaches in experiment 3.

The computer algorithm triggering the goal keeper animations was the same as in experiment 2.

2.3.2.4. Procedure and Design

Before being invited to the laboratory, healthy controls and ADHD patients went through different telephone interviews. For controls, the interview consisted of a number of sociodemographic questions, a short screening on ADHD symptoms, as well as a screening for symptoms of any psychiatric disorder on axis I or II according to the DSM-IV (see A 17). Only participants who did not report any psychopathologic abnormalities in this interview were invited for participation. ADHD patients were asked for age, gender, educational level, and pharmaceutic intake as well as substance abuse on the telephone. Furthermore, they went through a screening interview on ADHD symptoms in childhood and adulthood according to the DSM-IV, as described in Krause & Krause (2005).

After reading the information form (see A 18), participants and gave their written informed consent on participation (see A 4). They filled in a sociodemographic questionnaire (see A 5) and the German version of the Rosenberg Self Esteem Scale (Collani & Herzberg, 2003). They then went through an adapted version of the Implicit Association Test (IAT; Greenwald, Nosek, & Banaji, 2003). This test was developed as an implicit measure of self-esteem. It lasted for about 10 min. Exact methods and results of this test are reported elsewhere (Wagner, 2015). After the IAT, participants washed their hands with soapless water and the experimenter attached electrodes for measurement of facial muscle activity and skin conductance modulations. Participants then went through 4 blocks of the cyber ball game, thereby passing all experimental conditions (inclusion_non-regulate, ostracism_non-regulate, inclusion_hide, ostracism_hide).

After the cyber ball game, the experimenter told participants that they would now go through a virtual penalty kicking game on the power wall. She provided them with 3D-glasses, and explained to them how to operate the joystick (Mad Catz IV; Mad Catz Inc., San Diego, California) and the keyboard. The penalty kicking game was operated with CyberSession CS-Research 5.6.23 beta (VTplus GmbH, Würzburg, Germany). Participants were instructed both visually and verbally to imagine to take part in a test training of a representative soccer team which they absolutely wanted to join. They would be allowed to join the team if the three coaches that would watch them playing one after another were satisfied with their performance. Throughout the game, they would have to make as many goals as possible. At the same time, they would have to either show their emotions explicitly, not regulate their emotions, or hide their emotions, depending on each coach's preferences (see

A 20 for the original instructions). Before the start of the main experiment, participants went through 9 practice trials to get familiar with the experimental task and to habituate to the virtual environment. Those included each one pleasant, neutral, and unpleasant trial in which participants should not regulate their emotions, 1 pleasant and 2 unpleasant trials in which participants should explicitly show their emotions, and 2 pleasant and 1 unpleasant trials in which participants should hide their emotions. Afterwards, participants went through 3 blocks of the penalty kicking game (one “show” block in which participants were instructed to explicitly show their emotions, one “non-regulate” block in which participants were instructed to not regulate their emotions, and one “hide” block in which participants were instructed to hide their emotions). “Show”, “non-regulate”, and “hide” blocks each contained 5 pleasant and 5 unpleasant trials. Additionally, in the “non-regulate” block, 5 neutral trials were implemented. Trials within the different experimental blocks, and the blocks themselves were presented to controls and patients in separately pseudorandomized orders. Furthermore, the assignment of the 3 different coach models (see Figure 11) to different regulation conditions was pseudorandomized. This was done to prevent order effects. Pleasant and unpleasant trials consisted of shots onto the soccer goal with subsequent feedback from one of the three virtual coaches. Neutral trials consisted of shots over the free soccer field with subsequent feedback from a virtual coach. After the offset of each feedback phrase, the face of the coach was still visible for 4 s, showing an emotionally congruent facial expression in pleasant and unpleasant trials, and an emotionally neutral facial expression in neutral trials. After the offset of the coach face, participants rated emotional valence and arousal as well as the intensity to which they had just regulated their emotional expressions on the rating scales described above. After the rating period followed an intertrial interval varying from 6-8 s, before the start of the next trial. The trial structure in the penalty kicking game of the current experiment was the same as for trials with feedback in experiment 2 (see Figure 12).

After the penalty kicking game, the experimenter took off the electrodes and asked participants to fill in a number of post-experimental questionnaires: the “Igroup Presence Questionnaire” (IPQ; Schubert, 2003), the same questionnaires on experiences throughout the experiment and soccer and gaming experiences as in experiment 2 (see A 13 and A 8), as well as a questionnaire on applied emotion regulation strategies throughout the experiment (see A 21). Then, participants were asked to give a saliva probe which was collected with an Oragene OG-500 Saliva Self Collection Kit (DNA Genotek Inc., Ottawa, ON, Canada). If they felt they needed it, participants could now take a short break and leave the laboratory for a couple of minutes. Afterwards, they filled in a number of further questionnaires (“Emotionsregulationsinventar”, ERI, König, 2011; screening-questionnaire for axis II disorders according to the DSM-IV, Wittchen et al., 1997; German version of Beck's Depression Inventory-II BDI-II, Hautzinger et al., 2006; German trait version of the "State-Trait Anxiety Inventory", STAI-Trait, Laux & Spielberger, 2001; "ADHS-Selbstbeurteilungsskala" of the "Homburger ADHS Skalen für Erwachsene", HASE, Rösler et al., 2004; German version of the "Brief Symptom Inventory", BSI, Franke & Derogatis, 2000). At the end, the experimenter went through the German version of the structured clinical interview for axis I and axis II disorders according to the DSM-IV (SCID, Wittchen et al., 1997) with both controls and ADHD patients. In addition, with healthy controls, she went through a short interview on ADHD symptoms in childhood and adulthood, which ADHD patients had already gone through before the invitation to the laboratory on the telephone (Krause & Krause, 2005). Before leaving, participants were debriefed and received a short feedback on the clinical interview if they wished. They received 30 – 60 € payment for participation, depending on the length of the experimental session and their access route. See Figure 12 for an overview of the procedure applied to participants in experiment 3.

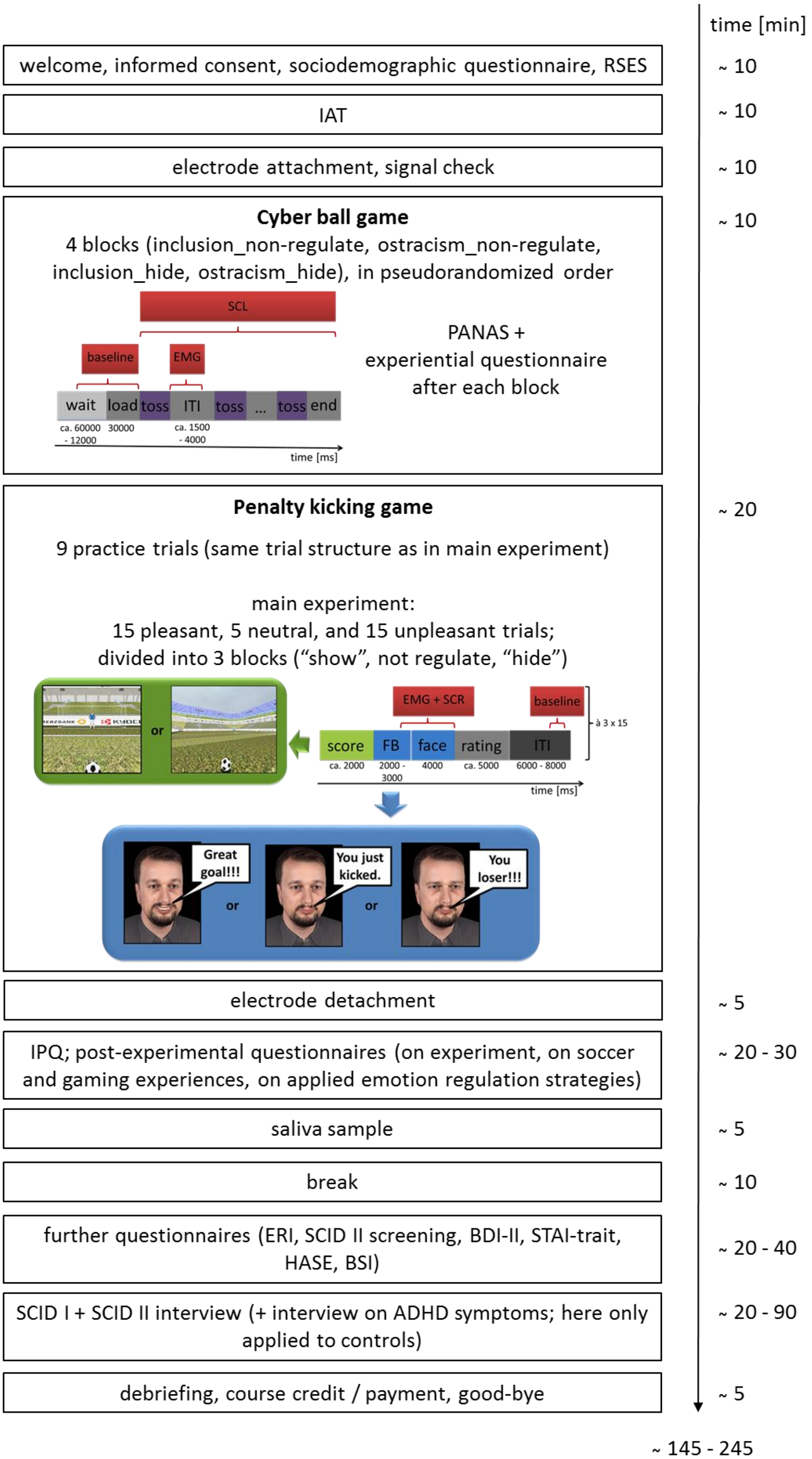


Figure 12. Procedure of experiment 3.

Comments: Structure of the Cyber Ball blocks: "wait" = waiting period before participants were allowed to start each block; "load" = time during which the loading symbol appeared on the screen; "toss" = tossing the ball between two of the three co-players; "ITI" = intertrial interval (time until participant or other co-player received the ball and prepared for the next toss); "end" = end of the cyber ball block; "EMG" = measurement of facial muscle activity; "SCL" = measurement of skin conductance level, "baseline" = baseline measurement of facial muscle activity and skin conductance level; one block involved 30 tosses; participants successively went through 4 blocks.
Structure of the Penalty Kicking Game: "Score" = kicking at the goal or over the free field with the joystick; "FB" = feedback from the virtual coach; "face" = period after the feedback during which the coach was still visible; "field" = period after the score during which the soccer field was still visible; "rating" = rating of emotional valence and arousal; "ITI" = inter trial interval (black screen); "EMG" = measurement of facial muscle activity; "SCR" = measurement of skin conductance responses, "baseline" = baseline measurement of facial muscle activity and skin conductance.

2.3.2.5. Data Recordings and Data Reduction

Physiological data

Recording of facial muscle activity and skin conductance modulations was done in the same way as in experiment 2. Data was recorded with BrainVision Recorder software (Brain Products GmbH, Gilching, Germany) and a V-Amp 16 amplifier (Brain Products GmbH, Gilching, Germany). Physiological data during virtual penalty kicking was preprocessed in the same way as for trials with feedback in experiment 2. Data was preprocessed with BrainVision Analyzer 2.1 (Brain Products GmbH, Gilching, Germany).

For the analyses of EMG modulations in reaction to the cyber ball game, a baseline correction (-1000 ms before each experimental block) was applied to the filtered data. Trials with strong artifacts during baseline (+/- 8 µV artifact correction applied to the 1000 ms baseline segments) were excluded from further analyses. The continuous data was then segmented into 2000 ms segments after the release of each toss, for each block separately. An artifact rejection excluded from further analyses trials with strong artifacts during measurement segments (+/- 30 µV). I Mean muscle activities of the 2000 ms segments after each toss were exported for each experimental block separately. The activation of those segments was then averaged across all trials of one experimental block before conducting statistical analyses. For the analyses of modulations of skin conductance levels across different cyber ball blocks, a baseline correction (- 60 000 ms before the start of the first experimental block) was applied to the continuously recorded data. For statistical analyses mean skin conductance levels over the first 100 000 ms of each cyber ball block were exported. For correction of skewness, I applied a logarithmic transformation to mean skin conductance levels (log[5+SCL]).

For the analyses of baseline differences in skin conductance levels in healthy controls vs. ADHD patients, average activations of 60 000 ms segments of continuously recorded, filtered

(50 Hz notch filter) skin conductance modulations before the beginning of the first cyber ball block were exported. These segments were not baseline corrected.

Behavioral observations

Participants were videotaped throughout the cyber ball and penalty kicking games with a camcorder (Sony DCR-SR72E; Sony Corporation, Tokyo, Japan). Video data of two patients had to be excluded from further analyses due to bad picture quality, resulting in a sample of 30 controls and 28 ADHD patients for behavioral observations.

The remaining videos were carefully watched and coded by two independent raters with the help of InterAct software (Mangold International GmbH, Arnstorf, Germany) according to a coding scheme adapted from Saarni (1984, 1992). See Table 7 for an overview of all categories included in the behavioral observation system in the current experiment. For reasons outlined in the discussion of experiment 1, much more categories of the original coding scheme were implemented than in experiment 1. After carefully watching the videos, I excluded from the original coding scheme (Saarni, 1992) only those categories that were never shown by participants in the current study. Not only categories of the “positive” and “negative” aggregates, but also behaviors indicating “tension” and “social monitoring” according to Saarni’s (1992) system were implemented. Two categories were slightly changed to make them more fitting for the present study. Moreover, two additional categories that were not included in Saarni’s (1992) system were implemented, as they seemed relevant for the current study (pleased, delighted comments; irritated comments).

Table 7. Behavioral categories included in the observation system in experiment 3.

Aggregate	Behavioral Categories	Percentage of agreement for each category[1]
Positive Aggregate	Relaxed, broad smile (teeth show or lips parted)	0.00% / 0.00%
	Raised eyebrows	76.40% / 55.74%
	Leans forward	86.67% / 15.66%
	Giggles or laughs	76.67% / 31.51%
	Pleased, delighted comments*	71.43% / 100.00 %
Negative Aggregate	Tense, square-looking smile (lips open and teeth showing)	10.00% / 41.67%
	Down-turned mouth (as in a frown or grimace)	8.00% / 25.00%
	Knits eyebrows	80.00% / 50.00%
	Leans backward	89.36% / 46.93%
	Sharp breath exhalation, snoring, grumping, or groaning	42.70% / 74.53%
	Sighing	0.00% / 0.00%
	Irritated comments*	70.24% / 89.39%
Tension Aggregate	Pressing, pursing, biting or sucking of lips	95.39% / 92.78%
	Cheek puffing	37.50% / 33.33%
	Prolonged tongue protrusions	1.74% / 75.00%
	Jaw wiggling, rotating, thrusting, and so on	65.22% / 54.88%
	Nose wrinkle	61.61% / 69.00%
	Rapid, nervous blinking	84.63% / 74.48%
	Looking around room or at ceiling in a scanning fashion; looking nervously into the camera#	86.92% / 42.66%
	Face/nose touching or scratching	91.30% / 90.00%
	Finger(s) in mouth, on lips, or nail biting; nose picking#	86.49% / 90.00%
	Touches/scratches hair, scalp, ears, and so on	72.22% / 56.52%
	Covers face or part of face with hands	0.00% / 0.00%
	Shrugs[2]	- / -
	Stretching[3]	0.00% / -
Social Monitoring Aggregate	Abrupt onset/offset of smile	84,81% / 17.82%
	Slight or closed lip smile	99.19% / 65.89%
	Tilts head	73.33% / 74.11%

Comments: [1]presented here are percentages of trials in which observer B coded a certain behavior, preceded by the same code given by observer A, and vice versa; * = categories not included in Saarni's system; # = categories changed slightly in comparison to Saarni's system; [2] behavior was never coded by observer A or B; [3] behavior was never coded by observer B.

Interrater reliabilities and internal consistencies of the different aggregates are depicted in Table 8. The two independent raters (two trained undergraduate students) were blind to the diagnostic group of the participants, to the cyber ball conditions, and to the regulation conditions throughout the penalty kicking game. Unfortunately, for technical reasons, it was not possible to keep them blind to the emotional condition in the penalty kicking game. The two raters watched the videos independently and rated whether or not a certain behavior was shown by the participants in every cyber ball block and every trial of the penalty kicking game (1 = "specific behavior was shown by the participant", 0 = "specific behavior was not shown by the participant"). Cohen's Kappa coefficients were calculated as a measure of interrater reliability for each aggregate according to the standard formula (Grouven et al., 2007; Landis & Koch, 1977). Kappa coefficients were interpreted according to the standards described in Landis & Koch (1977). Accordingly, coefficients < .00 represent "poor" agreement, .00-.20 "slight" agreement, .21-.40 "fair" agreement, .41-.60 "moderate" agreement, .61-.80 "substantial" agreement, and .81-1.00 "almost perfect agreement" between the two raters. Cronbach's Alpha coefficients (Cronbach, 1951) were calculated as a measure of internal consistency and interpreted according to the standards described in George & Mallery (2003). Accordingly, coefficients < .5 are "unacceptable", > .5 = "poor", > .6 = "questionable", > .7 = "acceptable", > .8 = "good", and > .9 = "excellent".

Table 8. Interrater reliabilities and internal consistencies of the behavioral observation system used in experiment 3.

	Cohen's Kappa	**Cronbach's Alpha**
Positive Aggregate	.077	.847
Negative Aggregate	.236	.880
Tension Aggregate	.581	.939
Social Monitoring Aggregate	.336	.859

Comments: included here are all categories presented in Table 7.

Behavioral categories with 0 % interrater agreement (see Table 7) were excluded from further analyses. For the remaining categories, the absolute number of each behavioral category shown in cyber ball blocks respectively penalty kicking trials of each experimental condition was averaged over both raters and over all categories belonging to one aggregate.

Genotype analyses

DNA was isolated from saliva samples collected with Oragene OG-500 Saliva Self Collection Kits (DNA Genotek Inc., Ottawa, ON, Canada). Unfortunately, no DNA could be isolated from the saliva sample of one patient, so that further analyses were conducted only with the DNA of 30 controls and 29 patients. Genotype variations were analyzed of two single nucleotide polymorphisms (SNPs) in healthy controls and ADHD patients that previously have been shown to be correlated with ADHD symptoms, respectively symptoms of emotion dysregulation. One of those is SNP 25 (rs4570625) of the tryptophan hydroxylase-2 gene (THP2), located at position -703 (Gutknecht et al., 2007). TPH2 codes for the rate limiting enzyme of serotonin (5-HT) synthesis and modulates responses of limbic brain circuits, comprising among others the amygdala. Those brain circuits in turn are strongly related to emotional reactivity. SNP 25 of the TPH2 gene can express two different alleles, a G-allele and a T-allele. Gutknecht et al. (2007) found an overrepresentation of the T-allele to be associated with emotional instability and affective spectrum disorders. Walitza et al. (2005) found a transmission disequilibrium of SNP 25 in children and adolescents diagnosed with ADHD, with an overexpression of the G-allele. A polymerase chain reaction (PCR) was conducted starting from position -703, using a forward primer (5'-tttccatgatttccagtagagag-3'), and a modifying reverse primer (5'-aagctttttctgacttgacaaat-3'). The PCR product was digested with ApoI, as described in Baehne et al. (2009).

The second SNP to be analyzed was SNP 5-HTT (rs4795542) of the serotonin transporter gene SLC6A4. SNP 5-HTT can express a long allele (l), and a short allele (s). Müller et al. (2008) and Retz et al. (2002) found associations between the l/l genotype and ADHD severity, respectively persistence of ADHD symptoms. However, results of previous studies on associations between SNP 5-HTT expressions and ADHD symptoms have been inconsistent. A PCR was conducted using a forward primer (5'-TGCCGCTCTGAATGCCAGCAC), and a reverse primer (5'-GGGATTCTGGTGCCACCTAGACG). The PCR product was digested with MspI.

2.3.2.6. Statistical Data Analyses

Statistical analyses were conducted with SPSS Statistics 23 (IBM Deutschland GmbH, Ehningen, Germany).

Emotion processing and emotion regulation in ADHD vs. HC

Emotion processing and regulation effects on emotional reactions throughout the cyber ball game were analyzed with split plot ANOVAs with the within-subjects factors inclusion (inclusion vs. ostracism) and regulation (not regulate vs. hide) and the between-subjects factor diagnostic group (healthy controls vs. ADHD patients).The influence of different emotional conditions in the penalty kicking game on emotional reactions was tested with split plot ANOVAs with the within-subjects factor emotion (pleasant vs. neutral vs. unpleasant) and the between-subjects factor diagnostic group (healthy controls vs. ADHD patients). Only data assessed in the non-regulation block of the penalty kicking game was implied. Regulation effects on emotional reactions throughout virtual penalty kicking were analyzed with split plot ANOVAs with the within-subjects factors emotion (pleasant vs. unpleasant), regulation (show vs. not regulate vs. hide), and the between-subjects factor diagnostic group (healthy controls vs. ADHD patients). Whenever the assumption of sphericity was violated, I reported Greenhouse-Geisser corrected degrees of freedom and *p*-values. Significant main effects and interactions were further analyzed with one-way ANOVAs and post-hoc *t*-tests with

Bonferroni-corrected *p*-values. The same analyses were conducted for all dependent variables on the experiential, physiological, and behavioral levels.

Baseline differences in skin conductance level between diagnostic groups were analyzed with a two-tailed *t*-test comparing average skin conductance levels (log[1+SCL]) of healthy controls vs. ADHD patients during 60 s segments before the beginning of the first cyber ball block. Additionally, ERI sub scores (König, 2011) of healthy controls vs. ADHD patients were compared with two-tailed *t*-tests.

Genotype analyses

Genotype influences on emotion processing and emotion regulation in both the cyber ball game and the penalty kicking game were analyzed with the same split plot ANOVAs and post-hoc *t*-tests as described above, with the within-subjects factor genotype (s-carrier vs. non-s-carrier[3]) instead of diagnostic group. This classification is in line with previous studies investigating 5-HTT influences on emotion processing and personality traits associated with emotion regulation deficits (Herrmann et al., 2007; Lesch et al., 1996; Lesch & Gutknecht, 2005).

2.3.3. Results

2.3.3.1. Emotion Processing Penalty Kicking

Ratings

Valence and arousal ratings of healthy controls and ADHD patients after emotion processing in the penalty kicking paradigm are depicted in Figure 13. Valence ratings were influenced by the emotional experimental condition differently in patients vs. controls. There was a significant main effect for emotion (F[1,68] = 64.02, p < .001, η_p^2 = .53, GG-ε = .59) and a significant interaction for diagnostic group x emotion (F[1,68] = 4.49, p = .031, η_p^2 = .70, GG-ε = .59), but no significant main effect for group (F[1,58] = 0.00, p = .962, η_p^2 = .00). Post-hoc *t*-tests revealed that ADHD patients in comparison to controls rated pleasant trials as marginally less pleasant (t[45] = 1.96, p = .057) and unpleasant trials as slightly, but not significantly more pleasant (t[58] = 1.44, p = .156). Valence ratings in response to neutral trials did not differ between diagnostic groups (t[58] = 0.20, p = .839). Both patients and controls rated pleasant trials as higher in valence and unpleasant trials as lower in valence, compared to neutral trials (Fs > 14.26, ps < .001, η_p^2 > .33; ts > 2.49, ps < .019). Valence ratings of the control group differed significantly from 5 in response to pleasant and unpleasant trials (ts > 2.92, ps < .007), but not in response to neutral trials (t[29] = 0.48, p =

[3] Throughout the rest of this thesis, I will refer to participants with the s/s or s/l genotypes as “s-carriers”, and to participants with the l/l genotype as “non-s-carriers”.

.636). For ADHD patients, valence ratings differed significantly from 5 only in response to pleasant trials ($t[29] = 4.75$, $p < .001$), but not in response to neutral and unpleasant trials (*t*s < 0.84, *p*s > .406).

Arousal ratings during penalty kicking were influenced mostly by the emotional experimental condition. There was a significant main effect for emotion ($F[1,109] = 23.02$, $p < .001$, $\eta_p^2 = .28$, $GG\text{-}\varepsilon = .95$), a marginally significant interaction for diagnostic group x emotion ($F[1,109] = 3.06$, $p = .054$, $\eta_p^2 = .50$, $GG\text{-}\varepsilon = .95$), and a nonsignificant main effect for diagnostic group ($F[1,58] = 1.82$, $p = .182$, $\eta_p^2 = .03$). For the whole sample, arousal ratings were highest in response to pleasant trials and lowest in response to neutral trials (*t*s > 3.14, *p*s < .003). Exploratory post-hoc *t*-tests revealed that ADHD patients, in comparison to healthy controls, rated pleasant and unpleasant trials as slightly less arousing (*t*s > 1.66, *p*s < .102). Arousal ratings in response to neutral trials did not differ between diagnostic groups ($t[58] = 0.35$, $p = .730$). For healthy controls alone, arousal ratings were highest in response to pleasant trials and lowest in response to neutral trials ($F[2,58] = 15.32$, $p < .001$, $\eta_p^2 = .35$; *t*s > 2.92, *p*s < .007). For ADHD patients alone, arousal ratings were higher in response to pleasant than in response to neutral or unpleasant trials ($F[2,58] = 8.08$, $p < .001$, $\eta_p^2 = .22$; *t*s > 2.71, *p*s < .001), but did not differ between neutral and unpleasant trials ($t[29] = 1.35$, $p = .187$).

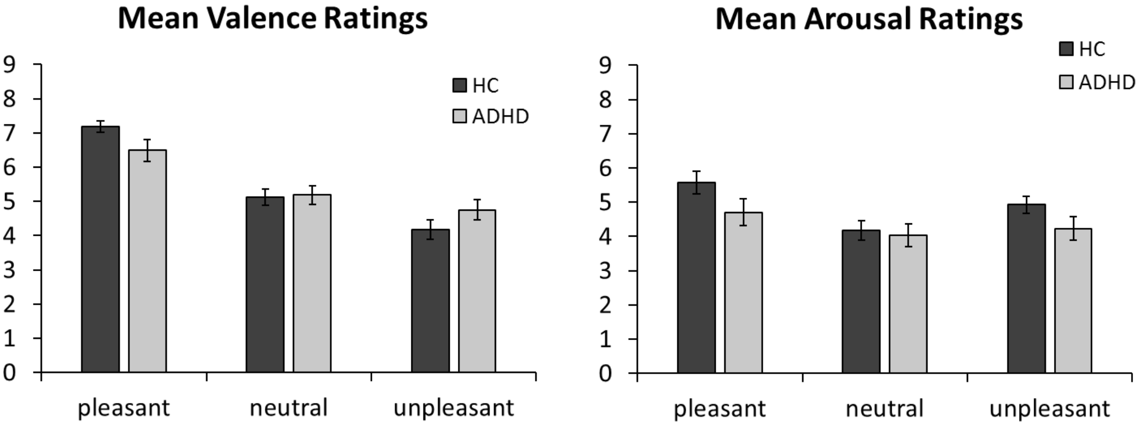


Figure 13. Means and standard errors of valence (left) and arousal (right) ratings of HC and ADHD in the penalty kicking paradigm in experiment 3.

Psychophysiological Recordings

Zygomaticus and corrugator modulations are depicted in Figure 14. Zygomaticus activations were overall lower in patients than in controls. There was a marginally significant main effect for emotion ($F[1,86] = 3.01$, $p = .069$, $\eta_p^2 = .05$, $GG\text{-}\varepsilon = .74$; pleasant = unpleasant > neutral), a nonsignificant interaction for diagnostic group x emotion ($F[1,83] = 1.51$, $p = .228$, $\eta_p^2 =$

.03, *GG-ε* = .74), and a significant main effect for diagnostic group (*F*[1,58] = 8.21, *p* = .006, η_p^2 = .12; HC > ADHD; *t*[58] = 2.87, *p* = .006). Corrugator activations did not differ in patients vs. controls. There was a significant main effect for emotion (*F*[1,102] = 5.44, *p* = .008, η_p^2 = .09, *GG-ε* = .87), but no significant interaction for diagnostic group x emotion, and no significant main effect for diagnostic group (*F*s < 0.32, *p*s > .704, η_p^2 < .01). Post-hoc *t*-tests for the whole sample revealed higher corrugator activations in response to neutral trials than to pleasant and unpleasant trials (*t*s > 2.30, ps < .025). Corrugator activations in response to pleasant and unpleasant trials were comparably low (*t*[59] = 0.97, *p* = .339).

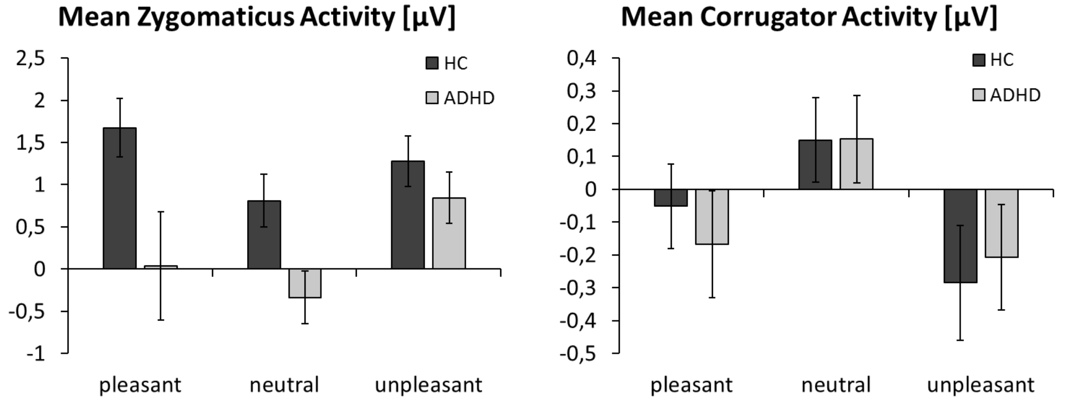


Figure 14. Mean activations and standard errors of M. zygomaticus major (left) and M. corrugator supercilii (right) of HC and ADHD in the penalty kicking paradigm in experiment 3.

SCR modulations of controls and patients are depicted in Figure 15. SCRs were marginally higher in controls than in patients across emotional conditions. There was a significant main effect for emotion (*F*[1,105] = 12.83, *p* < .001, η_p^2 = .18, *GG-ε* = .91), a nonsignificant interaction for diagnostic group x emotion (*F*[1,105] = 2.12, *p* = .130, η_p^2 = .04, *GG-ε* = .91), and a marginally significant main effect for diagnostic group (*F*[1,58] = 3.08, *p* = .085, η_p^2 = .05). For the whole sample, SCRs were higher in response to pleasant and unpleasant, compared to neutral trials (*t*s > 3.81, *p*s < .001) and comparably high in response to pleasant and unpleasant trials (*t*[59] = 1.60, *p* = .114).

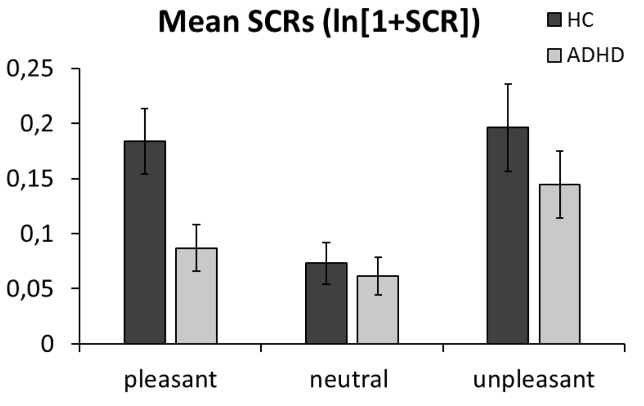


Figure 15. Means and standard errors of logarithmic skin conductance responses of HC and ADHD in the penalty kicking paradigm in experiment 3.

Behavioral Observations

Means and standard deviations of behavioral expressions belonging to the different aggregates of the behavioral observation system are summarized in Table 13 (A 22). Behavioral expressions during emotion processing in the virtual penalty kicking never differed in patients vs. controls. Expressions of the positive aggregate were not modulated by emotion or diagnostic group (*F*s < 1.59, *p*s > .211, $\eta_p^2 < .03$). Negative expressions were modulated by emotion (pleasant < neutral < unpleasant, *F*[1,85] = 10.27, *p* < .001, $\eta_p^2 = .16$, *GG-ε* = .76; *t*s > 2.44, *p*s < .018). The main effect for diagnostic group and the interaction for diagnostic group x emotion, however, revealed no significant results (*F*s < 2.39, *p*s > .128, $\eta_p^2 < .04$). The analyses of tension expressions revealed a significant main effect for emotion (*F*[2,112] = 8.65, *p* < .001, $\eta_p^2 = .13$), but no significant main effect for diagnostic group and no significant interaction for diagnostic group x emotion (*F*s < 1.36, *p*s > .249, $\eta_p^2 < .02$). The whole sample showed more tension behavior in unpleasant, compared to pleasant and neutral trials (*t*s > 3.13 *p*s < .003), and comparably little tension behavior in pleasant and neutral trials (*t*[57] = 0.90, *p* = .372). Social monitoring behavior was shown more frequently in pleasant trials than in neutral and unpleasant trials. The analyses here revealed a significant main effect for emotion (*F*[1,99] = 9.22, *p* < .001, $\eta_p^2 = .14$, *GG-ε* = .89), but no significant main effect for diagnostic group, and no significant interaction for diagnostic group x emotion (*F*s < 1.57, ps > .216, $\eta_p^2 < .03$). Post-hoc *t*-tests for the whole sample revealed significantly more social monitoring expressions in pleasant, compared to neutral and unpleasant trials (*t*s > 3.51, *p*s < .001), which in turn were comparably low (*t*[57] = 0.80, *p* = .428).

2.3.3.2. Emotion Regulation Penalty Kicking

Ratings

See Table 14 (A 22) for an overview over valence ratings in response to pleasant and unpleasant trials in the different regulation conditions. Valence ratings were hardly influenced by the regulation condition, either in the control group, or in the patient group. There was a significant main effect for emotion ($F[1,58] = 82.35$, $p < .001$, $\eta_p^2 = .59$), a significant interaction for diagnostic group x emotion ($F[1,58] = 5.71$, $p = .020$, $\eta_p^2 = .09$), and a marginally significant interaction for emotion x regulation ($F[2,116] = 2.72$, $p = .070$, $\eta_p^2 = .05$) due to slightly higher valence ratings in response to pleasant trials in the "show" condition and slightly lower valence ratings in response to unpleasant trials in the "show" condition, compared to "not regulate" and "hide". All other main effects and interactions did not reach significance (Fs < 0.76, ps $> .456$, $\eta_p^2 < .01$). Ratings were higher in response to pleasant, compared to unpleasant trials irrespective of the regulation condition for controls ($t[29] = 9.91$, $p < .001$) as well as for patients ($t[29] = 4.10$, $p < .001$). Patients gave lower valence ratings than controls in response to pleasant trials ($t[44] = 2.10$, $p = .041$). Ratings in response to unpleasant trials were slightly higher in the patient group, but did not differ significantly between diagnostic groups ($t[58] = 1{,}49$, $p = .141$).

The modulation of arousal ratings is depicted in

Figure 16. Arousal ratings were influenced by the regulation condition in both pleasant and unpleasant trials, independent of the diagnostic group. Showing emotions went along with increased arousal ratings, hiding emotions went along with decreased arousal ratings, compared to not regulating emotions. This effect was stronger for pleasant, compared to unpleasant trials. Arousal ratings of the whole sample were higher in response to pleasant, compared to unpleasant trials, for all regulation conditions. The split plot ANOVA revealed a significant main effect for emotion ($F[1,58] = 31.77$, $p < .001$, $\eta_p^2 = .35$), a significant main effect for regulation ($F[1,93] = 14.83$, $p < .001$, $\eta_p^2 = .20$, $GG\text{-}\varepsilon = .81$), a significant interaction for emotion x regulation ($F[1,93] = 4.93$, $p = .014$, $\eta_p^2 = .08$), and a marginally significant main effect for diagnostic group ($F[1,58] = 3.25$, $p = .076$, $\eta_p^2 = .05$) due to lower arousal ratings given by patients vs. controls. All other interactions did not reach statistical significance (Fs < 1.39, ps $> .253$, $\eta_p^2 < .20$). Post hoc t-tests for the ratings of the whole sample revealed that for pleasant trials, arousal ratings were higher when participants were instructed to show their emotions and lower when participants were instructed to hide their emotions, compared to trials with no regulation instruction ($F[1,107] = 18.62$, $p < .001$, $\eta_p^2 = .24$, $GG\text{-}\varepsilon = .91$; ts > 2.56, ps $< .013$). For unpleasant trials, arousal ratings differed only

marginally across regulation conditions, with highest ratings in response to “show” trials and lowest ratings in response to “hide” trials (*F*[1,85] = 3.01, p = .071, η_p^2 = .05, *GG*-ε = .72). Arousal ratings were higher in response to pleasant compared to unpleasant trials for all regulation conditions (*t*s > 2.32, *p*s < .024).

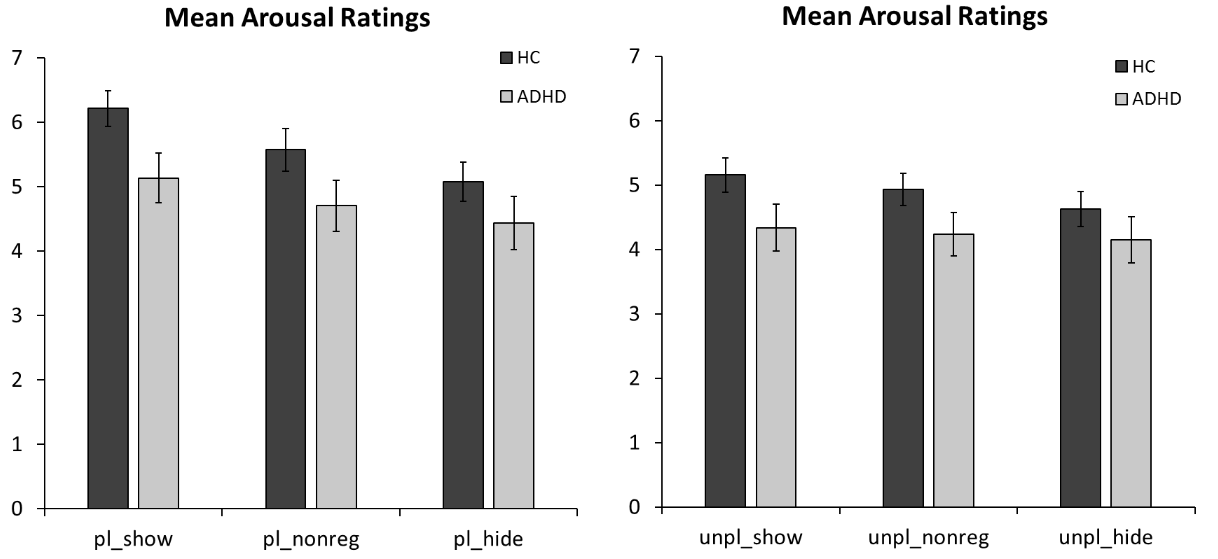


Figure 16. Means and standard errors of arousal ratings of HC and ADHD in response to pleasant (left) and unpleasant (right) trials in the different regulation conditions of the penalty kicking paradigm in experiment 3.

Psychophysiological Recordings

See Figure 17 for an overview of zygomaticus modulations through emotion regulation. For controls, activations were lower in “hide” trials compared to “show” and “not regulate” trials. For patients, activations did not differ across different regulation conditions. Patients showed lower activations than controls in unregulated trials, but not in “show” and “hide” trials. The main effect for emotion was not significant (*F*[1, 58] = 0.11, p = .746, η_p^2 = .02). The interaction for diagnostic group x emotion was marginally significant (*F*[1,58] = 3.33, p = .073, η_p^2 = .05) due to lower activities in patients vs. controls especially in pleasant trials. The main effect for regulation (*F*[1,105] = 12.66, p < .001, η_p^2 = .18, *GG*-ε = .91), the interaction for diagnostic group x regulation (*F*[1,105] = 3.91, p = .027, η_p^2 = .06, *GG*-ε = .91) and the interaction for emotion x regulation (*F*[1,101] = 3.49, p = .040, η_p^2 = .06, *GG*-ε = .88) all revealed significant effects. The main effect for diagnostic group and the interaction for diagnostic group x emotion x regulation failed to reach significance (*F*s < 2.20, *p*s > .144, η_p^2 < .04). Averaged over pleasant and unpleasant trials, activations were higher for controls compared to patients only in non-regulated trials (*t*[58] = 2.06, p = .044), but not in “show” and “hide” conditions (*t*s < 1.47, *p*s > .148). Controls showed lower zygomaticus activations in “hide” trials compared to “show” and “not regulate” trials (*F*[2,58] = 14.96, p < .001, η_p^2 =

.34; *t*s > 3.65, *p*s < .001) and comparably high activations in “show” and “not regulate” trials ($t[29] = 1.06$, $p = .297$). Patients showed comparably low activations across all regulation conditions ($F[1,45] = 1.36$, $p = .265$, $\eta_p^2 = .05$, $GG\text{-}\varepsilon = .79$). For the whole sample, zygomaticus activations in pleasant trials were comparably high when participants showed or not regulated their emotions ($F[1,107] = 9.78$, $p < .001$, $\eta_p^2 = .14$, $GG\text{-}\varepsilon = .91$; $t[59] = 0.45$, $p = .657$), which in turn were both significantly higher than when they hid their emotions (*t*s > 3.85, *p*s < .001). In unpleasant trials, activations were higher when participants did not regulate than when they hid their emotions ($F[1,105] = 7.18$, $p = .002$, $\eta_p^2 = .11$, $GG\text{-}\varepsilon = .89$; $t[59] = 4.68$, $p < .001$) and marginally lower when participants showed vs. not regulated their emotions ($t[59] = 1.88$, $p = .065$). Zygomaticus activations did not differ significantly when participants showed vs. hid their emotions in unpleasant trials ($t[59] = 1.63$, $p = .109$). Activations were higher in pleasant compared to unpleasant trials only in “hide” trials ($t[59] = 2.24$, $p = .029$), but not in “show” trials and unregulated trials (*t*s < 1.32, *p*s > .533).

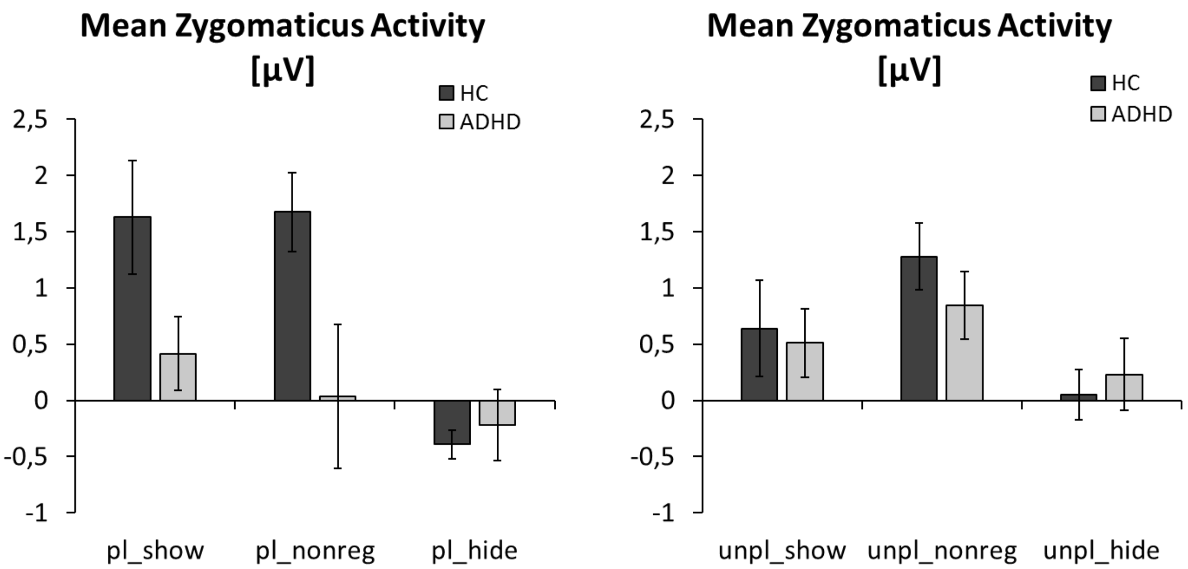


Figure 17. Mean activations and standard errors of M. zygomaticus major of HC and ADHD in pleasant (left) and unpleasant trials (right) in the different regulation conditions of the penalty kicking paradigm in experiment 3.

The analysis of M. corrugator modulations across different regulation conditions of pleasant and unpleasant trials revealed no significant main effects or interactions (*F*s < 2.37, *p*s > .113, $\eta_p^2 < .04$). Means and standard deviations of corrugator activities are summarized in Table 14 (A 22).

Modulations of SCRs in the different regulation conditions are depicted in Figure 18. SCRs were modulated by the regulation condition differently in healthy controls vs. ADHD patients and differently in different emotional conditions. The split plot ANOVA revealed a significant interaction for diagnostic group x regulation ($F[1,109] = 4.74$, $p = .012$, $\eta_p^2 = .08$, $GG\text{-}\varepsilon = .94$), and a significant interaction for emotion x regulation ($F[2,116] = 5.68$, $p = .004$, $\eta_p^2 = .09$). All main effects and all other interactions failed to reach statistical significance (Fs < 1.99, ps $> .144$, $\eta_p^2 < .03$). For healthy controls, SCRs averaged over pleasant and unpleasant trials were comparably high when participants showed their emotions and when they did not regulate their emotions ($F[1,44] = 3.78$, $p = .041$, $\eta_p^2 = .12$, $GG\text{-}\varepsilon = .78$; $t[29] = 0.07$, $p = .944$), which in turn were both higher than when they hid their emotions (ts > 2.19, ps $< .037$). For ADHD patients, SCRs averaged over pleasant and unpleasant trials differed only marginally across different regulation conditions, with slightly higher SCRs when they showed or hid their emotions than when they did not regulate their emotions ($F[1,46] = 3.08$, $p = .066$, $\eta_p^2 = .10$, $GG\text{-}\varepsilon = .80$). Healthy controls showed marginally higher SCRs than ADHD patients only in non-regulate conditions ($t[58] = 1.95$, $p = .057$), but not in “show” and “hide” conditions (ts < 0.58, ps $> .566$). For the whole sample, SCRs in pleasant trials were higher when participants showed vs. not regulated their emotions ($F[1,107] = 3.35$, $p = .043$, $\eta_p^2 = .05$, $GG\text{-}\varepsilon = .91$; $t[59] = 2.30$, $p = .025$), comparably high when they showed vs. hid their emotions ($t[59] = 0.37$, $p = .717$), and marginally higher when they hid vs. not regulated their emotions ($t[59] = 1.87$, $p = .066$). In unpleasant trials, SCRs for the whole sample were comparably high when participants showed vs. hid their emotions ($F[2,118] = 3.43$, $p = .036$, $\eta_p^2 = .06$, $GG\text{-}\varepsilon = .96$; $t[59] = 0.17$, $p = .868$), which in turn were both higher than when participants did not regulate their emotions (ts > 2.20, ps $< .032$). SCRs of the whole sample were higher in pleasant vs. unpleasant trials when participants hid their emotions ($t[59] = 2.99$, $p = .004$), and comparably high in pleasant and unpleasant trials when participants showed their emotions or did not regulate their emotions (ts < 1.60, ps $> .114$).

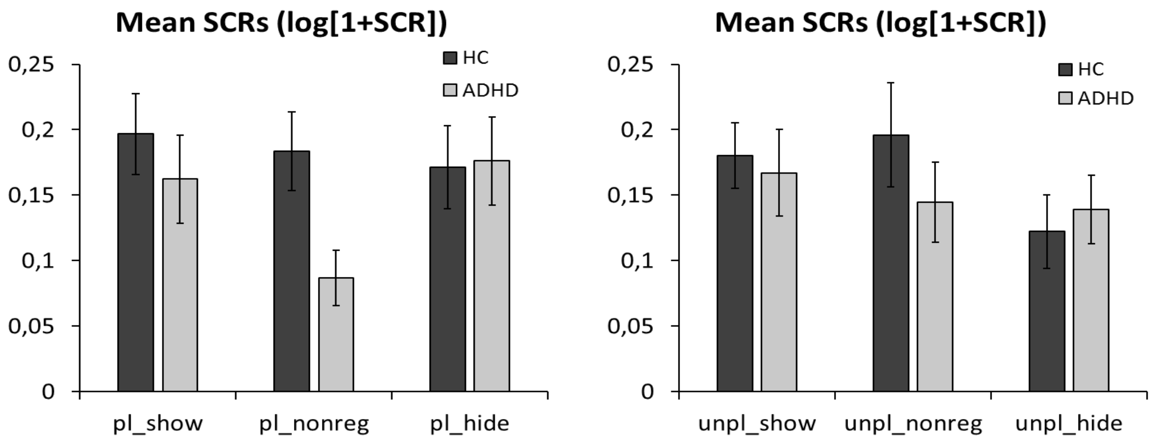


Figure 18. Means and standard errors of logarithmic skin conductance responses of HC and ADHD in pleasant (left) and unpleasant trials (right) in the different regulation conditions of the penalty kicking paradigm in experiment 3.

Behavioral Observations

Modulations of emotional expressions belonging to different aggregates are depicted in Figure 19. For positive expressions, there was a significant main effect for regulation (F[1,90] = 3.70, p = .037, $\eta_p{}^2$ = .06, GG-ε = .81). All other main effects and interactions revealed no significant results (Fs < 1.38, ps > .245, $\eta_p{}^2$ < .02). Positive emotional expressions were shown comparably often when participants showed vs. not regulated their emotions (t[57] = 0.00, p = 1.000), which were both higher than when they hid their emotions (ts > 2.21, ps < .031). Negative expressions were modulated by the regulation condition in both pleasant and unpleasant trials. There were significant main effects for emotion (F[1,56] = 24.61, p < .001, $\eta_p{}^2$ = .31), and regulation (F[1,105] = 13.37, p < .001, $\eta_p{}^2$ = .19, GG-ε = .95), and a significant interaction for emotion x regulation (F[2,112] = 5.02, p = .008, $\eta_p{}^2$ = .08). The main effect for diagnostic group (F[1,56] = 2.16, p = .148, $\eta_p{}^2$ = .04) and all other interactions (Fs < 0.80, ps > .376) revealed no significant results. Negative expressions were shown more frequently in unpleasant than in pleasant trials across all regulation conditions (ts > 3.73, ps < .001). In pleasant and unpleasant trials, negative expressions were shown comparably often in “show” and “not regulate” trials (Fs > 3,86, ps < .029, $\eta_p{}^2$ > .06; ts < 0.35, ps > .727), which in turn were both higher than expression rates in “hide” trials (ts > 2.10, ps < .040). Tension expressions were shown slightly more often by patients than by controls. The ANOVA revealed a significant main effect for emotion (F[1,56] = 17.04, p < .001, $\eta_p{}^2$ = .23; unpleasant > pleasant; t[57] = 4.15, p < .001), a significant main effect for regulation (F[1,104] = 15.29, p < .001, $\eta_p{}^2$ = .21, GG-ε = .94; show = not regulate > hide), and a marginally significant main effect for diagnostic group (F[1,56] = 3.87, p = .054, $\eta_p{}^2$ = .07; ADHD > HC). The interaction for diagnostic group x regulation (patients showed higher tension expression rates than controls especially in "show" and "hide" trials) scarcely failed to reach marginal significance ($F[1,104] = 2.35$, $p = .104$, $\eta_p^2 = .04$, $GG\text{-}\varepsilon = .94$). All other interactions failed to reach statistical significance (Fs < 1,91, ps < .156, $\eta_p^2 < .03$). Averaged across pleasant and unpleasant trials and over patients and controls, tension expressions were shown less frequently in "hide" trials than in "show" and "not regulate" trials (ts > 4.42, ps < .001), which in turn did not differ ($t[57] = 1.33$, $p = .188$).

Social monitoring expressions were modulated by the emotional condition and by the regulation condition differently in controls vs. patients. The split plot ANOVA revealed a significant main effect for emotion ($F[1,56] = 20.49$, $p = < .001$, $\eta_p^2 = .27$), a significant main effect for regulation ($F[2,112] = 22.47$, $p < .001$, $\eta_p^2 = .29$), a significant interaction for diagnostic group x regulation ($F[2,112] = 3.45$, $p = .035$, $\eta_p^2 = .06$), and a significant interaction for emotion x regulation ($F[2,112] = 4.34$, $p = .015$, $\eta_p^2 = .07$). The main effect for diagnostic group and all other interactions revealed no significant effects (Fs < 1.71, ps > .186). The whole sample showed social monitoring behavior more often in pleasant trials than in unpleasant trials when participants had to show or not regulate their emotions (ts > 3.51, ps < .001), and marginally more often in pleasant compared to unpleasant trials when participants had to hide their emotions ($t[57] = 1.96$, $p = .055$). Moreover, in pleasant as well as in unpleasant trials, social monitoring behavior was shown more often when participants showed or did not regulate their emotions than when they hid their emotions (Fs > 7.19, ps < .001, $\eta_p^2 > .11$; ts > 3.01, ps < .004) and comparably often when participants showed vs. did not regulate their emotions (ts < 0.90, ps > .373). Averaged across pleasant and unpleasant trials, patients showed marginally more social monitoring behavior than controls when hiding their emotions ($t[41] = 1.78$, $p = .083$), and comparably high social monitoring behavior as controls when showing or not regulating their emotions (ts < 1.43, ps > .159). Averaged across pleasant and unpleasant trials, controls showed less social monitoring behavior when hiding vs. showing or not regulating their emotions ($F[2,58] = 23.12$, $p < .001$, $\eta_p^2 = .44$; ts > 6.25, ps < .001), which in turn did not differ ($t[29] = 0.19$, $p = .852$). ADHD patients showed significantly higher social monitoring behavior when showing vs. hiding their emotions ($F[1,43] = 4.74$, $p = .020$, $\eta_p^2 = .15$, $GG\text{-}\varepsilon = .80$; $t[27] = 2.52$, $p = .018$), marginally higher social monitoring behavior when showing vs. not regulating their emotions ($t[27] = 1.71$, $p = .098$), and marginally lower social monitoring behavior when hiding vs. not regulating their emotions ($t[27] = 1.82$, $p = .080$), averaged across pleasant and unpleasant trials.

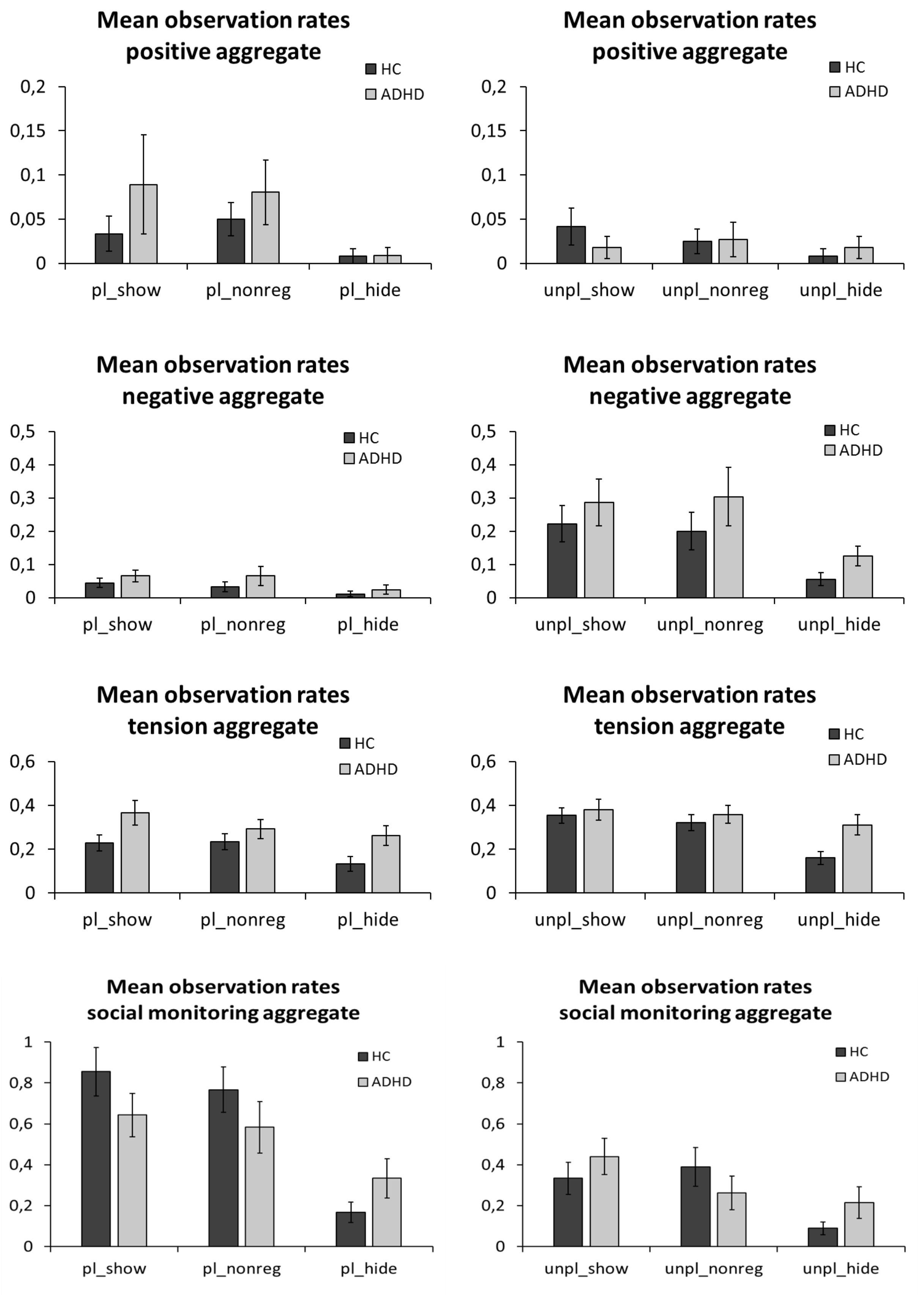


Figure 19. Mean observation rates and standard errors for different behavioral expressions of HC and ADHD in the different regulation conditions of the penalty kicking paradigm in experiment 3.

2.3.3.3. *Emotion Processing and Emotion Regulation Cyber Ball*

Ratings

See Table 15 (A 22) for an overview over means and standard deviations of valence and arousal ratings given by controls and patients throughout different cyber ball blocks. Valence ratings did not differ between patients and controls (Fs < 0.81, ps > .373, η_p^2 < .01). There was a significant main effect for inclusion (F[1,58] = 52.77, p < .001, η_p^2 = .48; inclusion > ostracism) and a significant interaction for inclusion x regulation (F[1,58] = 6.23, p = .015, η_p^2 = .10). Valence ratings were higher after inclusion vs. ostracism blocks in both regulation conditions (ts > 5.75, ps < .001). After inclusion blocks, valence ratings were higher when participants did not regulate their emotions than when they hid their emotions (t[59] = 2.13, p = .037). After ostracism blocks, valence ratings were comparably low when participants did not regulate their emotions or hid their emotions (t[59] = 1.06, p = .293).

Arousal ratings were higher when participants did not regulate their emotions than when they hid their emotions. Here, there was a significant main effect for regulation (F[1,58] = 8.19, p = .006, η_p^2 = .12; t[59] = 2.86, p = .006). Moreover, the interaction for diagnostic group x inclusion was marginally significant (F[1,58] = 3.85, p = .054, η_p^2 = .06) due to slightly higher arousal ratings after inclusion blocks in the control group and slightly higher arousal ratings after ostracism blocks in the patient group. All other main effects and interactions did not reach significance (Fs < 1.43, ps > .237, η_p^2 < .02).

Means and standard deviations of positive affect measured with the German version of the PANAS (Krohne et al., 1996) throughout different cyber ball conditions are summarized in Table 15 (A 22). Patients reported slightly lower positive affect than controls irrespective of the cyber ball condition. The split plot ANOVA revealed a significant main effect for inclusion (F[1,58] = 42.93, p < .001, η_p^2 = .43; t[59] = 6.59, p < .001; inclusion > ostracism), a marginally significant main effect for regulation (F[1,58] = 3.35, p = .073, η_p^2 = .06; not regulate > hide), and a marginally significant main effect for diagnostic group (F[1,58] = 3.50, p = .066, η_p^2 = .06; controls > patients). All interaction effects did not reach statistical significance (Fs < 1.79, ps > .186, η_p^2 < .03).

Modulations of negative effect throughout cyber ball are depicted in Figure 20. Negative affect was modulated differently in controls vs. patients. There was a significant main effect for inclusion (F[1,58] = 16.75, p < .001, η_p^2 = .22; include < ostracize), a marginally significant interaction for diagnostic group x inclusion (F[1,58] = 3.52, p = .066, η_p^2 = .06), a significant interaction for diagnostic group x regulation (F[1,58] = 4.82, p = .032, η_p^2 = .08), and a significant interaction for inclusion x regulation (F[1,58] = 4.46, p = .039, η_p^2 = .07).

All other main effects and interactions did not reach statistical significance (*F*s < 2.45, *p*s > .123, η_p^2 < .04). Patients reported higher negative affect compared to controls irrespective of the inclusion condition after "non-regulate" (*t*[41] = 2.20, *p* = .033), but not after "hide" blocks (*t*[41] = 0.77, *p* = .448). Negative affect was higher after "non-regulate" vs. "hide" blocks in the patient group (*t*[29] = 3.00, *p* = .005), but not in the control group (*t*[29] = 0.09, *p* = .932). Exploratory post-hoc *t*-tests revealed that negative affect ratings were marginally higher for patients than for controls after ostracism (*t* [48] = 1.84, *p* = .072), but not after inclusion (*t*[49] = 0.04, *p* = .969). For the whole sample, negative affect was higher in response to ostracism vs. inclusion, in "non-regulate" as well as in "hide" blocks (*t*s > 3.00, *p*s < .004). This effect was bigger for "non-regulate" blocks. Negative affect of the whole sample did not differ significantly in "non-regulate" vs. "hide" blocks either in response to inclusion or ostracism (*t*s < 1.44, *p*s > .156).

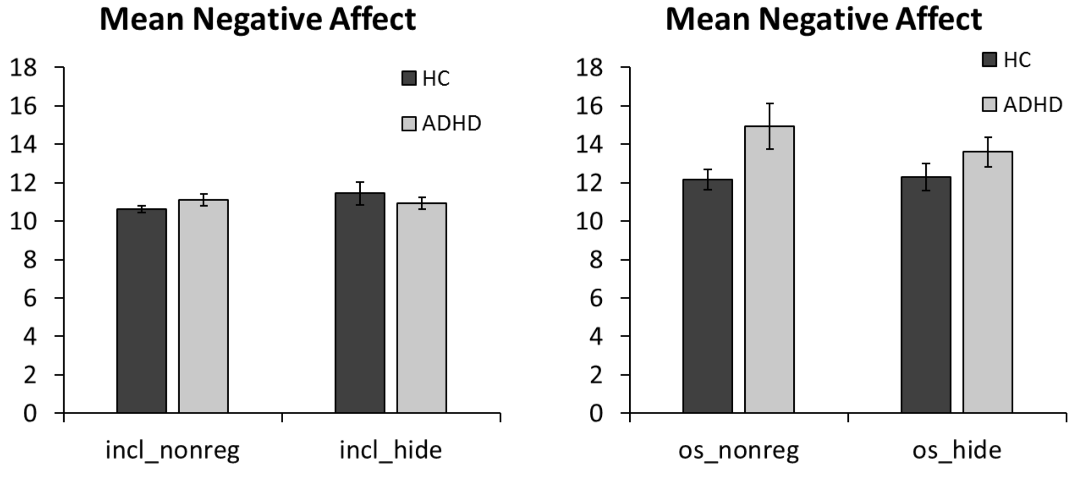


Figure 20. Means and standard errors of negative affect of HC and ADHD when not regulating vs. hiding their emotions in inclusion (left) and ostracism blocks (right) of the cyber ball game.

Psychophysiological Recordings

Zygomaticus modulations of controls and patients throughout cyber ball are depicted in Figure 21. Zygomaticus activations were modulated dependent on the inclusion condition, the regulation condition, and the diagnostic group of the participants. Correspondingly, there were significant main effects for inclusion (*F*[1,58] = 8.41, *p* = .005, η_p^2 = .13; ostracism > inclusion; *t*[59] = 2.89, *p* = .005), regulation (*F*[1,58] = 6.21, *p* = .016, η_p^2 = .10; not regulate > hide; *t*[59] = 2.48, *p* = .016), and diagnostic group (*F*[1,58] = 5.10, *p* = .028, η_p^2 = .08; HC > ADHD; *t*[58] = 2.26, *p* = .028). All interactions revealed nonsignificant effects (*F*s < 1.67, *p*s > .201, η_p^2 < .03).

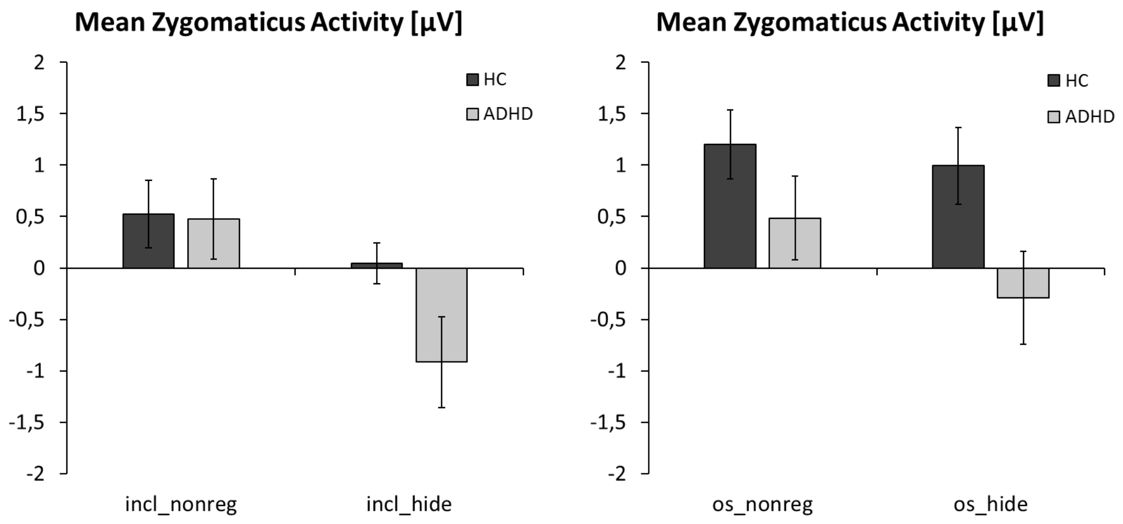


Figure 21. Means and standard errors of M. zygomaticus major activations of HC and ADHD when not regulating vs. hiding their emotions in inclusion (left) and ostracism blocks (right) of the cyber ball game.

Corrugator activations were not modulated by inclusion, regulation, or diagnostic group (*F*s < 1.55, *p*s > .217, $\eta_p^2 < .03$). Means and standard deviations of corrugator activity throughout cyber ball are summarized in Table 15 (A 22).

SCL modulations throughout cyber ball are depicted in Figure 22. SCLs were modulated differently in controls vs. patients. There was a significant interaction for diagnostic group x inclusion ($F[1,58] = 9.16$, $p = .004$, $\eta_p^2 = .14$), a significant interaction for inclusion x regulation ($F[1,58] = 7.07$, $p = .010$, $\eta_p^2 = .11$), and a significant interaction for diagnostic group x inclusion x regulation ($F[1,58] = 11.26$, $p < .001$, $\eta_p^2 = .16$). All main effects and all other interactions revealed nonsignificant effects (*F*s < 1.88, *p*s > .176, $\eta_p^2 < .03$). I conducted inclusion x regulation ANOVAs for the two diagnostic groups separately. For controls, there was a significant main effect for inclusion ($F[1,29] = 11.56$, $p = .002$, $\eta_p^2 = .29$), a nonsignificant main effect for regulation ($F[1,29] = 0.45$, $p = .506$, $\eta_p^2 = .02$), and a significant interaction for inclusion x regulation ($F[1,29] = 10.94$, $p = .003$, $\eta_p^2 = .27$). Post-hoc *t*-tests revealed that controls showed higher SCLs in inclusion vs. ostracism blocks when not regulating their emotions ($t[29] = 3.69$, $p < .001$), but not when hiding their emotions ($t[29] = 1.64$, $p = .112$). SCLs of controls were marginally higher when they did not regulate their emotions vs. when they hid their emotions in inclusion blocks ($t[29] = 1.85$, $p = .075$), but not in ostracism blocks ($t[29] = 1.04$, $p = .309$). For ADHD patients, SCLs did not differ significantly between different cyber ball blocks (*F*s < 1.18. *p*s > .287, $\eta_p^2 < .04$).

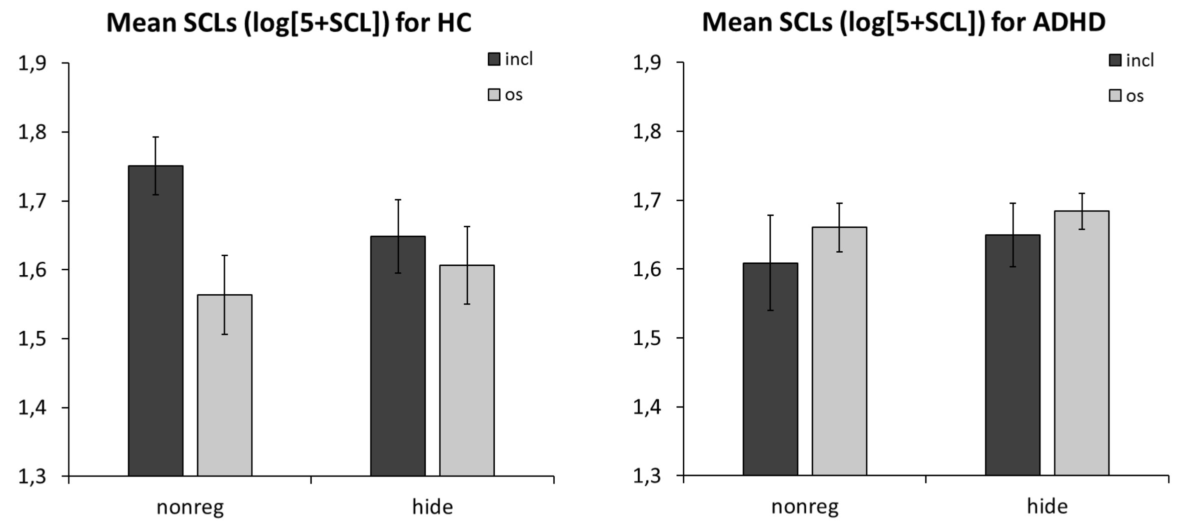


Figure 22. Means and standard errors of logarithmic skin conductance levels of HC (left) and ADHD (right) in inclusion (incl) and ostracism (os) blocks of the cyber ball game while not regulating (nonreg) and hiding (hide) emotions.

Behavioral Observations

Behavioral expressions of the positive, negative, and social monitoring aggregates throughout cyber ball are shown in Figure 23. Positive expressions were modulated by the inclusion and regulation conditions of the cyber ball game and were overall higher in patients vs. controls. There were significant main effects for inclusion (F[1,56] = 10.32, p = .002, η_p^2 = .16), regulation (F[1,56] = 7.93, p = .007, η_p^2 = .12), and diagnostic group (F[1,56] = 4.50, p = .038, η_p^2 = .07; t[34] = 2.07, p = .046), and a significant interaction for inclusion x regulation (F[1,56] = 4.61, p = .036, η_p^2 = .08). All other interactions did not reach significance (Fs < 1.15, ps > .288). Positive expressions were shown more frequently in ostracism vs. inclusion blocks when participants did not regulate their emotions (t[57] = 3.22, p = .002), but not when they hid their emotions (t[57] = 0.72, p = .477). When participants were included, the regulation condition did not influence expression frequencies (t[57] = 0.41, p = .687). In ostracism blocks, positive emotional expressions were shown more frequently when participants did not regulate their emotions than when they hid their emotions (t[57] = 2.96, p = .004).

Negative expressions were shown marginally more often by patients vs. controls irrespective of the experimental condition. There were significant main effects for inclusion (F[1,56] = 11.81, p < .001, η_p^2 = .17; ostracism > inclusion; t [57] = 3.47, p < .001) and regulation (F[1,56] = 5.30, p = .025, η_p^2 = .09; not regulate > hide; t[57] = 2.33, p = .023), and a marginally significant main effect for diagnostic group (F[1,56] = 3.56, p = .064, η_p^2 = .06;

ADHD > HC; $t[49] = 1.87$, $p = .068$). All interactions failed to reach statistical significance (Fs < 1.45, ps > .233).

Means and standard deviations of expression rates of the tension aggregate throughout different cyber ball conditions are summarized in Table 15 (A 22). Tension expressions were not modulated by the regulation condition or the diagnostic group of participants. There was a significant main effect for inclusion ($F[1,56] = 5.65$, $p = .021$, $\eta_p^2 = .09$; ostracism > inclusion; $t[57] = 2.40$, $p = .020$). All other main effects and interactions failed to reach statistical significance (Fs < 2.48, ps > .121).

Expressions of social monitoring were shown more frequently in ostracism vs. inclusion blocks ($F[1,56] = 28.96$, $p < .001$, $\eta_p^2 = .34$; $t[57] = 5.30$, $p < .001$), more frequently when participants did not regulate their emotions vs. when they hid their emotions ($F[1,56] = 22.35$, $p < .001$, $\eta_p^2 = .29$; $t[57] = 4.71$, $p < .001$), and marginally more often in patients vs. controls ($F[1,56] = 3.48$, $p = .067$, $\eta_p^2 = .06$; $t[44] = 1.84$, $p = .073$). All interactions did not reach statistical significance (Fs < 1.93, ps > .170).

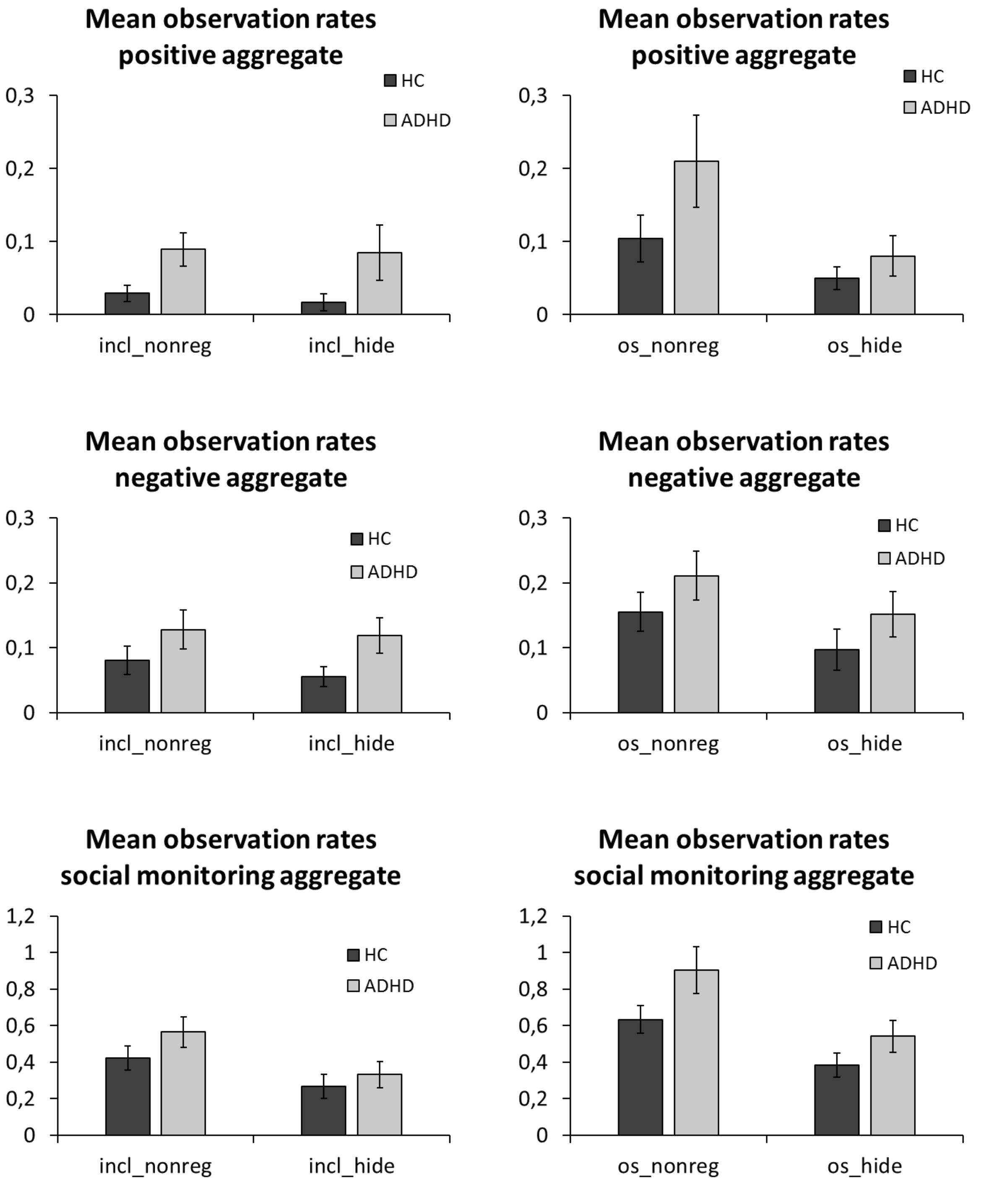


Figure 23. Mean observation rates and standard errors for expressions of the positive, negative, and social monitoring aggregates of HC and ADHD when not regulating vs. hiding their emotions in inclusion (left) and ostracism blocks (right) of the cyber ball game.

2.3.3.4. Baseline Skin Conductance Level

At baseline, ADHD patients showed significantly lower SCLs than healthy controls (t[58] = 2.30, p = .025; see Figure 24).

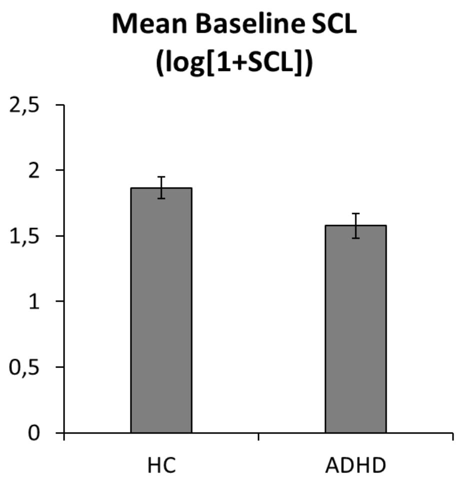


Figure 24. Logarithmic skin conductance levels of HC and ADHD during a 60 s baseline period prior to the cyber ball game.

2.3.3.5. Habitual Emotion Regulation

Differences in habitually applied emotion regulation strategies according to the ratings given in the ERI (König, 2011) between healthy controls and patients are depicted in Figure 25. The analyses of ERI sub scores revealed that patients vs. controls habitually applied significantly more reappraisal strategies when experiencing negative emotions ($t[53] = 4.29$, $p < .001$). Moreover, patients vs. controls showed marginally higher scores for uncontrolled expressions of positive emotions ($t[58] = 1.89$. $p = .064$), significantly higher scores for empathetic suppression of positive emotions ($t[58] = 2.60$, $p = .012$), significantly higher scores for distraction from positive emotions ($t[58] = 3.44$, $p < .001$), and significantly higher scores for expression of positive emotions ($t[50] = 2.09$, $p = .042$). On the other subscales (controlled expression of negative emotions, uncontrolled expression of negative emotions, empathetic suppression of negative emotions, distraction from negative emotions, controlled expression of positive emotions), scores did not differ for healthy controls vs. ADHD patients (ts < 1.51, ps > .138).

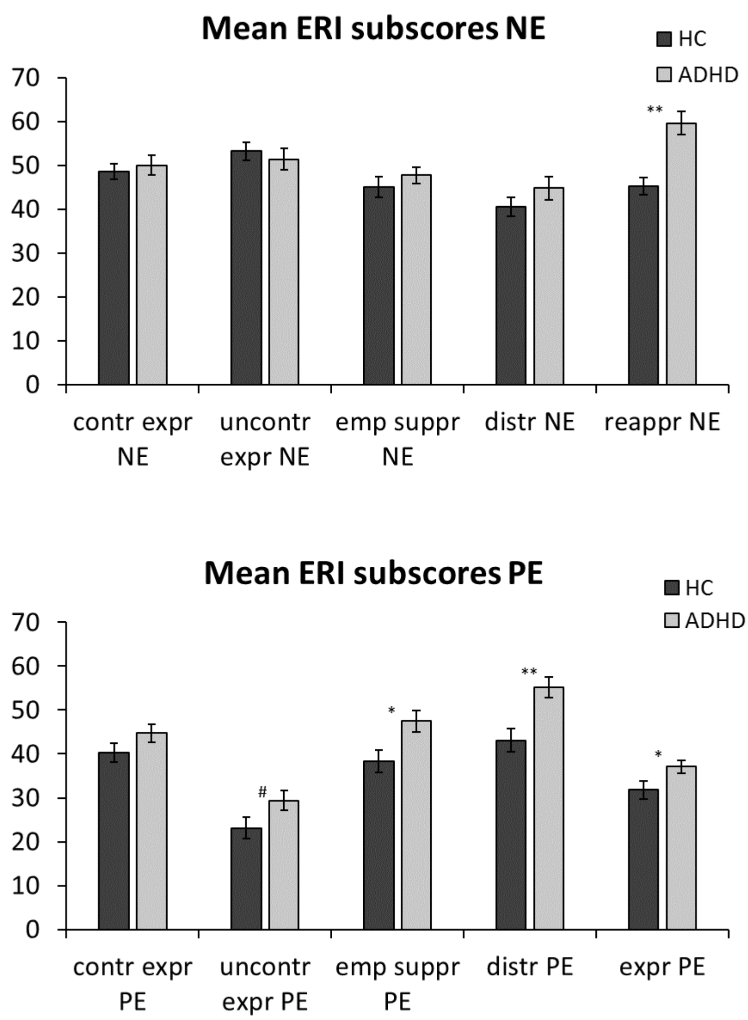


Figure 25. Means and standard errors of ERI subscores of HC and ADHD for the regulation of positive (up) and negative (down) emotions.
contr expr NE = controlled expression of negative emotions, uncontr expr NE = uncontrolled expression of negative emotions, emp suppr NE = empathetic suppression of negative emotions, distr NE = distraction from negative emotions, reappr NE = reappraisal of negative emotions, contr expr PE = controlled expression of positive emotions, uncontr expr PE = uncontrolled expression of positive emotions, emp suppr PE = empathetic suppression of positive emotions, distr PE = distraction from positive emotions, expr PE = expression of positive emotions. ** $p < .01$, * $p < .05$, # $p < .10$.

2.3.3.6. Genotype Analyses

Genotype influences on emotion processing and emotion regulation were tested with the same split plot ANOVAs and *t*-tests as described above, with the within-subjects factor 5-HTT expression instead of diagnostic group. Participants showing s/l and s/s expressions were subsumed in one group as “s-carriers”, and compared with participants showing l/l expressions (“non-s-carriers”). For easier readability, I only report exact statistical values and post-hoc tests of significant effects pertaining 5-HTT expression throughout this chapter.

Emotion processing during virtual penalty kicking was hardly influenced by 5-HTT expression. The analyses of valence and arousal ratings, zygomaticus and corrugator activations, skin conductance responses, and behavioral observation rates of the positive, negative, and tension aggregates revealed no significant main effects for 5-HTT expression and no significant interactions for emotion x 5-HTT expression (*F*s < 2.34, *p*s > .131, η_p^2 < .04). S-carriers showed overall higher social monitoring expressions than non-s-carriers (*F*[1,57] = 4.74, *p* = .034, η_p^2 = .08; *t*[57] = 2.18, *p* = .034). 5-HTT expression had some influence on emotion regulation outputs during virtual penalty kicking. The analyses of valence and arousal ratings, corrugator activations, and behavioral expressions of the positive and tension aggregates revealed no significant effects pertaining 5-HTT expression (*F*s < 2.13, *p*s > .124, η_p^2 =.04). Modulations of zygomaticus activations during penalty kicking are depicted in Figure 26. The analysis of zygomaticus activations revealed a marginally significant interaction for 5-HTT expression x regulation (*F*[1,106] = 2.50, *p* = .090, η_p^2 = .04, *GG-ε* = .94). This was due to s-carriers showing higher activations than non-s-carriers especially when showing their emotions.

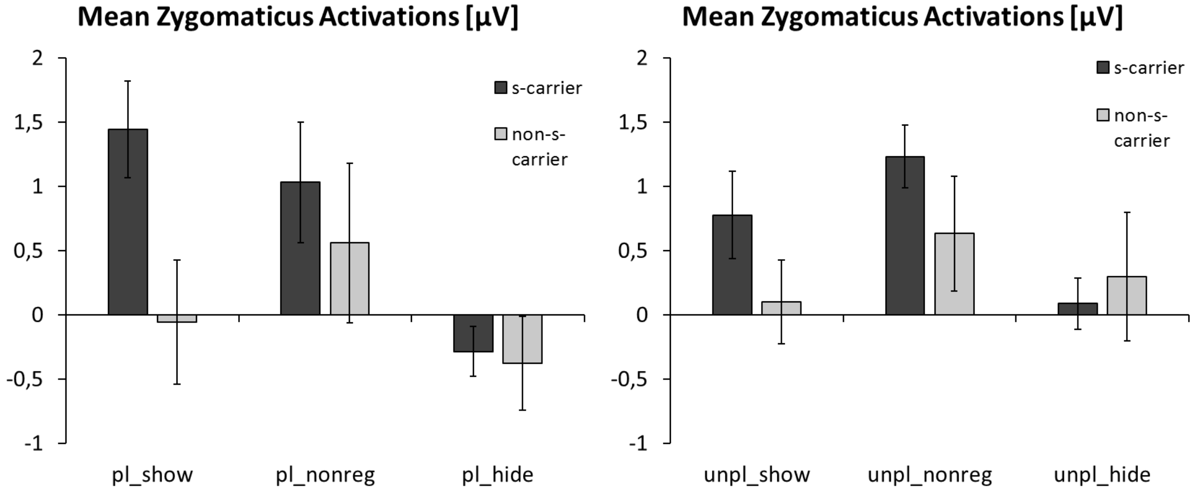


Figure 26. Mean activations and standard errors of M. zygomaticus major of s-carriers and non-s-carriers in pleasant (left) and unpleasant trials (right) in the different regulation conditions of the penalty kicking paradigm in experiment 3.

Modulations of SCRs during penalty kicking are depicted in Figure 27. The analysis of SCRs revealed a significant interaction for emotion x regulation (*F*[2,114] = 6.59, *p* = .002, η_p^2 = .10) and a significant interaction for 5-HTT expression x regulation (*F*[1,104] = 3.27, *p* = .046, η_p^2 = .05, *GG-ε* = .92). The latter effect remained even in a post-hoc 5-HTT expression x regulation ANOVA with SCRs averaged over pleasant and unpleasant trials (*F*[1,104] = 3.27, *p* = .046, η_p^2 = .05, *GG-ε* = .92). For s-carriers, SCRs were higher when showing vs.

hiding their emotions ($t[42] = 3.13$, $p = .003$), and marginally lower when hiding vs. not regulating their emotions ($t[42] = 1.86$, $p = .071$), but did not differ when showing vs. not regulating their emotions ($t[42] = 1.25$, $p = .218$). SCRs of non-s-carriers, however, were not modulated by the regulation condition (ts < 1.26, ps > .226). Non-s-carriers showed marginally higher SCRs than s-carriers only when hiding their emotions ($t[18] = 1.91$, $p = .072$), but not when showing or not regulating their emotions (ts < 0.97, ps > .338).

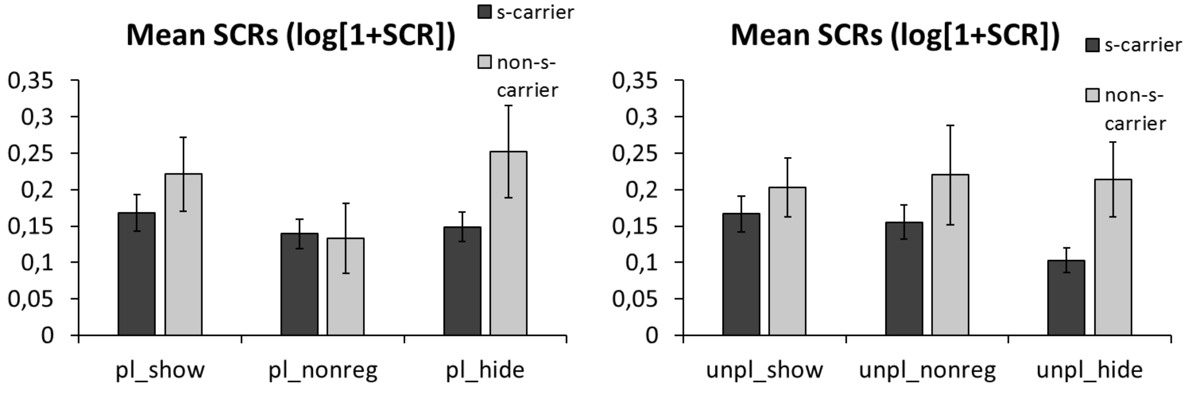


Figure 27. Means and standard errors of logarithmic skin conductance responses of s-carriers and non-s-carriers in pleasant (left) and unpleasant trials (right) in the different regulation conditions of the penalty kicking paradigm in experiment 3.

Modulations of negative behavioral expressions and social monitoring expressions of s-carriers and non-s-carriers during penalty kicking are depicted in Figure 28. For negative expressions, the analysis revealed a significant main effect for emotion ($F[1,57] = 17.78$, $p < .001$, $\eta_p^2 = .24$), a significant main effect for regulation ($F[1,105] = 9.56$, $p < .001$, $\eta_p^2 = .14$, $GG\text{-}\varepsilon = .93$), a significant interaction for emotion x regulation ($F[1,106] = 4.92$, $p = .010$, $\eta_p^2 = .08$, $GG\text{-}\varepsilon = .94$), and a marginally significant interaction for 5-HTT expression x emotion x regulation ($F[1,106] = 2.68$, $p = .076$, $\eta_p^2 = .05$, $GG\text{-}\varepsilon = .94$). The three-way interaction was due to non-s-carriers showing more negative emotional behavior when instructed to show or hide vs. not regulate their emotions in response to pleasant trials, but less negative emotional behavior when instructed to show vs. not regulate their emotions in response to unpleasant trials. For social monitoring expressions, the analysis revealed a significant main effect for emotion ($F[1,57] = 16.92$, $p < .001$, $\eta_p^2 = .23$), a significant main effect for regulation ($F[2,114] = 12.50$, $p < .001$, $\eta_p^2 = .18$), a marginally significant interaction for emotion x regulation ($F[2,114] = 2.69$, $p = .072$, $\eta_p^2 = .05$), and a marginally significant interaction for 5-HTT expression x regulation ($F[2,114] = 2.93$, $p = .058$, $\eta_p^2 = .05$). The latter was due to s-carriers showing slightly more social monitoring behavior than non-s-carriers when showing or not regulating their emotions, but not when hiding their emotions.

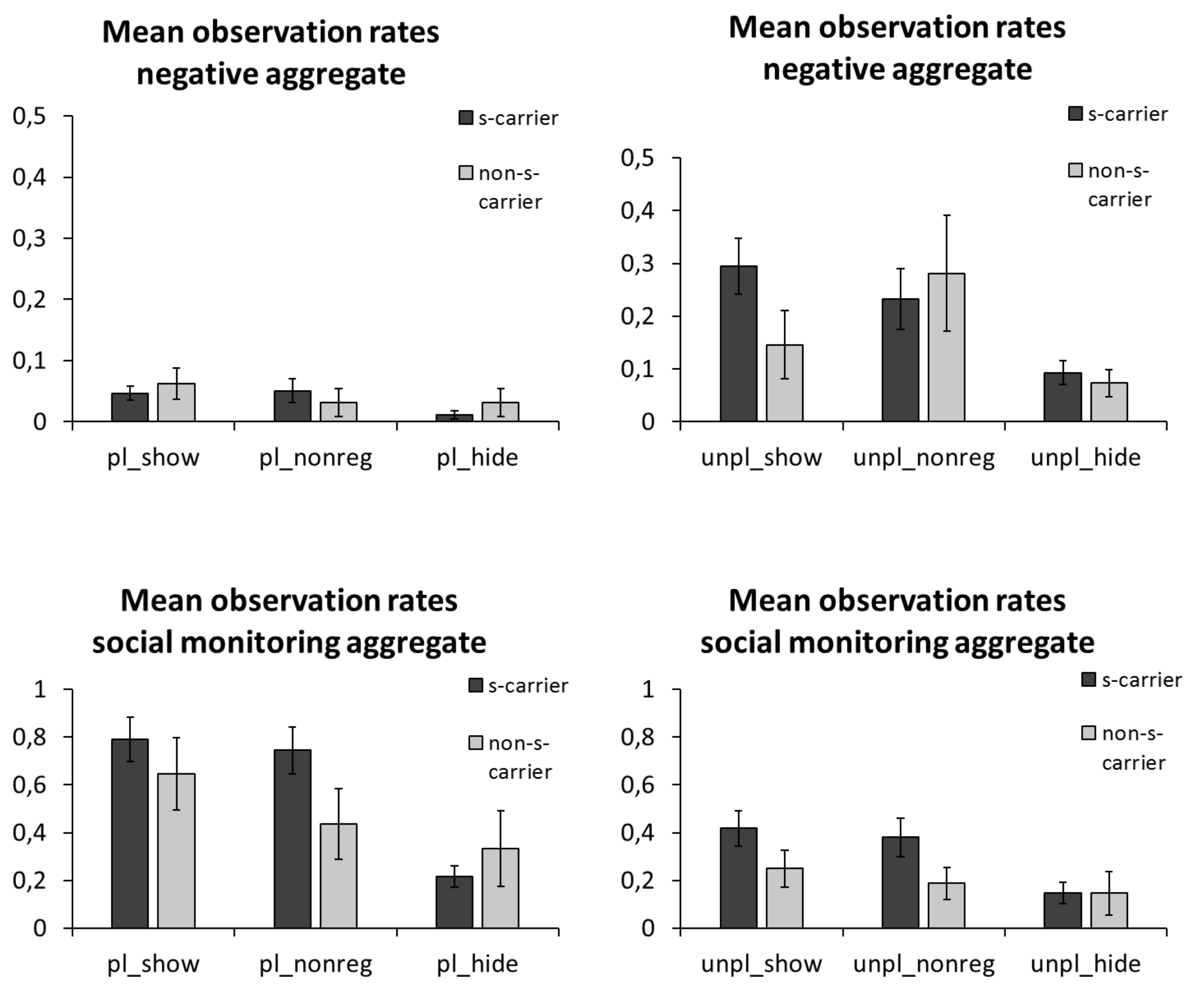


Figure 28. Mean observation rates and standard errors for expressions of the negative and social monitoring aggregates of s-carriers and non-s-carriers in the different regulation conditions of the penalty kicking paradigm in experiment 3.

Cyber ball emotion processing and emotion regulation analyses of valence and arousal ratings, ratings of positive and negative affect, corrugator activations, skin conductance levels, and behavioral observation rates of the positive, negative, and social monitoring aggregates revealed no significant effects pertaining 5-HTT manifestation (*F*s < 2.76, *p*s > .102, η_p^2 < .05). S-carriers showed overall higher zygomaticus activations than non-s-carriers across different cyber ball conditions (*F*[1,57] = 4.10, *p* = .048, η_p^2 = .07; *t*[57] = 2.03, *p* = .048). Non-s-carriers showed overall marginally higher tension expression rates than s-carriers (*F*[1,57] = 2.80, *p* = .100, η_p^2 = .05).

Baseline skin conductance levels of s-carriers and non-s-carriers were comparably high (*t*[21] = 1.02, *p* = .318).

Differences of habitually applied emotion regulation strategies in s-carriers vs. non-s-carriers are depicted in Figure 29. S-carriers and non-s-carriers reported to habitually apply controlled expression of negative emotions, uncontrolled expression of negative emotions, empathic suppression of negative emotions, controlled expression of positive emotions, uncontrolled expression of positive emotions, distraction from positive emotions, and overall expression of positive emotions comparably often (*t*s < 1.22, *p*s > .226). Non-s-carriers reported to distract from negative emotions marginally more often than s-carriers (*t*[56] = 1.79, *p* = .08). Non-s-carriers reported to reappraise negative emotions more frequently than s-carriers (*t*[56] = 2.88, *p* = .006). Non-s-carriers reported to empathically suppress positive emotions more frequently than s-carriers (*t*[57] = 2.25, *p* = .028).

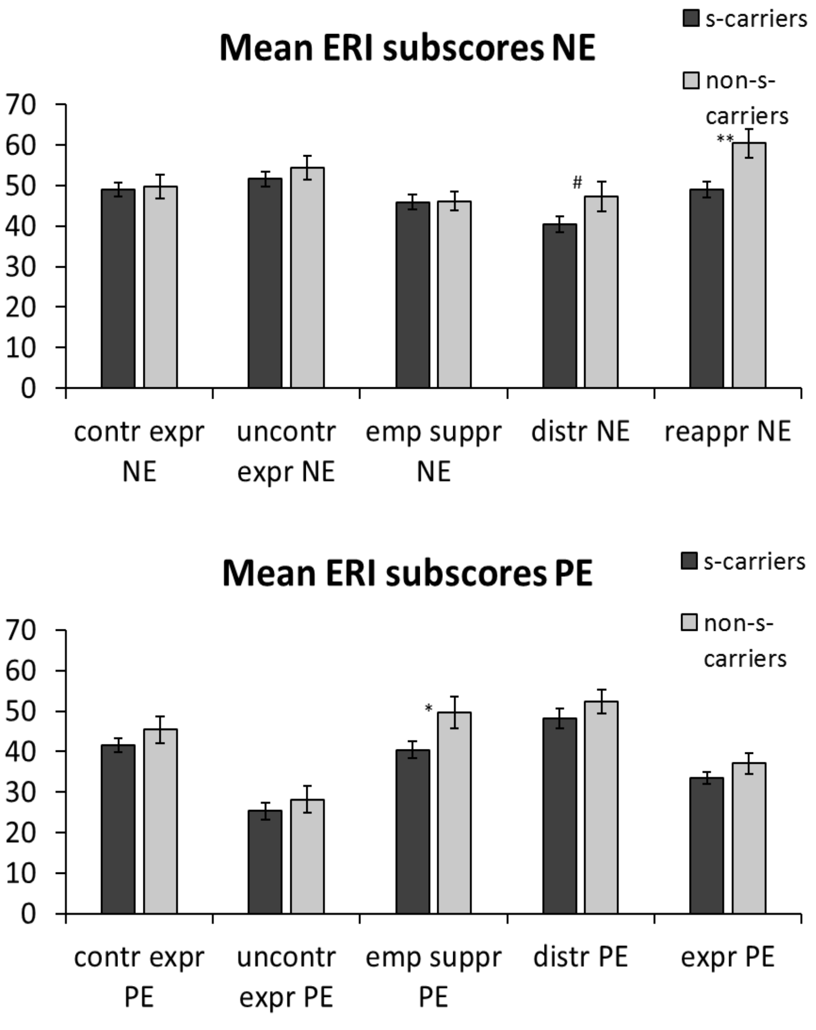


Figure 29. Means and standard errors of ERI subscores of s-carriers and non-s-carriers for the regulation of positive (up) and negative (down) emotions.
contr expr NE = controlled expression of negative emotions, uncontr expr NE = uncontrolled expression of negative emotions, emp suppr NE = empathetic suppression of negative emotions, distr NE = distraction from negative emotions, reappr NE = reappraisal of negative emotions, contr expr PE = controlled expression of positive emotions, uncontr expr PE = uncontrolled expression of positive emotions, emp suppr PE = empathetic suppression of positive emotions, distr PE = distraction from positive emotions, expr PE = expression of positive emotions. ** *p* < .01, * *p* < .05, # *p* < .10.

2.3.4. Discussion

The aim of the present study was to investigate emotion processing and emotion regulation in pleasant and unpleasant experimental conditions in adult ADHD patients vs. healthy controls. This was tested with an adapted version of the virtual penalty kicking paradigm established in experiments 1 and 2 and an adapted version of the cyber ball paradigm (Williams & Jarvis, 2006). Emotional reactions were assessed on experiential (valence and arousal ratings, PANAS scores), physiological (activity of M. zygomaticus major and M. corrugator supercilii, skin conductance modulations), and behavioral levels (emotional expressive behavior assessed with a categorical observation scheme). To my knowledge, this is the first study systematically investigating emotional reactions to pleasant as well as unpleasant events on different levels in ADHD patients and healthy controls. Moreover, this study differentiated thoroughly between emotional reactions after processing of pleasant and unpleasant events vs. emotional reactions after instructed emotion regulation. In line with Bunford et al. (2015), I consider a systematic investigation of those processes important to gain better understanding of specific strains that especially adult ADHD patients suffer from, and to develop specific interventions. Furthermore, I was interested in baseline differences of autonomic arousal and the habitual application of different emotion regulation strategies in ADHD patients vs. healthy controls. At last, I investigated the modulation of emotional reactions dependent on different genotypes previously associated with ADHD and emotional responding. I will discuss findings of emotion processing and emotion regulation analyses in the cyber ball game and the virtual penalty kicking paradigm, baseline autonomic arousal, habitually applied emotion regulation strategies, and genotype analyses successively.

2.3.4.1. Emotion Processing Penalty Kicking

Valence and arousal ratings during penalty kicking were less extreme in ADHD vs. healthy controls in response to pleasant as well as unpleasant trials. Lower valence ratings of ADHD in response to pleasant trials are in line with my hypothesis and in line with previous findings indicating deficient reward processing in ADHD (Conzelmann et al., 2009; Plichta et al., 2009; Plichta & Scheres, 2014). Valence ratings in response to unpleasant trials were slightly higher in patients vs. controls, but did not differ significantly between diagnostic groups. Slightly lower emotional responses of ADHD patients to unpleasant trials on the experiential level are in line with findings by Braaten & Rosen (1997) who reported lower reactivity to negative consequences of adults with high symptoms of ADHD. However, those findings are contrary to Conzelmann et al. (2009) who, on a physiological level, found even slightly increased reactivity in combined-type ADHD vs. controls to unpleasant stimuli. Those findings suggest impaired emotional reactivity in ADHD primarily in response to pleasant events. The peculiarities of ADHD patients' emotional reactivity to unpleasant events seem to be contradictory and not fully understood. In the present study, patients vs. controls showed slightly diminished arousal ratings in response to pleasant and unpleasant, but not to neutral trials. This is in line with my hypothesis and in line with theories suggesting hypoarousal not only at baseline, but also in response to emotional stimuli, as an endophenotype for ADHD (Doyle et al., 2005; Sergeant, 2005).

In line with my expectations, zygomaticus activations were lower for patients vs. controls irrespective of the emotional experimental condition. As outlined above, this finding might reflect impaired reward processing in ADHD, resulting in lower baseline levels of positive affectivity (Plichta & Scheres, 2014; Sonuga-Barke, 2002). Against my expectations, zygomaticus activities were highest in response to unpleasant, and not in response to pleasant pictures. This finding (in line with zygomaticus modulations in experiment 2, but not in experiment 1) was mainly due to ADHD patients, in contrast to healthy controls, showing higher zygomaticus activations in response to unpleasant, compared to pleasant trials. Differences in zygomaticus activations between patients and controls were most obvious in response to pleasant trials where controls, but not ADHD patients showed zygomaticus activations. Again, impaired psychophysiological reactivity to pleasant events is in line with previous findings (Conzelmann et al., 2009; Conzelmann et al., 2011). Contrary to my expectations, but in line with the findings in the cyber ball game, corrugator activations across pleasant, neutral, and unpleasant trials did not differ in patients vs. controls. This suggests that on a physiological level, ADHD patients do not differ from controls in the amount of negative affectivity, either at baseline, or in response to emotional events. This is partly in line with the studies by Conzelmann et al. (2009) and Conzelmann et al. (2011) who found impaired responsiveness of ADHD patients primarily to pleasant stimuli.

In line with suggestions of impaired arousal modulation in response to emotional stimuli in ADHD (Doyle et al., 2005; Sergeant, 2005), skin conductance responses in the penalty kicking game were slightly lower in patients vs. controls across emotional conditions. This is also in line with a study by Conzelmann et al. (2014) who found decreased skin conductance responses in boys with ADHD in response to pleasant, neutral, and unpleasant pictures. However, the results of the present study concerning autonomic hyporesponsiveness to emotional stimuli in adult ADHD were less clear than in the study by Conzelmann et al. (2014) investigating children. One might conclude from the results of the present study and the study by Conzelmann et al. (2014) that autonomic hyporesponsiveness to emotional stimuli diminished at least in some ADHD patients with age. The distinct findings of autonomic hyporesponsiveness in children vs. adults parallel findings from EEG studies where cortical hypoarousal has been replicated in children (Barry et al., 2009; Clarke et al., 1998; Snyder & Hall, 2006), but results in adult populations are less consistent (Clarke et al., 2008; Koehler et al., 2009; Snyder & Hall, 2006).

Against my expectations, expression rates of positive emotional behavior in the penalty kicking game did not differ in patients vs. controls, or across experimental conditions. One reason for this might be the overall low expression rates, resulting in floor effects and the impossibility to statistically detect small effects (Groth-Marnat, 2009). Also expression rates of behaviors belonging to the negative, tension, and social monitoring aggregates did not differ between patients and controls throughout emotion processing during penalty kicking. This is not in line with my expectations and not in line with findings in the cyber ball game where positive and negative emotional expressions as well as social monitoring expressions were shown more often by patients vs. controls. One reason for those divergent findings on the behavioral level might be the divergent nature of experimental paradigms. Whereas social exclusion in the cyber ball paradigm has been proven successful for the induction of negative affective states (Abrams et al., 2011; Barkley et al., 2012; Bolling et al., 2012; Kawamoto et al., 2013; Kelly et al., 2012), experiments 1 and 2 indicated that the virtual penalty kicking paradigm was suitable to induce positive, but not so much negative affective states. Previous studies (Conzelmann et al., 2009; Conzelmann et al., 2011; Plichta & Scheres, 2014) as well as the current results on experiential and physiological levels have suggested ADHD patients to show impaired emotional responding primarily to pleasant experiences. Consequently, patients might have experienced relatively weaker emotional states in the penalty kicking paradigm vs. the cyber ball paradigm. Healthy controls, in contrast, might have experienced stronger emotions during penalty kicking than during cyber ball. This dissociation might have resulted in the patients’ emotional over-expressiveness becoming important in the cyber ball game, but not so much in the penalty kicking game. Unfortunately, the different design of the cyber ball and penalty kicking paradigms does not allow for direct comparisons between the two. Thus, the preceding argumentation remains speculative. To empirically test those considerations, one would have to assess experiential, physiological, and behavioral responses of ADHD patients and controls to pleasant and unpleasant events in one paradigm.

Taken together, the results of emotion processing during virtual penalty kicking seem to replicate overall diminished positive affectivity of ADHD patients vs. controls (reflecting in lower zygomaticus major activations), which was also found in the cyber ball game. Moreover, valence and arousal ratings speak for diminished emotional reactivity of patients on an experiential level, especially to pleasant experiences. As outlined above, this is in line with theories of impaired reward processing (Plichta & Scheres, 2014; Sonuga-Barke, 2002) in ADHD. Modulations of skin conductance responses supply evidence for autonomic hyporesponsiveness to emotional experiences in ADHD, which has been suggested as an endophenotype for ADHD (Doyle et al., 2005; Sergeant, 2005). Results on the behavioral level are less clear, possibly due to innate deficiencies of the applied observation system.

2.3.4.2. Emotion Regulation Penalty Kicking

Against my expectations but in line with cyber ball results, patients did not perform worse than healthy controls at altering their emotional experiences throughout the penalty kicking game through response modulation. As outlined above, this indicates that patients were well able to deliberately apply response modulation strategies. Partly in line with my hypothesis, valence ratings in response to pleasant trials were slightly higher when participants were instructed to show vs. to not regulate or hide their emotions. Moreover, valence ratings in response to unpleasant trials were slightly lower when participants were instructed to show vs. to not regulate or hide their emotions. However, hiding emotions did not influence valence ratings of patients or controls in response to pleasant or unpleasant trials. This is at odds with Gross & Levenson (1997) who found decreased amusement ratings of healthy controls in response to sad, neutral, and amusing films when hiding vs. not regulating their emotions. More extreme valence ratings of participants when explicitly showing vs. not regulating and hiding their emotions are in line with Strack et al. (1988) who found facial feedback to operate on explicit affective responses. In line with my expectations, arousal ratings were higher when participants explicitly showed their emotions and lower when participants hid their emotions, than when they did not regulate their emotions. Those findings are in line with the studies by Gross & Levenson (1997) and Strack et al. (1988) mentioned above. However, arousal ratings were not modulated due to emotion regulation differently in patients vs. controls. Again, this suggests that ADHD patients were able to successfully up- and down-regulate their emotional experiences through response modulation.

Zygomaticus activations were modulated by the regulation condition differently in patients vs. controls. Healthy controls showed lower zygomaticus activations when hiding vs. not regulating their emotions in response to pleasant and unpleasant trials, higher activations when showing vs. not regulating their emotions in response to pleasant trials, and slightly lower activations when showing vs. not regulating their emotions in response to unpleasant trials. Those findings suggest successful regulation of emotional responses in healthy controls, as expected. Zygomaticus activations of ADHD patients, however, were not modulated across different regulation conditions, suggesting impaired emotional response modulation. However, this finding might partly be due to patients, but not controls, showing very low baseline activations. Those low baseline activations might have resulted in floor effects in the patient group (Groth-Marnat, 2009). Corrugator activations were not modulated across different regulation conditions in patients or controls. As outlined above, this might be due to overall very low corrugator activations and resulting floor effects (Groth-Marnat, 2009).

Skin conductance responses in reaction to trials of different regulation conditions were modulated differently in patients vs. controls. Patients showed slightly lower skin conductance responses than healthy controls only in non-regulate conditions, and especially in unregulated pleasant trials. One might conclude from this that ADHD patients' diminished psychophysiological arousal in response to emotional stimuli normalizes when they perform a regulation task. This explanation would be in line with a study by Loo et al. (2009) who found increased cortical arousal in adults with ADHD vs. healthy controls during a cognitively demanding task. Possibly, the increase in electrodermal activity in ADHD patients in the present study might be moderated by cognitive demands that the emotion regulation task brings along. However, this explanation is at odds with skin conductance modulations during cyber ball and the study by Musser et al. (2011) mentioned above. Those suggest a lack of autonomic modulations through emotion regulation in ADHD.

Behavioral expressions of the positive and negative aggregates were shown comparably often when participants showed or did not regulate their emotions and less frequently when they hid their emotions. Against my expectations, but in line with the majority of hitherto reported results, patients were as successful as controls at suppressing positive and negative emotional expressions. Tension expressions were shown by both patients and controls equally often in "show" and "non-regulate" trials, and least frequently in "hide" trials. Patients showed overall higher tension expressions than healthy controls, and especially so in "show" and "hide" trials. This might result from emotion regulation being more effortful for patients than for controls, thus going along with higher psychological strain. Social monitoring behavior was shown more often by both patients and controls when showing or not regulating their emotions than when hiding their emotions. However, expression rates were slightly higher in patients vs. controls when hiding emotions. This is partly in line with modulations of tension expressions and with previous studies suggesting ADHD patients to have difficulties in suppressing behavioral emotional expressions (Maedgen & Carlson, 2000; Walcott & Landau, 2004).

Taken together, analyses of emotion regulation during the penalty kicking paradigm suggest that ADHD patients seem to be able to successfully apply response modulation strategies. Analyses of emotional reactions on experiential and behavioral levels dependent on emotion regulation revealed similar patterns in patients and controls. As stated above, previously reported impairments of ADHD patients in emotion regulation might result from aberrant emotion processing and/or difficulties in automatic emotion regulation. The present findings mostly speak against ADHD patients having major problems in deliberate emotion regulation when provided with a specific, response-focused emotion regulation strategy. Modulations of skin conductance responses indicate that emotion regulation might be more effortful for ADHD patients than for healthy controls, going along with increased autonomic arousal especially when suppressing emotional reactions.

2.3.4.3. Emotion Processing and Emotion Regulation Cyber Ball

Against my expectations, valence ratings throughout the cyber ball game did not differ in patients vs. controls. As expected, participants reported higher valence ratings in response to inclusion than in response to ostracism. Patients as well as controls reported lower emotional valence when instructed to hide their emotions than when instructed to respond freely during inclusion in the cyber ball game. During ostracism, valence ratings of patients and controls were not modulated by the regulation condition. Arousal ratings were slightly higher in controls vs. patients in inclusion blocks and slightly higher in patients vs. controls in ostracism blocks. The patients' lower experienced arousal in inclusion blocks might be due to patients showing lower baseline levels of emotional arousal, as suggested by Doyle et al. (2005), Sergeant (2005), and Conzelmann et al. (2014). An increased sensitivity for social rejection in ADHD (Bondü & Esser, 2015) might go along with increased emotional arousal in ostracism blocks especially in the patient group. Arousal ratings were not modulated differently in patients vs. controls dependent on the regulation condition. Patients as well as controls reported higher emotional arousal when responding freely than when hiding their emotions. Those findings suggest that, against my expectations, ADHD patients are able to diminish their emotional reactions on an experiential level just as well as healthy controls.

Ratings of positive affect were lower in response to ostracism than in response to inclusion. Overall slightly lower positive affect in patients than in controls is in line with theories of diminished reward processing in ADHD (Conzelmann et al., 2009; Conzelmann et al., 2011; Conzelmann et al., 2016; Plichta & Scheres, 2014; Sonuga-Barke, 2002). In line with my expectations, ADHD patients reported overall higher negative affect than healthy controls, and especially so in response to ostracism when not regulating their emotions. This finding is again in line with findings by Bondü & Esser (2015) who reported children and adolescents with ADHD symptoms to be more sensitive to social rejection than controls. Positive affect was not modulated differently in patients vs. controls depending on the regulation condition. Patients as well as controls reported slightly higher positive affect when responding freely than when hiding their emotions during cyber ball, irrespective of the inclusion condition. Interestingly, negative affect ratings were modulated differentially in patients vs. controls across different regulation conditions. Patients reported higher negative affect than controls when not regulating their emotions, but comparably low negative affect as controls when hiding their emotions. This is against my expectations that patients would perform worse than healthy controls at down-regulating negative emotions. On the contrary, this finding suggests that providing ADHD patients with a specific emotion regulation instruction (like response modulation in the present study) might help them to decrease the intensity of their experienced negative affect. Previous studies investigating emotion regulation on an experiential level in ADHD did so mostly with the help of retrospective questionnaires or parent ratings, assessing trait emotion regulation rather than state emotion regulation (Edel et al., 2015; Oliver et al., 2015; Sjöwall et al., 2013; Steinberg & Drabick, 2015; van Eck et al., 2015). The only published study on instructed state emotion regulation in ADHD I am aware of (Matthies et al., 2014) found adult ADHD patients to be able to diminish film-induced sadness on an experiential level through acceptance and expressive suppression strategies. However, that study lacked a healthy control group, making it impossible to tell whether patients performed differently than healthy controls. The findings of the present study suggest that deficient emotion regulation capacities of ADHD patients might result from deficits in automatic emotion regulation, rather than from deficiencies in effectively applying a regulation strategy when instructed to do so.

In line with the rating data and current theories on deficient reward processing in ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002), patients showed overall lower zygomaticus activations than healthy controls. However, this effect occurred irrespective of inclusion vs. ostracism in the cyber ball game. Moreover, analyses of zygomaticus modulations across all cyber ball blocks revealed increased activations in ostracism vs. inclusion blocks. This is against my expectations and against previous findings suggesting cyber ball ostracism to induce negative, rather than positive affect (Abrams et al., 2011; Barkley et al., 2012; Bolling et al., 2012; Kawamoto et al., 2013). However, zygomaticus activations have been reported to be increased during negative, compared to neutral emotional states before (Lang et al., 1993). Kunz et al. (2009, 2013) reported increased smiling behavior in response to painful compared to neutral experimental conditions. Suggesting that cyber ball inclusion induces rather neutral and not positive affective states, increased zygomaticus activations in ostracism vs. inclusion blocks would be consistent. Contrary to my hypothesis but in line with results on the experiential level, zygomaticus activations were not modulated by the regulation condition differently in patients vs. controls. Patients as well as controls showed higher zygomaticus activations when not regulating vs. hiding their emotions in both inclusion and ostracism blocks. This suggests that response modulation was applied successfully by patients and controls and went along with decreased positive emotional responses on a physiological level. This finding is again in line with the study by Matthies et al. (2014) who found sadness-induced psychophysiological activation to be decreased in adult ADHD patients when applying expressive suppression. Corrugator activations were not modulated throughout different cyber ball conditions, in patients or controls. Keeping in mind that corrugator activations were overall very low, this might be due to floor effects (Groth-Marnat, 2009).

Skin conductance levels were modulated dependent on cyber ball inclusion and regulation conditions in healthy controls, but not in patients. Controls showed higher skin conductance levels when being included vs. ostracized, and marginally higher skin conductance levels when not regulating vs. hiding their emotions. Patients showed comparably low skin conductance levels across all experimental conditions. The modulation of skin conductance levels in controls might reflect psychological alertness, which was higher in inclusion vs. ostracism blocks due to active participation in the game, and slightly higher when freely expressing vs. hiding their emotions (Boucsein, 2012; Gale, Bull, & Haslum, 1972). The lack of autonomic modulations throughout different experimental conditions in patients is in line with findings in child samples (Musser et al., 2011) and in line with assumptions that ADHD patients show impaired arousal modulations in response to stimuli (Conzelmann et al., 2014; Sergeant, 2005).

In line with my expectations and in line with a previous study using a similar observation scheme (Maedgen & Carlson, 2000), patients showed overall higher expression rates of positive emotional behavior and slightly higher expression rates of negative emotional behavior than controls. Those findings are in line with Bunford et al. (2015) who reported an over-expression of both positive and negative emotions in youth with ADHD. In line with Maedgen & Carlson (2000), tension expressions were comparably high in patients and in controls. Social monitoring behavior was shown slightly more often by patients vs. controls. This is not in line with my hypothesis and not in line with findings by Walcott & Landau (2004) who reported that boys with ADHD performed worse than healthy controls at masking their emotions when receiving an undesirable prize. Maedgen & Carlson (2000) reported no differences in social monitoring expressions in combined-type ADHD children vs. healthy controls when receiving an undesirable prize. One reason for this unexpected finding might be that one behavioral category assigned to the social monitoring aggregate in the present study ("slight or closed lip smile") might actually indicate positive affectivity, rather than social monitoring. Slight smiles were expressed very often and are therefore very likely to have biased the present results. In fact, this very category was assigned to the positive aggregate in the older version of the modeling observation scheme (Saarni, 1984), but was then assigned to the social monitoring aggregate in the later version (Saarni, 1992).

Behavioral expressions indicating positive affect were higher in ostracism blocks when patients and controls did not regulate their emotions vs. when they hid their emotions. This is not in line with my expectation that patients would be worse than healthy controls at hiding their positive emotional expressions. On the contrary, patients successfully suppressed their positive emotional expressions during ostracism blocks when instructed to do so, although expression rates were higher than in the control group in unregulated blocks. This finding is in line with zygomaticus modulations. The modulation of negative emotional expressions dependent on regulation conditions points in the same direction. Patients did show slightly increased overall expressions of negative affect, but were as successful as controls in reducing expression rates when instructed to hide their emotions. Tension expressions were not modulated in patients or controls when instructed to hide vs. not regulate their emotions. Social monitoring behavior was shown more often when participants did not regulate their emotions vs. when they hid their emotions. Those findings once again underline the idea that when instructed to deliberately apply a certain regulation strategy, ADHD patients do not show major impairments in down-regulating their emotions. Previously reported emotion dysregulation in ADHD might thus rather reflect impairments in automatic emotion regulation.

Taken together, some results during emotion processing in the cyber ball game point to ADHD patients vs. healthy controls experiencing less positive affect in general and more negative affect especially in response to social ostracism. Patients vs. controls reported slightly diminished overall positive affect and showed diminished overall zygomaticus activations. Those findings are in line with theories suggesting deficient reward processing in ADHD, which on the long term might result in overall diminished positive affectivity (Plichta & Scheres, 2014; Sonuga-Barke, 2002). The higher negative emotional reactivity in response to social ostracism (patients vs. controls reported higher negative affect especially during ostracism) might result from increased rejection sensitivity in ADHD which was suggested by Bondü & Esser (2015). Behavioral over-expression of positive emotions in patients vs.

controls, however, is at strike with those suggestions, but in line with findings by Maedgen & Carlson (2000). Over-expression of positive as well as negative emotions in ADHD seems to come along with social impairment (Bunford et al., 2014). Diminished arousal ratings and skin conductance levels in patients vs. controls during inclusion blocks are in line with considerations by Sergeant (2005) and Doyle et al. (2005) who suggested arousal deficits as an endophenotype for ADHD. Impaired autonomic modulations (patients showed no modulation of skin conductance levels across experimental conditions) have previously been reported in ADHD children (Conzelmann et al., 2014; Musser et al., 2011) and might be interpreted as deficits in arousal modulation in response to stimuli, as suggested by Doyle et al. (2005) and Sergeant (2005). The results of emotion regulation during cyber ball do not underline the initial hypothesis that ADHD patients show major difficulties in applying output strategies of emotion regulation. Though showing slightly stronger emotional reactions induced by ostracism, ADHD patients were equally successful as healthy controls at diminishing their emotional reactions on experiential, physiological, and behavioral levels through response modulation. One explanation for the repeatedly reported emotion regulation dysfunctions might be that ADHD patients do suffer from deficits in automatic emotion regulation (Mauss, Bunge et al., 2007), but are able to successfully apply emotion regulation strategies when instructed to do so. Interestingly, and in line with previous findings (Musser et al., 2011), the successful application of response-focused emotion regulation did not reflect in modulations of autonomic nervous activity in patients, but in controls.

2.3.4.4. Baseline Skin Conductance Level

As expected, baseline skin conductance levels were lower for patients than for healthy controls. This is in line with suggestions by Sergeant (2005) and Doyle et al. (2005) who postulated ADHD to be characterized by arousal deficits at baseline and in reaction to emotional stimuli. Conzelmann et al. (2014) found boys with ADHD to show lower baseline skin conductance levels than healthy controls. The present study in an adult population points to baseline deficits in autonomic arousal to persist even into adulthood. Arousal deficits in response to emotional experiences showed only weakly in the present study. Consequently, baseline arousal deficits might be more persistent across age than response modulations.

2.3.4.5. Habitual Emotion Regulation

Against my expectations and against conclusions from previous studies, ADHD patients in the current study reported to habitually use adaptive emotion regulation strategies even more frequently than healthy controls. Patients vs. controls did not differ in reported frequency of “controlled expression of negative emotions”, “uncontrolled expression of negative emotions”, “empathic suppression of negative emotions”, and “distraction from negative emotions". Patients reported to use reappraisal when experiencing negative emotions more often than healthy controls. Considering the habitual regulation of positive emotions, patients reported equally high scores as healthy controls for "controlled expression of positive emotions" and slightly higher scores than healthy controls for "uncontrolled expression of positive emotions". Moreover, patients vs. controls reported higher scores for "empathic suppression of positive emotions", "distraction from positive emotions", and overall "expression of positive emotions".

Equally high scores of patients and controls on the sub scales "controlled expression of negative emotions", "uncontrolled expression of negative emotions", and "controlled expression of positive emotions", as well as slightly higher scores of "uncontrolled expression of positive emotions" in the patient group are in line with results on the behavioral level. The latter indicate that ADHD patients expressed negative emotions comparably often as healthy controls throughout different cyber ball and penalty kicking blocks. Positive emotional expressions were shown more frequently by patients vs. controls in the cyber ball game, but comparably often by patients and controls in the virtual penalty kicking game. However, findings concerning habitual emotion regulation are partly at odds with a number of studies indicating an over-expression of especially negative, and, to some degree, also positive emotions, in ADHD (Bunford et al., 2014; Maedgen & Carlson, 2000; Walcott & Landau, 2004).

I am not aware of any study to date systematically investigating the habitual application of different emotion regulation strategies according to Gross (1998b, 2002) in ADHD vs. healthy controls. However, Melnick & Hinshaw (2000) reported highly aggressive ADHD boys confronted with a frustrating puzzle to engage less in adaptive emotion regulation strategies (like problem solving or seeking help) than less aggressive ADHD boys and healthy comparison boys. In the present study, ADHD vs. healthy controls did not show major impairments in state emotion regulation through response modulation on experiential, physiological, and behavioral levels. The analyses of habitually applied emotion regulation strategies do not speak for impaired trait emotion regulation, either. However, previous research findings as well as findings from the current study do provide evidence that ADHD patients suffer from aberrant emotion processing. Moreover, ADHD patients might face problems in automatic emotion regulation. ADHD patients vs. healthy controls seem to respond less to pleasant experiences, and stronger to at least some unpleasant experiences. This might result in overall higher levels of negative affectivity, and lower levels of positive affectivity, and might bring along motivation deficits. This conclusion is in line with a study by Edel et al. (2015) who reported adult ADHD patients to have problems in emotion processing, rather than emotion regulation.

2.3.4.6. Genotype Analyses

Against my expectations and not in line with previous research (Walitza et al., 2005), I found no differences between healthy controls and ADHD patients in expression rates of G and T alleles of SNP 25-TPH2. An over-expression of the G-allele of this polymorphism has previously been reported in children and adolescents with ADHD (Walitza et al., 2005), but not so in the present study investigating adult patients. The main reason for this might be the small sample size of the present study. While Walitza et al. (2005) investigated 225 children with ADHD and their families, genotype analyses were conducted for only 29 ADHD patients in the current study. However, the present findings are in line with other studies reporting no associations between TPH2 expressions and ADHD symptoms in adult populations (Baehne et al., 2009; Franke et al., 2011; Jacob et al., 2010; Johansson et al., 2010).

In line with my expectations and in line with previous studies (Franke et al., 2011; Müller et al., 2008; Retz et al., 2002), I found a slight over expression of two long alleles (l/l) in SNP 5-HTT in ADHD patients vs. healthy controls. Keeping in mind the small sample size of the present study, this is particularly interesting. However, there are also numerous studies reporting no associations or opposite associations between SNP 5-HTT expressions and ADHD (Franke et al., 2011; Grevet et al., 2007; Johann, Bobbe, Putzhammer, & Wodarz, 2003; Kim et al., 2006). I conducted statistical analyses of genotype influences on emotional reactions comparing s-carriers (s/l or s/s genotypes) vs. non-s-carriers (l/l genotype). Against my expectations, most emotional reactions throughout different penalty kicking and cyber ball blocks did not differ in s-carriers vs. non-s-carriers. Especially for reactions on the experiential level, there were no differences in s-carriers vs. non-s-carriers. One reason for this might be the rather small sample size which did not allow for the statistical detection of small effects (Cohen, 2013).

In line with analyses based on diagnostic groups, s-carriers showed overall higher zygomaticus activations than non-s-carriers throughout different cyber ball blocks. This finding is in line with Herrmann et al. (2007) who reported increased emotional responsiveness of s-carriers to both pleasant and unpleasant pictures. Zygomaticus modulations during emotion regulation throughout virtual penalty kicking point in the same direction. Here, s-carriers showed higher zygomaticus activations than non-s-carriers especially when showing their emotions in response to pleasant trials. Those findings are also in line with theories of deficient reward processing in ADHD (associated with an over-expression of the l-allele). Interestingly, patients vs. controls showed lower zygomaticus activities during penalty kicking especially in response to pleasant trials. Taken together, the findings of phenotype (diagnostic group) and genotype (5-HTT expression) analyses of zygomaticus modulations might be interpreted as further evidence for deficient reward processing to be an endophenotype for ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002).

Modulations of skin conductance responses throughout virtual penalty kicking differed in s-carriers vs. non-s-carriers. S-carriers showed highest skin conductance responses when showing their emotions and lowest skin conductance responses when hiding their emotions. Non-s-carriers showed comparably high skin conductance responses across different regulation conditions. This finding might be interpreted as a reflection of deficient arousal modulations in ADHD patients through emotion regulation (Musser et al., 2011) on the genetic level. However, conclusions concerning 5-HTT influences on skin conductance modulations from the present study are rather speculative, and a lot more research is necessary on this topic.

Negative emotional expressions were shown slightly more often by non-s-carriers vs. s-carriers in response to pleasant penalty kicking trials when instructed to show or hide their emotions. Negative expressions were shown slightly more often by s-carriers vs. non-s-carriers in response to unpleasant trials when instructed to show their emotions. Social monitoring expressions during penalty kicking were shown slightly more often by s-carriers vs. non-s-carriers when showing or not regulating their emotions, but not when hiding their emotions. Tension behavior was shown slightly more often by s-carriers vs. non-s-carriers throughout cyber ball emotion processing blocks. All of those effects were very weak and do not allow for substantial interpretation. Further research in bigger samples would be necessary to disentangle possible modes of action. During emotion processing throughout virtual penalty kicking, s-carriers showed more social monitoring behavior than non-s-carriers. This is not in line with analyses based on diagnostic groups. ADHD patients showed slightly more social monitoring behavior than healthy controls during emotion processing throughout cyber ball. Over-expression of social monitoring behavior in s-carriers might be interpreted as increased social adaptation, possibly as a result of increased anxiety traits which have previously been associated with the s-allele of 5-HTT (Canli & Lesch, 2007; Lesch et al., 1996).

In line with results from analyses based on diagnostic groups, non-s-carriers reported to habitually apply adaptive emotion regulation strategies even more frequently than s-carriers.

Non-s-carriers reported to apply distraction from negative emotions and reappraisal of negative emotions, as well as empathic suppression of positive emotions more frequently than s-carriers. Those findings are also in line with Gilman et al. (2015) who reported weakened down-regulation of negative emotions in healthy participants of the s/s genotype. Also findings on associations between the s-allele and anxiety-like traits (Canli & Lesch, 2007; Lesch et al., 1996) are in line with the present findings on habitual emotion regulation.

The results of genotype analyses alongside phenotype results provide some evidence for deficient reward processing as an endophenotype for ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002). Diminished positive emotional responsiveness was shown in ADHD patients, and in the genotype expression associated with ADHD (l/l). However, results in genotype analyses showed only partly and only on the physiological level. Further research in bigger samples is necessary to replicate the current findings.

2.3.4.7. Shortcomings

Limitations of the present study concern first of all the small sample size. The heterogeneity of the invested patient group brings along numerous confounding variables, making it difficult to statistically detect medium or small effects. Part of this heterogeneity might be inherent in the heterogeneity of ADHD itself. Part of it might also result from co-morbid disorders that varied across patients participating in the study. Especially the systematic investigation of potential genetic influences on differential characteristics and impairments of ADHD requires for larger samples (Faraone et al., 2015; Hawi et al., 2015). Moreover, in future studies, it would be interesting to systematically investigate differences of the three ADHD presentations according to the DSM-V (predominantly inattentive, predominantly hyperactive/impulsive, and combined presentations), or gender differences. Furthermore, it would be of interest to systematically compare emotion processing and emotion regulation of ADHD vs. healthy controls with the same paradigm in child vs. adult samples.

Further limitations come along with the realization of two different paradigms in one experimental study. The successive application of the cyber ball paradigm and the virtual penalty kicking paradigm does not allow for direct comparison of processing of strong positive and negative emotions. The virtual penalty kicking paradigm (which elicited strong positive emotions) was always presented after the cyber ball paradigm. Keeping in mind that a core symptom of ADHD comprises deficiencies in sustained attention (American Psychiatric Association, 2013), order effects might have confounded the assessment of patients' emotional reactions especially in the second, the virtual penalty kicking paradigm. Thus, the weaker experiential and physiological reactions of ADHD vs. controls and the lack of stronger behavioral reactions of ADHD vs. controls in the penalty kicking paradigm might at least partly be explained by higher fatigue in patients than in controls. For future studies, it would be ideal to elicit strong positive and strong negative emotions in one paradigm.

Activations of zygomaticus major and corrugator supercilii might not only be indicators of positive and negative affect, as has long been suggested (Dimberg, 1990), but underlie social motives, like affiliation (Seibt et al., 2015). Those bring to bear especially in a social setting, and probably even in interactions with virtual agents (Weyers et al., 2006; Weyers, Mühlberger, Kund, Hess, & Pauli, 2009). Consequently, for future studies, it would be interesting to implement measures of emotional valence on a physiological level that are less prone to such biases. One suggestion is to assess affect-modulated startle response, as has been done in studies by Conzelmann et al. (2009) and Conzelmann et al. (2011). Moreover, Edel et al. (2015) pointed out that impaired emotion processing in ADHD patients might be predicted by attachment-related features, rather than by core ADHD symptoms. Steinberg & Drabick (2015) pointed out the importance of parenting behavior alongside ADHD symptoms in the development and persistence of emotional dysfunctions. Gilissen, Bakermans-Kranenburg, van Ijzendoorn, & Linting (2008) pointed to genetic influences on emotional responding being moderated by attachment style. The current study did not assess attachment styles during childhood or in adult relationships. It would be interesting to do so in future studies to test for correlative or moderating effects between core ADHD symptoms, emotional dysfunctions, and attachment style.

Finally, the present study investigated only response-focused deliberate emotion regulation. For the development of effective therapeutic interventions, I consider it crucial to also investigate ADHD patients' ability to deliberately apply antecedent-focused emotion regulation strategies, like attention allocation, or cognitive reappraisal. Moreover, some studies suggested ADHD patients to have difficulties in applying acceptance strategies, especially the acceptance of negative emotions (Edel et al., 2015). Considering the fact that ADHD patients might experience stronger negative emotions than healthy controls in many situations, especially when being socially rejected (Bondü & Esser, 2015), it seems logical that accepting negative emotions for them is more difficult than for healthy controls.

2.3.4.8. Conclusions

Taken together, the results of the present study could replicate previous findings of aberrant emotion processing in ADHD, especially considering the processing of positive emotions. Diminished positive affectivity on a physiological level was also found in a genetic risk group for ADHD (l/l genotype of SNP 5-HTT). This is in line with theories suggesting deficiencies in reward processing as an endophenotype for ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002). Deficiencies in the processing of negative emotions showed primarily in a virtual ball-tossing game during social ostracism. However, throughout a virtual penalty kicking paradigm, patients vs. controls did not show major aberrances in the processing of negative emotions. One explanation for those divergent findings might be the different nature of negative emotions elicited during social ostracism in the cyber ball game vs. misses and subsequent feedback from an irritated coach during virtual penalty kicking. Presumably, social ostracism induced primarily avoidance-associated negative emotions like sadness or anxiety, whereas the dominating negative emotion in response to bad performance during penalty kicking and congruent coach feedback might be anger, which is associated rather with approach motivation (Harmon-Jones, Harmon-Jones, Abramson, & Peterson, 2009). The present study points to ADHD patients vs. controls showing slightly diminished processing of negative emotions associated with approach motivation (i.e., anger), and increased processing of negative emotions associated with avoidance motivation (i.e., fear or sadness). This is in line with previous studies that found adult ADHD patients vs. healthy controls to be more sensible to social rejection (Bondü & Esser, 2015), but less sensitive to external punishment (Braaten & Rosen, 1997). Moreover, the present study replicated baseline differences in psychophysiological arousal and, to a lesser extent, in response to emotional events in adult ADHD patients vs. healthy controls, which have previously been reported in children (Conzelmann et al., 2014). Patients vs. controls showed lower skin conductance levels at baseline and lower skin conductance responses when not regulating their positive and negative emotions in a virtual penalty kicking game. This is in line with Sergeant (2005) and Doyle et al. (2005) who suggested arousal deficits both at baseline and in response to stimuli as an endophenotype for ADHD, possibly coming along with motivational deficits.

Against the initially formulated expectations, patients vs. controls in the present study did not show major difficulties in deliberately applying response-focused emotion regulation. On average, patients were able to alter their emotional reactions on experiential, physiological, and behavioral levels when instructed to explicitly show or hide their feelings as successfully as healthy controls. Counterintuitively, patients reported to habitually apply adaptive emotion regulation strategies like cognitive reappraisal even more frequently than healthy controls. One possible conclusion from those results is that affective problems in ADHD patients might reflect problems in emotion processing or in automatic emotion regulation rather than problems in deliberate emotion regulation in the sense of Mauss, Bunge et al. (2007). Those problems were referred to as “emotional dysregulation” or “emotion regulation deficits” without conceptual refinement especially in older studies (Maedgen & Carlson, 2000;

Melnick & Hinshaw, 2000; Walcott & Landau, 2004). However, it is possible that studies investigating deliberate emotion regulation with antecedent-focused strategies would reveal different results. It would therefore be interesting to systematically investigate the effects of attention allocation and/or cognitive reappraisal on emotional reactions of ADHD patients vs. healthy controls.

3. General Discussion

ADHD is defined as a disorder characterized by attention deficits and symptoms of hyperactivity/impulsivity (American Psychiatric Association, 2013; World Health Organization, 1992). However, more and more studies as well as clinical experience point to ADHD patients additionally showing major strains due to emotional dysfunctions. ADHD is highly prevalent in childhood (about 5 %, Polanczyk et al., 2007), and frequently persists into adulthood (Haavik et al., 2010; Simon et al., 2009). While research to date has mostly concentrated on the core symptoms of inattentiveness and/or hyperactivity/impulsivity in children, research on emotional deficits, especially in adult populations, is very rare.

The aim of this thesis was to investigate emotional deficits in adult ADHD patients of the combined presentation (American Psychiatric Association, 2013). Emotional reactions were assessed after emotion processing and deliberate response-focused emotion regulation in the sense of Gross (1998b, 2002). Previous studies on emotion processing and emotion regulation mostly used pictures, sounds, or film clips to induce positive and negative affective states (Baur et al., 2015; Hewig et al., 2005; Plichta et al., 2011). While those classical methods bring along advantages like high controllability and exact timing of experimental paradigms, one major disadvantage is the lack of ecological validity. The latter restricts the transferability of study results into everyday life. Therefore, the present thesis aimed at implementing a virtual reality paradigm for emotion induction, combining high ecological validity with high controllability of experimental conditions. Two studies were conducted to develop and test a virtual penalty kicking paradigm in healthy samples. The third study investigated emotion processing and emotion regulation in adult ADHD patients and healthy controls during the aforementioned virtual penalty kicking game and during social ostracism in an ostensible ball-tossing game (Williams & Jarvis, 2006). Emotional responses were assessed on experiential (valence and arousal ratings, ratings of positive and negative affect), physiological (activations of M. zygomaticus major and M. corrugator supercilii, skin conductance modulations), and behavioral levels (emotional-expressive behavior assessed with a behavioral observation scheme), as suggested by Gross (1998b, 2002). The virtual penalty kicking paradigm proved to be suitable to investigate emotional reactions during emotion processing and deliberate emotion regulation on different levels. Participants reported to have been highly motivated throughout the experiments. The paradigm seems to be suitable to investigate clinical samples suffering from motivational deficits, like ADHD patients.

3.1. EMOTION PROCESSING IN ADHD

Experiment 3 provided some evidence for differential emotion processing of adult ADHD patients vs. healthy controls in two different experimental paradigms. Participants subsequently went through an adapted version of the cyber ball paradigm (Williams & Jarvis, 2006) and an adapted version of the virtual penalty kicking paradigm established in experiments 1 and 2. I expected ADHD patients in comparison with healthy controls to show overall lower positive affectivity, and to respond weaker to pleasant events as a result of deficient reward processing (Conzelmann et al., 2009; Conzelmann et al., 2011; Conzelmann et al., 2016; Plichta & Scheres, 2014; Sonuga-Barke, 2002). Moreover, in line with Bondü & Esser (2015), I expected patients vs. controls to respond stronger to unpleasant events, especially social ostracism. In line with theories of hypoarousal as an endophenotype for ADHD (Conzelmann et al., 2014; Doyle et al., 2005; Sergeant, 2005), I expected patients vs. controls to show arousal deficits at baseline and in response to emotional events. In line with previous studies (Maedgen & Carlson, 2000; Walcott & Landau, 2004), I expected patients vs. controls to behaviorally over-express positive and negative emotions.

Results on experiential, physiological, and behavioral levels provide some evidence for aberrant emotion processing in adult ADHD. Especially processing of positive emotions seems to be impaired in ADHD. Throughout penalty kicking, patients in comparison to controls showed overall lower zygomaticus activations and gave lower valence ratings especially in response to pleasant trials. Throughout cyber ball, patients vs. controls showed overall lower zygomaticus activations and gave overall lower ratings of positive affect. Those results are in line with previous findings (Conzelmann et al., 2009; Conzelmann et al., 2011) and with suggestions of impaired reward processing as an endophenotype for ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002). Apart from that, patients in comparison to controls gave higher ratings of negative affect, especially in response to cyber ball ostracism. This is in line with suggestions of ADHD patients being over-sensitive to social rejection (Bondü & Esser, 2015). Interestingly, valence ratings in response to unpleasant penalty kicking trials did not differ in patients vs. controls. The divergent modulations of emotional experiences in response to cyber ball ostracism vs. misses and irritated coach feedback during penalty kicking might result from the different nature of induced negative emotions in the two paradigms. Presumably, cyber ball ostracism induced primarily feelings of anxiety or sadness, associated with avoidance motivation (Harmon-Jones et al., 2009). Misses and irritated coach feedback during penalty kicking, however, might have induced primarily feelings of anger, associated with approach motivation (Harmon-Jones et al., 2009). Possibly, ADHD patients in comparison to healthy controls show increased emotional reactions to unpleasant events associated with avoidance-related negative emotions, like anxiety or sadness. Reactions to approach-related negative emotions (e.g., anger) seem to differ less in ADHD vs. healthy controls.

Lower baseline skin conductance levels of patients vs. controls, lacking skin conductance modulations of patients throughout cyber ball, lower arousal ratings and lower skin conductance responses of patients vs. controls throughout penalty kicking speak for arousal deficits of ADHD both at baseline and in response to stimuli. Those results are in line with previous findings of impaired autonomic responsiveness in child samples (Conzelmann et al., 2014; Musser et al., 2011) and with suggestions of arousal deficits as an endophenotype for ADHD (Doyle et al., 2005; Sergeant, 2005). To my knowledge, baseline differences in autonomic arousal between ADHD and healthy controls have not previously been reported in adults, but only in child samples (Conzelmann et al., 2014).

Modulations of behavioral expressions seem to partly contradict findings on experiential and physiological levels. Patients in comparison to controls over-expressed primarily positive emotions, but partly also negative emotions, tension, and social monitoring behavior. As far as I know, this is the first study systematically investigating behavioral expressions in response to pleasant and unpleasant social interactions in adult ADHD patients. Results point in the same direction as results of previous studies investigating emotional expressive behavior in children with ADHD (Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Walcott & Landau, 2004). Excessive behavioral expression of positive emotions in ADHD might result from automatic response-focused emotion regulation (Mauss, Bunge et al., 2007). Over-expression of both positive and negative emotional behavior has been associated with social impairments in ADHD (Bunford et al., 2014).

3.2. Emotion Regulation in ADHD

Besides emotion processing, experiment 3 aimed at investigating emotional reactions after deliberate response-focused emotion regulation in ADHD vs. healthy controls. Participants were instructed to explicitly show their emotions, not regulate their emotions, or hide their emotions in different experimental blocks. In addition, participants filled in a questionnaire on habitually applied emotion regulation strategies when facing positive and negative emotions (ERI, König, 2011). I expected ADHD patients to be less successful than healthy controls at deliberately showing and hiding their emotions, reflecting in weaker modulations of emotional reactions on different levels. Furthermore, I expected ADHD patients to habitually apply adaptive emotion regulation strategies less frequently than healthy controls.

Results were mostly not in line with my expectations. Patients compared to healthy controls showed equally strong, and partly even stronger alterations of emotional reactions due to response modulation. Valence and arousal ratings were mostly altered successfully by response modulation in patients and in controls. Showing emotions went along with more extreme ratings, hiding emotions went along with less extreme ratings, compared to not regulating emotions. Ratings of positive affect as well as zygomaticus activations during cyber ball were slightly higher when patients and controls did not regulate their emotions than when they hid their emotions. Negative affect ratings during cyber ball were diminished in patients, but not in controls when hiding vs. not regulating their emotions. Those findings suggest that patients were as successful as healthy controls in altering their emotional experiences through response modulation when instructed to do so. The modulations of negative affect ratings suggest that patients were even better than healthy controls at reducing negative emotional experiences during cyber ball through response modulation.

Skin conductance levels throughout cyber ball were modulated by inclusion and regulation conditions in controls, but not in patients. This might reflect impaired modulations of autonomic activity through emotion regulation in ADHD, as previously reported in children (Musser et al., 2011). However, patients' slightly increased skin conductance responses when showing and hiding vs. not regulating their emotions during penalty kicking are at odds with this explanation. Further research in adult populations is necessary to disentangle the influence of emotion regulation on autonomic activity in ADHD.

Behavioral expressions throughout penalty kicking and cyber ball were mostly successfully modulated by patients and controls when instructed to hide their emotions, but not when instructed to explicitly show their emotions. Taken together, patients were as successful as controls at suppressing expressions of positive and negative affectivity, tension, and social monitoring. However, even if patients in the current study were able to reduce their emotional expressions to the same degree as healthy controls, overall expression rates of patients were slightly higher than those of controls. This suggests that even if successfully engaging in emotion regulation, adult ADHD patients still over-express their emotions. Against my expectations, patients reported to habitually apply reappraisal strategies more often than healthy controls when facing negative emotions.

To sum up, the findings of experiment 3 suggest that adult ADHD patients do not face major problems in deliberate emotion regulation through response modulation. Moreover, patients in experiment 3 reported to habitually apply adaptive emotion regulation strategies even more frequently than healthy controls. Previously reported deficits of ADHD in emotion regulation as well as overall aberrant emotional reactions of patients in the current study might result from aberrant emotion processing and/or deficits in automatic emotion regulation (Mauss, Bunge et al., 2007). However, it would be important to systematically investigate deliberate antecedent-focused strategies of emotion regulation like attention allocation or cognitive reappraisal in ADHD vs. healthy controls. Moreover, children with ADHD might show more deficits in deliberate emotion regulation than adults.

3.3. GENETIC INFLUENCES ON EMOTION PROCESSING AND EMOTION REGULATION

Genotype expressions differed slightly in patients vs. controls only for the expression of SNP 5-HTT, but not for the expression of SNP 25 TPH2. Patients in the present sample showed a slight over-expression of the l-allele, resulting in the l/l genotype being more frequent in patients than in controls. This is in line with previous studies reporting an association between the l/l genotype and ADHD (Franke et al., 2011; Müller et al., 2008; Retz et al., 2002). Statistical analyses comparing participants (patients and controls) showing the l/l genotype with participants showing s/s or s/l genotypes revealed mostly insignificant results. Those might to some degree be explained by the small sample size, which might not have allowed for the detection of weak effects (Cohen, 2013).

The modulation of zygomaticus activations revealed some evidence for diminished reward processing of participants with the l/l expression of SNP 5-HTT. Participants with the l/l genotype showed slightly lower zygomaticus activations than s/l or s/s when explicitly showing their emotions during penalty kicking. Moreover, l/l showed overall lower zygomaticus activations than participants with s/l or s/s genotypes throughout different cyber ball conditions. Those findings might indicate that 5-HTT risk expression contributes to diminished reward processing in ADHD. This in turn would further underline suggestions of diminished reward processing as an endophenotype for ADHD (Plichta & Scheres, 2014; Sonuga-Barke, 2002). However, effect sizes were rather small and further replication in larger samples is necessary.

Throughout penalty kicking, s/l or s/s showed highest responses when showing their emotions, and lowest responses when hiding their emotions. In contrast, l/l showed no modulation of skin conductance responses throughout different regulation conditions. This finding is in line with analyses based on diagnostic groups, and in line with a study by Musser et al. (2011) who reported deficient autonomic responsiveness through emotion regulation in ADHD children. It might vaguely be interpreted as further evidence for deficits in arousal modulation as an endophenotype for ADHD (Doyle et al., 2005; Sergeant, 2005). Also here, I point out the necessity of further research and the replication in larger samples.

Against my expectations but in line with results of analyses based on diagnostic groups, l/l did not report deficient application of habitual emotion regulation strategies. Rather, l/l reported to use attention allocation and reappraisal strategies when facing negative emotions more often than s/l or s/s. Those findings are in line with Gilman et al. (2015) who reported weakened down-regulation of negative emotions in s/s.

3.4. Emotion Processing during Virtual Penalty Kicking

The first and second experiments were conducted to develop and test a virtual penalty kicking paradigm suitable to induce positive and negative affective states through hits and misses and subsequent feedback from a virtual coach. Pleasant trials (hits and pleased coach feedback) should induce positive emotional reactions, unpleasant trials (misses and irritated coach feedback) should induce negative emotional reactions, compared to neutral trials. Neutral trials consisted of teleports to different spots of the virtual soccer stadium in experiment 1, and of shots over the free soccer field with subsequent neutral coach feedback in experiments 2 and 3.

Pleasant trials induced higher valence and arousal ratings than neutral trials in experiments 1-3. Unpleasant trials induced lower valence ratings and higher arousal ratings than neutral trials in experiments 1-3. Negative emotional expressions were shown more frequently in unpleasant, compared to pleasant and neutral trials, in experiments 1 and 3. Those findings are in line with my expectations. However, neutral trials in experiments 1-3 were rated as slightly pleasant, and unpleasant trials in experiment 2 were rated as emotionally neutral. Zygomaticus activations were higher in response to pleasant and unpleasant, compared to neutral trials in experiments 1-3, but never differed between pleasant and unpleasant trials. Corrugator activations were diminished in pleasant and unpleasant, compared to neutral trials, in experiments 1-3. Moreover, in experiment 1, positive emotional expressions were increased especially in pleasant vs. neutral trials, but partly also in unpleasant vs. neutral trials. Taken together, emotional responses on experiential, physiological, and behavioral levels seemed to be positively biased in the virtual penalty kicking paradigm.

One reason for this might be that the negative facial expressions designed for the current studies were not intense enough to induce strong negative emotional reactions. Moreover, context conditioning effects might have become important (Glotzbach et al., 2012; Holmes & Westbrook, 2014; Kastner, Flohr et al., 2015; Kastner, Pauli et al., 2015). Supposedly, study participants in experiments 1-3 had made repeated positive experiences in soccer stadiums, or in association with soccer stadiums (e.g., while watching soccer on TV) prior to their participation. Those repeated positive experiences might have resulted in positive emotional reactions in response to a soccer stadium, an intrinsically neutral context. Moreover, emotional reactions to any experiences made in this positive context might have been positively biased (Holmes & Westbrook, 2014), resulting in more positive reactions even to neutral and unpleasant trials. Facial mimicry effects specific for a social setting might have added on zygomaticus and corrugator modulations. Interpersonal motives, e.g. affiliation, very likely become important in social interaction settings. Those motives facilitate the expression of positive emotional expressions (going along with zygomaticus activations), and dampen the expression of negative emotional expressions (going along with corrugator deactivations; Hess & Bourgeois, 2010; Seibt et al., 2015; Weyers et al., 2006). It is difficult to tell which modes of action are responsible for the specific modulation of facial muscle activity in response to unpleasant trials in the current experiments. Conceivably, intrinsically weak negative responses to unpleasant trials were further dampened by both contextual influences and socially motivated facilitation of positive expressions and dampening of negative expressions.

Skin conductance responses were stronger in pleasant and unpleasant, compared to neutral trials, in experiments 2 and 3, but did not differ across experimental conditions in experiment 1. Findings of experiments 2 and 3 suggest that pleasant and unpleasant trials were emotionally more arousing than neutral trials, reflecting in increased activity of the autonomic nervous system (Boucsein, 2012). The reason for the lack of skin conductance modulations across experimental conditions in experiment 1 probably lies in methodological shortcomings. Neutral trials were presented before pleasant and unpleasant trials in the beginning of experiment 1. In experiments 2 and 3, by contrast, neutral trials were presented within the same experimental blocks as pleasant and unpleasant trials, and after the presentation of practice trials. Consequently, skin conductance responses in neutral trials in experiment 1, but not in experiments 2 and 3, were heavily influenced by order effects. Especially trials presented in the beginning of the experiment were very likely biased by reactions to the virtual environment in general (Aymerich-Franch, 2010; Peperkorn et al., 2015). The novelty of the virtual soccer stadium might have induced increased excitement, resulting in higher autonomic responsiveness (Boucsein, 2012).

Taken together, the findings on experiential, physiological, and behavioral levels speak for the induction of positive affective states in response to pleasant trials (hits and subsequent feedback from a virtual coach) during virtual penalty kicking. Results in response to unpleasant trials (misses and subsequent feedback from a virtual coach), however, are less clear. Especially findings on the physiological level, and partly also on experiential and behavioral levels, might indicate increased positive affect, possibly alongside concurrently increased negative affect, in response to unpleasant trials.

3.4.1. Relationship between Presence and Emotional Reactions

Correlational analyses between presence scores (IPQ; Schubert, 2003) and emotional reactions on different levels revealed a positive relationship between presence in the virtual penalty kicking game and the intensity of emotional reactions. The more participants felt present in the virtual environment the stronger their emotional reactions in response to pleasant, neutral, and unpleasant trials. Those correlations were strongest with emotional reactions on the experiential level. Those results are in line with previous suggestions that presence is related to the strength of induced emotions in virtual environments (Diemer et al., 2015). Peperkorn et al. (2015) for the first time conducted a study suggesting that presence in virtual reality causally influences the intensity of emotional reactions. Interestingly, presence ratings could be improved in experiment 2 vs. experiment 1 through a number of technical improvements. Those technical improvements presumably increased immersion (referring to the technical aspects of a virtual environment), which in turn has been reported to impact feelings of presence (Diemer et al., 2015; Slater & Wilbur, 1997).

3.4.2. Social Influences on Emotional Reactions

The primary aim of experiment 2 was to disentangle differential influences of shots onto a virtual soccer goal alone vs. shots followed by feedback from a virtual coach on emotional reactions. In line with my expectations, I found stronger emotional reactions to hits and feedback than to hits alone and to misses and feedback than to misses alone. Those differences showed mainly on an experiential, and partly also on a physiological level. Valence and arousal ratings were more intense after shots with feedback than after shots alone across emotional conditions. Zygomaticus activations were higher in response to shots with feedback vs. shots alone across emotional conditions. Corrugator activations were lower in response to hits or misses with feedback vs. hits or misses alone. Skin conductance responses were higher in response to hits or misses with feedback vs. hits or misses alone.

Modulations of valence and arousal ratings as well as skin conductance responses speak for intensified emotional reactions through social interactions. This is in line with Tiedens & Leach, (2004) and van Kleef & Fischer (2016) suggesting that social interactions are important elicitors of emotions. Modulations of M. zygomaticus major and M. corrugator supercilii, however, speak for overall more positive emotional reactions in trials with social feedback vs. trials without social feedback. This might be due to the inherently rewarding nature of social interactions (Krach, Paulus, Bodden, & Kircher, 2010). Processing of social stimuli goes along with the activation of reward-related circuits in the brain of healthy individuals (Bhanji & Delgado, 2014; Krach et al., 2010). Accordingly, trials with feedback (in which participants were presented a social cue, the virtual coach) might have been more rewarding than trials without feedback (in which no social cue was presented). Interestingly, results speak for overall increased positive affectivity in trials with feedback vs. trials without feedback only in the modulation of facial muscle activity, but not on the experiential level. As outlined above, affiliation motives might have biased facial muscular activations especially in trials with feedback, resulting in overall higher zygomaticus activations and overall lower corrugator activations (Seibt et al., 2015). It is difficult to disentangle different modes of action on the divergent modulation of emotional responses to trials with feedback vs. trials without feedback. For future studies, it would be interesting to implement a physiological measure of emotional valence that is less prone to bias by interpersonal motives, e.g. affect-modulated startle responses.

To sum up, experiment 2 could provide evidence that social interactions seem to crucially influence emotional reactions on experiential and physiological levels. However, it is not possible to unmistakably tell whether positive and negative emotional reactions were intensified by social feedback, or if social feedback went along with overall more positive emotional reactions.

3.4.3. Evaluation of the Virtual Penalty Kicking Paradigm

Taken together, although facing some limitations, the virtual penalty kicking paradigm successfully induced emotions in a game-like manner, implying interaction with a virtual agent. Advantages of the paradigm encompass the high ecological validity while at the same time keeping the controllability of experimental conditions high. Emotional reactions induced in social interactions are highly relevant in everyday life (Godbold, 2015; van Kleef & Fischer, 2016) and are therefore relevant to be investigated in experimental settings. The paradigm proved to be successful at implying experiential, psychophysiological, and behavioral assessments. Moreover, emotional reactions were successfully assessed after emotion processing and response-focused emotion regulation (Gross, 1998b; Gross, 2002). Participants in the three experiments reported to have been highly motivated to participate in the experiment and to have experienced the experiment as not very tiring. Those characteristics are especially important when investigating clinical samples or child samples. Limitations of the paradigm are discussed further down.

3.5. LIMITATIONS

Some limitations have to be considered when discussing the results of experiments 1-3. First of all, those concern limitations of the applied paradigms. As outlined in the discussion of experiment 2, some participants suspected their influence on their scoring performance to be rather low. This might have weakened emotional reactions. For future studies, it might thus be worth to consider altering the algorithm triggering goal keeper animations, so that hits and misses are not predefined any more. However, this would come along with a number of constraints, among them the fact that the number of pleasant and unpleasant trials would not be controllable by the experimental script any more. To further disentangle the impact of the participants' conviction of controllability on their scoring performance, it would be interesting to realize a version of the penalty kicking game in which participants can actively control the number of hits and compare it with the current version in a randomized controlled trial. Although participants' suspicion of low influence certainly is a shortcoming, results of experiment 2 suggest that the feedback given by the virtual coach contributed sufficiently to the induction of strong emotions. Moreover, many participants throughout the cyber ball game suspected to not play with real co-players. However, the problem of participants in a cyber ball game suspecting to not play with real other players has been reported before (Bolling et al., 2012; Zadro, Williams, & Richardson, 2004), and has been shown to not have any impact on self-reported distress induced by ostracism. Zadro et al. (2004) found comparably high impact of cyber ball ostracism on self-reported distress when participants knew they were playing with a computer, and even when they were told that the computer was scripted what to do in the game, as when participants believed they were playing with real other players.

A further shortcoming concerning experiment 3 is the realization of two different paradigms in one experimental study. The different nature of the two paradigms does not allow for direct comparison of the data collected in both. The fact that strong negative emotions were elicited primarily in the cyber ball paradigm (which was always presented first) and strong positive emotions were elicited only in the virtual penalty kicking paradigm might bring along order effects. Those in turn might become more important in ADHD than in the control group. ADHD is characterized, among others, by deficits in sustained attention (American Psychiatric Association, 2013). Thus, the weak responsiveness of ADHD to pleasant events (which were presented in the second, the penalty kicking paradigm) might have been biased by decreased attention levels among patients, but not so much among controls. However, patients' lower zygomaticus activations already during cyber ball speak for lower positive affectivity of patients vs. controls irrespective of possibly confounding order effects. For future studies it would be ideal to induce both positive and negative emotions in one paradigm. Another possibility would be to present cyber ball and virtual penalty kicking to patients and controls in separately counter-balanced orders.

As outlined above, the interpretation of zygomaticus and corrugator activations as unmistakable indicators of positive and negative affect, which has long prevailed in literature (Dimberg, 1990), might be wrong. Facial muscle activations underlie social motives like affiliation, and are therefore prone to bias especially in social interactions, and even in interactions with virtual agents (Seibt et al., 2015). For future studies, it might therefore be important to implement a dependent variable measuring emotional valence on a physiological level which is not prone to such bias. One example would be to assess affect-modulated startle responses, as has been done in studies using images for emotion induction (Conzelmann et al., 2009; Conzelmann et al., 2011). However, implementing startle measurement in the virtual penalty kicking paradigm might come along with a number of difficulties. Those comprise the timing of startle noise without impairing semantic processing of feedback phrases, or the impairment of presence experience in the virtual soccer stadium, where a startle noise would not be a compatible sound.

Another methodological problem concerns the collection of observational data. Observers in experiments 1 and 3 were not blind to the emotional experimental condition. They heard the coach feedback when watching the videos, and could guess from that feedback whether the respective trial was pleasant, neutral, or unpleasant. This might have biased their ratings in line with study hypotheses. This problem arises also in previous studies investigating emotional-expressive behavior with observational coding (Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Saarni, 1984, 1992; Walcott & Landau, 2004). There is no easy methodological solution for this problem. As the observational categories contained also verbal utterances, video observation with off-turned sound would not have been possible. In experiment 3, observers were blind to the diagnostic group of participants, the regulation condition during penalty kicking, and to the cyber ball condition. Still, modulations of behavioral observations were in line with hypotheses mostly throughout cyber ball blocks, and throughout regulation conditions of the penalty kicking paradigm. This does not speak for results of observational coding being severely biased due to the observers' awareness of emotional conditions during penalty kicking.

As mentioned above, it might not be sufficient to distinguish between the processing and regulation of "positive" vs. "negative" emotions, as has been done in the present study and in most studies to date investigating emotional reactions in ADHD (Conzelmann et al., 2009;

Conzelmann et al., 2011; Conzelmann et al., 2014; Herrmann et al., 2009; Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Raz & Dan, 2015; Walcott & Landau, 2004). Experiment 3 provided some evidence that emotion processing in ADHD might not only depend on the emotional valence of experimental stimuli, but also on associated approach or avoidance motivation. For future studies, it would be interesting to systematically investigate emotion processing and emotion regulation of emotions going along with approach motivation (e.g., anger) vs. avoidance motivation (e.g., fear).

Further limitations concern sample characteristics throughout the different experiments. In experiment 1, the majority of participants were underclass psychology students. This is a rather homogeneous group, which limits transferability of study results into the general population. Samples in experiments 2 and 3, however, were much more heterogeneous. Similar response patterns dependent on emotional experiential conditions throughout experiments 1-3 speak for sufficient transferability into the general population. Experiment 3 investigated only adult ADHD patients with combined presentation (American Psychiatric Association, 2013). In future studies, it would be interesting to imply different ADHD presentations and child samples, as well. A further consideration that arises when investigating ADHD patients is the high number of co-morbidities which probably influence results differently. However, as ADHD patients rarely suffer from ADHD alone, but usually present with various co-morbidities (Faraone et al., 2015), the present patient sample can be considered as representative for the general population of adult ADHD patients. The relatively small sample size in experiment 3 is problematic especially in the investigation of genetic influences. The multifactorial genetic influence on ADHD requires for genome-wide association studies in large sample sizes to gain better understanding of the genetic determination of the disorder (Geissler & Lesch, 2011; Hawi et al., 2015; Kiser et al., 2015; Lesch et al., 2008). However, this was not the aim of this thesis. The deliberate investigation of two polymorphisms previously associated with ADHD and emotional dysfunctions was conducted to shed some extra light on possible mediating factors of ADHD and associated impairments, and not to systematically investigate genetic influences on the disorder.

A further shortcoming that needs to be discussed is the impossibility to disentangle emotional reactions after emotion processing from emotional reactions after automatic emotion regulation (Mauss, Bunge et al., 2007). It is very likely that participants in experiments 1 and 2, as well as participants in experiment 3 during emotion processing trials applied various forms of automatic emotion regulation. The present studies did not control for automatic emotion regulation. Neither did I assess automatically applied emotion regulation strategies on a trial-by-trial basis. Thus, it is impossible to tell whether emotional reactions in every single trial were the result of “pure” emotion processing, or if automatic emotion regulation strategies were involved. This problem arises in merely all studies comparing deliberate emotion regulation with “non-regulation”, or emotion processing. The post-questionnaire on habitually applied emotion regulation strategies (ERI; König, 2011) might give a hint on which strategies participants were likely to apply automatically. However, to systematically test automatic emotion regulation vs. emotion processing, it is necessary to actively manipulate the two, as has been done with a priming technique by Mauss, Cook et al. (2007).

Finally, experiment 3 assessed emotional reactions of patients vs. controls after deliberate response modulation. For future studies, it would be important to systematically investigate deliberate emotion regulation in ADHD vs. healthy controls through antecedent-focused emotion regulation strategies. Those have been found to be more effective at sustainably altering emotional reactions in healthy samples (Gross & John, 2003; MacNamara, Ochsner, & Hajcak, 2011), but to my knowledge have not been investigated in ADHD.

3.6. SUMMARY AND OUTLOOK

The aim of this thesis was to investigate emotion processing and emotion regulation of adult ADHD patients and healthy controls in an ecologically valid virtual reality paradigm realizing emotion induction through social interactions. Taken together, the results of experiments 1-3 speak for the induction of strong positive emotions on experiential, physiological, and behavioral levels in a virtual penalty kicking paradigm. The induction of negative emotions in the same paradigm seems to be less clear. The virtual penalty kicking paradigm proved to be successful at implementing assessment of emotional reactions on experiential, physiological, and behavioral levels after both emotion processing and emotion regulation, and was well accepted of adult ADHD patients. Advantages of the paradigm comprise most importantly high ecological validity and high motivation of participants. The importance of presence for the induction of strong emotions in virtual reality could be replicated. Social feedback in this paradigm seems to have a major impact on emotional reactions, although the exact modes of action remained unclear.

Experiment 3 provided evidence for deficient processing of positive emotions in adult ADHD patients vs. healthy controls, reflecting in aberrant reactions on experiential, physiological, and behavioral levels. This replicates previous findings (Conzelmann et al., 2009; Conzelmann et al., 2011). Diminished positive affectivity on a physiological level was even found for a genetic sub-group previously associated with ADHD (l/l genotype of SNP 5-HTT). Taken together, those findings speak for deficient reward processing as an endophenotype for ADHD, as previously suggested (Plichta & Scheres, 2014; Sonuga-Barke, 2002). Concerning the processing of negative emotions, results gained from two different experimental paradigms (cyber ball and virtual penalty kicking) are somewhat contradictory, possibly due to the divergent nature of negative emotions induced in the two paradigms. Lower baseline skin conductance levels, weaker skin conductance modulations throughout cyber ball, and lower skin conductance responses throughout virtual penalty kicking of patients vs. controls speak for impairments in autonomic arousal both at baseline and in response to emotional events. Those findings are in line with previous suggestions of arousal deficits as an endophenotype for ADHD (Doyle et al., 2005; Sergeant, 2005).

Against initial expectations, ADHD patients vs. controls did not show major difficulties in modulating their emotional reactions on experiential, physiological, and behavioral levels through deliberate response modulation and did not report deficits in the habitual application of adaptive emotion regulation strategies. In line with those findings, a genetic risk group for ADHD (l/l genotype of SNP 5-HTT) did not show aberrant alterations of emotional reactions through deliberate response modulation, and did not report impairments in the habitual application of adaptive emotion regulation strategies. Accordingly, previously reported deficiencies of ADHD patients in emotion regulation (Barkley, 2015; Bunford et al., 2015; Edel et al., 2015; Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Oliver et al., 2015; Sjöwall et al., 2013; Steinberg & Drabick, 2015; van Eck et al., 2015) might be due to baseline differences in emotional responding, or due to deficient automatic emotion regulation (Mauss, Bunge et al., 2007), rather than differences in deliberate emotion regulation. In future studies, it would be important to systematically investigate deliberate antecedent-focused emotion regulation in ADHD patients vs. controls in randomized controlled trials.

If adult ADHD patients are indeed able to apply adaptive emotion regulation strategies after training, it might be worth to provide them with psychotherapy more often. Especially psychotherapeutic programs including psychoeducation and practical training about emotions and adaptive emotion regulation should be efficacious at reducing emotional dysfunctions in affected patients. In fact, different cognitive-behavioral therapeutic programs have been proven successful at reducing core ADHD symptoms as well as co-morbid symptoms (mainly depression and anxiety symptoms) in adult patient groups (Hoxhaj & Philipsen, 2015). Among those were numerous studies applying mindfulness-based (Mitchell et al., 2013; Schoenberg et al., 2014; Zylowska et al., 2008) or dialectic-behavioral therapy programs (Hesslinger et al., 2002; Hirvikoski et al., 2011; Philipsen et al., 2007). Both approaches focus on the conscious awareness of present emotional states and the adaptive handling of various emotional states. Considering the findings of van Eck et al. (2015) that acceptance of negative emotions and emotional awareness are particularly difficult for ADHD patients, findings underlining the efficacy of mindfulness-based meditation training in reducing ADHD symptoms (Mitchell, Zylowska, & Kollins, 2015) seem promising. Against earlier findings (Conzelmann et al., 2011) methylphenidate seems to have no impact on emotional responding in adult ADHD patients when applied in a double-blind, placebo-controlled design (Conzelmann et al., 2016). The findings of the latest study by Conzelmann et al. (2016) point to methylphenidate having a beneficial affect primarily on inattentive symptoms, and, to a lesser degree, on symptoms of hyperactivity and impulsivity. Emotional dysfunctions, however, seem to not improve through methylphenidate. This underlines once more the importance of psychotherapy in the treatment of ADHD patients. In the present patient sample, only 6 out of 30 ADHD patients reported to have gone through any kind of psychotherapy, although mostly suffering from severe ADHD and numerous co-morbidities. It might be crucial to inform affected individuals more often about psychotherapeutic opportunities to sustainably reduce core ADHD symptoms, co-morbid symptoms, and emotional impairments. This might be especially important considering the numerous co-morbidities and psychosocial impairments that affected individuals and their families usually suffer from (Faraone et al., 2015).

Furthermore, to develop effective treatment methods, it is important to further address emotional dysfunctions of children and adults suffering from ADHD in research. It is particularly important to disentangle deficits in emotion processing and in different forms of emotion regulation on the background of a clear conceptual distinction and experimental operationalization.

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5. APPENDIX

A 1. Diagnostic Criteria for Different Presentations of ADHD in Adults according to the DSM-V
A 2. Feedback Phrases used in Experiment 1
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A 1. Diagnostic Criteria for Different Presentations of ADHD in Adults according to the DSM-V

ADHD predominantly inattentive presentation

- Fails to give close attention to details or makes careless mistakes
- Has difficulty sustaining attention
- Does not appear to listen
- Struggles to follow through with instructions
- Has difficulty with organization
- Avoids or dislikes tasks requiring sustained mental effort
- Loses things
- Is easily distracted
- Is forgetful in daily activities

ADHD predominantly hyperactive-impulsive presentation

- Fidgets with hands or feet or squirms in chair
- Has difficulty remaining seated
- Runs about or climbs excessively in children; extreme restlessness in adults
- Difficulty engaging in activities quietly
- Acts as if driven by a motor; adults will often feel inside as if they are driven by a motor
- Talks excessively
- Blurts out answers before questions have been completed
- Difficulty waiting or taking turns
- Interrupts or intrudes upon others

ADHD combined presentation

- The individual meets the criteria for both inattention and hyperactive-impulsive ADHD presentations.

A 2. Feedback Phrases used in Experiment 1

Pleasant feedback phrases after hits:

1. „Sehr schöner Treffer, weiter so!“
2. „Respekt, ein hammer Tor!“
3. „Wow, du hast’s aber echt drauf!“
4. „Respekt, gut gemacht!“
5. „Super, weiter so, du packst das!“
6. „Wow, genialer Treffer!“
7. „Super Schuss!“
8. „Schönes Tor!“
9. „Ein schönes Ding!“
10. „Sehr stark von dir!“
11. „Wow, spitze, das war echt toll!“
12. „Tolles Tor!“
13. „Schöner Schuss!“
14. „Super gemacht!“
15. „Schön versenkt!“
16. „Super reingehauen!“
17. „Das hast du aber voll super gemacht!“
18. „Ja, genial, mach weiter so und ihr gewinnt das Spiel!“
19. „Yeah, starke Leistung!“
20. „Ja, genau so will ich das sehen von dir!“
21. „Ja, jetzt zeigst du aber, was du wirklich drauf hast!“
22. „Jippiieee!“
23. „Wow, du machst deiner Mannschaft aber alle Ehre!“
24. „Weiter so!“
25. „Auf geht’s, weiter so!“
26. „Wahnsinns Treffer!“
27. „Ein hammer Tor!“
28. „Jawoll!“
29. „ Super, sehr schönes Tor!“
30. „Geniales Tor!“
31. „Ja, genau, sehr schön, mach weiter so!“
32. „Ja, wahnsinn, jetzt zeigst du dich aber von deiner besten Seite!“
33. „Unglaublich, wie du den reingemacht hast!“
34. „Ja, genau, so geht das.“
35. „Solche Spieler brauchen wir.“
36. „Ich bin stolz auf dich.“

Unpleasant feedback after misses:

1. „Oh Mann, jetzt streng dich doch mal an!“
2. „Oh Gott, wie konntest du da denn daneben schießen?!“
3. „Oh mann, wieso hast du denn den nicht rein gemacht???"
4. „Wenn du so weitermachst, wird das nichts mehr!“
5. „Oh Gott, da schießt ja meine Oma besser!“

6. „Jetzt streng dich doch mal endlich an!“
7. „Sag mal, du stellst dich aber heute an!“
8. „Wenn du jetzt nicht Gas gibst, wird das nichts mehr!“
9. „Oh Mann, du versaust uns allen noch den Sieg, wenn du so weitermachst!“
10. „SO wird das nichts“
11. „Jetzt streng dich doch mal bitte an!“
12. „Den musst du eigentlich reinmachen!“
13. „Der war doch einfach, so einer muss doch rein!“
14. „Wie kann man denn den verschießen!!??!!“
15. „Schwacher Abschluss!“
16. „So eine Chance musst du doch machen!“
17. „Schlechter Schuss!“
18. „So wird das nie was!“
19. „Das war echt schlecht!“
20. „Du Pfeife!“
21. „Das muss aber besser werden!“
22. „Pfeife!“
23. „Was ist los mit dir?“
24. „Was ist heute los mit dir?“
25. „Ich dreh durch“
26. „Ich dreh noch durch!“
27. „Junge Junge, das muss besser werden.“
28. „So ein Mist aber auch!“
29. „Oje, den hättest du aber machen müssen.“
30. „Konzentration jetzt!“
31. „Das war schwach von dir.“
32. „Schwacher Schuss!“
33. „Das ist ja wohl nicht dein Ernst.“
34. „Wie blöd kann man sein.“
35. „Ich bin echt enttäuscht von dir.“
36. „Die ganze Mannschaft verliert noch wegen dir.“

A 3. Information Form that Participants in Experiment 1 received before starting the Experiment

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Lehrstuhl für Psychologie I
Prof. Dr. Paul Pauli
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Information für Probanden der Studie „Würzburg vor, noch ein Tor"

Sehr geehrte Studienteilnehmerin, sehr geehrter Studienteilnehmer,

Vielen Dank für Ihr Interesse an unserer Studie. Bitte lesen Sie sich folgende Informationen zunächst sorgfältig durch und entscheiden Sie dann über Ihre Teilnahme an dieser Studie. Beides, Teilnahme oder Nichtteilnahme an dieser Studie steht Ihnen frei. Falls Sie über diese Information hinaus noch weitere Fragen haben, beantworten wir diese gerne.

Ziel dieser Studie ist es, Emotionen in einem Interaktionsparadigma in der virtuellen Realität zu untersuchen. Dabei werden Sie aufgefordert werden, per Joystick auf ein virtuelles Tor zu schießen und bekommen nach jedem Schuss Feedback von einem virtuellen Trainer. Danach sollen Sie jeweils auf einer Skala angeben, wie positiv oder negativ Sie sich während des Feedbacks gefühlt haben und wie aufgeregt Sie waren.
Zusätzlich werden Sie im Verlauf der Studie teilweise gebeten, Ihre Gefühle zu intensivieren oder abzuschwächen. Dazu folgen später noch genauere Instruktionen.

Sie werden zu Beginn und am Ende gebeten, einige Fragebögen auszufüllen. Zudem wird während der gesamten Sitzung ein Video aufgezeichnet, welches im Anschluss von den Untersuchern ausgewertet wird. Außerdem bitten wir Sie, uns eine Speichelprobe zu geben, da uns auch interessiert, wie die Variation verschiedener genetischer Merkmale mit verschiedenen Variablen zusammenhängt.
Des Weiteren wird die Aktivität bestimmter Muskeln in Ihrem Gesicht sowie ihre Hautleitfähigkeit aufgezeichnet. Dafür werden Elektroden oberhalb Ihres linken Auges und neben Ihrem Mund, sowie auf der Innenfläche Ihrer nichtdominanten Hand aufgeklebt, die sich am Ende rückstandslos wieder ablösen lassen. Dafür ist es nötig, die entsprechenden Hautstellen zuvor mit Alkohol zu reinigen und mit einer Peelingpaste leicht aufzurauhen. Dabei kann es zu leichten Hautrötungen in diesen Bereichen kommen die jedoch spätestens nach ein paar Stunden wieder verschwinden.
Während der gesamten Aufzeichnung müssen wir Sie bitten, sich ruhig zu verhalten, damit unsere Messungen nicht gestört werden.

Insgesamt wird mit einer Untersuchungsdauer von ca. zwei Stunden gerechnet, wofür Sie Versuchspersonenstunden gutgeschrieben bekommen. Zusätzlich erhalten am Ende der gesamten Studie die besten fünf Torschützen 10 Euro als Belohnung für ihre gute Leistung.

Die Daten werden nach der Untersuchung mit einer Codenummer versehen (pseudonymisiert) und auf unbestimmte Zeit gespeichert. Eine Weitergabe personengebundener Daten erfolgt nicht. Alle beteiligten Untersucher sind der Verschwiegenheit verpflichtet. Die Auswertung der Daten erfolgt gemittelt über viele Studienteilnehmer. Wir können daher keine Aussagen über Ihre individuellen Ergebnisse machen.

Ihre Teilnahme an der Studie erfolgt freiwillig. Durch die Nichtteilnahme an der Studie entstehen Ihnen keinerlei Nachteile.

Sie können Ihre freiwillige Teilnahme an der Studie jederzeit und ohne Angabe von Gründen abbrechen, ohne dass Ihnen daraus Nachteile entstehen.

A 4. Declaration of Consent Form applied in Experiments 1-3

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Einverständniserklärung
zur Teilnahme an der wissenschaftlichen Studie
„Würzburg vor, noch ein Tor"

Ich bin über den Zweck und den Ablauf der Studie informiert worden. Ich bin insbesondere auch über Wesen, Bedeutung und Tragweite sowie über mögliche Risiken und Nachteile der Untersuchung aufgeklärt worden und stimme der Erhebung sowie Auswertung der Daten zu. Ich habe eine schriftliche Probandeninformation erhalten und konnte in einem Gespräch meine Fragen klären. Alle mich interessierenden Fragen wurden in für mich verständlicher Weise beantwortet.

Ich wurde darüber aufgeklärt, dass die Teilnahme freiwillig ist und ich meine Einwilligung zur Untersuchung jederzeit ohne Angabe von Gründen und ohne Nachteile zurückziehen kann. Ich wurde darüber informiert, dass sämtliche erhobenen personenbezogenen Daten vertraulich behandelt und pseudonymisiert gespeichert sowie gemittelt über viele Studienteilnehmer statistisch ausgewertet werden.

Ich bin einverstanden mit der pseudonymisierten Weitergabe und Auswertung der in der Studie erhobenen Informationen für Forschungszwecke am Lehrstuhl I für Psychologie in Würzburg.

Prof. Dr. Pauli und Mitarbeiter dürfen die aus der Erhebung und Analyse gewonnenen Ergebnisse im Rahmen der Forschung nutzen und die gewonnenen Daten und Ergebnisse, ohne Bezug zu Namen und Person, in Fachzeitschriften publizieren.

Unterschrift des Untersuchungsteilnehmers:

Würzburg, den __________ ____________________________________
Name

____
Unterschrift

Unterschrift des aufklärenden Untersuchungsleiters:

Würzburg, den ___________ ____________________________________
Name

____
Unterschrift

A 5. Sociodemographic Questionnaire applied in Experiments 1-3

Datum: ____________________ Uhrzeit:___________________ Code:__________________

Bitte beantworten Sie folgende Fragen. Ihre Daten werden absolut vertraulich behandelt und anonymisiert abgespeichert. Obwohl wir einige Daten von Ihnen bereits bekommen haben, möchten wir Sie bitten, diese Fragen zu beantworten, da die Daten separat abgespeichert werden und sich möglicherweise nach dem letzten Untersuchungszeitpunkt Änderungen ergeben haben.

1. Geschlecht: ( ) männlich ( ) weiblich

2. Alter:____ Jahre Geb.-Dat..:__________

3. Schulbildung: höchster erreichter Schulabschluss

( ) kein Abschluss ( ) Volksschule/Hauptschule ( ) Realschule

( ) (Fach-)- Abitur ( ) anderes ______________________

Klassenwiederholungen: ___________________

4. Berufsausbildung / Studium: ( ) kein Abschluss ( ) in Ausbildung/Studium,

als:____________________________________

( ) erreichter Abschluss, Berufsbezeichnung: _______________________

5. Derzeitige Arbeitssituation (Beruf, Vollzeit oder Teilzeit):

____

6. Händigkeit: ( ) Linkshänder ( ) Rechtshänder

7. a) Tragen Sie eine Sehhilfe? ( ) Ja ( ) Nein

Wenn ja: ( ) kurzsichtig ( ) weitsichtig

Ist Ihre Sehschwäche ausreichend korrigiert? ( ) Ja ( ) Nein

b) Haben Sie Schwierigkeiten, Farben wahrzunehmen? ( ) Ja ( ) Nein

Wenn ja, welche Farben betrifft das? Wie äußert sich die Farbsehschwäche?____

Ist Ihre Farbsehschwäche ausreichend korrigiert? ( ) Ja ( ) Nein

8. Haben Sie Hörschwierigkeiten? ( ) Ja ( ) Nein

Wenn ja, welcher Art:________________

Sind die Schwierigkeiten ausreichend korrigiert? ( ) Ja ( ) Nein

9. Leiden Sie derzeit an einer akuten Erkrankung (z.B. Grippe)? Wenn ja, an welcher?

( ) Nein ( ) Ja, ____

10. Leiden Sie an einer chronischen Krankheit (z.B. Diabetes)? Wenn ja, an welcher?

( ) Nein ( ) Ja, ____

11. Haben oder hatten Sie psychische Erkrankungen? Bitte geben Sie auch unbedingt Veränderungen seit Ihrer letzten Untersuchung bei uns an.

( ) Nein

( ) Ja, folgende: _________________ ( ) aktuell ( ) im Zeitraum von ______ bis______

_________________ ( ) ( ) ______ ______

12. Machen oder machten Sie eine Therapie wegen psychischer Probleme? Bitte geben Sie auch unbedingt Veränderungen seit Ihrer letzten Untersuchung bei uns an.

( ) Nein

( ) Ja

Problematik/Erkrankung ________________ Wo (Klinik, Beratungsstelle, Psychologe, Psychiater): ________________

Art der Therapie (z.B. Gruppentherapie, Verhaltenstherapie) ________________ ( ) aktuell; seit wann___________ ( ) im Zeitraum von_____ bis_____

Problematik/Erkrankung ________________ Wo: ________________

Art der Therapie ________________ ( ) aktuell ( ) im Zeitraum von_____ bis_____

13. Nehmen Sie regelmäßig Medikamente ein (wegen körperlicher und psychischer Erkrankungen)? Wenn ja, <u>welche</u> und <u>in welcher Dosierung</u> und <u>zu welcher Tageszeit</u>? Bitte geben Sie auch genau an, **<u>wann Sie das letzte Mal</u>** welches Medikament eingenommen haben (Tag + Uhrzeit).

( ) Nein ( ) Ja, ____

14. Rauchen Sie regelmäßig Zigaretten? Wenn ja, wie viele?

( ) Nein ( ) Ja, _________am Tag

Wenn ja, wann haben Sie das letzte Mal geraucht?_________________Wieviele heute____________

15. Wie viele Tassen Kaffee haben Sie heute getrunken? _________________ Um wie viel Uhr das letzte Mal? ________________

16. Trinken Sie regelmäßig Alkohol? Wenn ja, wie viel (z.B. 5 Gläser Bier in der Woche)?

( ) Nein ( ) Ja, _________am Tag / in der Woche (*Unzutreffendes bitte durchstreichen)*

Wenn ja, wann haben Sie das letzte Mal Alkohol getrunken?_________________

17. Konsumieren Sie regelmäßig irgendwelche Drogen, wie z. B. Haschisch, LSD,

Kokain? Wenn ja, welche und in welcher Menge?

( ) Nein ( ) Ja, ____

Wenn ja, wann haben Sie das letzte Mal welche Droge konsumiert?

____

18. Wann haben Sie das letzte mal gegessen?: Vor _____________ Std.

A 6. Original Instructions presented to Participants throughout Experiment 1

Before practice trials:

Guten Tag!

Vielen Dank, dass Sie sich bereit erklärt haben, an unserem Experiment teilzunehmen.

Während des gesamten Versuchs ist es sehr wichtig, dass Sie versuchen, sich nicht zu viel zu bewegen, weil dadurch unsere Messungen gestört werden.

Sie werden im Folgenden in ein virtuelles Fußballstadion versetzt. Ihre Aufgabe ist es, Elfmeter zu schießen und dabei so viele Tore wie möglich zu machen.

Stellen Sie sich vor, Sie seien mit Ihrer Mannschaft im Finale eines wichtigen Tourniers und es kommt zum alles entscheidenden Elfmeterschießen. Wenn Sie genügend Elfmeter treffen, gewinnt Ihre Mannschaft das Tournier und somit den Pokal. Machen Sie hingegen zu wenig Tore, so verliert die gesamte Mannschaft das Finale und Sie gewinnen keinen Pokal. Zusätzlich wird Ihnen Ihr Trainer nach jedem Schuss Feedback geben, wie gut Sie spielen.

Nach jedem Feedback vom Trainer werden Sie aufgefordert, anzugeben, wie angenehm oder unangenehm Sie dieses fanden und wie sehr Sie das Feedback erregt hat.

Dafür verwenden wir verschiedene Skalen.

Das ist die Skala, auf der Sie angeben können, wie angenehm oder unangenehm Sie das Feedback fanden.

1---------2--------3--------4--------5--------6--------7--------8--------9

sehr unangenehm sehr angenehm

Bitte benutzen Sie die Tastatur, um Ihre Bewertung abzugeben.

Das ist die Skala, auf der Sie angeben können, wie sehr Sie das Feedback erregt hat.

1---------2--------3--------4--------5--------6--------7--------8--------9

gar nicht sehr stark

Bitte benutzen Sie die Tastatur, um Ihre Bewertung abzugeben.

Zu Beginn können Sie erst einmal das Stadion kennen lernen und üben, Ihre Gefühle zu bewerten.

Before main experiment:

Sehr gut. Sie haben jetzt geübt, Ihre Gefühle zu bewerten. Jetzt wird es ernst und Sie sollen tatsächlich auf’s Tor schießen.

Der gegnerische Torwart ist sehr gut, aber es ist wichtig, dass Sie Ihr Bestes geben und versuchen so oft wie möglich zu treffen, damit Ihre Mannschaft gewinnt. Selbst wenn Sie einmal verschießen, ist es wichtig, dass Sie sich danach wieder auf den nächsten Schuss konzentrieren, um insgesamt so viele Tore wie möglich zu schießen.

Bitte denken Sie dabei auch daran, sich nicht zu viel zu bewegen, damit unsere Messungen nicht gestört werden.

Haben Sie noch Fragen?

Sind Sie bereit? Dann geht es jetzt los.

After block 1:

Sehr gut gemacht, Sie haben schon viele Tore geschossen und sind ein echt guter Schütze.

Bevor es weiter geht, können Sie sich ein bisschen ausruhen.

Sind Sie bereit für das nächste Elfmeterschießen?

Dann geht es jetzt weiter.

After block 2:

Bevor wir das letzte Elfmeterschießen anpfeifen, dürfen Sie sich nochmal etwas ausruhen.

Sind Sie bereit für die letzte Runde?

Dann geht es jetzt weiter.

After main experiment:

Vielen Dank. Das haben Sie sehr gut gemacht. Sie haben viele Tore geschossen und sind ein echt guter Schütze. Danke, dass Sie unsere Forschung durch Ihre Teilnahme an diesem Experiment unterstützt haben. Abschließend würden wir Sie bitten, noch ein paar Fragebögen auszufüllen.

A 7. Questionnaire on Experiences throughout the Experiment applied in Experiment 1

1. Wie anstrengend/ermüdend fanden Sie die Untersuchung?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

2. Wie schwierig fanden Sie es, die Konzentration aufrecht zu halten?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

3. Wie stark haben Sie sich konzentriert?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

4. Wie hoch war Ihre Motivation an der Untersuchung teilzunehmen?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

5. Wie könnte die Motivation erhöht werden?

   ____

6. Wie schwierig fanden Sie die Untersuchungsaufgabe?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

7. Haben Sie sich viel bewegt?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

8. Wurden Emotionen ausgelöst?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

9. Bei welchen Ereignissen / Sätzen wurden besonders stark Emotionen ausgelöst? Welche Emotionen?

   - bei Treffern / positiven Sätzen

____

- bei Danebenschießen / negativen Sätzen

____

1. Wie wichtig war es Ihnen eine gute Leistung zu erbringen?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

2. Wie wichtig war für Sie der Aspekt der Belohnung?

   1----------2----------3----------4----------5----------6----------7----------8----------9
   gar nicht sehr

3. Wie könnte man mehr Emotionen auslösen?

- Bei Treffern / positiven Sätzen?

____

- Bei Verschießen / negativen Sätzen?

____

4. Haben Sie zu irgendeinem Zeitpunkt versucht, Ihre Emotionen zu verstärken oder zu vermindern / zu unterdrücken? Wenn ja, wie?

____

5. Worin könnte Ihrer Meinung nach die Untersuchungsabsicht liegen?

____

6. Ist Ihnen irgendetwas aufgefallen?

____

A 8. Questionnaire on Soccer and Computer Game Experiences applied in Experiments 1-3

Nachbefragung Fußball

1. Spielst du selber Fußball im Verein?

   ____

2. Wenn ja, in welchem Verein?

   ____

3. Wie lange schon?

   ____

4. Welche Farben haben deine Trikots?

   ____

5. Bist du Fußballfan?

   ____

6. Welcher ist dein Lieblingsfußballverein?

   ____

7. Wie sehr magst du deinen Lieblingsverein?

   1----------2----------3----------4----------5----------6----------7----------8----------9

   gar nicht sehr

8. Welchen Fußballverein magst du am wenigsten?

   ____

9. Wie sehr magst du diesen Verein?

   1----------2----------3----------4----------5----------6----------7----------8----------9

   gar nicht sehr

10. Machst du einen anderen Vereinssport außer Fußball?

____

11. Welchen Sport machst du im Verein?

____

12. Wie lange schon?

____

13. Welche Farbe haben deine Trikots?

____

14. Spielst du oft Play Station / Spielkonsole?

____

15. Wie viele Stunden spielst du durchschnittlich am Tag?

____

16. Spielst du gerne Play Station / Spielkonsole?

____

17. Wie gerne?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

18. Wie wichtig ist es dir, gut in Computer /Play Station Spielen zu sein?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

A 9. Additional Analyses Experiment 1

Sociodemographic Characteristics and Emotion Processing

There was no significant correlation between the participants' age and any of the dependent variables on the experiential or physiological levels. However, age correlated significantly with expression rates of "raised eyebrows" in pleasant (r = .643, p < .001) and unpleasant trials (r = .619, p < .001), and of "grumping" in pleasant (r = .824, p < .001), neutral (r = .863, p < .001), and unpleasant trials (r = .846, p < .001).

The gender of the participants did not influence valence ratings (Fs < 1.16, ps > .322, η_p^2 < .05). The analysis of the arousal ratings revealed a significant interaction for emotion x gender (F[1,39] = 5.47, p = .011, η_p^2 = .19, $GG\text{-}\varepsilon$ = .83) with women showing higher arousal ratings in response to pleasant and unpleasant trials, and lower arousal ratings in response to neutral trials, compared to men. However, those gender differences did not resist after post-hoc t-tests (ts < 1.22, ps > .233). There was no influence of the gender of the participants on zygomaticus or corrugator activations and skin conductance responses (Fs < 2.07, ps > .146, η_p^2 < .08).

The only observational category that was influenced by gender was "lip biting". The split plot ANOVA here revealed a significant interaction emotion x gender (F[2,46] = 4.05, p = .024, η_p^2 = .15) due to men showing "lip biting" slightly more often than women during neutral (t[23] = 2.11, p = .061), but not during pleasant and unpleasant trials (ts < .55, ps > .60).

Soccer and Gaming Experiences and Emotion Processing

Frequencies of participants reporting to fulfill certain criteria regarding soccer and gaming experiences according to the questionnaire depicted in A 8 are subsumed in Table 9.

Table 9. Absolute (*n*) and relative (%) frequencies of soccer players, soccer fans, other sportsmen than soccer, regular game players and game likers in the sample in experiment 1.

Due to missing data, sums of relative frequencies in two categories are < 100 %.

	Answer of participants (N = 26)	
Item No.	"yes"	"no"
(1) Do you play soccer in a club?	n = 2 (7.70 %)	n = 24 (92.30 %)
(5) Are you a soccer fan?	n = 16 (61.50 %)	n = 10 (38.50 %)
(10) Do you do another sport in a club?	n = 11 (42.30 %)	n = 15 (57.70 %)
(14) Do you often play console games?	n = 18 (69.20 %)	n = 7 (26.90 %)
(16) Do you like to play console games?	n = 14 (53.80 %)	n = 10 (38.50 %)

Split plot ANOVAs were conducted with the between-subject factors “soccer fan” (item 5), “sports club” (item 1 + item 10), “frequent console playing” (item 14), and “fondness of console playing” (item 16). Please note that for the analyses of the influence of membership in a sports club onto emotional reactions, all participants reporting to either play soccer or to do another sports in a club were subsumed in one group. For easier readability, I only report exact statistical values of significant main effects for the respective soccer and gaming variables and significant interactions.

Influence of Soccer Affinity

Whether or not participants reported to be soccer fans did not influence their valence and arousal ratings, or zygomaticus and corrugator activations (Fs < 1.15, ps > .326). The analysis of SCRs revealed a marginally significant interaction for soccer fan x emotion ($F[1,40] = 3.25$, $p = .058$, $\eta_p^2 = .12$). This interaction was due to non-soccer fans showing higher skin conductance responses than soccer fans in unpleasant ($t[24] = 2.26$, $p = .046$), but not in pleasant and neutral trials (ts < 0.52, ps > .605). The only observational category that was influenced by the participants being soccer fans vs. no soccer fans was “giggling”. The analysis here revealed a significant interaction for soccer fan x emotion ($F[2,46] = 3.77$, $p = .031$, $\eta_p^2 = .14$). Soccer fans showed more “giggling” behavior in pleasant ($t[15] = 2.79$, $p = .014$), but not in neutral and unpleasant trials (ts < 0.12, ps > .903).

Influence of Membership in a Sports Club

Whether or not participants were members in a sports club did not influence valence and arousal ratings, zygomaticus and corrugator activations, skin conductance responses, or behavioral reactions (Fs < 3.75, ps > .065, $\eta_p^2 < .14$) significantly.

Influence of Console Playing Frequency

Whether or not participants reported to play console games frequently did not influence valence and arousal ratings, zygomaticus or corrugator activations (Fs < 1.45, ps > .133, $\eta_p^2 < .10$). The analysis of SCRs revealed a significant interaction for frequency of console playing x emotion ($F[1,36] = 3.98$, $p = .036$, $\eta_p^2 = .15$, $GG\text{-}\varepsilon = .79$). Participants who reported playing console games frequently showed lower SCRs than participants who reported not playing frequently in pleasant and unpleasant trials, and higher SCRs in neutral trials. However, those group differences did not persist in post-hoc t-tests (ts < 1.13, ps > .157). Behavioral expressions were not influenced by console playing frequency (Fs < 3.43, ps > .078, $\eta_p^2 < .14$).

Influence of Console Playing Affinity

Whether or not participants reported to enjoy playing console games did not influence valence and arousal ratings, zygomaticus and corrugator activations, or SCRs (Fs < 2.40, ps > .118). The only observational category that was influenced by the console playing affinity of the participants was "smiling". Here, the analysis revealed a significant interaction for fondness of console playing x emotion ($F[2,42] = 3.23$, $p = .049$, $\eta_p^2 = .13$). Participants who reported to enjoy console playing smiled more frequently than participants who did not enjoy console playing in pleasant trials, comparably seldom in neutral trials, and less frequently in unpleasant trials. However, those group effects did not persist after post hoc t-tests (ts < 1.64, ps > .127).

Motivation and Experiences throughout the Experiment

Results of the post-experimental questionnaire (A 7) are subsumed in Table 10.

Table 10. Means (*M*) and standard deviations (*SD*) of the items of the post-experimental questionnaire for the sample in experiment 1.

Item No.	*M*	*SD*
(1) How tiring was the experiment? (1 = "not at all", 9 = „very much")	4.73	1.73
(2) How difficult was it to stay concentrated? (1 = "not at all", 9 = „very much")	4.58	2.14
(3) How much did you concentrate? (1 = "not at all", 9 = „very much")	6.65	1.29
(4) How high was your motivation to participate? (1 = "not at all", 9 = „very much")	7.04	1.34
(6) How difficult was the experimental task? (1 = "not at all", 9 = „very much")	2.23	1.24
(7) Did you move a lot? (1 = "not at all", 9 = „very much")	3.50	1.58
(8) Were emotions elicited? (1 = "not at all", 9 = „very much")	5.42	1.77
(10) How important was it for you to perform well? (1 = "not at all", 9 = „very much")	6.92	1.35
(11) How important was the possibility of a reward? (1 = "not at all", 9 = „very much")	5.58	2.37

A 10. Feedback Phrases used in Experiment 2

Pleasant feedback phrases after hits:

1. „Wow, du hast's aber echt drauf!“
2. „Super, du packst das!“
3. „Wow, genialer Treffer!“
4. „Ein schönes Ding!“
5. „Sehr stark von dir!“
6. „Super reingehauen!“
7. „Yeah, starke Leistung!“
8. „Ja, genau so will ich das sehen von dir!“
9. „Jetzt zeigst du aber, was du wirklich drauf hast!“
10. „Wow, du machst deiner Mannschaft aber alle Ehre!“
11. „Auf geht's, weiter so!“
12. „Ja, genau, sehr schön, mach weiter so!“
13. „Jetzt zeigst du dich aber von deiner besten Seite!“
14. „Unglaublich, wie du den reingemacht hast!“
15. „Solche Spieler brauchen wir.“

Unpleasant feedback phrases after misses:

1. „Wenn du so weitermachst, wird das nichts mehr!“
2. „Jetzt streng dich doch mal endlich an!“
3. „Sag mal, du stellst dich aber heute an!“
4. „Oh Mann, du versaust uns allen noch den Sieg!“
5. „Jetzt streng dich doch mal bitte an!“
6. „So eine Chance musst du doch machen!“
7. „Schlechter Schuss!“
8. „So wird das nie was!“
9. „Das war echt schlecht!“
10. „Ich dreh durch“
11. „Ich dreh noch durch!“
12. „Das ist ja wohl nicht dein Ernst.“
13. „Wie blöd kann man sein.“
14. „Ich bin echt enttäuscht von dir.“
15. „Die ganze Mannschaft verliert noch wegen dir.“

Neutral feedback phrases after free shots over the soccer field:

1. „Das war durchschnittlich.“
2. „Du hast gerade geschossen.“
3. „Ich habe deinen Schuss gesehen.“
4. „Du spielst hier Fußball.“
5. „Die Leistung lag im Mittelfeld.“
6. „Du hast den Ball gekickt.“
7. „Du schießt mit deinem starken Fuß.“
8. „Du stehst auf dem Spielfeld.“
9. „Du hast ordentlich gekickt.“
10. „Du hast fest geschossen.“

11. „Du hast über das Feld geschossen."
12. „Du hast nach vorne geschossen."
13. „Du bist ein Fußballspieler."
14. „Du strengst dich hier an, um ins Team zu kommen."
15. „Du trainierst für die Auswahlmannschaft."

Feedback phrases used in practice trials before the main experiment:

Pleasant phrases:

1. „Tolles Tor!"
2. „Schöner Schuss!"

Unpleasant phrases:

1. „Der war doch einfach, so einer muss doch rein!"
2. „Wie kann man denn den verschießen!!??!!"

Neutral phrase:

1. „Das war ein Schuss."

A 11. Information Form that Participants in Experiment 2 received before starting the Experiment

Julius-Maximilians-
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Information für Probanden der Studie „Würzburg vor, noch ein Tor"

Sehr geehrte Studienteilnehmerin, sehr geehrter Studienteilnehmer,

Vielen Dank für Ihr Interesse an unserer Studie. Bitte lesen Sie sich folgende Informationen zunächst sorgfältig durch und entscheiden Sie dann über Ihre Teilnahme an dieser Studie. Beides, Teilnahme oder Nichtteilnahme an dieser Studie steht Ihnen frei. Falls Sie über diese Information hinaus noch weitere Fragen haben, beantworten wir diese gerne.

Sie werden im Verlauf des Experiments aufgefordert, per Joystick auf ein virtuelles Tor zu schießen und bekommen nach jedem Schuss Feedback von einem virtuellen Trainer. Danach sollen Sie jeweils auf einer Skala angeben, wie positiv oder negativ Sie sich während des Feedbacks gefühlt haben und wie aufgeregt Sie waren.

Sie werden zu Beginn und am Ende gebeten, einige Fragebögen auszufüllen. Zudem wird während der gesamten Sitzung ein Video aufgezeichnet, welches im Anschluss von den Untersuchern ausgewertet wird.
Des Weiteren werden Elektroden oberhalb Ihres linken Auges und neben Ihrem Mund, sowie auf der Innenfläche Ihrer nichtdominanten Hand aufgeklebt, die sich am Ende rückstandslos wieder ablösen lassen. Dafür ist es nötig, die entsprechenden Hautstellen zuvor mit Alkohol zu reinigen und mit einer Peelingpaste leicht aufzurauhen. Dabei kann es zu leichten Hautrötungen in diesen Bereichen kommen die jedoch spätestens nach ein paar Stunden wieder verschwinden.
Während der gesamten Aufzeichnung müssen wir Sie bitten, sich ruhig zu verhalten, damit unsere Messungen nicht gestört werden.

Insgesamt wird mit einer Untersuchungsdauer von ca. einer Stunde gerechnet, wofür Sie eine Aufwandsentschädigung von 7 Euro bekommen. Zusätzlich erhalten am Ende der gesamten Studie die besten fünf Torschützen 10 Euro als Belohnung für ihre gute Leistung.

Die Daten werden nach der Untersuchung mit einer Codenummer versehen (pseudonymisiert) und auf unbestimmte Zeit gespeichert. Eine Weitergabe personengebundener Daten erfolgt nicht. Alle beteiligten Untersucher sind der Verschwiegenheit verpflichtet. Die Auswertung der Daten erfolgt gemittelt über viele Studienteilnehmer. Wir können daher keine Aussagen über Ihre individuellen Ergebnisse machen.

Ihre Teilnahme an der Studie erfolgt freiwillig. Durch die Nichtteilnahme an der Studie entstehen Ihnen keinerlei Nachteile.

Sie können Ihre freiwillige Teilnahme an der Studie jederzeit und ohne Angabe von Gründen abbrechen, ohne dass Ihnen daraus Nachteile entstehen.

A 12. Original Instructions presented to Participants throughout Experiment 2

Before practice trials:

Guten Tag!

Vielen Dank, dass du an unserem Experiment teilnehmen möchtest.

Während des gesamten Versuchs ist es sehr wichtig, dass du versuchst, dich nicht zu viel zu bewegen, weil dadurch unsere Messungen gestört werden.

Du wirst gleich in ein virtuelles Fußballstadion versetzt. Deine Aufgabe ist es, Elfmeter zu schießen und dabei so viele Tore wie möglich zu machen.

Stell dir vor, du nimmst an einem Testtraining für eine Auswahlmannschaft teil. Du willst unbedingt in die Mannschaft, in der nur die besten Spieler deiner Altersklasse spielen. Wenn du genügend Tore machst, wirst du ins Team aufgenommen, wenn nicht, darfst du nicht in der Mannschaft spielen.

Der Auswahltrainer Tobi wird dich dabei beobachten und dir zwischendurch Feedback geben, wie gut du spielst.

Nach jedem Schuss bzw. nach jedem Feedback vom Trainer sollst du angeben, wie du dich währenddessen gefühlt hast.

Dafür verwenden wir verschiedene Skalen.

Das ist die Skala, auf der du angeben kannst, wie angenehm oder unangenehm du dich gefühlt hast.

1---------2--------3--------4--------5--------6--------7--------8--------9

unangenehm angenehm

Bitte benutze die Tastatur, um deine Bewertung abzugeben.

Das ist die Skala, auf der du angeben kannst, wie erregt bzw. emotional bewegt du warst.

1---------2--------3--------4--------5--------6--------7--------8--------9

ruhig erregt

Bitte benutze die Tastatur, um deine Bewertung abzugeben.

Zu Beginn kannst du erst einmal üben, mit dem Joystick auf's Tor zu schießen und den Trainer Tobi kennenlernen. Außerdem kannst du üben, deine Gefühle zu bewerten.

Before main experiment:

Sehr gut. Du hast jetzt geübt, zu schießen und deine Gefühle zu bewerten. Jetzt wird es ernst. Also streng dich an und gib dein Bestes, um in die Auswahlmannschaft aufgenommen zu werden.

Der Torwart ist sehr gut, aber es ist wichtig, dass du so viele Tore wie möglich machst, um im Team mitspielen zu dürfen. Selbst wenn du einmal verschießt, ist es wichtig, dass du dich danach wieder auf den nächsten Schuss konzentrierst, um insgesamt so viele Tore wie möglich zu schießen.

Bitte denke dabei auch daran, dich nicht zu viel zu bewegen, damit unsere Messungen nicht gestört werden.

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

After block 1:

Sehr gut gemacht, Du hast schon viele Tore geschossen und bist ein echt guter Schütze.

Bevor es weiter geht, kannst du dich ein bisschen ausruhen.

Bist du bereit für das nächste Elfmeterschießen?

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

After block 2:

Sehr gut gemacht, Du hast schon viele Tore geschossen und bist ein echt guter Schütze.

Bevor wir das letzte Elfmeterschießen anpfeifen, darfst du dich nochmal etwas ausruhen.

Bist du bereit für die letzte Runde?

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

After main experiment:

Vielen Dank. Das hast du sehr gut gemacht. Du hast viele Tore geschossen und bist ein echt guter Schütze. In unserer Auswahlmannschaft dürftest du auf jeden Fall mitspielen.

Danke, dass du unsere Forschung durch deine Teilnahme an diesem Experiment unterstützt hast. Abschließend würden wir dich bitten, noch ein paar Fragebögen auszufüllen.

A 13. Questionnaire on Experiences throughout the Experiment applied in Experiments 2 and 3

1. Wie anstrengend/ermüdend fanden Sie die Untersuchung?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

2. Wie schwierig fanden Sie es, die Konzentration aufrecht zu halten?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

3. Wie stark haben Sie sich konzentriert?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

4. Wie hoch war Ihre Motivation an der Untersuchung teilzunehmen?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

5. Wie könnte die Motivation erhöht werden?

____

6. Haben Sie sich viel bewegt?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

7. Wurden Emotionen ausgelöst?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

8. Bei welchen Ereignissen / Sätzen wurden besonders stark Emotionen ausgelöst? Welche Emotionen?

a) bei Treffern / positiven Sätzen

____

b) bei Danebenschießen / negativen Sätzen

____

c) bei freien Schüssen / neutralen Sätzen

____

9. Wie könnte man mehr Emotionen auslösen?

- Bei Treffern / positiven Sätzen

____

- Bei Verschießen / negativen Sätzen

____

Wie wichtig war es Ihnen eine gute Leistung zu erbringen?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

10. Wie hoch schätzen Sie Ihren Einfluss auf Ihre Leistung ein?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

11. Wie wichtig war es Ihnen, Geld gewinnen zu können?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

12. Wie sympathisch war Ihnen der Trainer?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

13. Wie wichtig war es für Sie, ein gutes Feedback vom Trainer zu bekommen?

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

14. Worin könnte Ihrer Meinung nach die Untersuchungsabsicht liegen?

____

15. Ist Ihnen irgendetwas aufgefallen?

____

A 14. Additional Analyses Experiment 2

Motivation and Experiences throughout the Experiment

Table 11. Means (*M*) and standard deviations (*SD*) of the likert-scale items of the post-experimental questionnaire applied to the sample in experiment 2.

Item No.	*M*	*SD*
(1) How tiring was the experiment? (1 = “not at all“, 9 = „very much“)	3.64	1.84
(2) How difficult was it to stay concentrated? (1 = “not at all“, 9 = „very much“)	3.55	1.84
(3) How much did you concentrate? (1 = “not at all“, 9 = „very much“)	6.59	1.68
(4) How high was your motivation to participate? (1 = “not at all“, 9 = „very much“)	7.55	1.63
(6) Did you move a lot? (1 = “not at all“, 9 = „very much“)	3.14	1.58
(7) Were emotions elicited? (1 = “not at all“, 9 = „very much“)	5.00	1.63
(10) How important was it for you to perform well? (1 = “not at all“, 9 = „very much“)	7.23	1.31
(11) How high do you estimate your influence on your performance (1 = “no influence at all”, 9 = “very high influence”)	4.18	2.28
(12) How important was it for you to have the possibility to earn money? (1 = “not at all“, 9 = „very much“)	4.52	2.02
(13) How much did you like the coach (1 = “not at all”, 9 = “very much”)	4.14	2.08
(14) How important was it for you to get good feedback from the coach (1 = “not at all”, 9 = “very much”)	5.52	2.54

Correlations with valence and arousal ratings

The more the participants said they moved throughout the experiment (item 6) the higher their valence ratings in response to neutral trials with (r = .569, p = .006) and without feedback (r = .432, p = .045). The more participants stated that emotions were elicited throughout the experiment (item 7) the lower their valence ratings in response to pleasant trials without feedback (r = -.446, p = .037). The higher participants rated their experienced influence on their performance (item 11) the lower their valence ratings in response to unpleasant trials with feedback (r = -.471, p = .027). Participants who liked the virtual coach better (item 13) showed higher valence ratings in response to unpleasant trials without feedback (r = .457, p = .037). Participants who rated the experiment as more tiring (item 1) gave higher arousal ratings in response to neutral trials without feedback (r = .453, p = .034). The more participants stated to have concentrated throughout the experiment (item 3) the higher their arousal ratings in response to pleasant trials with (r = .527, p = .012) and without feedback (r

= .468, p = .028). The higher participants' motivation to participate in the experiment (item 4) the higher their arousal ratings in response to unpleasant trials with feedback (r = .475, p = .026). The more participants stated to have moved throughout the experiment (item 6) the higher their arousal ratings in response to pleasant trials with feedback (r = .524, p = .012). The more participants stated that strong emotions were elicited throughout the experiment (item 7) the higher their arousal ratings in response to pleasant trials with (r = .661, p < .001) and without feedback (r = .726, p < .001). The more participants stated that they wanted to perform well throughout the experiment (item 10) the higher their arousal ratings in response to neutral trials with feedback (r = .479, p = .024) and unpleasant trials with feedback (r = .425, p = .049). The higher participants rated their experienced influence on their performance (item 11) the higher their arousal ratings in response to unpleasant trials with (r = .652, p < .001) and without feedback (r = .487, p = .021).

Correlations with psychophysiological reactions

Participants who reported to have moved a lot throughout the experiment (item 6) showed higher zygomaticus activations in pleasant (r = .799, p < .001) and unpleasant trials with feedback (r = .472, p = .026). Participants who reported that strong emotions had been elicited throughout the experiment (item 7) showed higher zygomaticus activations in pleasant trials with feedback (r = .504, p = .017). Participants who rated their experienced influence on their performance higher (item 11) showed higher zygomaticus activations in pleasant trials with feedback (r = .526, p = .012). Participants who stated that it was important for them to earn money (item 12) showed lower zygomaticus activations in pleasant trials with feedback (r = -.485, p = .026). Participants who rated to like the coach better (item 13) showed higher zygomaticus activations in neutral trials with feedback (r = .493, p = .023) and in unpleasant trials with feedback (r = .601, p < .001). Participants who reported to have moved a lot (item 6) showed higher corrugator activations in unpleasant trials with feedback (r = .490, p = .021).

Participants who reported that they found it difficult to stay concentrated throughout the experiment (item 2) showed higher SCRs in neutral trials with feedback (r = .429, p = .047). Participants who stated to have concentrated strongly (item 3) showed higher SCRs in pleasant (r = .572, p = .005) and unpleasant trials with feedback (r = .455, p = .033). Participants who reported that strong emotions were elicited throughout the experiment (item 7) showed higher SCRs in pleasant trials with feedback (r = .424, p = .049). Participants who stated that it was important for them to earn money (item 12) showed lower SCRs in neutral trials with feedback (r = -.465, p = .034).

Sociodemographic Characteristics and Emotion Processing

Age and valence or arousal ratings did not correlate significantly (rs < .388, ps > .074). There were (marginally) significant correlations between age and zygomaticus activations in trials with feedback in pleasant (r = .484, p = .022), neutral (r = .479, p = .024), and unpleasant (r = .410, p = .058) trials, and between age and corrugator activity in unpleasant trials without feedback (r = .470, p = .027). Age and SCRs did not correlate (rs < .301, ps > .174).

Gender did not influence valence and arousal ratings, or zygomaticus activations. Split plot ANOVAs with the within-subjects factors emotion and feedback and the between-subjects factor gender revealed no significant main effects for gender and no significant interactions implying gender (Fs < 2.18, ps > .155, η_p^2 < .10). Modulations of corrugator activations for men vs. women are depicted in Table 12. Corrugator activations were influenced by emotion x gender (F[1.27] = 3.81, p = .049, η_p^2 = .16), and marginally by feedback x gender (F[1,20] = 4.07, p = .057, η_p^2 = .17) due to women showing higher activations than men especially in trials without feedback. Averaged over trials with feedback and trials without feedback, women showed higher corrugator activations than men in neutral (t[20] = 2.97, p = .013), but not in pleasant and unpleasant trials (ts < 1.03, ps > .314). Women showed higher corrugator activations in neutral, compared to pleasant and unpleasant trials (F[1,14] = 9.89, p = .004, η_p^2 = .473, GG-ε = .66; ts > 2.59, ps < .025), which in turn were comparably low (t[11] = 1.65, p = .127). Men showed comparably low corrugator activations across all emotional conditions (F[1,12] = 0.03, p = .968, η_p^2 = .004, GG-ε = .67). There were no significant influences of gender on SCRs (Fs < 2.45, ps > .117, η_p^2 < .11).

*Table 12.*Means (*M*) and standard deviations (*SD*) of corrugator activations for men and women in different experimental conditions in experiment 2.

Experimental Condition	**Gender**			
	men		women	
	M	*SD*	*M*	*SD*
with FB_pleasant	-0.33	0.39	-0.36	0.61
with FB_neutral	-0.12	0.40	0.10	0.36
with FB_unpleasant	-0.29	0.70	-0.55	0.60
without FB_pleasant	-0.12	0.33	0.12	0.40

without FB_neutral	-0.38	0.65	0.09	0.32
without FB_unpleasant	-0.11	0.57	0.14	0.49

A 15. Original Instructions for different Cyber Ball Blocks in experiment 3

Before first block:

Willkommen zu Cyberball, einem interaktiven Ballspiel zu mentaler Visualisierung!

Im Folgenden wollen wir den Zusammenhang zwischen der Fähigkeit, eine Situation mental zu visualisieren und der Fähigkeit, Gefühle zu kontrollieren, testen.

Deshalb müssen wir Ihre Fähigkeiten zu mentaler Visualisierung trainieren. Es hat sich gezeigt, dass dies gut geht, wenn Sie online ein Ballspiel spielen .Sie werden dieses Spiel mit jeweils zwei anderen Spielern spielen, die zur selben Zeit eingeloggt sind.

Das Spiel ist sehr einfach. Wenn Ihnen der Ball zugepasst wird, klicken Sie bitte einfach auf den Namen des Spielers, dem Sie den Ball als nächstes zuspielen wollen.

Sie werden insgesamt vier Durchgänge spielen. Nach jedem Durchgang erhalten Sie weitere Instruktionen.

Wichtig ist nicht Ihre Leistung beim Passen der Bälle, sondern, dass Sie Ihre Erfahrungen MENTAL VISUALISIEREN.

Stellen Sie sich genau vor, wie die anderen Spieler aussehen. Was für Menschen sind sie? Wo spielen Sie? Ist es warm und sonnig oder kalt und regnerisch? Kreieren Sie in Ihrem Kopf ein komplettes mentales Bild dessen, was geschehen würde, wenn Sie dieses Spiel im realen Leben spielen würden.

…..

Before second, third, and fourth block:

Im nächsten Durchgang werden Sie wieder mit zwei anderen Spielern über unser Netzwerk Cyberball spielen.

Dabei ist es wieder sehr wichtig, dass Sie Ihre Erfahrungen MENTAL VISUALISIEREN.

Stellen Sie sich genau vor, wie die anderen Spieler aussehen. Was für Menschen sind sie? Wo spielen Sie? Ist es warm und sonnig oder kalt und regnerisch? Kreieren Sie in Ihrem Kopf ein komplettes mentales Bild dessen, was geschehen würde, wenn Sie dieses Spiel im realen Leben spielen würden.

…..

Before non-regulate blocks:

…..

Im ersten Durchgang / In diesem Durchgang des Spiels sollen Sie Ihren Gefühlen beim Mentalisieren FREIEN LAUF LASSEN und GANZ NATÜRLICH REAGIEREN.

Sind Sie bereit? Bitte klicken Sie auf den folgenden Link, um das Spiel zu starten: Spiel starten

Before hide-blocks:

….

Im ersten Durchgang / In diesem Durchgang des Spiels sollen Sie Ihre Gefühle beim Mentalisieren MÖGLICHST GUT VERBERGEN.

Sind Sie bereit? Bitte klicken Sie auf den folgenden Link, um das Spiel zu starten: Spiel starten

A 16. Feedback Phrases used in the Virtual Penalty Kicking Game in experiment 3

Pleasant feedback phrases after hits:

1. „Wow, du hast’s aber echt drauf!“
2. „Super, du packst das!“
3. „Wow, genialer Treffer!“
4. „Ein schönes Ding!“
5. „Sehr stark von dir!“
6. „Super reingehauen!“
7. „Yeah, starke Leistung!“
8. „Ja, genau so will ich das sehen von dir!“
9. „Jetzt zeigst du aber, was du wirklich drauf hast!“
10. „Wow, du machst deiner Mannschaft aber alle Ehre!“
11. „Auf geht’s, weiter so!“
12. „Ja, genau, sehr schön, mach weiter so!“
13. „Jetzt zeigst du dich aber von deiner besten Seite!“
14. „Unglaublich, wie du den reingemacht hast!“
15. „Solche Spieler brauchen wir.“

Unpleasant feedback phrases after misses:

1. „Wenn du so weitermachst, wird das nichts mehr!“
2. „Jetzt streng dich doch mal endlich an!“
3. „Sag mal, du stellst dich aber heute an!“
4. „Oh Mann, du versaust uns allen noch den Sieg!“
5. „Jetzt streng dich doch mal bitte an!“
6. „So eine Chance musst du doch machen!“
7. „Schlechter Schuss!“
8. „So wird das nie was!“
9. „Das war echt schlecht!“
10. „Ich dreh durch“
11. „Ich dreh noch durch!“
12. „Das ist ja wohl nicht dein Ernst.“
13. „Wie blöd kann man sein.“
14. „Ich bin echt enttäuscht von dir.“
15. „Die ganze Mannschaft verliert noch wegen dir.“

Neutral feedback phrases after free shots over the soccer field:

1. „Das war durchschnittlich.“
2. „Du spielst hier Fußball.“
3. „Die Leistung lag im Mittelfeld.“
4. „Du hast über das Feld geschossen.“
5. „Du trainierst für die Auswahlmannschaft.“

Feedback phrases used in practice trials before the main experiment:

Pleasant phrases:

1. „Super Schuss!“
2. „Schönes Tor!“
3. „Tolles Tor!“
4. „Schöner Schuss!“

Unpleasant phrases:

1. „Der war doch einfach, so einer muss doch rein!“
2. „Wie kann man denn den verschießen!!??!!“
3. „Schwacher Abschluss!“
4. „Das war schwach von dir.“

Neutral phrase:

1. „Das war ein Schuss.“

A 17. Telephone Interview for Healthy Controls

Telefonscreening erwachsene Kontrollpersonen

Name:
Telefonnummer:
Handy:

Sehr geehrte/sehr geehrte
Im Rahmen unserer Untersuchung, bitten wir Sie folgende Fragen zu beantworten. Die von Ihnen gegebenen Antworten unterliegen selbstverständlich der Schweigepflicht.
Die Hauptuntersuchung wird am Institut für Klinische Psychologie, Marcusstraße 9-11, Raum 103, durchgeführt. Bei der Untersuchung handelt sich um eine Untersuchung in virtueller Realität, bei der Patienten mit ADHS untersucht werden. Dafür suchen wir Kontrollprobanden, die folgende Ausschlusskriterien nicht erfüllen:

Für die Untersuchung ist es wichtig, vorher ein Telefoninterview durchzuführen, um zu sehen, ob Sie für diese Untersuchung in Frage kommen. Das Telefoninterview wird ca. 15 Minuten dauern. Nach dem Telefoninterview werden wir entscheiden, ob Sie an der Hauptuntersuchung teilnehmen können.
Falls Sie nun gleich Zeit haben, würden wir nun ein ca. 15-minütiges Telefoninterview durchführen. Ansonsten können wir jetzt einen neuen Termin vereinbaren.

Wann sind Sie am besten zu erreichen:

Alter:
Geschlecht:
Höchster erreichter Schulabschluss:
Berufsausbildung oder Studium (Abschluss oder noch andauernd):
Derzeitige Arbeitssituation (ob und in welchem Beruf):
Haben Sie derzeit oder hatten Sie früher schon einmal eine psychische Erkrankung (falls ja, welche; Zeitraum angeben):
Haben Sie schon mal eine Psychotherapie gemacht (falls ja bitte Zeitraum und Grund angeben):
Haben Sie schon mal eine Beratungsstelle aufgesucht (falls ja bitte Zeitraum und Grund

angeben):

Haben Sie Kinder, Eltern, Großeltern oder Geschwister, die vom Aufmerksamkeitsdefizit-Hyperaktivitätssyndrom („Zappelphilipp-Syndrom“) betroffen sind?:

Nehmen Sie regelmäßig Medikamente ein (falls ja: was und welche Dosierung):

Leiden Sie unter einer körperlichen Erkrankung?

Leiden Sie unter epileptischen Anfällen?

Es folgen nun einige Fragen zu Problemen oder Schwierigkeiten, die sie möglicherweise haben oder gehabt haben? Mit JA und Nein antworten.

ADHS

1. Sind Sie unaufmerksam gegenüber Details oder machen Flüchtigkeitsfehler bei der Arbeit? JA/NEIN
2. Fällt es Ihnen bei der Arbeit oder sonstigen Aktivitäten (z.B. Lesen, Fernsehen, Spiel) schwer, konzentriert durchzuhalten? JA/NEIN
3. Hören Sie nicht richtig zu, wenn jemand etwas zu Ihnen sagt? JA/NEIN
4. Fällt es Ihnen schwer, Aufgaben am Arbeitsplatz, so wie sie Ihnen erklärt wurden, zu erfüllen? JA/NEIN
5. Fällt Ihnen die Organisation und Planung von Arbeiten, Vorhaben oder Aktivitäten schwer? JA/NEIN
6. Gehen Sie Aufgaben, die geistige Anstrengung erforderlich machen, am liebsten aus dem Weg? Mögen sie solche Arbeiten nicht, weil sie Ihnen nicht liegen? JA/NEIN
7. Verlegen Sie oft wichtige Gegenstände? JA/NEIN
8. Lassen Sie sich bei Tätigkeiten leicht ablenken? JA/NEIN
9. Vergessen Sie oft Verabredungen, Termine oder Rückrufe? JA/NEIN
10. Sind Sie zappelig? JA/NEIN
11. Fällt es Ihnen schwer, längere Zeit sitzen zu bleiben? JA/NEIN
12. Fühlen Sie sich innerlich unruhig? JA/NEIN
13. Können Sie sich schlecht leise beschäftigen? JA/NEIN
14. Sind sie ständig auf Achse und fühlen Sie sich wie getrieben? JA/NEIN
15. Fällt es Ihnen schwer abzuwarten, bis andere ausgesprochen haben und fallen Sie anderen oft ins Wort? JA/NEIN
16. Sind Sie ungeduldig und können schwer abwarten bis Sie an der Reihe sind (z.B. Einkaufen)? JA/NEIN
17. Unterbrechen und stören Sie andere, wenn Sie etwas tun? JA/NEIN

18. Reden Sie viel, auch wenn keiner Ihnen zuhören will? JA/NEIN
19. Hatten Sie diese Schwierigkeiten schon im Schulalter? JA/NEIN
20. Haben Sie diese Schwierigkeiten nicht nur in der Arbeit, sondern in mehreren Lebenssituationen? JA/NEIN
21. Leiden Sie unter diesen Schwierigkeiten? JA/NEIN
22. Haben Sie durch diese Schwierigkeiten schon Probleme im Beruf und im Kontakt mit anderen Menschen bekommen? JA/NEIN

Es folgen nun weitere Fragen zu Problemen, die möglicherweise in ihrem Leben einmal bei Ihnen aufgetreten sind. Ich würde Sie bitten, diese einfach mit Ja und Nein zu beantworten. Falls irgendetwas auf Sie zutrifft, werden wir darauf im persönlichen Interview eingehen.

SCID 1

Gab es einmal eine Zeit in Ihrem Leben, in der Sie an mehreren Tagen hintereinander täglich 5 oder mehr Gläser Alkohol getrunken haben?

Nein	Ja

Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Haben Sie jemals Drogen genommen (auch Cannabisprodukte)?

Nein	Ja

Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Fühlten Sie sich jemals von einem ärztlich verschriebenen Medikament abhängig oder nahmen Sie mehr davon ein, als Ihnen verschrieben wurde?:

Nein	Ja

Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie schon mehrfach in Ihrem Leben Angstanfälle, bei denen Sie ganz plötzlich in panischen Schrecken gerieten oder starke Angst hatten?:

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie schon mehrfach Angst alleine das Haus zu verlassen, sich in einer Menschenmenge zu befinden, in einer Schlange anzustehen oder mit dem Zug oder Bus zu fahren?:

Nein	Ja	Angst wovor?	
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie schon einmal Angst, in Gegenwart anderer Menschen zu sprechen, zu essen oder zu schreiben?:

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Gibt es noch Dinge, vor denen Sie besonders Angst haben, wie z.B. in einem Flugzeug zu sitzen, Blut zu sehen, sich in geschlossenen Räumen aufzuhalten, vor bestimmten Tieren oder vor Höhen?

Nein	Ja	Vor was?	
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Waren Sie in den letzten 6 Monaten besonders nervös oder ängstlich? Machen Sie sich viele Sorgen über Dinge, die passieren könnten?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Haben Sie jemals unter Gedanken gelitten, die unsinnig waren und immer wieder kamen, auch wenn Sie es gar nicht wollten?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Ist es schon einmal vorgekommen, dass Sie bestimmte Dinge immer und immer wieder tun mussten, wie z.B. sich immer wieder die Hände zu waschen oder etwas mehrmals zu kontrollieren, um sicherzugehen, dass Sie es richtig gemacht haben?:

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Kam es schon einmal vor, dass andere Menschen sagten Sie seien zu dünn (falls ja, bitte Größe und Gewicht angeben):

Nein	Ja	Größe	Gewicht
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie jemals Essanfälle, bei denen Sie das Gefühl hatten, Ihr Essverhalten nicht mehr kontrollieren zu können?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Haben Sie jemals in ihrem Leben ein schlimmes Ereignis, wie den Tod einer nahestehenden Person, einen Unfall oder eine Katastrophe, erlebt, das über einen längeren Zeitraum in Alpträumen, Vorstellungen oder Gedanken widerkehrt und das Sie nicht loswerden?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie schon irgendwann in Ihrem Leben eine Phase, in der Sie sich fast jeden Tag durchgängig depressiv oder niedergeschlagen fühlten und das Interesse oder die Freude an fast allen Aktivitäten verloren haben, die Ihnen gewöhnlich Freude machen? Hielt diese Phase zwei Wochen an?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Hatten Sie jemals eine Phase, in der Sie sich so gut oder übermäßig fühlten, dass andere dachten, es wäre etwas nicht in Ordnung? Oder waren Sie so in überschäumender Stimmung, dass Sie dadurch in Schwierigkeiten gerieten? Hielt diese Phase eine Woche lang an?

Gab es jemals eine Phase, in der Sie so reizbar waren, dass Sie andere anschrien oder in Streit oder Auseinandersetzung gerieten? Hielt diese Phase eine Woche lang an? Wann war das der Fall? In den letzten vier Wochen?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Litten Sie in den vergangenen zwei Jahren die meiste Zeit unter einer depressiven Stimmung? Fast den ganzen Tag lang? In mehr als der Hälfte der Zeit?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Fühlten Sie sich in letzter Zeit oder früher einmal häufig krank oder hatten Schmerzen, obwohl der Arzt, den Sie aufsuchten, keine Ursache finden konnte?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Haben Sie das Gefühl, dass andere Leute über Sie reden und mit besonderer Aufmerksamkeit betrachten oder dass jemand versucht Ihnen das Leben schwer zu machen?
Oder haben Sie das Gefühl, dass Sie Nachrichten aus ihrer Umwelt erhalten oder dass irgendeine Kraft oder Macht von außen ihre Gedanken steuern kann?
Oder sehen oder hören Sie Dinge, die andere Leute nicht sehen oder hören?
Oder haben Sie das Gefühl, dass ihre Gedanken laut nach außen übertragen werden?
Oder haben Sie das Gefühl, dass sie über besondere Kräfte verfügen oder Teile ihres Körpers krankhaft verändert sind?

Nein	Ja		
	Von	Bis	Aktuell

Falls ja: Ist bzw. war Ihr Alltag dadurch eingeschränkt? JA/NEIN

Es folgen nun Fragen zu ihrer Persönlichkeit, zu Einstellungen, Gefühlen, Empfindungen und Verhaltensweisen. Ich bitte Sie, auch diese wieder mit Ja oder Nein zu beantworten.

SCID 2

Selbstunsicher-vermeidend

1. Vermeiden sie oft den Kontakt mit anderen Menschen, außer wenn Sie sicher sind, dass diese Sie wirklich mögen, da Sie befürchten kritisiert oder abgelehnt zu werden ? Sind sie oft schweigsam und zurückhaltend und fällt es Ihnen schwer, offen zu sein?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Dependent

2. Benötigen Sie häufig Ratschläge oder Bestätigung von anderen bei alltäglichen Entscheidungen (Anziehen, im Restaurant bestellen) und fällt es Ihnen schwer anderen zu widersprechen? Brauchen Sie immer eine Person, die sich um Sie kümmert und auf die sie sich verlassen können?

Überdauerndes Muster? Leiden oder Beeinträchtigung(andere?)?

JA/NEIN

Zwanghaft

3. Legen sie großen Wert auf Ordnung, Details und Regeln undwollen Sie immer die Kontrolle behalten?

JA/NEIN

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

Negavistisch/Passiv-aggressiv

4. Haben Sie das Gefühl, dass es das Leben ungerecht mit Ihnen meint und neigen Sie oft dazu etwas, das Sie eigentlich nicht tun wollen, einfach zu vergessen oder nachlässig zu erledigen?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Depressiv

5. Fühlen Sie sich in der Regel unglücklich oder ohne Lebensfreude und halten sich selbst für minderwertig?

JA/NEIN

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

Paranoid

6. Zweifeln Sie oft daran, anderen Leuten trauen zu können und denken Sie, dass die meisten Menschen im Prinzip schlecht sind?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Schizotyp

7. Entdecken sie oft eine verborgene Bedeutung hinter dem, was andere tun (Denken sie zum Beispiel, dass andere Leute auf der Straße über Sie reden?) oder glauben sie, dass Dinge, die augenscheinlich nichts miteinander zu tun haben, ihnen eine besondere Botschaft vermitteln? Dauert es lange bis sie jemandem verzeihen können? Haben Sie persönlich Erfahrung mit übernatürlichen Dingen oder glauben Sie, Dinge im Voraus zu wissen oder vorhersagen zu können?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Schizoid

9. Gibt es außerhalb Ihrer Familie nur sehr wenige Menschen zu denen Sie eine wirklich enge Beziehung haben und ist es Ihnen gleichgültig, was andere über sie denken? Könnten Sie ohne enge Beziehungen auskommen?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Histrionisch

10. Stehen Sie gern im Mittelpunkt und versuchen Sie durch ihre äußere Erscheinung die Aufmerksamkeit anderer auf sich zu ziehen? Bekommen Sie schnell engen Kontakt zu fast allen Menschen?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Narzisstisch

11. Wurde Ihnen schon einmal gesagt, dass Sie eine zu hohe Meinung von sich selbst haben und ist es Ihnen wichtig, dass andere Sie in irgendeiner Weise bewundern? Glauben Sie, dass es sich nur lohnt, Zeit mit Menschen zu verbringen, die besonders wichtig sind und bestehen sie immer darauf, den höchsten Vorgesetzten zu sprechen? Denken Sie, dass sie selbst und ihre Bedürfnisse wichtiger sind als die von anderen?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Borderline

12. Sind Ihre Beziehungen zu Personen, an denen Ihnen viel liegt, von einem ständigen Auf und Ab gekennzeichnet und geraten Sie aus der Fassung, wenn Sie sich vorstellen, dass jemand, der Ihnen viel bedeutet, sie verlässt? Handeln sie oft impulsiv und neigen sie zu selbstverletzendem Verhalten?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Antisozial

13.Waren Sie jemals in Dinge verwickelt, die strafbar sind, wie z.B. Diebstahl, Drogenhandel, finanzieller Betrug oder Prostitution? Sind sie verantwortungslos bezüglich Normen, Regeln und Verpflichtungen und haben Sie absichtlich Menschen oder Tieren Schmerzen oder Leid zugefügt?

Überdauerndes Muster? Leiden oder Beeinträchtigung (andere?)?

JA/NEIN

Vielen Dank, das Sie sich die Zeit genommen haben. Wir werden uns dann demnächst bei Ihnen melden, ob Sie für die Studie in Frage kommen, und dann einen Termin für das persönliche Interview vereinbaren.

Wann sind Sie denn am besten zu erreichen?

A 18. Information Form for Participants in Experiment 3

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Lehrstuhl für Psychologie I
Prof. Dr. Paul Pauli
Biologische Psychologie, Klinische Psychologie und Psychotherapie

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Untersuchungsort:
Raum 103
Marcusstraße 9-11
97070 Würzburg

Information für Probanden der Studie „Würzburg vor, noch ein Tor"

Sehr geehrte Studienteilnehmerin, sehr geehrter Studienteilnehmer,

Vielen Dank für Ihr Interesse an unserer Studie. Bitte lesen Sie sich folgende Informationen zunächst sorgfältig durch und entscheiden Sie dann über Ihre Teilnahme an dieser Studie. Beides, Teilnahme oder Nichtteilnahme an dieser Studie steht Ihnen frei. Falls Sie über diese Information hinaus noch weitere Fragen haben, beantworten wir diese gerne.

Zu Beginn bitten wir Sie, einen Reaktionszeittest am PC durchzuführen, bei dem Sie verschiedene Wörter möglichst schnell zu Kategorien zuordnen sollen. Danach nehmen Sie an einem online Ballspiel zu mentaler Visualisierung teil, bei dem Sie sich zusammen mit anderen Spielern, die gleichzeitig an einem anderen Computer eingeloggt sind, einen Ball zupassen sollen. Zum Schluss dürfen Sie in einem virtuellen Fußballstadion ein Elfmeterspiel spielen.

Zu jedem einzelnen Untersuchungsteil folgen später noch genauere Instruktionen.

Sie werden zu Beginn und am Ende gebeten, einige Fragebögen auszufüllen. Zudem wird während der gesamten Sitzung ein Video aufgezeichnet, welches im Anschluss von den Untersuchern ausgewertet wird. Außerdem bitten wir Sie, uns eine Speichelprobe zu geben, da uns auch interessiert, wie die Variation verschiedener genetischer Merkmale mit verschiedenen Variablen zusammenhängt.

Des Weiteren müssen wir Elektroden oberhalb Ihres linken Auges und neben Ihrem Mund sowie auf der Innenfläche Ihrer nichtdominanten Hand kleben, die sich am Ende rückstandslos wieder ablösen lassen. Dafür ist es nötig, die entsprechenden Hautstellen zuvor mit Alkohol zu reinigen und mit einer Peelingpaste leicht aufzurauhen. Dabei kann es zu leichten Hautrötungen in diesen Bereichen kommen, die jedoch spätestens nach ein paar Stunden wieder verschwinden.

Ganz am Ende der Untersuchung führen wir noch ein persönliches Interview mit Ihnen.

Insgesamt wird mit einer Untersuchungsdauer von knapp drei Stunden gerechnet, wofür Sie eine Aufwandsentschädigung von 30 Euro bekommen. Zusätzlich erhalten am Ende der gesamten Studie die besten fünf Torschützen im Elfmeterschießen 10 Euro als Belohnung für ihre gute Leistung. Die Daten werden nach der Untersuchung mit einer Codenummer versehen (pseudonymisiert) und auf unbestimmte Zeit gespeichert. Eine Weitergabe personengebundener Daten erfolgt nicht. Alle beteiligten Untersucher sind der Verschwiegenheit verpflichtet. Die Auswertung der Daten erfolgt gemittelt über viele Studienteilnehmer. Wir können daher keine Aussagen über Ihre individuellen Ergebnisse machen.

Ihre Teilnahme an der Studie erfolgt freiwillig. Durch die Nichtteilnahme an der Studie entstehen Ihnen keinerlei Nachteile. Sie können Ihre freiwillige Teilnahme an der Studie jederzeit und ohne Angabe von Gründen abbrechen, ohne dass Ihnen daraus Nachteile entstehen.

A 19. Questionnaire after each Cyber Ball Block in experiment 3

VP_Nr_______

<u>Spiel 1)</u>

1. Wie lebhaft konnten Sie sich das Spiel vorstellen?

1---------2--------3--------4--------5--------6--------7--------8--------9
gar nicht lebhaft sehr lebhaft

2. Wie angenehm oder unangenehm haben Sie sich während dieses Spiels gefühlt?

1---------2--------3--------4--------5--------6--------7--------8--------9
unangenehm angenehm

3. Wie erregt bzw. emotional bewegt waren Sie während dieses Spiels?

1---------2--------3--------4--------5--------6--------7--------8--------9
ruhig erregt

4. Wie gut ist es Ihnen gelungen, Ihre Gefühle zu verbergen bzw. nicht zu beeinflussen?

1---------2--------3--------4--------5--------6--------7--------8--------9
sehr schlecht sehr gut

A 20. Original Instructions presented to Participants throughout Virtual Penalty Kicking in Experiment 3

Before practice trials:
Guten Tag!

Vielen Dank, dass du an unserem Experiment teilnehmen möchtest.

Während des gesamten Versuchs ist es sehr wichtig, dass du versuchst, dich nicht zu viel zu bewegen, weil dadurch unsere Messungen gestört werden.

Du wirst gleich in ein virtuelles Fußballstadion versetzt. Deine Aufgabe ist es, Elfmeter zu schießen und dabei so viele Tore wie möglich zu machen.

Stell dir vor, du nimmst an einem Testtraining für eine Auswahlmannschaft teil. Du willst unbedingt in die Mannschaft, in der nur die besten Spieler deiner Altersklasse spielen. Wenn du genügend Tore machst, wirst du ins Team aufgenommen, wenn nicht, darfst du nicht in der Mannschaft spielen.

Dabei werden dich der Reihe nach drei verschiedene Trainer beobachten und dir nach jedem Schuss Feedback geben, wie gut du spielst.

Nach jedem Feedback vom Trainer sollst du angeben, wie du dich währenddessen gefühlt hast.

Dafür verwenden wir verschiedene Skalen.

Das ist die Skala, auf der du angeben kannst, wie angenehm oder unangenehm du dich gefühlt hast.

1---------2--------3--------4--------5--------6--------7--------8--------9

unangenehm angenehm

Bitte benutze die Tastatur, um deine Bewertung abzugeben.

Das ist die Skala, auf der du angeben kannst, wie erregt bzw. emotional bewegt du warst.

1---------2--------3--------4--------5--------6--------7--------8--------9

ruhig erregt

Bitte benutze die Tastatur, um deine Bewertung abzugeben.

Das ist die Skala, auf der du angeben kannst, wie sehr du deine Gefühle gezeigt bzw. verborgen hast.

1---------2--------3--------4--------5--------6--------7--------8--------9

stark verborgen deutlich gezeigt

Bitte benutze die Tastatur, um deine Bewertung abzugeben.

Zu Beginn kannst du erst einmal üben, mit dem Joystick zu schießen und die drei Trainer kennenlernen. Außerdem kannst du üben, deine Gefühle zu bewerten.

Before “non-regulate” practice trials:
Zuerst wird dich der Trainer Max beobachten. Gib dein Bestes, um so viele Tore wie möglich zu schießen. Wenn Max mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Before “show“ practice trials:
Jetzt wird dich der Trainer Frank beobachten. Frank möchte, dass du deine Gefühle beim Fußballspielen möglichst deutlich zeigst.

Also gib wieder dein Bestes, um so viele Tore wie möglich zu schießen und zeige deine Gefühle möglichst deutlich.

Wenn Frank mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Before “hide” practice trials:
Jetzt wird dich der Trainer Georg beobachten. Georg möchte, dass du deine Gefühle beim Fußballspielen möglichst gut verbirgst.

Also gib wieder dein Bestes, um so viele Tore wie möglich zu schießen und verberge deine Gefühle möglichst gut.

Wenn Georg mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Before main experiment:
Sehr gut. Du hast jetzt geübt, zu schießen und deine Gefühle zu bewerten. Jetzt wird es ernst. Also streng dich an und gib dein Bestes, um in die Auswahlmannschaft aufgenommen zu werden.

Der Torwart ist sehr gut, aber es ist wichtig, dass du so viele Tore wie möglich machst, um im Team mitspielen zu dürfen. Selbst wenn du einmal verschießt, ist es wichtig, dass du dich danach wieder auf den nächsten Schuss konzentrierst, um insgesamt so viele Tore wie möglich zu schießen.

Before “non-regulate“ block:
Jetzt wird dich der Trainer Max beobachten. Max achtet nicht auf deine Gefühle beim Fußballspielen. Du kannst also ganz natürlich reagieren.

Also gib weiterhin dein Bestes, um so viele Tore wie möglich zu schießen. Wenn Max mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Bitte denke dabei auch daran, dich nicht zu viel zu bewegen, damit unsere Messungen nicht gestört werden.

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

Before “show“ block:
Sehr gut gemacht, Du hast schon viele Tore geschossen und bist ein echt guter Schütze.

Bevor es weiter geht, kannst du dich ein bisschen ausruhen.

Bist du bereit für das nächste Elfmeterschießen?

Jetzt wird dich der Trainer Frank beobachten. Frank möchte, dass du deine Gefühle beim Fußballspielen möglichst deutlich zeigst.

Also gib weiterhin dein Bestes, um so viele Tore wie möglich zu schießen und zeige deine Gefühle möglichst deutlich. Wenn Frank mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Bitte denke dabei auch daran, dich nicht zu viel zu bewegen, damit unsere Messungen nicht gestört werden.

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

Before “hide“ block:

Vielen Dank. Das hast du sehr gut gemacht. Du hast viele Tore geschossen und deine Gefühle gut gezeigt.

Bevor wir das letzte Elfmeterschießen anpfeifen, darfst du dich nochmal etwas ausruhen.

Bist du bereit für die letzte Runde?

Jetzt wird dich der Trainer Georg beobachten. Georg möchte, dass du deine Gefühle beim Fußballspielen möglichst gut verbirgst.

Also gib weiterhin dein Bestes, um so viele Tore wie möglich zu schießen und verberge deine Gefühle möglichst gut. Wenn Georg mit dir zufrieden ist, wirst du eher ins Team aufgenommen.

Bitte denke dabei auch daran, dich nicht zu viel zu bewegen, damit unsere Messungen nicht gestört werden.

Hast du noch Fragen?

Bist du bereit? Dann geht es jetzt los.

After main experiment:

Vielen Dank. Das hast du sehr gut gemacht. Du hast viele Tore geschossen und bist ein echt guter Schütze. In unserer Auswahlmannschaft dürftest du auf jeden Fall mitspielen.

Danke, dass du unsere Forschung durch deine Teilnahme an diesem Experiment unterstützt hast. Abschließend würden wir dich bitten, noch ein paar Fragebögen auszufüllen.

A 21. Questionnaire on applied Emotion Regulation Strategies throughout the Experiment, applied in Experiment 3

<u>Nachbefragung Emotionsregulation</u>

Bitte geben Sie hier noch an, wie sehr Sie beim Zeigen bzw. Verbergen oder nicht regulieren von Emotionen die folgenden Strategien benutzt haben. Ein Trial bezeichnet im Elfmeterspiel einen Schuss mit anschließendem Feedback durch den Trainer, im Cyberball-Spiel einen Pass. Positiv wäre ein Trial mit Treffer und entsprechendem Feedback bzw. ein Pass zu Ihnen, negativ ein Verschießen mit entsprechendem Feedback bzw. ein Pass zu einem anderen Spieler und neutral ein Schuss über das freie Feld mit entsprechendem Feedback. Falls etwas unklar oder unverständlich formuliert ist, wenden Sie sich gerne an die Versuchsleitung.

1. **Ich habe folgende Strategien angewendet: Mental mit mir reden/ mir sagen, die Situation sei nicht real/ den Inhalt der Situation uminterpretieren/ eine Beobachterperspektive einnehmen / an eine ähnliche Situation denken, die ich bereits selbst erlebt habe…**

   Bitte kreuzen Sie hier jeweils nur für die Strategien, welche für die jeweilige Aufgabe passend sind.

   Bei positiven Trials

   a. Beim Zeigen von Gefühlen

      1----------2----------3----------4----------5----------6----------7----------8----------9
      gar nicht sehr

   b. Beim Verbergen von Gefühlen

      1----------2----------3----------4----------5----------6----------7----------8----------9
      gar nicht sehr

   c. Beim nicht Regulieren von Gefühlen

      1----------2----------3----------4----------5----------6----------7----------8----------9
      gar nicht sehr

   Bei negativen Trials

   d. Beim Zeigen von Gefühlen

      1----------2----------3----------4----------5----------6----------7----------8----------9
      gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

Bei neutralen Trials

d. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

2. Ich habe folgende Strategien angewendet: mich auf emotionale vs. nicht emotionale Aspekte der Situation konzentrieren/ an etwas anderes denken/ wegschauen/ weghören/Entspannungsübung/…

Bei positiven Trials

a. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

b. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

c. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

Bei negativen Trials

d. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

Bei neutralen Trials

d. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

3. **Ich habe folgende Strategien angewendet: Meine Mimik verändern/ körperliche Reaktionen verändern/ Emotion einfach unterdrücken/ andere Emotion hervorrufen/…**

Bei positiven Trials

a. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

b. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

c. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

Bei negativen Trials

d. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

Bei neutralen Trials

d. Beim Zeigen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

e. Beim Verbergen von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9

gar nicht sehr

f. Beim nicht Regulieren von Gefühlen

1----------2----------3----------4----------5----------6----------7----------8----------9
gar nicht sehr

4. Ich habe weitere Strategien angewendet, um meine Gefühle zu regulieren, die hier nicht aufgelistet waren, und zwar:

a. Beim Zeigen von Gefühlen:
____

Gab es hier Unterschiede zwischen positiven, negativen und neutralen Trials?

____

b. Beim Verbergen von Gefühlen:
____

Gab es hier Unterschiede zwischen positiven, negativen und neutralen Trials?

____

c. Beim nicht Regulieren von Gefühlen:
____

Gab es hier Unterschiede zwischen positiven, negativen und neutralen Trials?

____

A 22. Supplement for Analyses of Experiment 3.

Table 13. Means (*M*) and standard deviations (*SD*) of behavioral expression rates of HC and ADHD during emotion processing throughout virtual penalty kicking.

Behavioral Aggregate	Penalty Kicking Condition	Group			
		HC		ADHD	
		M	*SD*	*M*	*SD*
Positive aggregate	pleasant	.05	0.10	.08	0.19
	neutral	.04	0.13	.08	0.18
	unpleasant	.03	0.08	.03	0.10
Negative aggregate	pleasant	.03	0.08	.07	0.15
	neutral	.09	0.16	.19	0.32
	unpleasant	.20	0.31	.30	0.47
Tension aggregate	pleasant	.23	0.20	.29	0.23
	neutral	.21	0.17	.28	0.23
	unpleasant	.32	0.20	.36	0.22
Social monitoring aggregate	pleasant	.77	0.61	.58	0.66
	neutral	.42	0.45	.36	0.52
	unpleasant	.39	0.52	.26	0.44

Table 14. Means (*M*) and standard deviations (*SD*) of valence ratings and corrugator activations of HC and ADHD during emotion regulation throughout virtual penalty kicking.

Dependent Variable	**Penalty Kicking Condition**	**Group**			
		HC		ADHD	
		M	*SD*	*M*	*SD*
Valence Ratings	pl_show	7.37	0.97	6.72	1.66
	pl_nonreg	7.19	0.95	6.49	1.71
	pl_hide	7.21	0.92	6.45	1.68
	unpl_show	4.06	1.39	4.74	1.67
	unpl_nonreg	4.17	1.56	4.75	1.60
	unpl_hide	4.25	1.60	4.75	1.66
Corrugator Activity	pl_show	-0.17	0.58	0.07	0.39
	pl_nonreg	-0.05	0.70	-0.17	0.89
	pl_hide	-0.17	0.48	0.27	1.50
	unpl_show	-0.13	0.80	0.10	0.56
	unpl_nonreg	-0.28	0.96	-0.21	0.88
	unpl_hide	-0.38	1.20	0.18	0.97

Comments: pl_show = pleasant show, pl_nonreg = pleasant not regulate, pl_hide = pleasant hide, unpl_show = unpleasant show, unpl_nonreg = unpleasant not regulate, unpl_hide = unpleasant hide

Table 15. Means (*M*) and standard deviations (*SD*) of valence and arousal ratings, positive affect ratings, corrugator activities and tension expressions of HC and ADHD throughout different Cyber Ball conditions.

Dependent Variable	**Cyber Ball Condition**	**Group**			
		HC		ADHD	
		M	*SD*	*M*	*SD*
Valence ratings	Incl_nonreg	7.31	1.37	6.93	1.62
	Os_nonreg	5.03	2.14	4.57	2.01
	Incl_hide	6.59	1.63	6.67	1.75
	Os_hide	5.21	2.02	4.80	2.04
Arousal ratings	Incl_nonreg	4.59	2.25	4.50	2.30
	Os_nonreg	4.38	2.34	5.17	2.34
	Incl_hide	4.48	1.83	3.92	2.44
	Os_hide	3.72	2.10	4.03	2.28
Positive affect ratings	Incl_nonreg	30.41	6.32	28.87	9.03
	Os_nonreg	25.83	5.65	23.20	8.21
	Incl_hide	30.00	6.24	26.50	9.42
	Os_hide	25.62	6.10	21.57	7.35
Corrugator activity [µV]	Incl_nonreg	-0.15	0.99	-0.29	1.13
	Os_nonreg	-0.19	1.11	-0.07	1.46
	Incl_hide	0.07	0.44	0.16	1.48
	Os_hide	-0.09	1.25	-0.17	0.97
Expression rate	Incl_nonreg	0.22	0.26	0.31	0.33
tension aggregate	Os_nonreg	0.28	0.22	0.31	0.31
	Incl_hide	0.23	0.27	0.30	0.32
	Os_hide	0.37	0.38	0.31	0.27

Comments: incl_nonreg = include, not regulate; os_nonreg = ostracize, not regulate; incl_hide = include, hide; os_hide = ostracize, hide.

PUBLICATION LIST

PAPERS

Baur, R., Conzelmann, A., Wieser, M. J., & Pauli, P. (2015). Spontaneous emotion regulation: differential effects on evoked brain potentials and facial muscle activity. *International journal of psychophysiology, 96* (1), 38–48. doi: 10.1016/j.ijpsycho.2015.02.022.

CONFERENCE PROCEEDINGS

Baur, R., Pauli, P., Nehfischer, M., Jost, M. S., Wagner, K., Schorb, M., Romanos, R., Lesch, K.-P., Mühlberger, A., & Conzelmann, A. (2015). Emotion Processing and Emotion Regulation in Adult ADHD – Preliminary Data. *EUREKA 10th International Symposium,* Würzburg, Germany.

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Baur, R., Conzelmann, A., Wieser, M. J., & Pauli, P. (2013). Association of ADHD Symptoms and Emotion Regulation in a non-clinical Sample. *4th World Congress on ADHD.* Milano, Italy.

Baur, R., Conzelmann, A., Wieser, M. J., & Pauli, P. (2013). Free-choice Emotion Regulation: An Analysis of Late Positive Potentials and Muscular Face Activity. *Psychologie und Gehirn,* Würzburg, Germany.

CURRICULUM VITAE

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WORKING EXPERIENCE

Since March 2016	**Department of Psychology I, University of Würzburg** Study coordinator and therapist in a project on virtual reality therapy for patients suffering from driving anxiety
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Since May 2012	**Department of Psychology I, University of Würzburg** Doctoral researcher at the department of biological psychology, clinical psychology and psychotherapy, work group Prof. P. Pauli
Since May 2012	**Graduate School of Life Sciences, University of Würzburg** Doctoral researcher in the Research Training Group 1253/2 “GK Emotions”
March 2014 – June 2015	**Kitzberg-Klinik Bad Mergentheim** Therapist in a clinic for psychosomatic medicine and psychotherapy specialized on post-traumatic disorders

June 2013 – Dec 2013	**Department of Medical Psychology, University of Würzburg**
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April 2011 – Jan 2013	**Protestant Student Community, University of Würzburg**
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Sep 2008 – Oct 2011	**Department of Psychology I, University of Würzburg**
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EDUCATION

Since Sep 2013	Studies of Psychological Psychotherapy (Cognitive-Behavioral Therapy) at the University of Würzburg
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____________________________ ____________________________

Place, Date Signature

AFFIDAVIT

I hereby confirm that my thesis entitled “Adult Attention-Deficit/Hyperactivity Disorder (ADHD), Emotion Processing and Emotion Regulation in Virtual Reality” is the result of my own work.

I did not receive any help or support from commercial consultants. All sources and/or materials applied are listed and specified in the thesis.

Furthermore, I confirm that this thesis has not yet been submitted as part of another examination process neither in identical nor in similar form.

Place, Date	Signature